APPLIED COMPUTER SCIENCE

The Journal is a peer-reviewed, international, multidisciplinary journal covering a broad spectrum of topics of computer application in production engineering, technology, management and economy.

The main purpose of Applied Computer Science is to publish the results of cutting-edge research advancing the concepts, theories and implementation of novel solutions in computer technology. Papers presenting original research results related to applications of computer technology in production engineering, management, economy and technology are welcomed.

We welcome original papers written in English. The Journal also publishes technical briefs, discussions of previously published papers, book reviews, and editorials. Especially we welcome papers which deals with the problem of computer applications in such areas as:

- manufacturing,
- engineering,
- technology,
- designing,
- organization,
- management,
- economics,
- innovations,
- competitiveness,
- quality and costs.

The Journal is published quarterly and is indexed in: BazTech, Cabell's Directory, CNKI Scholar (China National Knowledge Infrastucture), ERIH PLUS, Index Copernicus, J-Gate, Google Scholar, TEMA Technik und Management.

Letters to the Editor-in-Chief or Editorial Secretary are highly encouraged.

CONTENTS

Applied Computer Science, vol. 14, no. 3, pp. 5–14
doi:10.23743/acs-2018-17

Submitted: 2018-08-16
Revised: 2018-09-05
Accepted: 2018-09-10

audio fade, fade-out shape, real-time computing, HTML5, JavaScript

Lucian LUPŞA-TĂTARU[*]

NOVEL TECHNIQUE OF CUSTOMIZING THE AUDIO FADE-OUT SHAPE

Abstract

The fade-out sound effect designates a strict decreasing of the volume of an audio signal, starting from the detected initial level down to silence. Audio fade-outs are usually processed in off-line mode that is within audio editors, by employing different transcendental functions to set the time-related evolution of the audio level. However, the proliferation of mobile devices as well as the increasing popularity of web applications, implemented in HTML5/JavaScript, press for computing techniques suitable for real-time processing. In this context, having in view that the computation of the outputs of transcendental functions is very time-consuming, in order to construct the audio fade-out profile, a technique suitable for real-time computing is developed in the present investigation. The suggested technique is validated by means of an implementation in pure JavaScript, put forward with the purpose of immediate testing.

1. INTRODUCTION

The HTML5 version of the web core language has been designed to control multimedia content (*W3C Recommendation for HTML5*, 2017). Thus, complex web applications, implemented in HTML and JavaScript, have increased in popularity, especially in the activity areas of entertainment, education, and multimedia development (Devlin, 2012; Jacobs, Jaffe & Le Hegaret, 2012; Powers, 2011). Particularly, the HTML DOM Audio Object, brought in along with HTML5, combines advanced properties and methods that allow a straightforward real-time processing of audio content.

[*] Department of Electrical Engineering and Applied Physics, Faculty of Electrical Engineering and Computer Science, "Transilvania" University of Braşov, Bd. Eroilor No. 29, Braşov, RO-500036, Romania, https://iesc.unitbv.ro, lupsa@programmer.net, lucian.lupsa@unitbv.ro

In the field of audio engineering, the fade-out effect is related to volume processing and reflects a strictly monotonic decreasing of the audio level of the signal from a detected initial level down to silence. The fade-out sound effect is implemented in order to bring off a smooth ending of a certain audio content that is without perceivable "glitches" (clicks) (Case, 2007; Corey, 2017; Langford, 2014; Reiss & McPherson, 2015).

The fade-out length, i.e. the time interval over which the audio level is gradually reduced to zero, should be correlated with the detected music genre (Benetos & Kotropoulos, 2010; Panagakis, Kotropoulos & Arce, 2014). It has to be emphasized that long fade-outs, greater than 10 s, carried out at low absolute values of rates of change of the audio volume, are to be applied upon droning (sustained) sounds in order to enforce an obvious but extremely smooth ending (Langford, 2014; Potter, 2002).

The fade-out shapes are usually customized in off-line mode by employing various digital audio editors. The well-known preset shapes of the fade-out sound effect are of linear, exponential, logarithmic and S-curve type. More precisely, the preset shapes of the fade-out effect are determined by linear and transcendental functions (exponential, logarithm, sine) of time variable. Since a linear fade-out is performed at a constant rate of change of the audio level, smoothing the ending region of the signal is equivalent to increasing the fade-out length. This is the main reason why the fade-out shapes are also customized by means of transcendental functions of time variable. Moreover, various well-established psychophysical investigations highlight the benefits of implementing fade-outs of a variable rate of change of audio level (Case, 2007; Corey, 2017; Fastl & Zwicker, 2007; Hartmann, 1998; Roederer, 2008). In this context, it has to be emphasized that the employment of the exponential function to shape the fade-out profile determines a quick decay of the audio volume from the detected initial level down to the level at the halfway point (fade-out midpoint), followed by a soft decline of audio volume towards the end of the fade-out. Thus, by adopting the exponential shape for a fade-out effect, one perceives a smooth ending of the audio content i.e. a smooth transition to silence, without notable "clicks". Having in view that it is closely related to the manner in which sounds do naturally decay, such kind of time-related evolution of the audio level comes to be advantageous for fading-out synthesized soundscapes (Krause, 2008; Langford, 2014). The opposite of the exponential fade-out shape is the logarithmic curve shape, which determines a smooth decay of the audio volume in the beginning of the fading-out, followed by an abrupt transition to silence.

Taking into account that the computation of the outputs of transcendental functions is very time-consuming, the present investigation is directed towards customizing the shape of fade-out sound effect with a view to real-time volume processing. Such kind of approach is essential for the development of web applications requiring audio processing. By adopting a rational function that encompasses three coefficients in order to set the rate of change of the audio level,

it will be shown that the resulted fade-outs can act either as the fade-out effect of exponential type or as the fade-out effect of logarithmic type, depending on the values of the encompassed coefficients. Notice that, with the purpose of customizing the audio fade-in profile, a technique suitable for real-time computing has recently been introduced and implemented by considering that the audio volume is the output of a rational function that incorporates two coefficients (Lupsa-Tataru, 2017).

The employment of JavaScript programming language is justified by the fact that it supplements the enhanced functionality of HTML5 with a view to developing pervasive multimedia applications (Devlin, 2012; Jacobs, Jaffe & Le Hegaret, 2012; Powers, 2011). Particularly, the audio volume processing in HTML5/JavaScript is straightforward to perform by means of the "currentTime" and "volume" properties of HTML DOM Audio Object. While "currentTime" property is used to return the current playback time within the audio content, the "volume" property is used to set the audio level, considering that the level of 0 indicates silence whilst the level of 1 (the default value) corresponds to the highest volume. More precisely, the returned value of the "currentTime" property of the Audio Object is to be used as the input of the function of time variable that has been employed to customize the fade-out shape whilst the output of this function is to be used to set the value of the Audio Object "volume" property. On the other hand, the discrete-time processing can straightforwardly be accomplished by associating the "timeupdate" HTML DOM media event with the audio element.

2. THE FADE-OUT SHAPING

Since the valuation of the outputs of transcendental functions (exponential, logarithm, sine), intensively used to customize the fade-out profiles in off-line mode i.e. within digital audio editors, is very time-consuming and unsuitable for real-time computing, we consider here that the time-related evolution of the audio level during fading-out is determined by the following rational function:

$$\begin{cases} v(\tau) = \dfrac{\tau - \alpha}{\beta\tau - \gamma} \\ \tau \in [0, \tau_f] \end{cases} \tag{1}$$

wherein α, β, γ are the coefficients used to adjust the fade-out profile whilst τ_f represents the fade-out length.

Designating by t_{ref} the instant of time at which the fading-out effect is initiated, we have:

$$\tau = t - t_{ref} \tag{2}$$

One perceives that in contrast to implementing transcendental functions to shape the fade-out profile, the implementation of (1) comes to be straightforward since it does not call for additional methods to carry out complex mathematical tasks.

In order to depict the shape of a fade-out effect, function (1) has to be strictly decreasing. Hence, the following conditions have to be met:

$$v(0) = v_0 \tag{3}$$

$$v(\tau_h) = v_h \tag{4}$$

$$v(\tau_f) = 0 \tag{5}$$

$$0 < v_h < v_0 \tag{6}$$

where v_0 is the detected initial volume while τ_h is the halfway point i.e. the fade-out midpoint that is

$$\tau_h = \tau_f/2 \tag{7}$$

Taking into account (1), (3)–(5) and (7), one receives a system of three equations in the three variables (unknowns) α, β and γ, i.e.

$$\alpha/\gamma = v_0 \tag{8}$$

$$\frac{\tau_h - \alpha}{\beta\tau_h - \gamma} \equiv \frac{\tau_f/2 - \alpha}{\beta\,\tau_f/2 - \gamma} = v_h \tag{9}$$

$$\frac{\tau_f - \alpha}{\beta\tau_f - \gamma} = 0 \tag{10}$$

The solution to the system (8)–(10) provides the coefficients encompassed by (1) in terms of fade-out length τ_f, the detected initial volume v_0, and the ratio between the volume v_h at the midpoint τ_h and the initial volume, designated by variable ρ_h. More precisely,

$$\alpha = \tau_f \tag{11}$$

$$\beta = \frac{2\rho_h - 1}{\rho_h v_0} \tag{12}$$

$$\gamma = \tau_f/v_0 \tag{13}$$

where

$$\rho_h = v_h/v_0 < 1 \tag{14}$$

The derivative of function (1) yields the instantaneous rate of change of audio volume during fading-out i.e.

$$v'(\tau) \equiv \frac{dv}{d\tau} = \frac{\alpha\beta - \gamma}{(\beta\tau - \gamma)^2} \tag{15}$$

Having in view (11)–(13) and (14), respectively, it follows that

$$\alpha\beta - \gamma = \frac{\tau_f}{v_0}\left(1 - \frac{1}{\rho_h}\right) < 0 \tag{16}$$

and, implicitly,

$$v'(\tau) \equiv \frac{dv}{d\tau} < 0 \tag{17}$$

Hence, with condition (14), initially expressed by means of (6), the rational function (1), imposing the fade-out profile, is strictly decreasing, acting in the direction of decaying the audio level.

With a view to HTML5/JavaScript implementation, one has to consider that the default audio level is just the highest one, and corresponds to the value of 1 (Devlin, 2012; Lupsa-Tataru, 2017; Powers, 2011; WebPlat WG). Thus, if one assumes that the detected initial audio level is precisely the default one i.e. the highest one, then, based on (11)–(14), we have:

$$v_0 = 1$$

$$\rho_h = v_h$$

$$\alpha = \gamma = \tau_f$$

$$\beta = 2 - \frac{1}{\rho_h}$$

For this specific case, Figure 1 and Figure 2 highlight the fade-out curves i.e. the outputs of (1) for fade length $\tau_f = 8$ s and $\tau_f = 10$ s, respectively. Within each figure, the fade-out shape is determined by the value of ratio (14), which, in the present case, equals the audio level at the fade-out midpoint. Both figures clearly emphasize that the resulted fade-out effects corresponding to $\rho_h = 0.2$

and $\rho_h = 0.3$ will act similar to the fade-out of exponential type while the fade-outs obtained for $\rho_h = 0.7$ and $\rho_h = 0.8$ will act similar to the fade-out effect of logarithmic type. More precisely, the fade-out curves corresponding to $\rho_h = 0.2$ and $\rho_h = 0.3$ indicate a quick decline of the audio level in the beginning of fading-out, followed by a smooth transition to silence. On the other hand, the fade-out curves received for $\rho_h = 0.7$ and $\rho_h = 0.8$ emphasize a soft decay of the audio level in the beginning of fading-out, followed by a quick transition to silence.

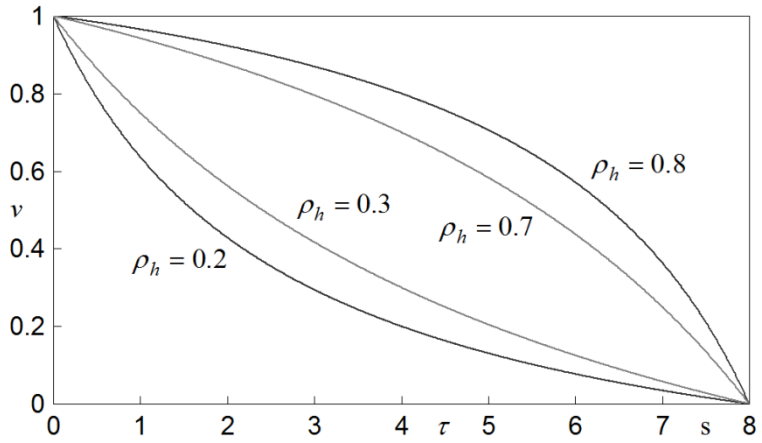


Fig. 1. Fade-out curves for fade length $\tau_f = 8$ s and the initial audio level $v_0 = 1$ (the default value in HTML5)

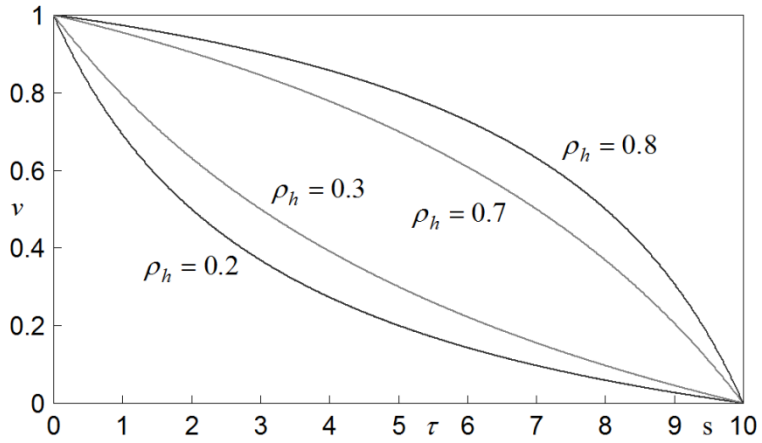


Fig. 2. Fade-out curves for fade length $\tau_f = 10$ s and the initial audio level $v_0 = 1$ (the default value in HTML5)

3. JAVASCRIPT IMPLEMENTATION

Both for the sake of simplicity and to plainly highlight the fade-out profiles that could be received by straightforwardly computing the output of (1), Figure 1 and Figure 2 have been plotted for the circumstance in which the initial audio level, occurring at the beginning of fade-out effect, is identical to the default audio level in HTML5 that, in this case, is the highest one.

However, the implementation advanced here has been structured for the most general case that corresponds to the situation in which, before the fading-out, the user is allowed to alter the audio volume during playback. This implies the computing of coefficients (11)–(13), shaping the fade-out profile, just prior to the fade-out initiation.

Although the fade-out length and the ratio (14) between the volume at the fade-out midpoint and the detected initial volume can be easily changed within the code, we have set $\tau_f = 10$ s and $\rho_h = 0.2$ in order to ensure a smooth transition to silence, without perceivable "clicks" (glitches). In this context, in Figure 3 we have illustrated the fade-out curves with the initial volume selected as parameter. As aforementioned, with a view to JavaScript implementation, the audio volume has to be located within the interval [0, 1] where the value of 0 denotes silence whilst the value of 1 indicates the highest level (the default volume). The fade-out profiles in Figure 3 clearly emphasize that the resulted fade-out effect will act similar to the fade-out effect of exponential type.

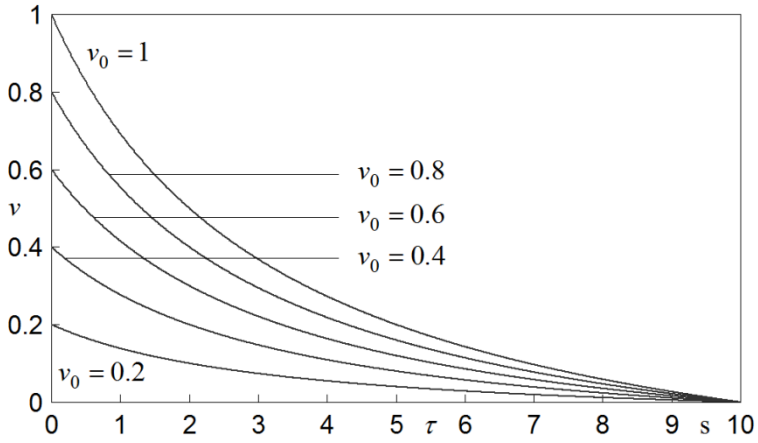


Fig. 3. Fade-out curves for fade length $\tau_f = 10$ s and ratio $\rho_h = 0.2$, with initial audio level v_0 as parameter

The code of the application developed to validate the suggested technique of audio fade-out shaping is given next, with the purpose of immediate employing.

```
<!DOCTYPE html>
<html>
<head>
   <title>Fade-out</title>
</head>
<body>
<script>
var ae = document.createElement( “AUDIO” );
                        // creates the audio element
ae.preload = “auto”;      // audio content is loaded with the page
ae.controls = true;       // displays the standard audio controls
ae.src = “sample.mp3”; // points to an audio/mpeg file
ae.addEventListener( “timeupdate”, setVol );
   // links the timeupdate event to the audio element
document.body.appendChild( ae );
   // appends the audio element to the document

var tauF = 10.0;          // fade-out length, in second
var rhoH = 0.2;
   // ratio between the volume at fade-out midpoint and the initial volume
var refTime = 20.0;
   // (expected) instant of fade-out initiation, in second
var alpha, beta, gamma;
   // the coefficients of function shaping the fade-out; global scope
var fadeOut = false;      // indicates the state of fading-out

function v( t ) {
   var newVol = ( t - alpha ) / ( beta * t - gamma );
   return newVol;
}
function setVol() {
   var tau = ae.currentTime - refTime;

   if ( fadeOut ) {
      var currentVol = v( tau );

      if ( currentVol > 0.0 ) {
         ae.volume = currentVol;
      }
      else {
         ae.volume = 0.0; ae.pause();
      }                   // end of fade-out
   }
   else if ( tau >= 0.0 ) {
      /* this block is executed only once */
      var initVol = ae.volume;
         // detects the initial volume

      alpha = tauF;
      beta = ( rhoH + rhoH - 1.0 ) / rhoH / initVol;
      gamma = tauF / initVol;
         // computes the coefficients of function shaping the fade-out
      fadeOut = true;
   }
}
</script>
</body>
</html>
```

One observes that the instant of fading-out initiation is here $t_{ref} = 20$ s. Moreover, having in view that the length of fade-out effect is 10 s, it follows that the duration of the audio content has to be greater than 30 s. Anyhow, it has to be pointed out that the initiation of the fade effect could be accomplished by means of an auxiliary event linked to the audio element, taking into account that the "timeupdate" media event is already associated with the audio element in order to achieve the discrete-time processing (Lupsa-Tataru, 2017).

To improve the computational capabilities, we have introduced the "fadeOut" variable of global scope. This variable plainly indicates the state of fading-out, i.e. it holds the value of false before the fading-out initiation whilst during fading-out, when volume processing is performed, it stores the value of true. Hence, the computation of coefficients (11)–(13) is executed only once that is the first time the returned playback position i.e. the value of "currentTime" property is greater than or equal to the expected instant of fade-out initiation. More precisely, the computation of coefficients (11)–(13), which determine the audio fade-out shape, is carried out immediately after detecting the initial value of audio volume, explicitly interfering in expressions (12) and (13), respectively.

4. CONCLUSIONS

The audio fade-out shapes are usually customized in off-line mode i.e. within various digital audio editors by employing transcendental functions in order to enforce the time-related evolution of the audio volume. On the other hand, the growing popularity of multimedia applications put forward in the form of web applications, developed in HTML5/JavaScript, has led to an increasing demand for multimedia computing techniques suitable for real-time processing.

In this context, the present investigation advances a novel technique of shaping the audio fade-out profile with a view to real-time computing. Taking into account that the valuation of the outputs of transcendental functions is time-consuming, the fade-out shape is customized, in the present paper, by means of a rational function that is a function defined by an algebraic fraction encompassing a set of three coefficients. It is shown that the resulted fade-outs, constructed by computing the output of the employed rational function, can act either as the exponential fade-out or as the fade-out of logarithmic curve shape, in accordance with the set of values adopted for the three coefficients incorporated by the algebraic fraction defining the adopted rational function.

The appropriate implementation in pure JavaScript, where the discretization has been achieved by means of the "timeupdate" HTML DOM media event, completely validates the proposed technique of audio fade-out shaping.

REFERENCES

Benetos, E., & Kotropoulos, C. (2010). Non-negative tensor factorization applied to music genre classification. *IEEE Transactions on Audio, Speech, and Language Processing, 18*(8), 1955–1967. doi:10.1109/TASL.2010.2040784

Case, A. U. (2007). *Sound FX: Unlocking the Creative Potential of Recording Studio Effects.* Burlington, MA, USA: Focal Press.

Corey, J. (2017). *Audio Production and Critical Listening: Technical Ear Training.* New York, NY, USA: Routledge.

Devlin, I. (2012). *HTML5 Multimedia: Develop and Design.* Berkeley, CA, USA: Peachpit Press.

Fastl, H., & Zwicker, E. (2007). *Psychoacoustics – Facts and Models (Springer Series in Information Sciences).* Berlin, Germany: Springer-Verlag. doi:10.1007/978-3-540-68888-4

Hartmann, W. M. (1998). *Signals, Sound, and Sensation (AIP Series in Modern Acoustics and Signal Processing).* New York, NY, USA: Springer-Verlag.

Jacobs, I., Jaffe, J., & Le Hegaret, P. (2012). How the open web platform is transforming industry. *IEEE Internet Computing, 16*(6), 82–86. doi:10.1109/MIC.2012.134

Krause, B. (2008). Anatomy of the soundscape: Evolving perspectives. *Journal of the Audio Engineering Society (JAES), 56*(1/2), 73–80.

Langford, S. (2014). *Digital Audio Editing: Correcting and Enhancing Audio in Pro Tools, Logic Pro, Cubase, and Studio One.* Burlington, MA, USA: Focal Press.

Lupsa-Tataru, L. (2017). Shaping the fade-in audio effect with a view to JavaScript implementation. *Journal of Computations & Modelling, 7*(4), 111–126.

Panagakis, Y., Kotropoulos, C. L., & Arce, G. R. (2014). Music genre classification via joint sparse low-rank representation of audio features. *IEEE/ACM Transactions on Audio, Speech, and Language Processing, 22*(12), 1905–1917. doi:10.1109/TASLP.2014.2355774

Potter, K. (2002). *Four Musical Minimalists: La Monte Young, Terry Riley, Steve Reich, Philip Glass (Series: Music in the Twentieth Century).* Cambridge, UK: Cambridge University Press.

Powers, S. (2011). *HTML5 Media.* Sebastopol, CA, USA: O'Reilly Media.

Reiss, J. D., & McPherson, A. (2015). *Audio Effects: Theory, Implementation and Application.* Boca Raton, FL, USA: CRC Press.

Roederer, J. G. (2008). *The Physics and Psychophysics of Music: An Introduction.* New York, NY, USA: Springer Science + Business Media. doi:10.1007/978-0-387-09474-8

WebPlat WG (Web Platform Working Group). (2017). *W3C Recommendation for HTML5*. W3C technical reports index: https://www.w3.org/TR/html

Applied Computer Science, vol. 14, no. 3, pp. 15–30
doi:10.23743/acs-2018-18

Submitted: 2018-08-16
Revised: 2018-09-5
Accepted: 2018-09-20

MS Access, MS Excel, similarity, differences, data, managing, fit choice, compression

Ali Fattah DAKHIL[*]*, Weffa Muhammed ALI*[**]*,*
Ali Atshan Abdul REDA[***]

PRIORITIZING SOFTWARE CAPABILITIES AND FOCAL POINTS OF MS ACCESS AND EXCEL IN PERSPECTIVE OF DATA MANAGEMENT

Abstract

Microsoft Corporation products have overwhelmed almost all organizations around the world even beside other operating systems like UNIX, Ubuntu and others. MS Office software products in particular, have being used widely in big portion of our work and business. In specific, MS Access and Excel are very famous and so usable software in between other Microsoft office products. Many similarities are shared between Access and Excel, meanwhile, many key differences are worth to point them out, too. Mainly, this research spotlights on primarily motivated topic of how they can manage data as they have been designed for. The mission of this research is to show how to employee MS Access and Excel in the right way in business work after indicating strength and weaknesses of both of them. Thus, we need to fulfill the right and suitable enough choice between Access and Excel that meets our business work requirements. A detailed list of significant features and key points are discussed and compered of both software leads to conducted proper software use.

[*] University of Sumer, Faculty of Computer Science and Information Technology, Computer Science Dept., Thi-Qar, Iraq, allee.fattah@gmail.com
[**] University of Thi-Qar, Educational Collage of Pure Science, Computer Science Dept., Thi-Qar, Iraq, wafaam20142015@gmail.com
[***] University of Sumer, Faculty of Computer Science and Information Technology, Computer Science Dept., Thi-Qar, Iraq, aliatshan_1969@yahoo.com

1. INTRODUCTION

Microsoft Access and Microsoft Excel have numerous likenesses and differences, which can make it hard to choose which program that we should use to satisfy our needs in business work in perspective of data management. For example, both software can do intensive operations and can store big data. There are many real life scenarios have failed to use such programs in the right way. Case studies showed that some organizations have transformed from Excel to Access and vice versa. Normally, these two software were designed to implement a particular job. It has to be said, it is a fallacy that both program can deliver exactly same work with little distinctions. Microsoft has built these two big achievements in order to each one can perform entirely different missions. Therefore, there are couple of points this paper adopts to juxtapose these programs. This search is not to compare between Access and Excel in a manner shows which good or not. This study has a strategy of adopting several keys of interesting in perspective of data management not in perspective of software specifications and how technical issued can be handled. Data manipulation with these programs focuses on data analyzing, data security, data capacity, and data accessibility. Each topics has several subtopics by which one program would have priority and more applicable at those features than other. For instance, Excel does mathematical operations with high potency than Access, Schmalz (2005). In addition, there are many details under these sub-topics are also precisely discussed among both software. After that, we prepare a collection of best situations and scenarios that these software can do. Finally, a good recommendation of using such programs with concluded an advice in which this paper can deliver the actual goal.

2. CASE STUDY

In many cases, business solutions are managed by MS Excel when MS Access is more proper and fits such requirements. Or on the other hand, maybe Excel was initially a smart thought, yet the information has outgrown an Excel arrangement and the time has come to utilize a database program. Luckily, we can see in some business data works and projects move from Excel to Access. One example, a non-profit organization called Cancer Lifeline based in Seattle, Microsoft ("Customer case study: Moving from Excel to Access", 2008), basically, it designed its grant tracking business with Excel. With the time, data redundancy has run into big difficulty. So, they deiced to transfer to Access.

A recent research by A. Hameed Yassir and A. Fatah Dakhil (2016) has shown improper use of Excel and Access by Thi-Qar province offices. Figure 1 shows the real percentage use of both Access and Excel. This research has been cross many offices, around 45 ones. Regards to its result by survey forms, many offices misuse Access and Excel. The total results have shown that 90% of works are

managed by Excel. On the other hand, 30% of works are managed by Access. However, these information refer for the actual usage of them does not mean the correct choice. After analyzing such information, we found that 40% out of Excel percentage are fit to use and the left portion were supposed to be managed by either Access or other software. Meanwhile, Access reached 95% out of its percentage of use. That means Access was employed properly rather than Excel.

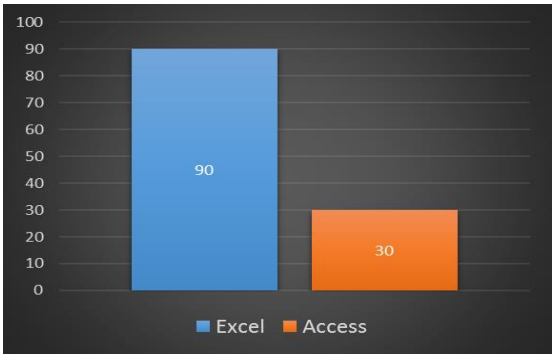


Fig. 1. Percentage use of Access and Excel in city of Thi-Qar offices

3. PROGRAMS BENEFITS AND COMPRESSION

In order to achieve a significant accuracy and performance on data manipulation, it is very critical for choosing the proper software among them regarding to their potency upon key point of what and how they manage data, Alexander (2007).

3.1. Data Analysis and Information Retrieving

Under this perspective view of point, there are three main topics to discuss:

- Data Modeling: What-if analysis tool is very useful to prognostic a worksheet's model result. This tool allows us to find worst case scenarios and best case scenarios with comparative results in concise report. This feature is only supported in *Excel*.
- Information Querying: Access would be best choice in term we aim to view information (extracted data) in diversity ways based on interchangeable events and conditions. As SQL supplied with Access, so it is highly supported to manage data with SQL's ability to retrieve data from different tables, using expressions, calculated fields … etc. Thus, *Access* is better to go with this option.
- Charts and PivotTable: Even both software provide these tools, however, Excel has advanced charting features and supreme PivotTable. *Excel* has priority here for these features.

Below is a brief description for all previous features.

Tab. 1. Data Analysis and Information Retrieving Compression

Data Analysis and Information Retrieving	
Features	**Software**
Data Modeling	Excel
Information Querying	Access
Charts and PivotTable	Excel

3.2. Security

Generally, both program have same similarity of security capabilities as password and data encryption techniques. However, there are some variations in concept of how user-level preservation works Microsoft ("Protection and security in Excel", 2016) and Help4Access ("MS Access Security", 2016). Therefore, couple of points are mentioned here:

- Data Restriction: with Excel, user-based permissions can be applied to reach information or simply by perform read-only privileges which forbid others from accessing such data. However, user-level protection feature is not supported with Access, but Access does provide a model of user security of any database server.
- File-level Security: Encryption can be applied by both program. Also, we would also ask for password to reveal encrypted data. In addition, digital signature is used to secure database file or workbook.
- User-level Security: In Excel, crucial data are private or hidden by hiding rows and columns. Also, protecting all worksheet to manage user control over hidden data. Locking and unlocking cells in Excel to prevent unintentional modification.
- Data Loss Policy: Access provides wonderful features to backup database in a schedule that fulfills our needs. In addition, database recovering is allowed to restore entire database or even some object such as tables. Meanwhile, in Excel, we can use AutoRecover data while we modifying data. Table 2 shows these features in compression view.

Tab. 2. Security Features Compression

Security	
Features	**Software**
Data Restriction	Both, with efficient of Access
File-level Security	Both
User-level Security	Excel
Data Loss Policy	Both[1], with efficient of Access

3.3. Data Saving and Storage

There are some key points about amount of data and how to save them in both software, Walkenbach (2015) and Alexander & Kusleika (2016).

- Data flexibility and integrity: Data integrity is preserved by unique identifiers, and this is to vouch that all records or rows are distinct. This is important for search and sort operation on our data. Access, utilizes this feature by applying AutoNumber data type. No "orphan" records would be exist when Access ensures data integrity, so that any new records have a corresponding record and other related table. Excel allows us to manipulate data in a free-form method, however, Excel does not deal with relationship model data, so it does not support referential integrity. Excel can apply Data Validation to manage entry of data.
- Relational and Flat Data: Worksheet or single table is called nonreltional or flat data. Excel is the better choice when we want to create a list of students' names with solely one address. On the other hand, Access fits the requirement of store students' list that have many addresses for each one.
- External and Local Data: Both software have commands to communicate with diverse of external data sources without importing it. Table 3 illustrates these features all together.

Tab. 3. Data Saving and Storage Compression

Data Saving and Storage	
Features	**Software**
Data flexibility and integrity	Both, with efficient of Access
Relational and Flat Data	Access
External and Local Data	Both

3.4. Users-Cooperation

Excel and Access have potency to work in collaborative soundings, for example, file sharing, network and SharePoint Services. Even though, there are some remarkable points in the manner that data would be accessed and managed, Alexander (2010).

- Multi-user Cooperation: In Excel, collaboration functionality is best when users access data that a workbook at various times instead of at the same time, so it only allow for share workbook. In Access, users can use a single database simultaneously as Access lock solely records that under editing.

– SharePoint Services: Excel supplies just a single method to work together with various users on a SharePoint Services site. We could transfer a workbook to Windows SharePoint Services archive libraries, where singular users can look at the workbook to roll out improvements, keeping different users from changing the workbook in the meantime. Users can alter a workbook without looking at it of the document library, in which case they should arrange with different users to stay away from information clashes.
– Windows Shared Folder: In case users access database in shared folder, simultaneously they can open and use such file. However, a particular records are locked when it is under editing by other users. Table 4 has all of them in compression view.

Tab. 4. Users-Cooperation Compression

Users-Cooperation	
Features	**Software**
Multi-user Cooperation	Excel
SharePoint Services	Excel
Windows Shared Folder	Both

4. FEATURES COMPARISON BETWEEN EXCEL AND ACCESS

After traversing among many key points of features, it is time to put together all their capabilities in such arbitrage and compare them individually. In fact, these tables below shows how each feature should be highlighted according its possibility to apply. Legend: ● = Recommended (Full), ◒ = Acceptable (Partial), ○ = Doesn't Apply (None).

4.1. Data managing

This attribute has some keys of discussion as listed and compared in table 5.

After evaluating these attributes, and we give 1 for recommended (full), 0.5 for acceptable (partial) and 0 for does not apply (none). We got a result like: Access = 8 and Excel = 4.5. Thus, managing data in Access has higher grade than Excel.

Tab. 5. Data managing comparison of MS Excel and Access

Feature	Access	Excel	Comments
Storage quantity	●	●	Both Excel and Access can have millions of records.
Data types diversity	●	●	Both well support with numbers, text, dates, and others data types.
Validation and verification	●	◒	Both programs allow to control data. Access offers to us more flexibility and control, like determining data input masking.
Security	●	●	Both programs manage access to our data by applying a diversity of security features, like signatures, passwords, encryption, data protection and digital.
Objects oriented and Rich text	●	○	Access characteristics with many facilities to work with large objects like images and documents as well as rich text.
Tables relationships corporation	●	○	Access allows creating several kinds of relationships between tables to ensure data integrity.
Data sharing	●	◒	In Access, users can work concurrently with same data and offers firm choices for changing like conflict and locking
Compile and amalgamate dissimilar data	●	◒	Access has feature of data gathering and collection

4.2. Data Importing and Exporting

This attribute focuses on data integration with external world and data source around these software. Table 6 shows these attributes with comparison.

Tab. 6. Data Exchange comparison of MS Excel and Access

Feature	Access	Excel	Comments
Data importing and exporting.	●	●	Several data resources would integrate with both programs for importing and exporting data, like database, XML, spreadsheet and text.
Editing, Querying and viewing external data.	●	◒	Access allows us for reach other data sources with linked tables and it would communicate easily with SQL server.
Web page deployment	●	●	Both programs can publish dynamic and static web pages. With Excel, interactive pages would be delivered by Excel facilities. With Access, conflict resolve applied by SharePoint
SharePoint lists influence	●	○	Access has effect on SharePoint list

Now, after grading these attributes with numeric values as previous, we would have Access 4 and Excel 2.5. That is to say Access has higher effectiveness on data deploying and exchanging.

4.3. Forms and Reporting

This attributes deals with the ability of creating forms and friendly interface that a developer can use or design. As there are couple of features, table 7 shows them in comparison manner.

Tab. 7. Using forms and reports in MS Excel and Access

Feature	Access	Excel	Comments
Converting and exporting to XPS and PDF	●	●	Both can do this
Reporting	●	●	Both programs can quickly generate reports for data summarization, sorting, filtering and grouping
Forms supporting	●	◒	With Access, we develop forms that could ease to manage, and manipulate our data.
Labeling mail to produce addresses	●	○	Access only has this option

In this attributes we also Access has scored over Excel. Access got 4 scores and Excel obtained 2.5 only. This result guides us for preferring Access instead of Excel.

4.4. Data querying

Querying data is to retrieve information that has been stored in software tables or sheets. Table 8 shows these attributes.

Tab. 8. Data querying in MS Excel and Access

Feature	Access	Excel	Comments
Data sorting and filtering	●	●	Both can do this
Querying complex demands and variety views	●	◒	Access has this option more than Excel

Access is more sufficient working with data querying because it is supported with SQL alongside with power data extraction tools. Also, here in the feature we can find Access reached 2 scores and Excel 1.5 scores.

4.5. Data visualization

Table 9 shows the main attributes of graphically showing data and information result.

Tab. 9. Data visualization in MS Excel and Access

Feature	Access	Excel	Comments
Graphics and SmartArt usage	○	●	Excel only has this option
Charts accessibility	◒	●	Excel has this option over Access
Format data restrictively	◒	●	Excel has this option over Access

In this attribute of visualize information with variety of tools, Excel has high score over Access in opposite of other attributes. Excel is 3, however Access is 1 only.

4.6. Data Calculation

Mathematics operations and numeric calculations are so required tasks in data management area. Table 10 shows list of some features under this topic.

Tab. 10. Data calculation in MS Excel and Access

Feature	Access	Excel	Comments
what-if analysis support	○	●	Excel only has this option
Functions and formulas	◒	●	Excel has this option over Access
Use of PivotChart and PivotTable views	◒	●	Excel has this option over Access
Operating Complicated math and calculated to derive desired information	◒	●	When mainly need to run statistical and sophisticated works, such as data analysis, Excel is considerably is the choice to apply and execute such missions chiefly in terms data was numeric and so on

Again, Excel here has reached high score against Access. Back to numerical evaluation, we can have Excel with 4 scores, meanwhile Access got only 1.5 score.

5. EVALUATION RESULTS

So far, we went inside some attributes and features within those attributes. Conducted results would have been drawn here in data table and comparison. As we have given a numeric values in our evaluation processes, now we are going to map all of the in one place. Table 11 depicts this fact as following.

Tab. 11. Evaluation results in MS Excel and Access

Attributes	Access	Excel	Priority
Data managing	8	4.5	Access
Data Exchange	4	2.5	Access
Forms and Reporting	4	2.5	Access
Data querying	2	1.5	Access
Data visualization	1	3	Excel
Data Calculation	1.5	4	Excel
total	20.5	18	Access = 4 Excel = 2

In short words, we can see the evaluation and comparison results. This results proves that Access hits some major points in four criteria but Excel reached two significant categories.

6. BEST USE OF EXCEL TASKS

Excel program considered a spreadsheet program. Excel file is organized as workbooks that contains one or many worksheets. Excel is optimized for mathematic calculation and data analysis more than as serving database engine. This flexibility of Excel would create an analyzing data model, executing simple or complicated formulas to apply math calculations, pivoting information and many manners, and show data in professional looking. Below are some use of Excel, (Humphrey, 2010):

- In case there is a need to track an item in a list whatever for personal purpose or team use.
- Applying graphical emphasizing tools such as icons for conditional formats, bars and colors.
- Planning to build charts occasionally.
- Trying to use report in pivot table in order to explore hierarchal information and flexible view.
- Occasionally applying statistical comparison and analysis tasks on the data.

- Requiring to perform advanced applications math such as what-if operations on data, for example regression tasks, engineering… etc.
- Needs only flat view of table that is not relational tables which depend on multi tables related.
- When data is almost numeric.

6.1. Popular Scenarios Applied for Excel

- Tracking: Excel used to pursuit data in time worksheet. In example of this, tracking time work and inventory menus.
- Sailing and Billing: Excel is very useful for managing sales and billing like for purchase order, packing slips and sales invoices.
- Budgeting: Whatever purpose, business or personal depending Excel can create any type of budget. For example, budget for event, marketing plan and retirement.
- Usability of calendars: Excel has grid-like nature view. Because of this, Excel has good tools to offer calendar to track school activities for example or business events.
- Planning: Excel offers sophisticated tools to create plans for many future events.
- Reporting: As Excel does summering and statistics information, it also provides professional reports for several tasks.
- Financial and Accounting: Many rich calculations capabilities are embedded in excel as well as financial features such as income declaration, or cash flow declaration or profit and loss declaration.

7. BEST USE OF ACCESS TASKS

For occasionally using, is to record data and then export, reporting subset of that data and export. Appropriate forms are supply within Access than a worksheet as in Excel do work with data conveniently. Reports in Access allow us to epitomize information in GUI forms or printed hard paper based on frequently automate performed tasks. Access would comply data under predefined structure such as controlling data types that can be provided in software. Also, how data in table is related to another data in other tables. Thus, Access leads to ensure data validation and accuracy. We can simply say that Access tables are manipulated for complex query in corresponding to data in other relation even though Excel worksheet looks much as Access table. Below are some actions that Access fits to, MacDonald (2010):

- Foreseeing database works under several users' access and we want to firm options sufficiently managing updates such as conflict results and record locking.
- Expecting for requiring more tables to nonrelational or flat originated data set.
- Need to accomplish compound queries.
- Demand to produce assortment of report or mailing tags.

7.1. Popular Scenarios Applied for Access

- Planning events: Access operates event locations, participate and dates and produce it out.
- Tracking order: Managing information about customers, orders, products and generating reports of employees' sales, time period, region and other related topics.
- Contacts: Managing mailing addresses and contacts information and them in MS Word to issue envelopes, from letter or mailing tags.
- Saving and inventory tracking: Access is employed to store and retrieve track of daily work and enquiries

8. RECOMMENDATIONS AND ADVICE USAGE OF BOTH SOFTWARE

As it has been mentioned before that each software has its own strengths and weaknesses. So, it would be very useful to get advantages of both of their capabilities. In example of this, if we have an Excel worksheet to analyze and calculate data, with time it has become very big and complicated. Also, numerous of users try to access such data. In this situation, we then would to link or import this worksheet to an Access database instead of dealing with it within Excel. On the other side, perhaps we have data inside Access in order to create elaborated pivot table view reports and sophisticated Excel graphics charts. Actually, it doesn't matter which program has been chosen first, as it easily can share and transfer data among each other, by which we can sustain our work. In fact, it is so handy to practice both software as we do not need to have a connection between them, only we can apply importing, exporting and copying. (Monk, Brady & Mendelsohn, 2017).

9. ACCESS AND EXCEL INTEGRATION

Based on the fact and need of using and employing both software in our enterprise also to have optimum solution, here we put some important reasons and situation that we should use both program same time under proper communications. Using Access with Excel is that best use of both of them. Now, let us list those key points in which we would have best practice of software.

9.1. All kind of user can use Access

Normal people can use easily use Access as it can gather data and query it in many handy ways. We can and use any different tables with particular join among them. Figure 2 illustrate this fact.

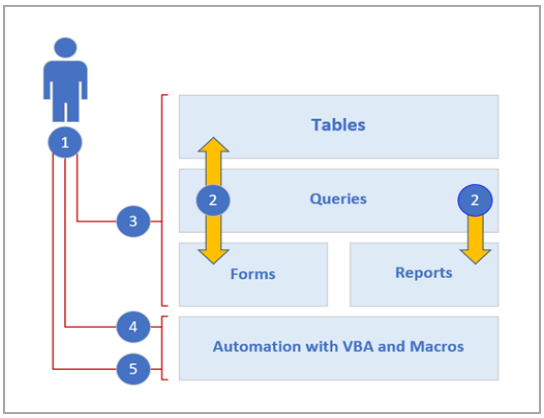


Fig. 2. MS Access Layer of Usage

So, we have five kinds of use about Access. First, in three ways we can use Access: as a developer, an occasional user, or a power user. Second, the core of a database application is made up of Tables, queries, forms, and reports objects. Third, occasional users can use Excel-like features, fluent user-interface and wizards. Fourth, power users can apply database design, expressions and macros. Fifth, developers would work VBA code to develop database applications.

9.2. Excel Sheets to Access Table

A decent method to begin is to copy information from Excel into Access. You can make an Access table and show it in datasheet, which intently looks like an Excel worksheet. You can do basic table creation tasks. When you copy information from Excel into Access, you don't have to make a table to start with, or open a table in datasheet panel. Access naturally inquires as to whether your information has headers, makes great conjectures at utilizing the right data type, and makes an Access table. It couldn't be less difficult.

9.3. Linking Excel worksheet with Access

One of the most straightforward approaches to derive the advantages of both Excel and Access is to link an Excel worksheet to an Access table. Utilize an Access link when you intend to keep the information in Excel, yet additionally frequently use a portion of the numerous Access features, for example, querying and reporting. You link data from Access, but not from Excel.

9.4. Importing Data from Excel to Access

In Access and Excel world, the word importing has two different meanings. In excel, when importing data, a live update still there between excel and data source. In Access, importing is one way method. So, after importing data into Access, it is being stored there permanently (Monk, Brady & Mendelsohn, 2017).

9.5. Import data to Excel from Access

In opposite of importing, this way of connecting is to transfer data to excel. In this manner, live update and date refreshing occur whenever data modified in Access.

10. CONCLUSION

After this concise journey of discussing and pointing out both software capabilities, this research has shown how to properly use Access and Excel and employing them with fit empirical business as they were designed to. Also, this paper has classified, in details, the variety of disciplines and categories of data management areas that these programs perform and deliver. Now, it is plain to guide ourselves when to use them in a way that in future, such work can be handled and no problems would emerge due to proper usage of such software. In brief, as we easily can conclude here, there are some tasks that only Excel can perform. Others, only Access can achieve. Some tasks can be done with both of them. Finally, the optimum use of both Access and Excel, is when we apply proper integration and communications between them. With both software integration, we can get advantage of their abilities without forfeiting one's specifications. Thus, there are four aspects that we have come with. First, Excel missions, the tasks which only Excel can deliver. Second, Access missions, the tasks which only Access can deliver. Third, Shared tasks, are the tasks that both of them can deliver. Forth, tasks are implemented within both software communications and exchange.

Acknowledgment

I would to thank all the resources which helped me to come up with this paper.

REFERENCES

Hameed Yassir, A., & Fatah Dakhil, A. (2016). Information Technology Services in Thi-Qar Province Analysis Study. *Journal of Univesity of Thi-Qar*, *11*(4), 1–10.

Alexander, M. (2007). *Microsoft Access 2007 data analysis: Unleashing the analytical power of Access.* Indianapolis, IN: Wiley Technology Pub.

Alexander, M., & Kusleika, D. (2016). *Access 2016 bible* (pp. 33–131). Indianapolis, IN: Wiley Technology Pub.

Alexander, M. (2010). *The Excel analysts guide to Access* (p.345). Indianapolis, IN: Wiley Pub Technology Pub.

MS Access Security. (n.d.). Retrieved May 7, 2018, from https://www.help4access.com/ms-access-security

Protection and security in Excel. (n.d.). Retrieved March 8, 2018, from https://support.office.com/en-us/article/protection-and-security-in-excel-be0b34db-8cb6-44dd-a673-0b3e3475ac2d

MacDonald, M. (2010). *Access 2010 the missing manual.* Sebastopol, CA: OReilly.

Customer case study: Moving from Excel to Access. (n.d.). Retrieved January 7, 2018, from https://support.office.com/en-us/article/customer-case-study-moving-from-excel-to-access-9bc87c0c-4d94-488b-9629-b74b712840b8

Humphrey, M. L. (2010). *Microsoft Excel for beginners.* Eastlake, Oh.: Web Wise Seniors, Inc.

Monk, E. F., Brady, J. A., & Mendelsohn, E. I. (2017). *Problem-solving cases in Microsoft Access and Excel.* Boston, MA: Cengage Learning.

Schmalz, M. (2005). *Integrating Excel and Access*. Beijing, China: OReilly Media.

Walkenbach, J. (2015). *Excel 2016 Bible* (pp. 109 - 170). USA: John Wiley & Sons, Inc..

Applied Computer Science, vol. 14, no. 3, pp. 31–42
doi:10.23743/acs-2018-19

Submitted: 2018-09-02
Revised: 2018-09-10
Accepted: 2018-09-27

Social Media, Social Relationships, Family bonding, Educational awareness, social presence, self-esteem

Mazen GHAREB[*], *Hawraman KARIM*[**], *Shvan SALIH*[*], *Hiwa HASSAN*[*]

SOCIAL MEDIA AND SOCIAL RELATIONSHIPS: A CASE STUDY IN KURDISTAN SOCIETY

Abstract

These days, Social Media which is includes (Facebook, Instagram, Twitter, Linkedin) is an extremely well known social correspondence media. Individuals use Social Media to express their musings, thoughts, sonnets, and distresses on them. In the period of data superhighway, greater part of the young people are not sharing their challenges, issues, irregularity, powerlessness and disappointment with their folks in Kurdistan of Iraq. Be that as it may, they share with their companions on Social Media. Hence, their companions are making remarks, giving havens and affections to them. Because of absence of instruction and encounters on innovation, gatekeepers in Kurdistan don't know about the correspondences and addictions on social Medias. In this manner, there are producing holes in social relationships in the community. In this paper, a review has based and finding the effect of social media on personal and community relationships. Calculation dissects the practices of youngsters' by gathering data from a survey. Guardians and educators conclusions are additionally viewed as about the exercises of understudies on home and foundations. Here, age cutoff points of focused adolescents are somewhere in the range of 16 and 60. From this investigation, powerless connection amongst guardians and their adolescent youngsters have been taken note. The significant issue was that teenagers are investing more energy on social media and guardians need them to the table amid contemplate time and educational time.

[*] Computer Science Department, University of Human Development, Iraq Sulaymaniyah, Iraq, mazen.ismaeel@uhd.edu.iq, shvan.omar@uhd.edu.iq, hiwa.hassan@uhd.edu.iq
[**] Assistant Lecturer, Cihan University, Sulaymaniyah, Iraq, horamansociology@gmail.com

1. INTRODUCTION

The centre estimation of informal organization locales (SNSs henceforth) lies in the related relationship-building: making companions and partaking in social associations, networks, what's more, even insignificant cooperation and trades? Associations with others are essential both for producing disconnected advantages – most generally, social capital – and for mental improvement in youngsters (Steinfield, Ellison & Lampe, 2008). Keeping up companions through SNSs enables clients to participate in social exercises and in addition to assemble social capital in online settings (Ellison, Steinfield & Lampe, 2007). Many scientists have explored the importance of correspondence and connections with regards to online SNSs. As of late, a few noteworthy diaries, including the Journal of Computer-Mediated Communication, the International Journal of Advertising, the Journal of Interactive Marketing, and the International Journal of Electronic Commerce have distributed uncommon issues with respect to Internet-based life (on Myspace, Twitter, Cyworld, and other online networks), social capital, and the connection between client conduct and correspondence technologies. Related articles have concentrated on the connection between life fulfillment and Facebook utilize (Valenzuela, Park & Kee, 2009), the connection between the power of Facebook utilize, measures of mental prosperity, and crossing over social capital (Steinfield, Ellison & Lampe, 2008), and contrasts between how young people and grown-ups utilize social capital (Pfeil, Arjan & Zaphiris, 2009). In spite of the fact that (Steinfield, Ellison & Lampe, 2008) found that confidence is a component of the self-system (an arrangement of intellectual procedures through which an individual sees, assesses, furthermore, manages her own particular conduct to react adequately to ecological conditions) and that fulfillment with life factors was unequivocally connected with social capital results, we don't yet completely comprehend the social brain research of SNS utilize. Without a doubt, a couple of observational thinks about have endeavoured to assemble a hypothetical model that clarifies individual Facebook clients' self-frameworks as a factor influencing social connections or directing social capital impacts. Along these lines, the objectives of this investigation are to see how the structure of a person Facebook client's self-framework influences his or her social connections and intervenes social capital impacts and to recommend a model that clarifies the connection between a man's self-framework and social capital. This examination will give important information to help a hypothesis of SNS utilize. Youngsters utilize the social in positive approaches to compose and keep up their social systems. Be that as it may, there are likewise adverse effects on youthful people groups' associate connections. These can incorporate alienation and cyberbullying. Thus, the web based life has prompted changed progression in the family, with issues of wellbeing and observation from a parental viewpoint prompting arranged changing opportunities for youngsters.

While useful coordination can be helpful for the family, different issues can emerge, for example, budgetary troubles, non-custodial parent access, and also a lot of dependence on a web based life for security issues and interruption into youthful people groups' lives. The effect of the social media is huge on the university students, be that as it may, got as much research. Disturbances to exercises, occurrences of duping and harassing are a portion of the negative effects. internet based life stages significantly affect understudies' scholastic execution in Kurdistan establishment. This is on account of time administration assumes a basic part in deciding the achievement or disappointment of a person. Along these lines understudies who need time administration can undoubtedly fall prey to the negative effect which web based life stages present to its employment. In like manner, wellbeing enslavement, students who are charmed with web based life stages winds up skirting their dinners which has wellbeing sway on them. Such understudies end up malnourished what's more, could fall sick which is will specifically affect students (Ghareb, Ahmed & Ameen, 2018; Ghareb & Sharif, 2015). In this research we have been created survey of 10 questions to examine the effect the social media on people relationships in sample of 250 person from various social media users.

2. EXISTING RESEARCH

From the earliest starting point of the interpersonal organization locales (SNS)- based research, different factors and measurements have considered and performed. The essential discoveries on SNS inquire about have focused on administration and companionship execution; arrange structure and system (Donath &Boyd, 2004.). Analysts have attempted to center the positive side of the SNS to the clients, particularly towards the young people. Their worry with respect to the site is the capability of SNS to connect among different perspectives, for example, lifetime, on the web and disconnected associations. Ongoing review (Junco, 2015.) from in excess of 1600 universities saw that increasingly the time understudies spent on Facebook, the more they endure in their evaluations. This review was done in the USA, a created nation; in any case, they are not free from same complexities. Bangladeshi understudies and their folks are likewise enduring the antagonistic impacts of the Facebook. Gatekeeper accepts as their youngsters won't think about additional, they will be not able to land position and foundation. They utilized push weights for contemplating however their youngsters need to invested energy in Facebook than ponder by avoiding their folks. As a result, it makes misconception among guardians and kid imperiling their family holding. This negative connection amongst Facebook and family holding is greater issue now. The significant concern emerges when understudies get poor CGPA in their exam and watchmen used to check their tyke, and after that, they discover the peculiarities.

Ongoing exploration by the American Academy of Pediatrics mirrors that extensive parts of the kids are investing energy in Social media (Lauricella, Wartella &Rideout, 2015). Same effects are accessible in Bangladesh. The distinction amongst Bangladesh and USA Facebook client is that Bangladeshi watchmen are extremely delicate than that of American gatekeepers because of need o training, mindfulness and socio-sparing hindrances. Since Watchmen and guardians are being trusted that lone appropriate instructions guarantee a great job for their youngster. There are certain variables additionally saw for Facebook in instruction among understudy's joint efforts (Lauricella, Wartella &Rideout, 2015). In addition, social Medias are the wellspring of online data sharing framework (Al-Dhanhani, Mizouni, Otrok & Al-Rubaie, 2015). Reenactment consequence of Facebook additionally mirrors the same (Bouraga, Jureta &Faulkner, 2015). The different research found that the connections that make in online through SNS may not increment solid ties among people, rather it makes frailties among them and in addition misrepresentation relations are made (Kamal & Arefin, 2015.). The primary reason is that innovation is making connections economically and effortlessly. Anyone can awe anybody in the event that she or he has great composition abilities or inspiration capabilities. The review among US college understudies has demonstrated that SNS has loads of negative effect in view of first world nation. SNS makes crucial issues for their family too companionship.

Ellison, Steinfield & Lampe (2007) exactly confirms this suggestion on college understudy at New York and discovered negative effect on that. He has Applied's (Putnam, 2001.) structure of "spanning" and "holding" social capital and in light of Ellison and her partners (Boyd & Ellison, 2007) found that utilization of Facebook had a solid coordination to keep up or relates existing disconnected connections, rather than meeting new individuals. Research demonstrated that, Facebook utilize may give more noteworthy advantages to clients encountering low confidence and heel fulfillment. It additionally found that SNSs can cultivate clients' prosperity and social capital does not imply that they generally do likewise. Another Survey explores Nyland, Marvez & Beck (2007) found that substantial clients of MySpace felt less socially required with the network around them than light clients. For a huge extent of clients, this informal organization is for amusement, instead of keeping up or reinforcing disconnected relationships. This echoes a standout amongst the most unavoidable reactions against SNS, which is that they prompt clients' disconnection (Valenzuela, Park & Kee, 2008). As indicated by Ellison, Steinfield & Lampe (2007) and Boyd & Ellison (2007.), SNSs are 'online administrations that permit people to build an open or semi-open profile inside a limited framework, express a rundown of different clients with whom they share an association, and view and cross their rundown of associations and those made by others inside the framework' (Ellison, Steinfield & Lampe, 2007). As Boyd & Ellison (2007) and Ellison, Steinfield & Lampe (2007) take note of, the terms 'informal

organization site' and 'long range interpersonal communication site' are regularly utilized as a part of open talk conversely, yet for the reasons for this examination they ought to be recognized. The wonder of long range informal communication may happen utilizing an interpersonal organization, yet organizing stresses the utilization of a social medium (not really electronic) or get-together to start connections, to meet new individuals who by definition are outsiders. Most SNS clients don't arrange in a similar sense: as opposed to taking part fundamentally to start associations with individuals with whom they are unacquainted, they try to expand or improve existing connections. Along these lines, this examination utilizes the term SNS, following Boyd & Ellison (2007) and Ellison, Steinfield & Lampe (2007), who contend that SNSs 'empower clients to well-spoken and make noticeable their interpersonal organizations'. Social systems are basic to mental prosperity (Durden, Hill & Angel, 2007). SNSs are intended to 'cultivate social association in a virtual situation' (Pempek, Yermolayeva & Calvert, 2009), giving electronic administrations that enable people to frame 'gatherings of individuals with whom they are not generally familiar who readily collaborate with them over the Web'. An interpersonal organization is 'a design of individuals associated with each other through relational means, for example, companionship, normal interests, or thoughts' (Coyle & Vaughn, 2008). SNSs commonly enable a client to fabricate also, keep up a system of companions for social or expert association. The center utilization of a 'SNS comprises of customized client profiles' (Trusov, Bucklin & Pauwels, 2009). SNSs may enable people to make and keep up social capital on the grounds that the 'specialized what's more, social affordances of SNSs empower communication, and consequently correspondence, inside a bigger system of social associations' (Steinfield, DiMicco, Ellison & Lampe, 2009). SNSs may not increment the quantity of solid ties that individuals have, however the SNS innovation bolsters the arrangement and support of powerless ties, expanding what is known as 'spanning' social capital for its clients (Donath & Boyd, 2004). Putnam (2001) recognized connecting and holding social capital. Crossing over social capital includes free associations or then again powerless ties between people, the thin and unoriginal assume that we create with outsiders we meet through business or social commitment, while holding social capital is portrayed by cozy connections in which enthusiastic help is traded in the setting of thick, multipractical ties that can unite heterogeneous gatherings in important or profitable associations (Pfeil, Arjan & Zaphiris, 2009). In light of this refinement, this examination endeavors to research the connection between Facebook clients' self-frameworks and both crossing over and holding social connections and additionally social capital. Finally it become very challenging for the students to control their time management when using social media (Ghareb & Mohammed, 2015, 2016).

3. QUESTIONNAIRE

We have been design a survey consist of ten questions with two sections first section is about General information, Second section is about using social media behaviors . These questions have been examined and scientifically evaluated before applied and send it to the users. The main objective of this research is to find the effect of social media in family and community relationships. One of the important questions was age of the social media users as it shows in figure 1 the majority if users from age 25 and 35 that use the social media.

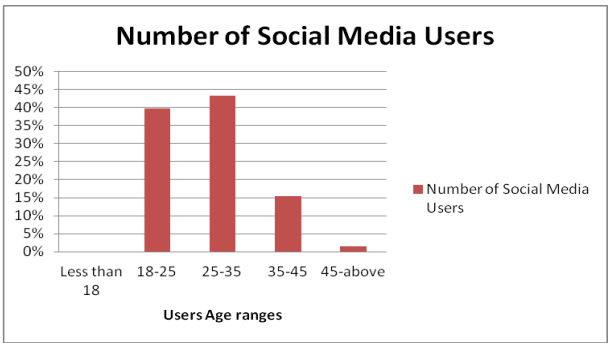


Fig. 1. Numbers of Social Media Users

Second Question was about marital state the majority of users were single as shown in the Figure 2.

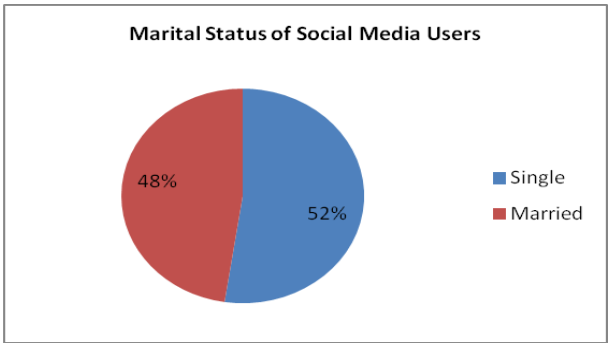


Fig. 2. Marital users of Social Media

In addition of personal information section question we considered the educational level and occupations and place as an important question to measure. The majority of users regarding the survey result have Bachelor degree 66.3% and 20.7% was have Master degree, 6% have Phd degree and 3% have high school degree and 1% has no degree. This results shows that the educational

people most interesting in different activities of social media. Regarding the occupation questions 49% of survey results were employees ad 41% were students and 10% an employee people. These answers indicate that the students spent much so time on it and also the employees because in both case the internet exists in their places. Final question in section one was place the majority of users from Sulaymaniyah city 77% and 11%from Erbil and 6% from halabja and 4% from Dhok and 2% from Kirkuk city, as it is shows in Figure 3. This indicates that there is very fewer people participate in ou survey in other city because the lack of logistics plan we have, but we can reflect on these percentage regarding Sulaymaniyah city answers.

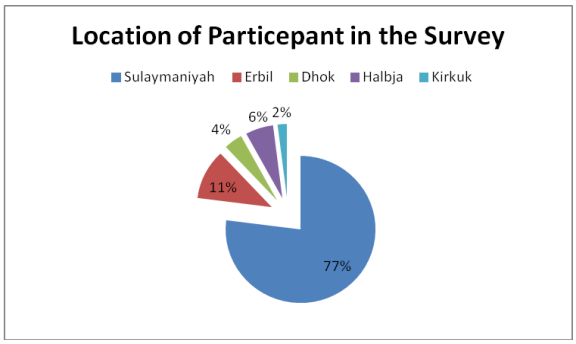


Fig. 3. Locations of Social Media Users

The second Section of the survey was working on using technology and internet and social media. The main aspect how much time you spent on using these technology? What is your main purpose of using social media? For how long you have been active on these activities?

The First Question in section 2 was how long you have use mobile phone the answers were 46% using it for more than 10 years and other answer were between 3–9 years the use mobile phone. The second question was how long you use internet the answers were 51% using for more than 10 years and other answers used between period of 1 and 9 years. Third questions was which device you have used to surf internet and social media the majority answers were mobile phone with 75% then tablet with 25% and Computer with 5%.

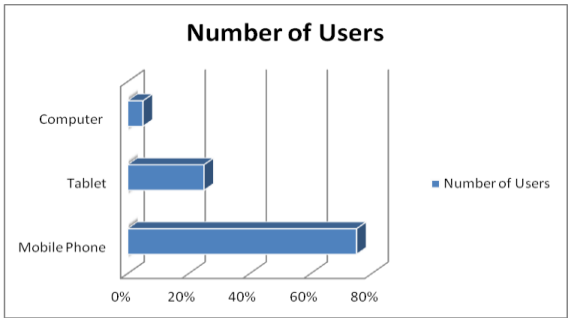


Fig. 4. Device used among Users

The results shows that the mobile phone is smaller in size and weight and become a daily life routine to be with you all the time with these faculties of surfing the social media it will be such very challenging that can manage the time especially with students. Third concern with which most Social media users use the majority used Facebook with 41% then Instagram with 27% and so on. Figure 5 shows the results.

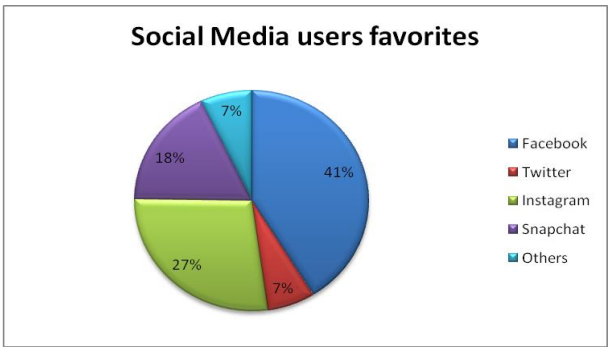


Fig. 5. Social Media users favorites

Forth Question was about what are the purposes of using the social media. The results showed the percentages very closed for reasons use of social media between family bonding and reading and surfing it with 28% and 25% and 24% for following the new, 12 and 11% this is used waiting time on gaming and watching and listen to the music. The results shows how the users spent so much time on do all these activity if not have a plan to control it may addict and wasting so many hours without have any results. Figure 6 shows the results.

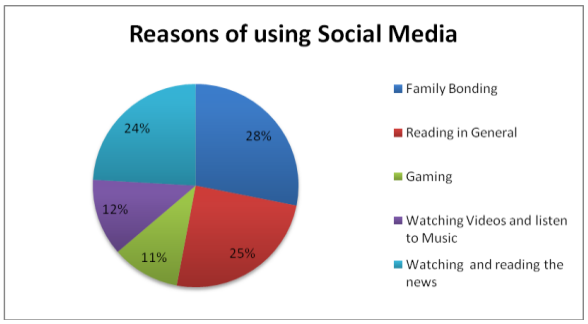


Fig. 6. Reason of Using Social Media

Fifth Question was how to communicate with your family members or relatives by social media or phone call, the 72% answer both way. Sixth Question focused on how much time you spent daily on Social media the average answer was 2–3 and 1–2 hours daily and other answers were between 30 minutes to 5 hours. As it shows in figure 7. This mean the average of using social media is about 1.5 have an hour daily life and if there is no awareness how to use this time it become a very negative aspect of our society.

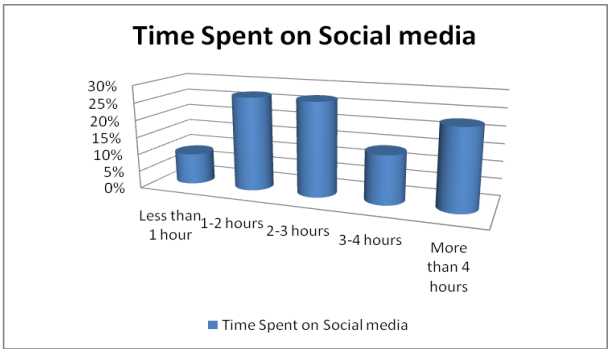


Fig. 7. Times Spent on Social Media

Sixth questions was about spending time communicate with your family member and relatives %35 spent less than 10 minutes and 38% spent half an hour for communication and 17% less than an hour and 10% spent more than one hours. From the results it shows that the communication for family bonding is not so important for majority of users. Final Question was about users opinion regarding social media negatively affect family and relative relationships or not 51% believe it lead to less communication with them and 49% answer the appositive opinion. Figure 8 shows the results.

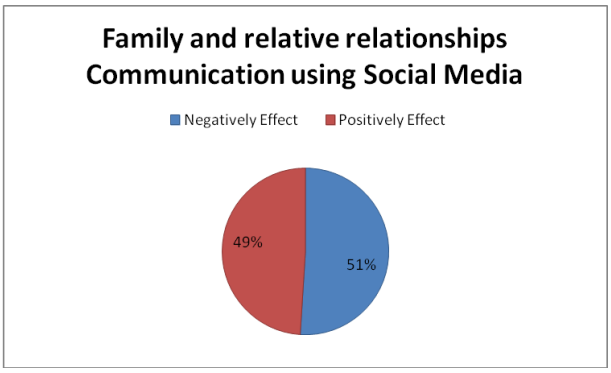


Fig. 8. Reason of Using Social Media

4. CONCLUSION AND RECOMMENDATIONS

Many scientists have explored the importance of correspondence and connections with regards to online SNSs. As of late, a few noteworthy diaries, including the Journal of Computer-Mediated Communication, the International Journal of Advertising, the Journal of Interactive Marketing, and the International Journal of Electronic Commerce have distributed uncommon issues with respect to Internet-based life (on Myspace, Twitter, Cyworld, and other online networks), social capital, and the connection between client conduct and correspondence technologies. In this research we have conducted a survey to investigate the role of social media in family and relative relationships, 254 persons from 5 cities participate in this survey. The survey consists of two sections. First section was about personal information the second section was about the daily time, activities and behaviors of users in Kurdistan includes students, lecturers, employees and ordinary people. The results shows that the users spent 2 hours daily on social media and mostly will use it to reading social media posts and feeds including family bonding. Generally the user believes that the social media has negative impacts on family and relative relationships. Adding more The examination found a noteworthy connection between clients' confidence and crossing over social connections, however, did not locate a comparing

relationship with respect to confidence also, holding social connections. This examination additionally found that clients with bringing down confidence are more drawn in with crossing over social connections than withholding social connections. The power of Facebook utilize assumes a more imperative part in holding social relationship than in crossing over social connections. Clients who tend to utilize Facebook much of the time, particularly when it turns out to be a piece of their day by day schedules, demonstrated an eagerness to shape crossing over social connections and holding social connections. Both spanning and holding social connections interceded the connection between self-frameworks and social capital impacts. Albeit more grounded crossing over social connections is related with the successful social capital building, holding social connections are similarly as emphatically connected with the powerful social capital building.

Acknowledgment

We would like to thank university of Human Development for their usual support for encourage our staff to continue research.

REFERENCES

Al-Dhanhani, A., Mizouni, R., Otrok, H., & Al-Rubaie, A. (2015). Analysis of collaborative learning in social network sites used in education. *Social Network Analysis and Mining*, *5*(1), 65. doi:10.1007/s13278-015-0303-z

Bouraga, S., Jureta, I., & Faulkner, S. (2015). An empirical study of notifications' importance for online social network users. *Social Network Analysis and Mining*, *5*(1), 51. doi:10.1007/s13278-015-0293-x

Boyd, D. M., & Ellison, N. B. (2007). Social network sites: Definition, history, and scholarship. *Journal of computer‐mediated Communication*, *13*(1), 210–230.

Coyle, C., & Vaughn, H. (2008). Social networking: communication revolution or evolution? *Bell Labs Technical Journal*, *13*(2), 13–18. doi:10.1002/bltj.20298

Donath, J., & Boyd, D. (2004). Public displays of connection. *BT technology Journal*, *22*(4), 71–82.

Durden, E. D., Hill, T. D., & Angel, R. J. (2007). Social demands, social supports, and psycho-logical distress among low-income women. *Journal of Social and Personal Relationships*, *24*(3), 343–361.

Ellison, N. B., Steinfield, C., & Lampe, C. (2007). The benefits of Facebook "friends:" Social capital and college students' use of online social network sites. *Journal of Computer–Mediated Communication*, *12*(4), 1143–1168. doi:10.1111/j.1083-6101.2007. 00367.x

Ghareb, M. I., & Mohammed, S. A. (2015). The role of e-learning in producing independent students with critical thinking. *International Journal Of Engineering And Computer Science*, *4*(12).

Ghareb, M. I., & Mohammed, S. A. (2016). The effect of e-learning and the role of new technology at university of human development. *International Journal of Multidisciplinary and Current Research*, *4*, 299–307.

Ghareb, M. I., & Sharif, H. O. (2015). Facebook effect on academic performance and social life for undergraduate students of university of human developments. *International Journal of Multidisciplinary and Current Research*, *3*, 811–820.

Ghareb, M. I., Ahmed, Z. A., & Ameen, A. A. (2018). The Role Of Learning Through Social Network In Higher Education In KRG. *International Journal Of Scientific & Technology Research*, *7*(5), 20–27.

Junco, R. (2015). Student class standing, Facebook use, and academic performance. *Journal of Applied Developmental Psychology*, *36*, 18–29. doi:10.1016/j.appdev.2014.11.001

Kamal, S., & Arefin, M. S. (2015). Impact analysis of facebook in family bonding. *Social Network Analysis and Mining*, *6*(1), 1-14. doi:10.1007/s13278-015-0314-9

Lauricella, A. R., Wartella, E., & Rideout, V. J. (2015). Young children's screen time: The complex role of parent and child factors. *Journal of Applied Developmental Psychology*, *36*, 11–17. doi:10.1016/j.appdev.2014.12.001

Nyland R, Marvez, R., & Beck J. (2007). MySpace: Social networking or social isolation? *Proceedings of the Midwinter Conference of the Association for Education in Journalism and Mass Communication* (23–24 February 2007). Reno, NV, USA.

Pempek, T. A., Yermolayeva, Y. A., & Calvert, S. L. (2009). College students' social networking experiences on Facebook. *Journal of applied developmental psychology*, *30*(3), 227–238. doi:10.1016/j.appdev.2008.12.010

Pfeil, U., Arjan, R., & Zaphiris, P. (2009). Age differences in online social networking–A study of user profiles and the social capital divide among teenagers and older users in MySpace. *Computers in Human Behavior*, *25*(3), 643–654. doi:10.1016/j.chb.2008.08.015

Putnam, R. D. (2001). *Bowling alone: The collapse and revival of American community*. New York, USA: Simon and Schuster.

Steinfield, C., DiMicco, J. M., Ellison, N. B., & Lampe, C. (2009). Bowling online: social networking and social capital within the organization. In *Proceedings of the fourth international conference on Communities and technologies* (pp. 245–254). New York, USA: ACM.

Steinfield, C., Ellison, N. B., & Lampe, C. (2008). Social capital, self-esteem, and use of online social network sites: A longitudinal analysis. *Journal of Applied Developmental Psychology*, *29*(6), 434–445. doi:10.1016/j.appdev.2008.07.002

Trusov, M., Bucklin, R. E., & Pauwels, K. (2009). Effects of word-of-mouth versus traditional marketing: findings from an internet social networking site. *Journal of marketing*, *73*(5), 90–102.

Valenzuela, S., Park, N., & Kee, K. F. (2008). Lessons from Facebook: The effect of social network sites on college students' social capital. In *9th International Symposium on Online Journalism* (pp. 4-5). Austin, Texas: University of Texas.

Valenzuela, S., Park, N., & Kee, K. F. (2009). Is there social capital in a social network site?: Facebook use and college students' life satisfaction, trust, and participation. *Journal of computer-mediated communication*, *14*(4), 875–901. doi:10.1111/j.1083-6101.2009.01474.x

Applied Computer Science, vol. 14, no. 3, pp. 43–53
doi:10.23743/acs-2018-20

Submitted: 2018-04-13
Revised: 2018-05-21
Accepted: 2018-09-03

deep-drawing, finite element method, sheet metal forming

Damian KRASKA[*], *Tomasz TRZEPIECIŃSKI*[*]

FINITE ELEMENT BASED PREDICTION OF DEFORMATION IN SHEET METAL FORMING PROCESS

Abstract

In this paper the sheet forming process of cylindrical drawpieces was simulated based on the finite element method by the explicit approach in the presence of contact conditions with isotropic and anisotropic friction. The experimental and numerical results obtained in the Abaqus finite element (FE) based program are presented. The aim of the experimental study is to analyse material behaviour under deformation and in addition to use the results to verify numerical simulation results. It was found that, although, the anisotropy of resistance to friction affects the height of ears, the influence of the friction formulation is relatively small in comparison with material anisotropy. The study indicates that FE analysis with 3-node triangular shell element S3R elements ensures the best approximation of the numerical results to the real process when both material and friction anisotropy are taken into account.

1. INTRODUCTION

The sheet forming process of complicated shell elements allows the production of thin walled parts. The design and analysis of sheet metal forming operations requires knowledge of the deformation mechanisms, material properties and boundary conditions (Affronti & Merklein, 2018; Hattalli & Srivatsa, 2018). The analytical analysis of the forming process is very complicated due to the strong nonlinear nature of the numerical procedures. For this reason,

[*] Rzeszow University of Technology, Faculty of Mechanical Engineering and Aeronautics, al. Powst. Warszawy 8, 35-959 Rzeszów, tel.: 17865 1714, e-mail: kraska94@gmail.com, tomtrz@prz.edu.pl

numerical modelling based on the finite element method (FEM) is currently a widely used approach because it ensures the simulation of a large number of parameters over a short duration.

The accuracy of the numerical results depends on several parameters including the types of finite mesh, material model of the yield criterion, and boundary conditions. The correctness of the material model and correctness of the experimental determination of material properties are two of the most important elements in modelling of FE data. The type of elements (shell, solid) decides on the representation of the contact conditions with moderate computing time. For the analysis of forming thin walled structures, shell elements are mostly used (Falsafi, Demirci & Silberschmidt, 2016; Ramzi, Sebastien, Fabrice, Gemala & Pierrick, 2017). When a material exhibits anisotropic properties, i.e., the value of the material parameters depends on the orientation according to the rolling direction of the sheet, an incorrect selection of the yield criterion does not reflect the complex material behaviour. The distortion of the yield surface shape due to the microstructural state of the material is named as plastic anisotropy (normal or planar). In planar anisotropy the properties vary with the orientation in the sheet plane. In normal anisotropy the properties differ in the direction of sheet thickness. Various approaches have emerged for developing the anisotropic yield criteria. A review and description of many proposals for anisotropic yield criteria has been prepared by e.g.. Banabic (2010).

In this paper the results of experiments and numerical simulations of forming cylindrical cups are presented. The aim of the experimental study is to analyse the material behaviour under deformation and further use the results to verify numerical simulation results. In FE models, the mesh density, the number of elements and the type of material and the friction model are taken into account.

2. EXPERIMENTAL

2.1. Material

The drawpieces analysed in this paper were manufactured from deep drawing 1-mm-thick steel sheet DC04. The basic mechanical parameters of this material were determined in the uniaxial tensile test according to the procedure described in the PN-EN ISO 6892-1:2010 standard. The specimens for the tensile test were cut at angles of 0°, 45° and 90° with respect to the rolling direction of the sheet metal. The following parameters were determined (Table 1): the ultimate tensile strength R_m, field stress $R_{p0,2}$, elongation A_{50}, strain hardening exponent n, strain hardening coefficient K, and Lankford's (anisotropy) coefficient r. Five specimens were tested for three orientations (0°, 45° and 90°), and the average values of specific parameters were determined.

Tab. 1. Basic mechanical properties of DC04 steel sheet

Sample orientation	$R_{p0.2}$, *MPa*	R_m, *MPa*	A_{50}	*C*, *MPa*	*n*	*r*
0°	176	301	0.42	500	0.19	1.81
45°	180	293	0.39	497	0.17	1.88
90°	192	315	0.41	477	0.17	1.4

2.2. Method

The cylindrical drawpieces were fabricated using a special device shown in Fig. 1. The drawpieces were formed from discs with diameters of 56 mm. To prevent wrinkling of the drawpiece flange, a blankholder was applied. In the stamp-ing tool, the blankholder pressure is forced by screwing the pressure plate onto the body using a torque wrench. An increase of moment at the torque wrench at about M = 15 Nm causes an increase of normal pressure force at P_{bd} = 1 kN. The diameter of the cylindrical punch is 29.3 mm. The diameter of the hole in the die is 32.3 mm. The edges of die and punch were rounded with a radius of 3 mm. The complete drawing operation was conducted using the hydraulic test machine at room temperature.

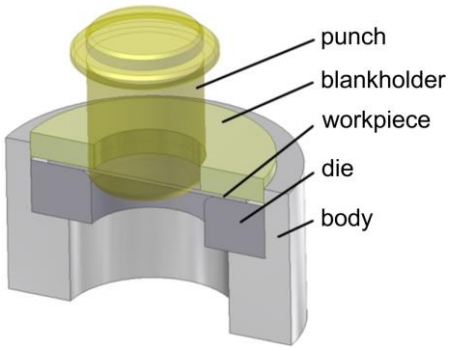


Fig. 1. Schematic of stamping tool

The results of numerical modelling were verified on the basis of measurements of the wall thickness of the drawpieces in characteristic locations (Fig. 2a). The drawpieces were cut along the rolling direction of the sheet using a mechanical metal saw (to minimise the influence of heat on the cross-sectional structure of the material). Then the cutting surface was ground using sandpaper with P80, P200, P800 and P2000 grains. The measurement of wall thickness of the drawpieces based on the sectional photos of thickness variation (Fig. 2b) made by Alicona's InfiniteFocusG4.

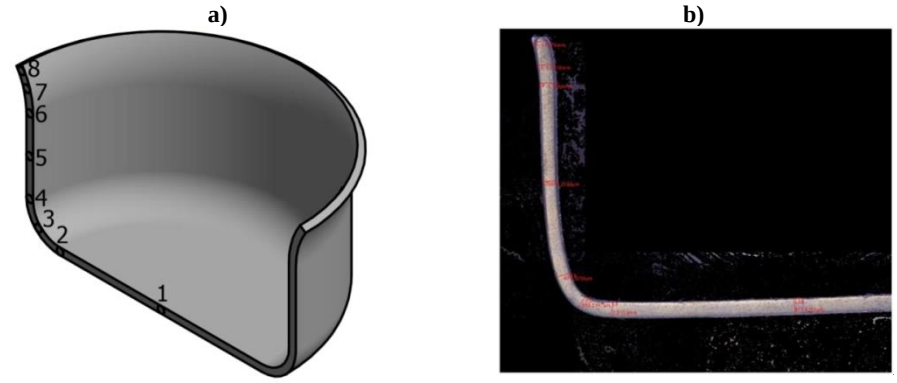


Fig. 2. a) The location of the characteristic locations for detection of thickness measurements and b) an typical picture of drawpiece section

3. NUMERICAL MODELING

A 3D numerical model of the drawpiece forming was built in Abaqus 6.14-5 finite element code used for the computer aided analysis of sheet metal forming processes (Li et al., 2017; Trzepieciński & Gelgele, 2011). The geometry of the tools and sheet in the numerical simulation (Fig. 3) corresponds to the experimental setup shown in Fig. 1.

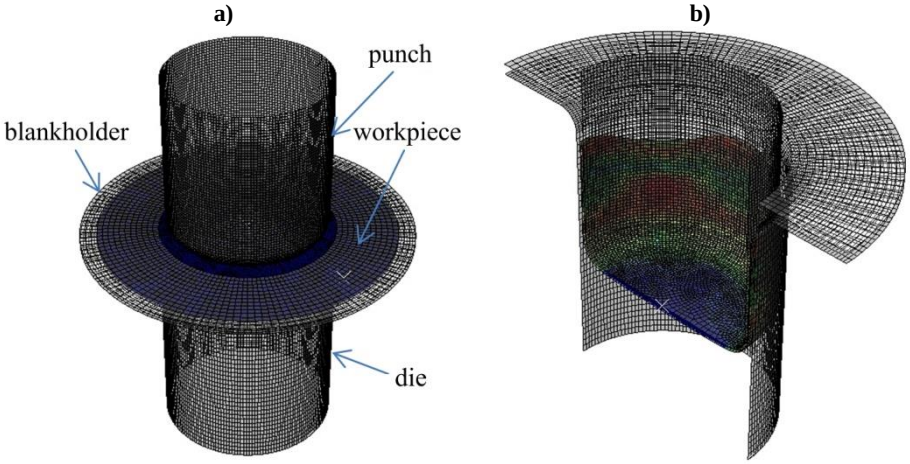


Fig. 3. Numerical model of the stamping process: a) initial stage and b) final stage of forming

The surface of tools was discretised using 4-node bilinear rigid quadrilateral R3D4 shell elements. To find the optimal parameters of the numerical model, the following parameters were considered:

- mesh density: 4475, 11160, 30876 elements,
- element type: S3R, S4, S4R, S4RS,
- material model: isotropic, anisotropic,
- friction model: isotropic, anisotropic.

An elastic-plastic material model approach was implemented and two material models have been simulated. In the case of the first isotropic material behaviour approach the von Mises yield criterion (von Mises, 1913) is used. In the second numerical model, the anisotropy of the material has been established using Hill's (1948) yield criterion which is commonly used for the material description of steel sheet metals. The Hill (1948) formulation is an extension of the isotropic von Mises function, and can be expressed in terms of rectangular Cartesian stress components as:

$$\bar{\sigma} = \sqrt{F(\sigma_{22} - \sigma_{33})^2 + G(\sigma_{33} - \sigma_{11})^2 + H(\sigma_{11} - \sigma_{22})^2 + 2L{\sigma_{23}}^2 + 2M{\sigma_{31}}^2 + 2N{\sigma_{12}}^2} \quad (1)$$

where $\bar{\sigma}$ is the equivalent stress, and indics 1, 2, 3 represent the rolling, transverse and normal directions to the sheet surface. The constants F, G, H, L, M and N define the anisotropic state of the material and are equal to:

$$F = \frac{1}{2}\left(\frac{1}{{R_{22}}^2} + \frac{1}{{R_{33}}^2} - \frac{1}{{R_{11}}^2}\right),\ G = \frac{1}{2}\left(\frac{1}{{R_{11}}^2} + \frac{1}{{R_{33}}^2} - \frac{1}{{R_{22}}^2}\right),\ H = \frac{1}{2}\left(\frac{1}{{R_{11}}^2} + \frac{1}{{R_{22}}^2} - \frac{1}{{R_{33}}^2}\right),$$
$$L = \frac{3}{2{R_{23}}^2},\ M = \frac{3}{2{R_{13}}^2},\ N = \frac{3}{2{R_{12}}^2} \quad (2)$$

The parameters R_{11}, R_{22}, R_{33}, are defined in ABAQUS from user input consisting of ratios of yield stress in different directions with respect to a reference stress. The elastic properties of the sheet are specified using the following properties: Young's modulus: E = 2.1 GPa, Poisson's ratio ν = 0.3. The mass density was ρ = 7860 kg·m^{-3}. The isotropic hardening behaviour implemented in the numerical model uses the Hollomon power-type law:

$$\sigma = K\varphi^n \quad (3)$$

with the parameters specified in Table 1.

Five integration points through the thickness direction are employed. This number of integration points through the shell thickness is sufficient for an acceptable solution (Larsson, 2009). The *explicit* direct integration available from Abaqus is used in the model to handle nonlinearity from large displacements, material non-linearity and boundary non-linearity such as contact, sliding and friction.

In the *explicit* procedure, the displacements, velocities and accelerations of each node are advanced explicitly through time. This means that the state of the model at the end of time $t+\Delta t$ is solely based on the displacements, velocities and accelerations at the beginning of time t.

To describe the contact conditions between sheet and tools, the classical friction model following Coulomb's law is assumed, in which the relationship between frictional stresses τ and normal stresses σ may be expressed as:

$$\tau = \mu\sigma \tag{4}$$

The anisotropic elliptical friction model was implemented by specifying different friction coefficients in the two orthogonal directions on the contact surface. To use an anisotropic friction model built in Abaqus, the two friction coefficients (0.12 and 0.15) were specified. The methodology and device for determination anisotropic friction coefficient have been described in the previous paper of authors (Trzepieciński & Gelgele, 2011). In the isotropic friction model, the average friction coefficient 0.135 was specified.

3. RESULTS AND DISCUSSION

As regards the effect of the type of finite element on the accuracy of predicting the thickness changes of the drawpiece wall (Fig. 2a), the best approximation of experimental data was observed for elements of the S3R type (Fig. 4). The smallest value of the errors of thickness prediction is observed on the upper edge of the drawpiece (point 8 in Fig. 4). The sheet thickness distributions presented in Fig. 4 relate to a drawpiece formed from a disc with a diameter of 56 mm.

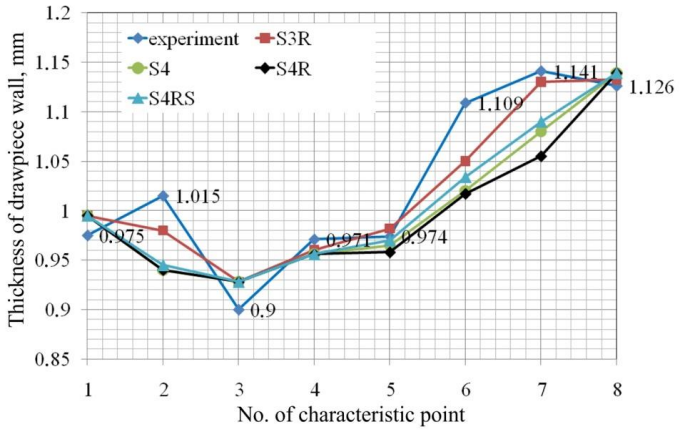


Fig. 4. Distribution of wall thickness of a cylindrical drawpiece along the sheet rolling direction

The type of finite element has a significant effect in determining the duration of the calculation. The calculation time for a model containing the elements of S4 type is almost five times greater than for the simulation of a blank model discretised with the elements of the S3R type (Fig. 5). The distributions of wall thickness of the drawpieces shown in Fig 6, indicate that although the type of element significantly affects the calculation time, both the distribution, the value of the maximum wall thickness and its location of occurrence, according to Fig. 2a, are very similar for the types of elements analysed.

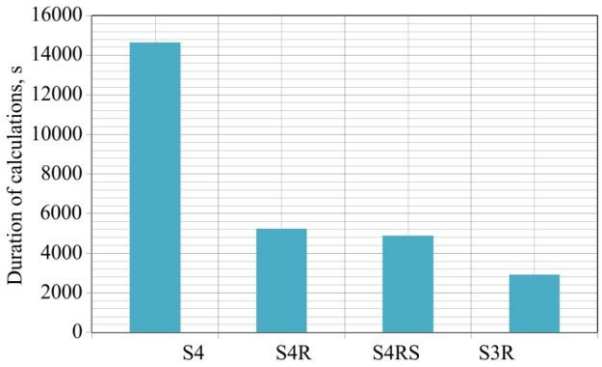


Fig. 5. Duration of calculation for specific types of finite elements

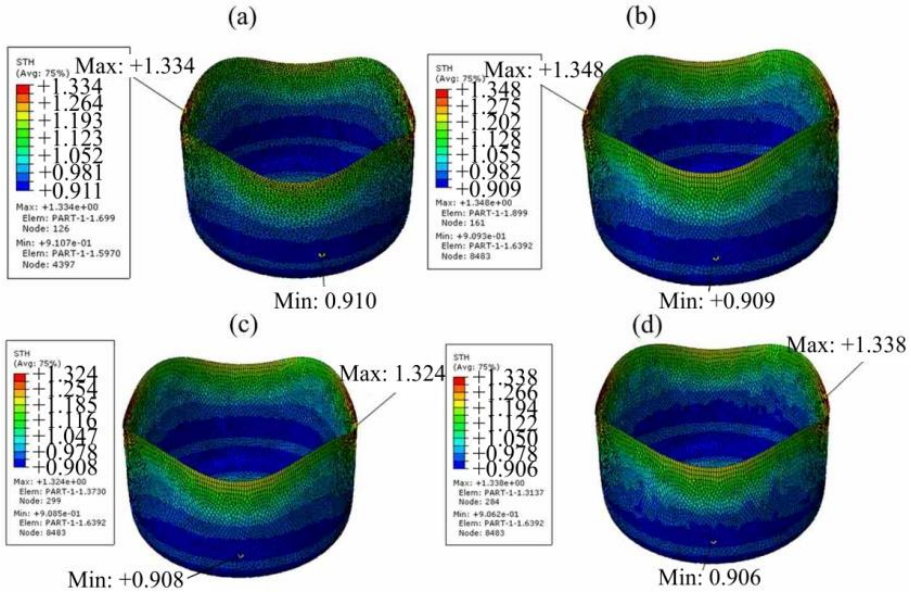


Fig. 6. Distribution of wall thickness of a drawpiece in relation to element type: a) S3R b) S4 c) S4R d) S4RS

As previously shown, the best approximation of experimental data is ensured by the use of S3R type elements, for which an analysis was performed which examined the impact of the material model and the friction model on the change of the wall thickness distribution (Fig. 7). Taking the isotropic properties of the material in the numerical model into account in combination with both models of friction causes a significant overestimation of the wall thickness of the drawpiece in the area of the flange (Fig. 7). The best adaptation of the numerical data to the experimental data is clearly visible for (i) the zone of the cylindrical side wall, (ii) the edge of the drawpiece and (iii) the point located in the middle of the bottom of the drawpiece.

The best prediction of the maximum force of drawpiece forming in comparison with the experimentally recorded data (26.5 kN) provides a numerical model which takes into account the anisotropy of the material and the isotropy of changes in the coefficient of friction (Fig. 8).

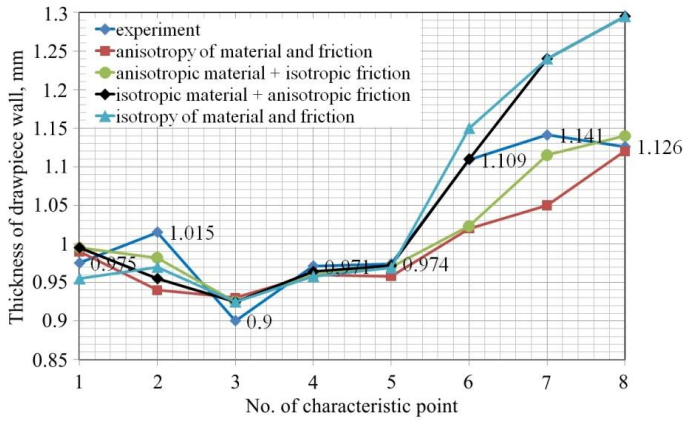


Fig. 7. Effect of both the material and friction model on the distribution of the thickness of an axisymmetric drawpiece

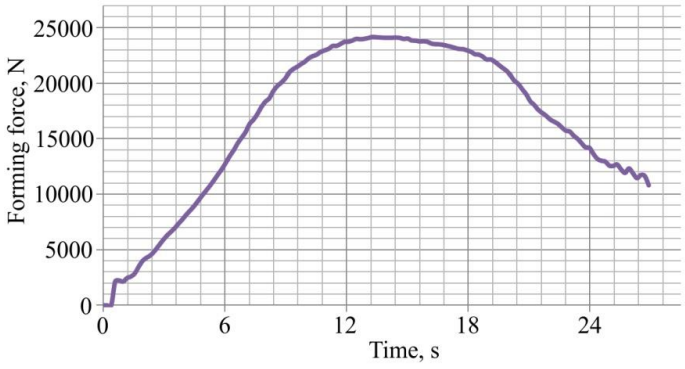


Fig. 8. Distribution of the forming force for an anisotropic model of the material and isotropy of friction

The material model adopted (isotropic, anisotropic) has a crucial influence on the value of the forming force. Additional consideration of the nature of changes in the coefficient of friction (isotropy, anisotropy) affects the change in the value of the forming force to lesser extent. Taking into account the anisotropy of both factors studied (friction and material) requires more computing power and is the most time consuming. (Fig. 9).

Material anisotropy is the decisive factor from the point of view of the ability to simulate the formation of the drawpiece ears (Fig. 10).

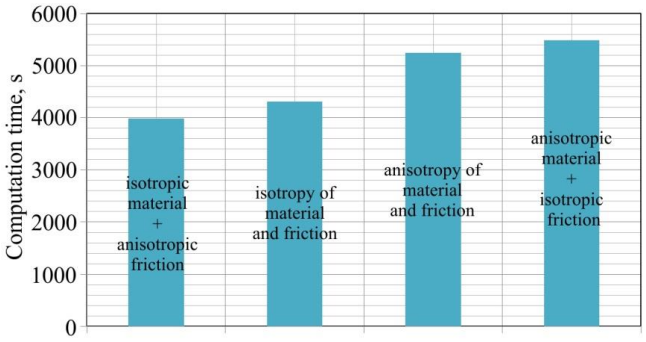


Fig. 9. Effect of friction and material model configurations on the computation time

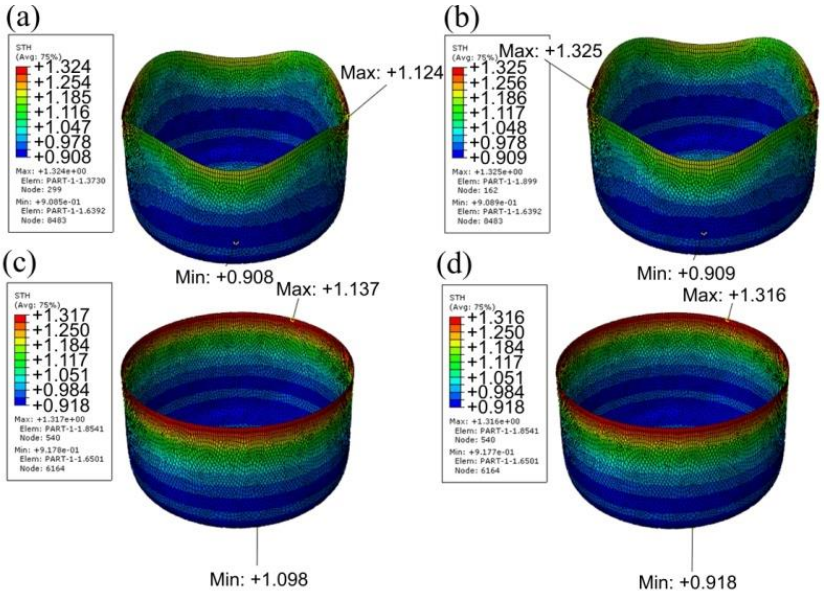


Fig. 10. The distribution of wall thickness of a cylindrical drawpiece under different modelling strategies: (a) anisotropy of both material and friction, (b) anisotropy of material and isotropy of friction, (c) isotropic material and frictional anisotropy, (d) isotropy of both material and friction

The assumption of an anisotropic friction model, coupled with the isotropic model of the material, does not provide an accurate prediction of material flow consistent with the experiment. The height of the drawpiece is very similar on the perimeter of the cup. Therefore, it can be concluded that the assumption of an anisotropic model of the material with frictional isotropy is a more correct solution than the inverse situation that takes into account the isotropic model of the material with frictional anisotropy.

3. SUMMARY AND CONCLUSIONS

The analysis of sheet metal forming requires the taking into account of non-linear phenomena, i.e. material non-linearity including the strain hardening phenomenon, and boundary conditions. The investigations of many research projects are focused on a suitable selection of the material model. However, the research on forming cylindrical cups presented in this paper confirms that to accurately predict the material flow, frictional anisotropy should be also taken into account. Although, the anisotropy of resistance to friction affects the height of ears, the influence of the friction formulation is relatively small in comparison with material anisotropy. An explicit procedure used to handle nonlinearity from large displacements, material non-linearity and boundary non-linearity shows that a large-strain 3-node triangular shell element S3R, which is a degenerated version of an S4R shell element, ensures the best prediction of the thickness of the drawpiece wall. In the future, analysis will be carried out of the prediction of material flow of different anisotropic materials and friction models.

REFERENCES

Affronti, E., & Merklein, M. (2018). Analysis of the bending effects and the biaxial pre-straining in sheet metal stretch forming processes for the determination of the forming limits. *International Journal of Mechanical Sciences, 138–139,* 295–309. doi:10.1016/j.ijmecsci.2018.02.024

Banabic, D. (2010). S*heet metal forming processes. Constitutive modelling and numerical simulation*. Berlin Heidelberg: Springer-Verlag.

Falsafi, J., Demirci, E., & Silberschmidt, V. V. (2016). Computational assessment of residual formability in sheet metal forming processes for sustainable recycling. *International Journal of Mechanical Sciences*, *119*, 187–196. doi:10.1016/j.ijmecsci.2016.10.013

Hattalli, V. L., & Srivatsa, S. R. (2018). Sheet metal forming processes – recent technological advances. *Materials Today – Proceedings*, *5*(1), 2564–2574. doi:10.1016/j.matpr.2017.11. 040

Hill, R. (1948). A theory of the yielding and plastic flow of anisotropic metals. *Proceedings of the Royal Society A, 193,* 281–297. doi:10.1098/rspa.1948.0045

Larsson, M. (2009). Computational characterization of drawbeads: A basic modelling method for data generation. *Journal of Materials Processing Technology*, *209*(1), 376–386. doi:10.1016/ j.jmatprotec.2008.02.009

Li, P., He, J., Liu, Q., Yang, M., Wang, Q., Yuan, Q., & Li, Y. (2017). Evaluation of forming forces in ultrasonic incremental sheet metal forming. *Aerospace Science and Technology*, *63*, 132–139. doi:10.1016/j.ast.2016.12.028

Ramzi, B. H., Sebastien, T., Fabrice, R., Gemala, H., & Pierrick, M. (2017). Numerical prediction of the forming limit diagrams of thin sheet metal using SPIF tests. *Procedia Engineering*, *183*, 113–118. doi:10.1016/j.proeng.2017.04.029

Trzepieciński, T., & Gelgele, H. L. (2011). Investigation of anisotropy problems in sheet metal forming using finite element method. *International Journal of Material Forming*, *4*(4), 357–369. doi:10.1007/s12289-010-0994-7

von Mises, R. (1913). Mechanik der festen Kö¨rper im plastisch deformablen Zustand. *Nachrichten von der Köngl. Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-Physikalische Klasse 1913*, 582–592.

Applied Computer Science, vol. 14, no. 3, pp. 54–68
doi:10.23743/acs-2018-21

Submitted: 2018-08-05
Revised: 2018-09-05
Accepted: 2018-09-20

Simulation, injection, mold, medical industry

Sebastian BIAŁASZ[*]

INJECTION SIMULATION FOR THE MOLD PROCESS IN THE MEDICAL INDUSTRY

Abstract

This paper presents information on the methods of construction and selection of materials, for the manufacturing of a medical device – a syringe filter. The main scope of the research was numerical simulation made in order to optimize the injection process. This simulation comprised of two parts: the first in which the chosen optimal number and position of injection points on the surface, and a second with the chosen optimum wall thickness, using a pre-selected injection points.

1. INTRODUCTION

In medicine industry, there are plenty of products made using polymer processing methods (Kołtowska & Klepka, 2015; Canal, Sanchis & Vicent, 2011; Olędzka, Sobczak & Kołodziejski, 2007; Sikora, 2006; Sikora, 1993). An example of the product is a filter for separating solid contaminants from liquids applied with a medical syringe.

To prepared a filter, it is necessary to use methods of polymers processing in order to obtain the upper and lower housing as well as the connecting ring. For this purpose, the methods of precision injection with welding, overmolding or injection molding are recommended.

Currently known constructional solutions are made on the basis of patent application (Shick & King, 2012). An exemplary syringe filter is shown in Figure 1.

[*] Department of Polymer Processing, Mechanical Engineering Faculty, Lublin University of Technology, sebastian.bialasz@gmail.com

Fig. 1. A syringe filter

2. CHARACTERISTICS OF POLYMER MATERIALS FOR MEDICAL APPLICATIONS

Polymeric materials have been used in medicine since the beginning of the 19th century. An example of one of the first applications are galital hammers for neurological tests, as well as subsequent bakelite stethoscopes, or the use of celluloid to replenish bone defects in the skull. Polymer plastics to a large extent exceed the percentage of used materials for the manufacture of pharmaceutical packaging, which in 2006 was 67% of all materials used. Due to the ease of processing and the price of both materials and processing technology, polymeric materials are increasingly used for the manufacture of medical devices, such as, for example, syringes, disposable gloves, drains and parts of diagnostic machines. The most commonly used polymeric materials in medicine are: polyvinyl chloride (PVC), polypropylene (PP), polyethylene (PE) and polyamide (PA) (fig. 2) (Garbacz & Sikora, 2012; Harper, 2006; Jachowicz & Klepka, 2012; Pielichowski & Pruszyński, 1998).

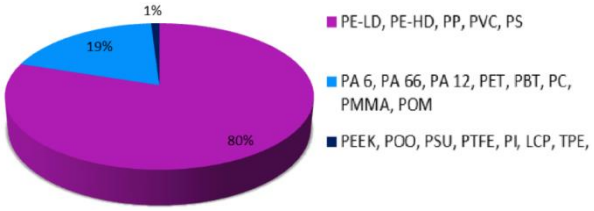


Fig. 2. Percentage of polymeric materials used in medicine

Due to the specificity of the industry, which is medicine, the materials used in it must meet a large number of properties, such as: sterility, biocompatibility or chemical resistance. One of the most important features of this type of products is sterility. The material must display good resistance to sterilizing agents, so that the shape of the product is not deformed, toxic substances are not released or the material

does not disintegrate. Table 1 shows the susceptibility of selected polymer materials to sterilization and compliance with applicable standards (Tadmor & Gogos, 2006).

Tab. 1. The susceptibility of some technical polymer materials used in medicine for sterilization and applicable standards.

Type of mat.	Sterilization methods			Compliance with standards	
	C_2H_4O	Steam	γ rad.	C_3H_7NO	Biocompatibility
POM	yes	yes	no	yes	ISO 10993-1
PBT	yes	once	yes	yes	ISO 10993-1
TPE	yes	once	yes	yes	ISO 10993-1
LCP	yes	once	yes	yes	ISO 10993-1
COC	yes	once	yes	yes	ISO 10993-1
PE-UHMW	yes	yes	yes	yes	ISO 10993-1

For the needs of medicine, many materials have been developed, dedicated to manufacturing products for various applications. The disadvantage of polypropylenes is the lack of radiation resistance required for some products for medicine. Under the influence of the fast electron beam during the sterilization, a radiolysis process takes place, i.e. radicals are formed as a result of detachment (elimination) of the electron at the weakest point of the polymer chain. In the case of polypropylene, as a result of this process, the chain breaks (degradation) and the small-molecule chemical compounds capable of migrating to water and other liquid systems form. Accordingly, modified materials are developed that have improved radiation resistance. An example of such a material is PP-Mod (Bojarski & Zimek, 1997). The basic ingredient of the PP-Mod composition is polypropylene homopolymer, Malen P J601 (so-called medical). It accounts for 80% of the content of the composition. An important addition is also poly (propylene-co-ethylene) copolymer, Malen P J330 characterized by increased resistance, which acts as an internal protective effect in this composition. Additionally, the poly (ethylene-co-vinyl acetate) copolymer, Eseorene UL00115, is resistant to radiolysis below 60 kGy, which in addition to the additional protective effect allows for even distribution of ingredients in the composition (the so-called dispersion process) (Grabowska, 2010; Kołtowska & Klepka, 2015; Olędzka, Sobczak & Kołodziejski, 2007; Rabek, 2008).

Available polymer materials can be modified depending on specific requirements. The manufactured plastic compositions can be checked for the required properties using methods such as, for example, electron paramagnetic resonance (EPR) (Ananthanarayanan, 2009; Beaumont, 2004; Beaumont, Nagel & Sherman, 2002; Kazmer, 2007; Knights, 2007).

3. NUMERICAL SIMULATION IN THE PROCESSING OF POLYMERIC MATERIALS

Nowadays, the entire manufacturing process is more and more often integrated with computer processing CAE (Computer-Aided Engineering). Thanks to such methods, there is a possibility of eliminating errors in later stages of production, already at the design level of a given product or process. One of the functions of computer-aided production is the possibility of computer simulations. The most popular software for simulating the injection process is: MOLDFLOW, CAD-MOULD, MOLDEX3D and VISI-Flow.

Due to the fact that most of the defects of molds are the result of construction errors of the injection mold in connection with the product's geometry, it is reasonable to use numerical simulations at the design stage. The use of injection molding simulation offers a multitude of benefits that are presented in table 2.11. (Fathi & Behravesh, 2004; Nabiałek & Koszkul, 2007; Sykutera, 2012; Wilczynski, 1999).

Tab. 2. Benefits of using numerical simulation.

QUALITY	ECONOMY
obtaining information about phenomena occurring during solidification of the compact inside the socket	reduction of prototyping costs and preparation of the so-called first injection
determining the kinetics of nest filling (pressure gradient, temperature)	reduction of time from the first steps related to the construction of the model to the first molding or extrudate
marking the level of stress arising inside the nest	material saving
indication of critical areas from the point of view of filling the nest	optimization of the injection process – shorter cycle time
indication of air traps together with the markings of the line connecting the streams of the material with the temperature given during the connection	reducing the amount of defective parts by indicating critical places in the volume of moldings
determination of the contraction distribution and deformation of the compact	precise cost estimation
estimation of the level of tangential stresses arising during the nest filling	reducing the costs of tool design

4. PROGRAM AND RESEARCH OBJECT

The aim of the research was to select the number and position of injection points and the appropriate wall thickness of the upper and lower housing of the syringe filter, shown in Figure 3, by performing a numerical simulation of the injection process.

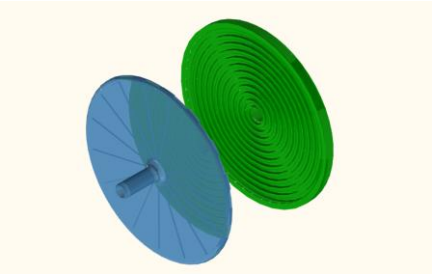


Fig. 3. The design of the syringe filter (exploded view)

The research program included the determination of injection points and the optimal wall thickness of the syringe filter. Fixed, variable and interfering factors are summarized in Table 3.

Tab. 2. Benefits of using numerical simulation.

FIXED FACTORS	
TYPE	***PARAMETER***
Geometric structure	*Construction*
Production technology	*Precision injection*
Material	*Polypropylene modified*
Injection parameters	*Suitable for selected mat.*
VARIABLE FACTORS	
TYPE	***PARAMETER***
Position and number of injection points (Figure 5)	*a) 1 point axially* *b) 2 points radially outward* *c) 2 points radially - bottom* *d) 3 axial-radial points* *e) 2 points in the middle*
Wall thickness (Figure 6)	*I: Normal; II. Bold; III. Thinned*
INTERFERING FACTORS	
All material data is missing	
Inaccuracy of mesh mesh approximation	

5. RESEARCH AND TESTS

5.1. Selection of injection simulation parameters

After checking the accuracy of the mesh geometry, the parameters for the selected material (PP-Mod), such as the plasticizing temperature, the wall temperature or the mold removal temperature, were selected. In addition, an injection pressure simulation was set in order to ensure a more accurate reproduction of the compact. The following is a p-V-T diagram for the selected PP-Mod material (Fig. 4).

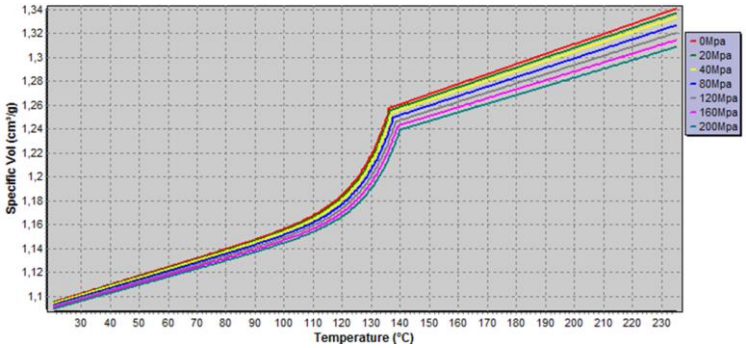


Fig. 4. Diagram p-V-T for PP-Mod plastic

Simulation parameters were used to perform the simulation, differing (by +10%) from the catalogs, recommended by the manufacturer, in order to make a better quality molding with complex and small-sized surfaces.

5.2. Selection of injection points

The selection of the best location and number of injection points was obtained as a result of five simulations. They differed in terms of the number and position of these points on the surface of the molding. The exact location of injection points is shown in Figure 5 (Nabiałek & Koszkul, 2007).

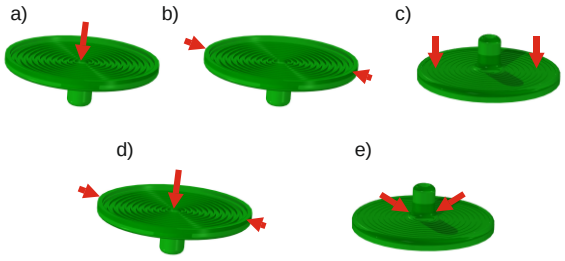


Fig. 5. Location of injection points

The first distribution of the injection point (a) is found in the center of the molding (x = 0, y = 0, z = 1.9), in order to obtain equal flow of material over the entire surface.

The second variant of the position of the injection points (b) was selected symmetrically on the diameter of the compact (I: x = 30, y = 0, z = 2, II: x = 30, y = 0, z = 2), due to the ease of bringing inlet channels with gates and symmetrical flow path of the material.

The third solution (c) is the arrangement of points symmetrically over a smaller radius, from the bottom of the molding, due to the symmetrical flow of the material (I: x = 20, y = 0, z = 0; II: x = -20, y = 0, z = 0).

The fourth option (d) is a combination of variant a and b (I: x = 30, y = 0, z = 2; II: x = -30, y = 0, z = 2; III: x = 0, y = 0, z = 1.9), designed to provide a symmetrical flow path for the material, easy to obtain supply of inlet channels with gates and faster feeding of the material to the middle parts of the compact.

The last solution (e) is to determine the injection points in place of the largest wall thickness on the compact (I: x = 0, y = 2.67, z = -0,125; II: x = 0, y = -2.67, z = -0.125) (Malloy, 1994).

5.3. Selection of wall thickness of the housing

The optimal solution of the position and number of injection points obtained was used to simulate the selection of the wall thickness. Simulation of the wall thickness selection was carried out for three structural solutions of the lower and upper part of the syringe filter.

The thickness of the wall was modified by adding or subtracting the thickness of the bottom wall of the compact (so-called addition and subtraction of the shell). The measured (modified) dimension is shown in Figure 6.

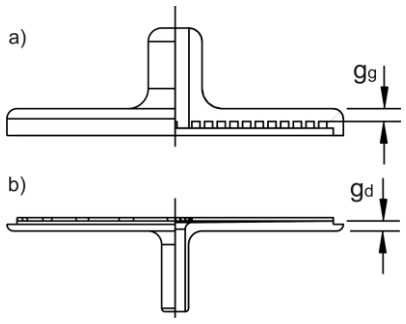


Fig. 6. Thickness of the wall at the point g: a) top cover (g_g), b) bottom cover (g_d)

The first wall thickness, called normal, was determined on the basis of the constructor's knowledge, the specification of the patented filter and general knowledge about the processing of polymer materials, and was for the upper part of g_g = 1.9 mm, and for the lower g_d = 1.5 mm.

In order to obtain the second version of the filter construction, the wall thickness was increased by 1 mm for both parts of the filter. Increasing the wall thickness, in principle, is supposed to have an impact on reducing the deformation of the compact, occurring at the thin walls. Hypothetically increasing the wall thickness, however, affects the greater value of local shrinkage.

The third structure was created by lowering the wall thickness by 1 mm for the upper part and 0.5 mm for the lower part, in relation to the "normal" thickness. The use of this treatment was to help eliminate shrinkage, reduce injection time and pressure drops. The occurrence of stagnation of the material during the flow could have negative impact on deformation of the compact in place of thin walls.

Table 4 shows the obtained wall thicknesses.

Tab. 4. Thick walls of the cover used during numerical simulation

Cover / thickness	***Normal***	***Bold***	***Thinned***
Top cover (g_g)	*1.9 mm*	*2.9 mm*	*0.9 mm*
Bottom cover (g_d)	*1.5 mm*	*2.5 mm*	*1.0 mm*

6. RESULTS AND DISCUSSION

Performing a numerical injection simulation enabled obtaining information on the flow path of the material, shrinkage strains (sags), temperature distribution of the plastic stream face, pressure distribution, time of plastic welding, sinks, problems with plastic distribution, etc.

In the case of the simulation of the selection of injection points, the following results are shown in Tables 5-9 (points a,b,c,d,e from Figure 5):

Tab. 5. Simulation calculation results for injection points a)

Filling problems	0.0 [%]
Min. FF Temp.	230.4 [°C]
Max. FF Temp.	250.4 [°C]
Max. Pressure	91.2 [bar]
Warnings	Sink marks may occur

Tab. 6. Simulation calculation results for injection points b)

Filling problems	0.0 [%]
Min. FF Temp.	233.3 [°C]
Max. FF Temp.	250.0 [°C]
Max. Pressure	94.2 [bar]
Warnings	Sink marks may occur

Tab. 7. Simulation calculation results for injection points c)

Filling problems	0.0 [%]
Min. FF Temp.	230.7 [°C]
Max. FF Temp.	250.4 [°C]
Max. Pressure	66.3 [bar]
Warnings	Sink marks may occur

Tab. 8. Simulation calculation results for injection points d)

Filling problems	0.0 [%]
Min. FF Temp.	185.7 [°C]
Max. FF Temp.	250.4 [°C]
Max. Pressure	63.8 [bar]
Warnings	Sink marks may occur May lead to surface defects

Tab. 9. Simulation calculation results for injection points e)

Filling problems	0.0 [%]
Min. FF Temp.	229.6 [°C]
Max. FF Temp.	250.1 [°C]
Max. Pressure	75.7 [bar]
Warnings	Sink marks may occur

The distribution of shrinkage strains, pressure drops, collapses, etc., was additionally depicted on the simulation, using a scale with colors, which allowed to determine the number and distribution of these parameters. Shrinkage deformations during simulation a) are shown in Figure 7.

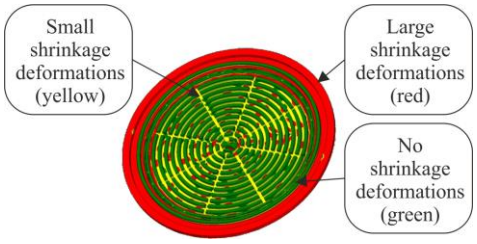


Fig. 7. Shrinkage deformations during simulation (points a))

To simulation of the wall thickness, the arrangement of injection points b) was chosen, i.e. two injection points radially outward (fig.8).

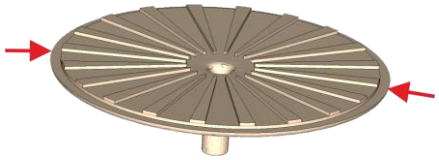


Fig. 8. Injection points for wall thickness simulation

The simulations carried out allowed to obtain the following data contained in table 10.

Tab. 10. Simulation results of wall thickness selection

	Bottom cover			**Top cover**		
	Normal	Bold	Thinned	Normal	Bold	Thinned
Filling problems [%]	10	15	0	0	0	0
Min. FF Temp. [°C]	142.7	152.3	132.4	2160	175.9	215.9
Max. FF Temp. [°C]	210.2	240.7	240.2	240.0	240.0	240.0
Max. Pressure [bar]	400.8	226.8	252.7	25.2	12.6	84.2
Sink marks [%]	120.9	364	91.3	0	0.3	9.8

Figure 9 shows a graph of the number of wall inclusions in each injection simulation, for a normal, thickened and thinned wall, an upper housing and a lower syringe filter. Figure 10 shown a graph the problem of filling the seat with plastic during the simulation of the down cover (for the up cover the value was equal to zero for all three wall thicknesses).

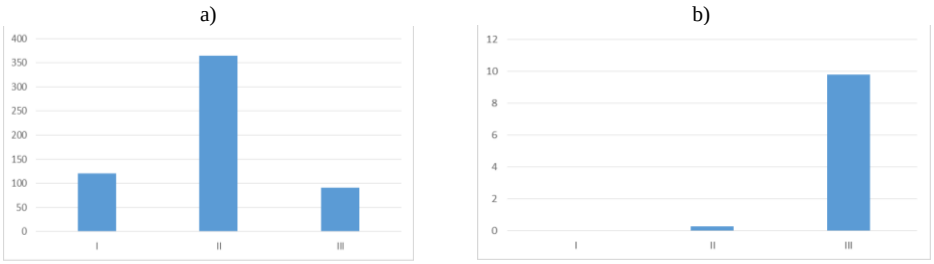


Fig. 9. Graph of wall collapse values: a) bottom cover, b) top cover, for three wall thicknesses: I – normal, II – bold, III – thinned

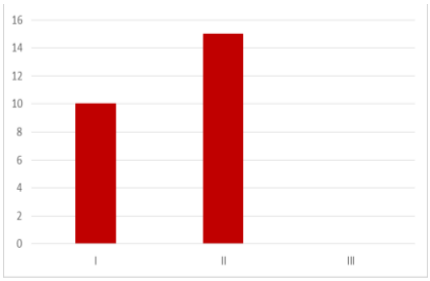


Fig. 10. Problem with filling the seat with plastic during simulation of injection of the bottom cover of the syringe filter: I – wall normal, II – bold wall, III – thinned wall

The results of the simulation also provided information about a possible problem with filling the mold cavity in the case of normal wall and bold lower housing, possible occurrence of surface collapse for all types of walls of the lower housing and walls of the thinned upper housing, possible surface deformations due to insufficient wall temperature during injection for all the walls of the lower and upper housing, and the maximum shear rate exceeding 200,000 [1/s] for the wall of the thickened lower base and the wall of the thinned upper housing. All these errors are only hypothetical and do not have to occur in physical processing conditions.

Conducting the simulation gave the opportunity to visualize individual behaviors (parameters) during the injection process. On the basis of these images, one could learn about problems that arose during numerical simulation. The image results of the injection simulation process are presented in Figures 11.

In addition, it was possible to get an image of the order of flow of the material in time, or the temperature distribution of the plastic stream during the injection. Moreover, the simulation of the injection allowed to obtain such data as the injection pressure in time, the place of stagnation of the material during injection, the flow directions of the material, the plastic flow path and others.

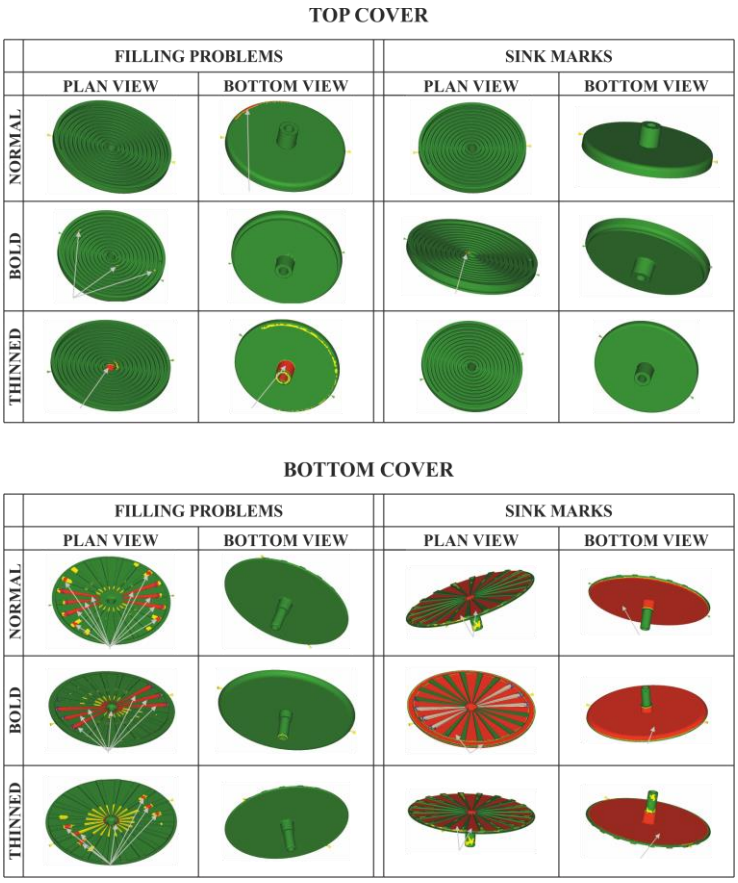


Fig. 11. Results of the injection simulation process (green = no problems, yellow = medium problems, red = big problems)

7. SUMMARY AND CONCLUSIONS

Methods for producing a syringe filter

The filter housings should be made of plastic used for medical applications, free of harmful contaminants. For the production of these parts, modified polypropylene (PP-Mod), radiation-resistant in medical quality (Zimek, Bułhak, Bojarski, Mirkowski & Stachowicz, 1992), obtained as a result of combining Malen P J601 polypropylene (80% of total content), poly (propylene-co-ethylene copolymer)) with the designation Malen P J330 and copolymer poly) ethylene-co-vinyl acetate) with the designation Escorene UL00115, with the addition of an amide lubricant, also used to manufacture syringes (in accordance with PN-EN ISO 7886-1: 2000).

The coupling ring of the housing can be made of polypropylene (e.g. Malen P J601) or high density polyethylene. Due to the processing properties, however, the use of polypropylene is recommended (in order to optimally connect to the casings).

The filter material is supplied by an external manufacturer, due wide range of variations of this element.

Selection of number and position of injection points

The numerical simulation of the injection molding process of the syringe filter showed that the shrinkage (and collapse) deformations for one injection point are the largest, and for case II and V the smallest. The other two cases (III and IV) are comparable but unsatisfactory. This is caused by a longer flow path of the material, in case of one point and incorrect placement of two injection points. It also causes higher pressure and temperature drops. This leads to differentiation of the local shrinkage and consequent increase of deformation of the entire molding. For two injection points positioned correctly and for three injection points, the deformation and collapse are of low value and can be eliminated by increasing the pressure value.

Therefore, cases I, III and IV have been eliminated for further simulation.

In the case of using three injection points (V), due to the flow of the material, there is a temperature difference greater than 20 ° C, which may result in stagnation due to the curing of the material and blocking of the further flow path.

In addition, with comparable results of injection time and molding quality, the use of three injection points is not economical.

The best solution is to choose two injection points arranged radially externally (system b)). Both the injection time, the flow temperature of the material, the pressure drop and the sealing time of the material are appropriate for the injecttion process.

The choice of wall thickness of the filter housing

The simulation of the choice of the wall thickness of the upper and lower casing made it possible to choose the right thickness from the point of injection technology.

In the case of the lower housing for a normal and thickened wall, problems with filling the seat with plastic were observed. This problem can be solved by controlling the parameters of the injection process (increasing the injection pressure, increasing the temperature). It does not appear in a thinned construction. The structure also has the smallest surface collapse that can be eliminated by modifying the injection parameters and secondary pressure.

In connection with the above, the optimal thickness of the bottom wall is a thinned construction, which additionally saves material, which translates into an economic factor.

In the case of simulation of the upper part, there were no problems with filling the socket. In the simulation of the thinned and bold construction, however, there was a problem with the surface collapse. While in the case of a thickened construction it is not significant, in the latter it would be necessary to control the injection parameters in order to eliminate it.

Based on the simulation, it was found that the optimal wall thickness for the upper housing is "normal" thickness.

All in all, there is need to remember that the simulation results are only an approximation of the actual conditions for the constitution of the compact, and the material model used in the processing process does not fully reflect the behavior of the material in real conditions. The correct interpretation of the simulation results is knowledge of the algorithms used in the description of the model (e.g. mass, motion and energy behavior equations). The accuracy of the simulation results is a derivative of the quality of preparation of the mold model in CAD programs. FEM mesh is only an approximation of the actual geometry of the molding, so the correctness of its execution depends, for example, on the relation of the thickness of the actual molding to the simulation model.

REFERENCES

Ananthanarayanan, A. (2009). *Development of In-Mold Assembly Methods for Producing Mesoscale Revolute Joints* (Doctoral dissertation). Retrieved from University of Maryland

Beaumont, J. P., Nagel, R., & Sherman, R. (2002). *Successful Injection Molding: Process, Design, and Simulation*. USA: Hanser Gardner Publications.

Beaumont, J. P. (2004). *Runner and Gating Design Handbook: Tools for Successful Injection Molding*. USA: Hanser Gardner Publications.

Bojarski, J., & Zimek, Z. (1997). Polipropylen modyfikowany odporny radiacyjnie. In *IV Szkoła Sterylizacji Radiacyjnej Sprzętu Medycznego, Przeszczepów, Farmaceutyków i Kosmetyków* (pp. XVII/1–XVII/7). Warszawa: Instytut Chemii i Techniki Jądrowej.

Canal, F., Sanchis, J., & Vicent, M. J. (2011). Current Opinion in Biotechnology. *Chemical biotechnology and Pharmaceutical biotechnology*, *22*(6), 894–900.

Fathi, S., & Behravesh, A. H. (2004). Visualization of in-mold shrinkage in injection molding process. *Polymer Engineering and Science*, *47*(5), 750–756.

Garbacz, T., & Sikora, J. (2012). *Przetwórstwo tworzyw polimerowych, ćwiczenia laboratoryjne, część 1*. Lublin: Wydawnictwo Politechniki Lubelskiej.

Grabowska, B. (2010). Biodegradacja tworzyw polimerowych. *Archives of foundry engineering*, *10*(2), 57–60.

Harper, C. A. (2006). *Handbook of Plastic Processes*. Hoboken: John Wiley & Sons Inc.

Jachowicz, T., & Klepka, T. (2012). *Przetwórstwo tworzyw polimerowych, ćwiczenia laboratoryjne, część 2*. Lublin: Wydawnictwo Politechniki Lubelskiej.

Kazmer, D. O. (2007*). Injection Mold Design Engineering*. USA: Hanser Gardner Publications.

Knights, M. (2007, January 3). In-Mold Assembly: The New Frontier of Multi-Shot Molding. *Plastics Technology*. Retrieved from https://www.ptonline.com/articles/in-mold-assembly-the-new-frontier-for-multi-shot-molding.

Kołtowska, M., & Klepka, T. (2015). Charakterystyka nowoczesnych strzykawek medycznych wytwarzanych z tworzyw polimerowych. In T. Jachowicz, & M. Kłonica (Eds.), *Nowoczesne Technologie w projektowaniu, inżynierii i wytwarzaniu* (pp. 173–186). Lublin: Perfekta Info.

Malloy, R. A. (1994). *Part Design for Injection Molding*. USA: Hanser Gardner Publications.

Nabiałek, J., & Koszkul, J. (2007). Modelowanie przepływu podczas wypełniania gniazda. *Zeszyty Naukowe Politechniki Poznańskiej*, *4*, 167–172.

Olędzka, E., Sobczak, M., & Kołodziejski, W. L. (2007). Polimery w medycynie – przegląd dotychczasowych osiągnięć. *Polimery*, *11–12*, 795–803.

Pielichowski, J., & Pruszyński, A. (1998). *Technologia tworzyw sztucznych*. Warszawa: Wydawnictwa Naukowo-Techniczne.

Sikora, R. (2006). *Przetwórstwo tworzyw polimerowych. Podstawy logiczne, formalne i terminologiczne.* Lublin: Wydawnictwo Politechniki Lubelskiej.

Rabek, J. F. (2008). *Współczesna wiedza o polimerach*. Warszawa: Wydawnictwo Naukowe PWN.

Shick, L. L., & King, B. W. (2012). *U.S. Patent No. 0264266 A1*. Washington, USA: U.S. Patent and Trademark Office.

Sikora, R. (1993). *Przetwórstwo tworzyw wielocząsteczkowych*. Warszawa: Wydawnictwo Edukacyjne.

Sykutera, D. (2012). *Wspomaganie komputerowe w procesach przetwórczych – materiały wykładowe*. Bydgoszcz: UTP Bydgoszcz.

Tadmor, Z., & Gogos, C. G. (2006). *Principles of Polymer Processing*. Hoboken: John Wiley & Sons.

Wilczynski, K. (1999). CADMOULD-3D – computer modeling of polymers injection process simulation of filling phase. *Polymers*, *44*(6), 407–412.

Zimek, Z., Bułhak, Z., Bojarski, J., Mirkowski, K., & Stachowicz, W. (1992). *European Patent No. PL 169177*. Warszawa, Poland: European Patent Office.

Applied Computer Science, vol. 14, no. 3, pp. 69–80
doi:10.23743/acs-2018-22

Submitted: 2018-08-03
Revised: 2018-08-15
Accepted: 2018-08-28

heat transfer, energy saving, temperature, model of walls layers

Marian JANCZAREK[*]

COMPUTER MODELLING OF THERMAL TECHNICAL SPACESS IN ASPECT OF HEAT TRANSFER THROUGH THE WALLS

Abstract

This paper presents the analysis of complex problems in the field of energy savings and it is focused on the new concept of thermal analysis derived from harmonic character of temperature changes in building environment – especially in a fruit storages – with aspect on conductive heat transfers through walls. This changeable influence of variable weather temperature on internal temperature of technical chamber depends on thermal inertia of building. The paper describes research work on methods concerning heat transfers through walls of thermal technical chambers in the impact of sinusoidal nature of the changes in atmospheric temperature. The purpose for the research is to point out areas subjected to the highest energy losses caused by building's construction and geographical orientation of walls in the aspect of daily atmospheric temperature changes emerging on chamber exterior. The paper presents exemplary measurement results taken in Lublin region during various periods throughout a year.

1. INTRODUCTION

The presented new concept of thermal analysis is derived from periodic character of temperature changes in storage environment (Bzowska, 2005; Janczarek M. M, 2000). The paper presents also the physical model of heat transfer through chamber walls by means of a mathematical model suitable for sine waveform of internal temperature changes. The analysis has been performed on the basis of original numerical algorithms. They take into consideration hourly changes of ambient temperature in the central – eastern region of Poland (Fig. 1).

[*] Lublin University of Technology, Institute of Technological Systems of Information, 20-618 Lublin, Nadbystrzycka 36, e-mail: m.janczarek@pollub.pl

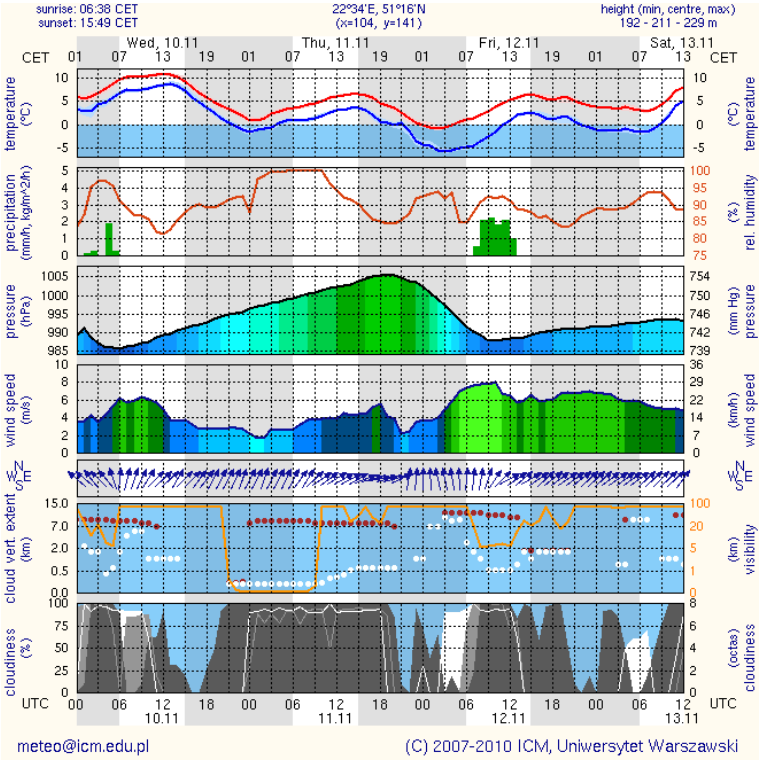


Fig. 1. Periodically temperature signal on the wall – image source: (Meteorological diagrams, 2017)

The accepted methodology of performance takes advantage of temperature dynamics which is necessary to solve physical and mathematical problems related to heat transfer processes occurring in chambers (Etheridge, 2002). The main purpose for fruit storage in central European climate is to provide products of high consumption quality during autumn, winter and spring (Hunt & Linden, 2001). Financial inputs connected with the maintenance of the storage are obviously related with the final cost of apple or any other fruit. It is necessary to prolong storage period energetically efficiently to maintain affordable price of apple. Contemporary technological processes make possible to inhibit biochemical and physiological processes that lead to ripening or overripe fruit. The prolongation of storage period is mainly achieved by the storage of apple of pear in chambers that can maintain low temperature of fruit, i.e.: within the range between 0÷ +1.5°C. Beside temperature conditions, it is necessary to provide the air of low oxygen and carbon dioxide contents and of high humidity and circulation in the interior of the cooling chamber. The differences among particular cases of thermal energy demand for storage depends mainly on different construction of cooling chambers. The construction can differ in materials and dimensions which results

in different thermal resistance of external walls. Problems of thermal conductivity can be analyzed by many methods, for example: Laplace transformations method, Fourier transforms, etc. The paper presents two models: analog one and differential one. They can help to control heat processes during storage periods.

The above-mentioned diagram of atmospheric temperature changes indicates its sinusoidal nature at our latitude – Central and Eastern Europe. The picture of changes in atmospheric temperature refers to the month of November, but in the remaining months it is similar (Etheridge, 2002; Fracastaro, Mutani, & Perino, 2002). This indicates that in the design of external walls, this dynamics of atmospheric temperature changes should be taken into account (Chwieduk, 2006).

2. RESEARCH AND EXPERIMENTAL WORK OF HEAT TRANSFER THROUGH WALL

The originally constructed laboratory system consists of fully automatic stands to test construction material thermal characteristics (Fig.2). These characteristics form the basis to formulate the principles of temperature changes between adjacent layers. The laboratory enables also to trace the heat transfer on external border surfaces. The experimentally obtained results have been subjected to computer analysis (Janczarek & Świć, 2012).

Fig. 2. Registering positions laboratory with two temperature chambers and the test material in the middle

In aim of determined of coefficient of heat transfer of bricks in dependences upon of degree her moistures one chose method experimental. Research one passed on laboratory – position in Technical University of Lublin and referred of measurement of temperatures, thickness of streams warm and moistures relative bricks (Janczarek & Bulyandra, 2016). As material to driven researches used brick full red both wet and then this oneself brick dried in stove. In time of a few days' measurements driven former at a help of computer registration of temperatures in four points on external surfaces examined bricks as also in two central points in interior. Simultaneously driven former computer registration of moisture at help of two searchers of type WHT installed in center of brick. Values of thickness led of warm density became measured at help of electronic sensors of type PTP, which connected former to universal measure APPA (Suchorab, Sobczuk, & Lagod, 2016).

Position laboratory – to qualifications of coefficient of heat flow in aspect different moistures of equipped brick was in two chambers. Different conditions thermal in chambers held former at help of aggregates cooling and of controlled warmers. Among chambers one installed investigative sample in typical form full red bricks placed tight to capacity in plate of polystyrene about thickness 20 cm. Polystyrene. Plate used former in aim of isolating of surface external bricks from influence undesirable temperatures. Surfaces external bricks surrendered became {remained} to activity from one side of chamber to temperature +25°C and from second side of chamber to temperature +1,5°C. Values these of temperatures registered former independently for every from six sensors, and then recorded on disc of computer at measuring – step carrying out 15 of minutes. Simultaneously with measurement of temperature registered former at help of programmed computer values of moisture of brick on two separate files. Obtained from measurements of value of temperatures, of streams and moistures became placed in programmer EXCEL. At the help of suitable mathematical transformations coded values of temperatures and moistures exchanged on suitable individuals on degrees °C and on per cent definite values of relative moisture. Correlations among obtained values of coefficient of heat conduction permit on determination of characterizations of graphic coefficient for chance dry and wet bricks.

Obtained results of measurements permitted on qualification of dependence of coefficient of heat transfer from internal temperatures in full red brick wet and dry (Janczarek, Sklaski, Bulyandra, & Sobczuk, 2006).

Simultaneously obtained results of value of coefficient of heat transfer permitted on determination of coefficient lambda. From represented below graphs results difference among courses for wet and dry bricks (Fig. 3 and Fig. 4).

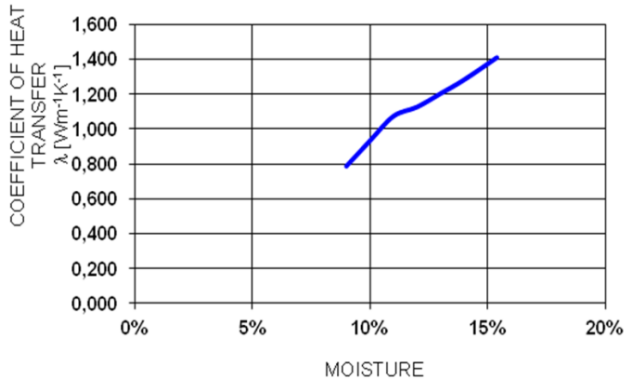


Fig. 3. Characterizations of changes of coefficient of heat transfer in wet full brick

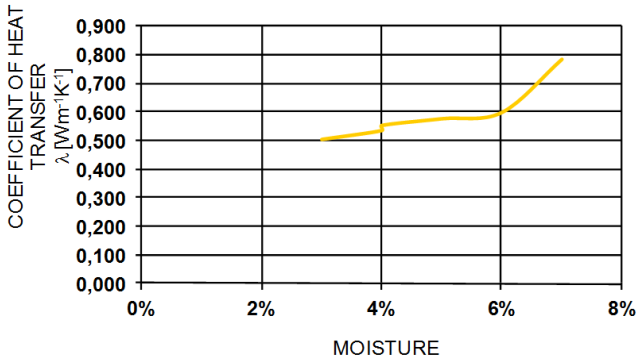


Fig. 4. Characterizations of changes of coefficient of heat transfer in dry full brick

The above graphs are the results confirming the dependence of the heat conduction coefficient on the moisture content in building materials. It is clear from them that in the energy balance of heat and mass exchange, we must pay attention to adequately insulating external building materials. Otherwise, we will suffer losses due to the increased heat transfer rate through the walls. On the upper picture of a damp brick, you can see a steep increase in the thermal conduction coefficient with an increase in the degree of humidity. The bottom picture shows the stabilized value of lambda coefficient in the humidity range for dry bricks.

3. EXPERIMENTAL WORK OF MEASUREMENT OF HEAT TRANSFER ON THE REAL OBJECT

The verification of the accepted methodology and results have been performed on the data thermal flux density obtained from rural thermal chamber in Radzyń Podlaski (Poland). The small sensor of low inertia has been developed especially for the purpose of the research. This sensor has been used to measure the heat flux density. The experimental analysis proves the necessity to consider the dynamic character of internal temperature when thermal chamber analysis is performed. The thesis includes also the presentation of elaborated methodology of analysis of industrial long term storage.

Two fruit storages have been subjected to the analysis of temperature distribution on the surfaces of technical chambers (Fig. 5.). The storages are constructed of materials of different physical properties

The purpose for the research is to point out areas subjected to the highest energy loss caused by building construction and geographical orientation of walls. Thermal detectors have been installed on external surfaces, internal surfaces and inside wall layers to measure temperature. The graphical presentation of temperature field distribution on wall surfaces have been performed by means of a thermal vision camera. The camera enables to distinguish visually the areas of the highest thermal loss from storages. The analysis of temperature distribution on vertical walls of storages makes possible to indicate proper building construction of objects. The analysis results are presented in figures. Moreover, temperature measurements taken on chamber external surfaces let us distinguish rooms that serve for other purpose than storage, e.g. a technical room. This room additionally protects the storage from disadvantageous influence of atmospheric conditions.

Article includes analysis of changeable influence in time of variable weather temperature on internal temperature of construction object depending on thermal inertia of building. Taken advantage influence of sinusoidal change external temperature on internal temperature of thermal technical spaces of thermo stability object will allow to get drop of cost of expendable energy of construction object on keeping of definite thermal condition in accommodation properly spaces. It shows harmonist of exemplary characteristic depending on length of time of measurement course of temperature and seasons of the year.

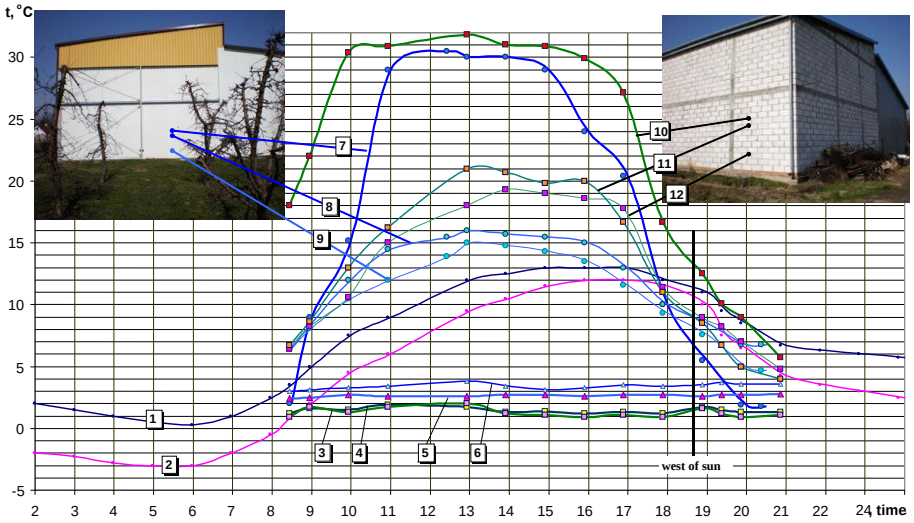


Fig. 5. Presentation of temperature field distribution on wall surfaces.

In the above picture we can see the distribution of sensors that measure the temperature on the two surfaces of the outer walls, which is an hour-long registration. They show the sinusoidal nature of changing the temperature with the maximum during the day and the minimum at the night. Characteristic curves represent also the course of the heat flux in the same figure below.

4. MODELS OF HEAT TRANSFER THROUGH WALL

The purpose of this paper is to describe the design of control systems of cooling and air conditioning systems in storage spaces. For a control systems its necessary to use only three elements: sensor, controller and controlled device. The main of those elements is temperature sensor which shows the picture of thermal decomposition in cold store. The very important are also devices, which provide control of humidity and cyclic potential motion of air in space. It must be noted, that all the control actions depend mainly on measurement of a controlled variable. It is, therefore, necessary to analyze very carefully what is actually being measured, how it may vary with time and which degree of accuracy is necessary in the measurement. Mostly, the temperature of the surfaces on which the sensors are mounted is different from the air temperature.

Conduction take place when a temperature gradient exists in a solid (or stationary fluid) medium. Energy is transferred from the more energetic to the less energetic molecules when neighboring molecules collide. Conductive heat flow occur in the direction of decreasing temperature because higher temperature is associated with higher molecular energy (Dzieniszewski, 2005).

The equation used to express heat transfer by conduction is known as Fourier's Law. The article presents the physical model of heat transfer through chamber walls by means of a mathematical model suitable for sine waveform of internal temperature changes. Below is a universal analog model for an external wall using an electrical analogy. It presents the wall as a layer having its resistance and thermal capacity (Janczarek & Bulyandra, 2017). Besides, the resistance resulting from heat transfer from the outside air is shown in the model. Also in the model there is a flux of heat flowing into the wall from outside as well as inside to the chamber.

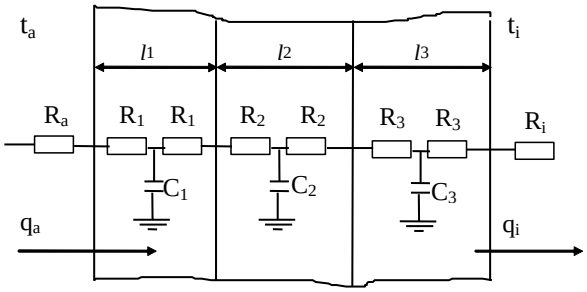


Fig. 6. Model of wall composed of three layers in electrical analogy

From it we can get matrix notation (eventually for n – layers of wall) and the final result of this calculation is a pair of linear relations between the temperature and fluxes at the two surfaces of the composite slabs (Janczarek M. M, 2000).

$$[\Delta t_i(p), \Delta q_i(p)] = [\Delta t_a(p); \Delta q_a(p)] \begin{bmatrix} 1 & 0 \\ -R_1 & 1 \end{bmatrix} \begin{bmatrix} 1 & -pC_1 \\ 0 & 1 \end{bmatrix} \dots \begin{bmatrix} 1 & -pC_n \\ 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 \\ -R_{n+1} & 1 \end{bmatrix} \quad (1)$$

where: Δt – temperature increase,
Δq – thermal flux,
p – domain by Laplace transform,
R – thermal resistence,
C – thermal capacity,
1 – thickness of the wall layer,
i – index meaning internal,
a – index meaning outside.

The relation is precisely analogous to Ohm's law for the steady flow of electric current: the flux corresponds to the electric current, and the drop of temperature to the drop of potential. Thus R may be called the thermal resistance of the slab. Next suppose we have a composite wall composed of n slabs of different thickness

and conductivities. If the slabs are in perfect thermal contact mat their surfaces of separation, the fall of temperature over the whole wall will be the sum of the falls over the component slabs and since the flux is the same at every point, this sum is evidently (Janczarek, 2013).

This is equivalent to the statement that the thermal resistance of a composite wall is the sum of the thermal resistance's of the separate layers, assuming perfect thermal contact between them. Finally, consider a composite wall as before, but with contact resistances between the layers such that the flux of heat between the surfaces of consecutive layers is H times the temperature difference between these surfaces. The differential equation to be solved is Fourier's equation.

These models we can confront with digital computer program Modelica, which allow to construct the walls of technical chambers. This model is similar to analogue but much more convenient due to the simple input of data. We can use it to enter any thermal conditions inside and outside the chamber. We can also use it to enter any physical values of the wall, causing specific functions.

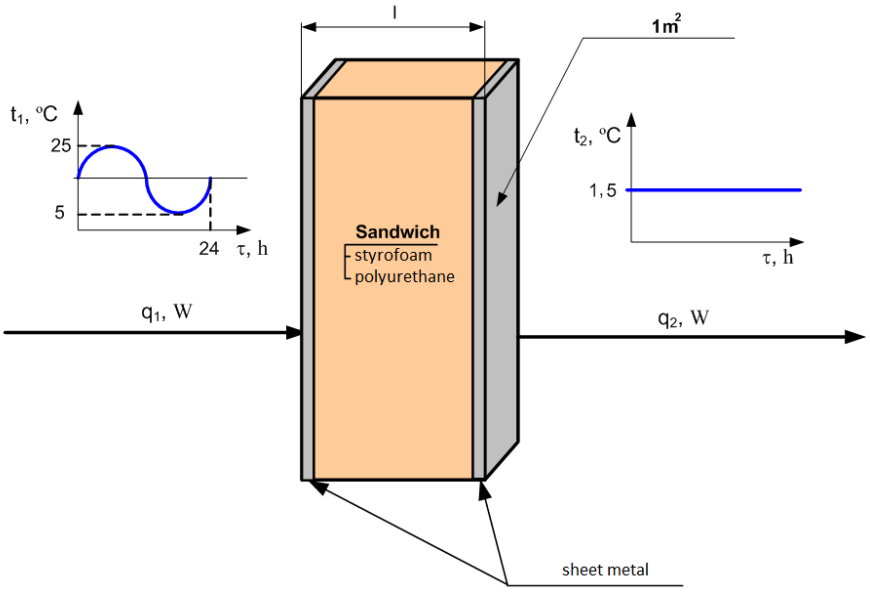


Fig. 7. Ideal model of wall

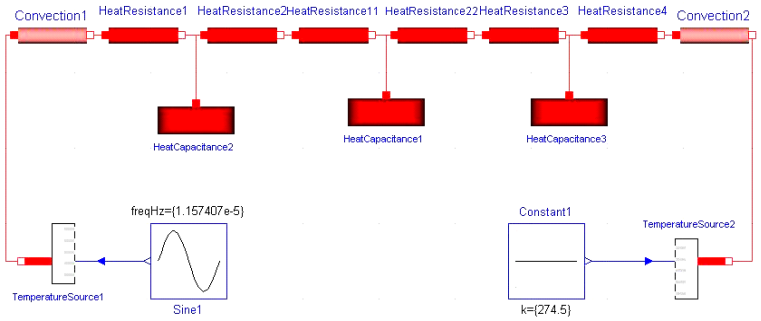


Fig. 8. Block schema using electrical analogue

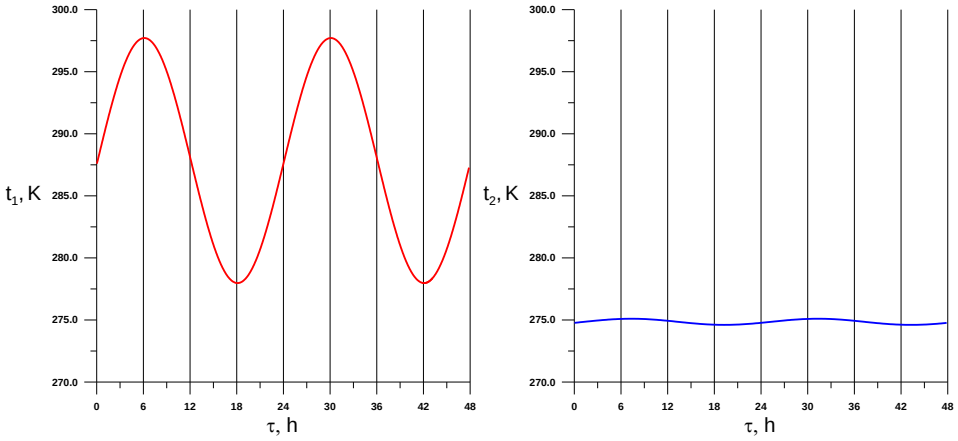


Fig. 9. Periodically temperature signal on the wall

By the suitable construction of the enclosure walls composed of several slabs of different thicknesses and conductivities, we can obtain phase shift (when the time lag attains twelve hours it is the best situation), which reduce the amplitude of internal temperature inside technical chamber and, in consequence, give equivalent of using energy. The influence of this periodically changing weather temperature upon the inside storages climate is depending on the material of walls and inertial property of thermal technical spaces, it means a fruit storage.

This analysis shows the periodic variability of outside temperature, changing in periods of each day and also in the year with maximum value in the afternoon or in summer and minimum value in the night or winter time. The influence of this periodically changing temperature on the inside storages climate is depending on thermal inertia of technical spaces. The proper construction of an object with prescribed thermo-stability characteristic can use the phase difference between internal and external temperature and allow to lower costs of energy, necessary for cooling or heating the technical spaces (Calderaro & Agnoli, 2007).

5. CONCLUSIONS

The paper describes atmospheric temperature analysis and their variability in time in aspect of their influence upon the thermal technical chambers – fruit storages. The influence of this periodically changing weather temperature upon the inside storages climate is depending on the material of walls and inertial property of thermal technical spaces, it means a fruit storage.

As a result of the tests it was found that a properly designed technical chamber can bring significant energy savings. In addition, energy savings can bring about the appropriate location of the building due to the geographic side of the world. Moreover, energy savings can be brought by the appropriate location of the building's cooling chamber in the north – this will provide additional cooling and a possible warehouse located in the south. Thanks to the Modelica computer program, we can simulate various variants of atmospheric conditions both inside and outside the object. Modeling appropriate layers of the external barrier will allow obtaining time constants that are a combination of thermal resistance and thermal capacity. Using the developed partition model in the RC electrical analogy, we can choose the components of the partition to achieve the desired phase shift. Resistance values and thermal capacity depend on the physical properties of the materials used to build the object. Optimal conditions of phase shift of the heat flow through the outer wall will allow to stabilize the thermal conditions inside the room, and thus save energy on the refrigeration unit.

REFERENCES

Bzowska, D. (2005). Natural ventilation induced by weather parameters in two-zone building. *Archives of Civil Engineering*, *51*(1), 135–151.

Calderaro, V., & Agnoli, S. (2007). Passive heating and cooling strategies in an approaches of retrofit in Rome. *Energy and Buildings*, *39*(8), 875–885. doi:10.1016/j.enbuild.2006.10.008

Chwieduk, D. (2006). *Modelowanie i analiza pozyskiwania oraz konwersji termicznej energii promieniowania słonecznego w budynku*. Warszwa: Prace Instytutu Podstawowych Problemów Techniki PAN.

Dzieniszewski, W. (2005). *Procesy cieplno-przepływowe w budynkach: podstawy modelowania matematycznego*. Łódź: Komitet Inżynierii Lądowej i Wodnej PAN.

Etheridge, D. (2002). Nondimensional methods for natural ventilation design. *Building and Environment*, *37*(11), 1057-1072. doi:10.1016/S0360-1323(01)00091-9

Fracastaro, G., Mutani, G., & Perino, M. (2002). Experimental and theoretical analysis of natural ventilation by window openings. *Energy and Buildings*, *34*(8), 817–827. doi: 10.1016/S0378-7788(02)00099-3

Hunt, G. R., & Linden. P. F. (2001). Steady-state flows in an enclosure ventilated by buoyancy forces assisted by winds. *Journal of Fluid Mechanics*, *426*, 355–386.

Janczarek M. M. (2000). Models of heat transfer through walles of thermal technical spaces, In *Výrobní stroje, automatizace a robotizace ve strojírenství: Společná problematika všech sekcí : Sborník přednášek* (pp. 145–150). Praha, Praha: České Vysoké Učení Techniceské v Praze – Fakulta Strojní.

Janczarek M., Bulyandra O. (2017). Computer aided thermal processes in technical spaces. *Applied Computer Science*, *13*(2), pp. 82–93. doi:10.23743/acs-2017-16.

Janczarek, M. M. (2013). Analiza matematyczno-fizyczna cieplnych komór technicznych. In M. Janczarek & J. Lipski (Eds.), *Technologie informacyjne w technice i kształceniu* (pp. 127–137). Lublin, Polska: Politechnika Lubelska.

Janczarek, M. M., & Świć, A. (2012). Scientific and technological description of heat and mass transfer processes in chambers. *Annals of Faculty of Engineering Hunedoara – International Journal of Engineering*, *10*, 55–60.

Janczarek, M., & Bulyandra, O. (2016). Computer modeling of energy saving effects. *Applied Computer Science*, *12*(3), 47–60.

Janczarek, M., Sklaski, P., Bulyandra, A., & Sobczuk, H. (2006). Przewodność cieplna zewnętrznych ścian budynków w aspekcie wilgotności i oszczędności energii: Thermal conductivity of external walls of buildings in aspects of moistness and energy saving, *Rynek Energii*, *4*, 32–35.

Meteorological diagrams [online image]. (2017). Retrieved September 15, 2017 from http://http://www.meteo.pl

Suchorab, Z., Sobczuk, H., & Lagod, G. (2016). Estimation of Building Material Moisture Using Non-invasive TDR Sensors. In L. Pawłowski (Ed.), *Environmental Engineering IV* (pp. 433–439). London: Taylor & Francis Group. doi:10.1201/b14894-64

Applied Computer Science, vol. 14, no. 3, pp. 81–95
doi:10.23743/acs-2018-23

Submitted: 2018-08-03
Revised: 2018-09-03
Accepted: 2018-09-25

Simulation, extrusion, mini-tube, head

Sebastian BIAŁASZ[*], *Ramon PAMIES*[**]

NUMERICAL SIMULATION OF THE DESIGN OF EXTRUSION PROCESS OF POLYMERIC MINI-TUBES

Abstract

In this paper we represent a study reporting the numerical simulation of small-diameter pipes extrusion process. Polypropylene and low density polyethylene were chosen as plastics and a selected transverse head as a tool in the simulations. The aim of the study is to examine the distribution of temperature in the individual sections of the bagasse and tools, in order to optimize the parameters and process flow extrusion and validate the implementation tools, by simulating the flow of plastic by the head.

1. INTRODUCTION

Modern plastics are used in various branches of technology, and currently are used daily around the world. The term plastic is used for the material and the basic component to determine its properties and structure is a polymeric chain. From a chemical point of view, polymers are a chemical substance of natural origin, synthetic (manufactured in chemical synthesis), modified by the addition of chemical excipients such as stabilizers or plasticizers. The low cost of production, good physical and chemical properties relative to other materials, and good strength properties in relation to low density plastic, have an impact on their increasing usage as a replacement for materials construction such as steel. The ability to change their properties and characteristics in the right conditions has an impact on their extensive use in the processing of polymers on a global scale, such as extrusion or injection.

[*] Department of Polymer Processing, Mechanical Engineering Faculty, Lublin University of Technology, sebastian.bialasz@pollub.edu.pl
[**] Department of Materials and Manufacturing Engineering, Universidad Politécnica de Cartagena, ramon.pamies@upct.es

For precise selection of the extrusion process conditions, it is necessary to examine the technological properties of thermoplastics, the most important of which are indicators of the speed of flow: mass and volume. Flow rate indicator is a factor that defines the thermoplastic materials, because it determines their vulnerability to changes in physico-chemical structure and properties (Garbacz, 2012; Jachowicz & Klepka, 2012; Klepka, Jeziórska & Szadkowska, 2015; Pielichowski & Pruszyński, 1998; Sikora, 2006).

During the extrusion process, derived products may have different forms depending on the type of process and tools. In the process of extrusion of pipes are used special tools, which is the initial shape of the flowing material in the form of the head, which may be linear or transverse (Klepka, 2001; Rabek, 2008; Rydzkowski, 2011).

The characteristic feature of the extrusion is tempering materials under high temperature, push it through the channels of the tools, then rapid cooling in order to harden the resulting bagasse. Depending on the requirements of the requirements of extrudates there are less or more complex technological lines (shown in Figure 1)(Garbacz & Sikora, 2012; Jachowicz & Klepka, 2012; Tor-Świątek, Garbacz & Jachowicz, 2016):

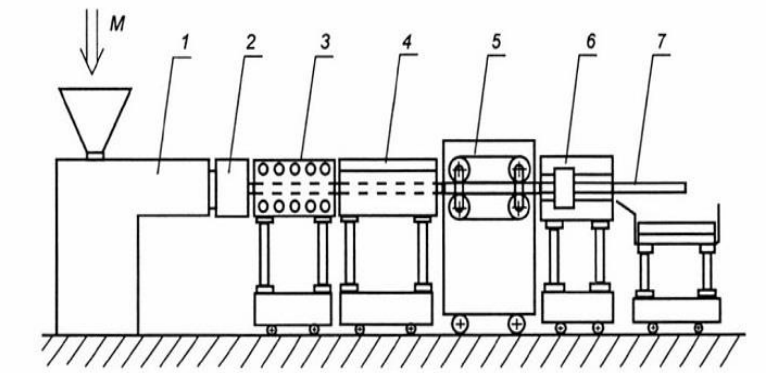


Fig. 1. Diagram of the line leading to the extrusion of pipes. M-polymer material, 1 – extruder, 2 – head, 3 – calibrator, 4 – cooling device, 5 – receiving device, 6 – shut-off device, 7 – extrudate ("Wytłaczanie - linia technologiczna", 2018)

The basic elements of the extrusion line are extruder that includes elements such as a cylinder, a snail with radiators which are plasticizer system, forming tools, such as the head and calibrator, and cooling baths constitute an additional element of the line.

Extrusion head is called the simple device mounted at the end of the cylinder, ended with an extrusion nozzle. As a result of the occurrence of different types of polymer flow direction in the head there are linear and transverse heads. The selection of the head depends on the shape of what we want to get in the end.

For example, a polymer tubes, extruded are using head linear or transverse. Sample diagram of head is shown in Figure 2 (White & Potente, 2003; Sikora, 1993, 2006; Sikora, 2008).

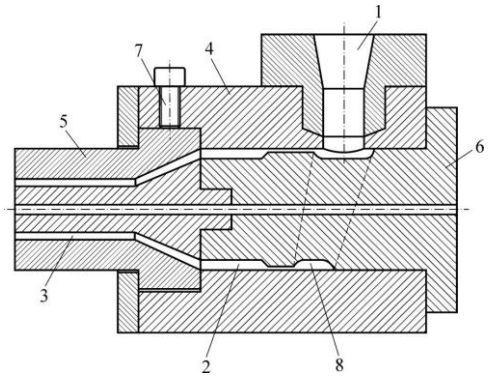


Fig. 2. Diagram of the transverse extrusion head; 1 – inlet channel, 2 – annular distributing channel, 3 – die, 4 – main body of the extrusion head, 5 – die body, 6 – heart-shaped mandrel, 7 – adjusting bolt, 8 – manifold

Other elements which form part of the extrusion line are the calibrators, cooling baths, and extraction. All these elements are responsible for the shape, dragging a plastic head for subsequent line items, and the final product as a result of temperature changes that occur in the solidification between the cooling bath and plasticized material. The change in temperature in the extrudate can be realized by immersion in a hot tub with a coolant (usually water), through the compressed air cooling (blowing) or ambient air (at room temperature) (Rauwendaal, 2014; Sasimowski, Sikora & Królikowski, 2014).

2. NUMERICAL SIMULATION IN THE PROCESSING OF POLYMERIC MATERIALS

With the development of numerical simulation techniques, the tools to carry out the process simulation of polymer extrusion process, in order to optimize the process, starting with the design of the tools by asked the process parameters, to define the conditions after leaving bagasse extrusion head. Thus, it is possible to carry out the entire process of extrusion in "virtual reality", in accordance with the data in order to validate the intended process.

There are several systems to design processes such as extrusion or injection. There is a division of universal and special software. Special simulation systems include MOLDFLOW, CADMOULD whether MOLDEX3D. A general software used to simulate processes is the SolidWorks CAD system, which is a simple

effective tool to design the tool parts, assemblies, components, the execution of the drawings, and then carrying out the tests simulation on the component (Githuku & Giacomin, 1993; Koutelieris, Kioupi, Haralampous, Kitsakis, Vaxevanidis & Kechagias, 2017; Sykutera, 2012).

To simulate the Flow Simulation a tool based on a method of CFD (computational fluid dynamics) has been utilized. This technique allows to perform a flow analysis for liquids or gases. Process simulation involves several steps (fig. 3) (Wilczyński, Garbarski, Nastaj & Lewandowski, 2009):

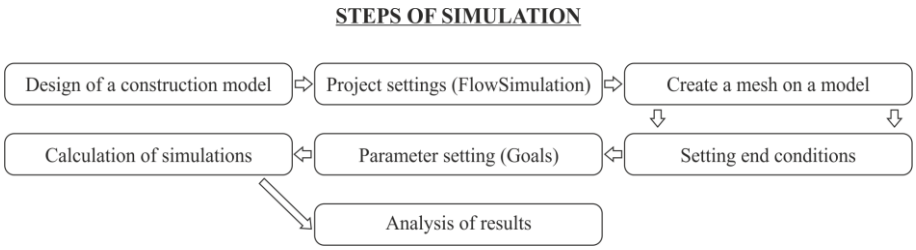


Fig. 3. Stapes of simulation in the Flow Simulation module

3. MATERIALS AND METHODS

3.1. Simulation Techniques

Our principal aim in this research is to analyze the flow temperature in the cylinder and the flow of plastic and to simulate the process of extruding a small diameter pipe, in order to analyze the process and select the optimal process parameters.

In order to analyze the temperature of the material during heating and cooling, a cylinder with a nozzle was designed in the SolidWorks 2015 (Fig. 4). The dimensions of the nozzle are 2.00 mm, length 6 mm, with a flow channel diameter 4.50 mm, and a total length of 180 mm, with a built-in core 180 mm long.

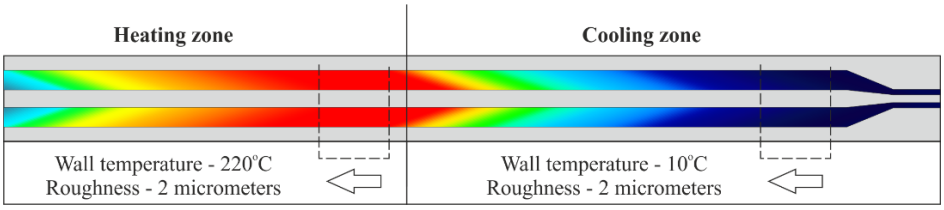


Fig. 4. Diagram of temperature distribution in the cylinder used for flow simulation

In order to obtain the results of temperature distribution in the cross-section of the material flowing through the cylinder channel at high temperature, the model has been divided into two main zones: heating and cooling.

The temperature in the zones was successively: in the heating zone: 185°C, 205°C, in the cooling zone: 225°C, 15°C, 25°C, 35°C. It was assumed that the temperature of the material at the inlet is 25°C. The factors investigated were the external temperature of the fluid, the internal temperature of the fluid and the temperature of the core. The variable factor was the temperature of the walls, and the constant factors were: the temperature of the material at the inlet, the pressure, the flow velocity and the roughness of the walls.

To simulate the mini-tube extrusion a transverse head was designed. The head was connected to the cylinder (Fig. 5, 6) through which plasticized plastic flows. One of the most important elements of the head design is the splitter connected to the core, which allows, as a final effect, to obtain the product, with a circular shape in the form of a mini-tube. The purpose of the simulation process of mini-tube extrusion is:

- analysis of the transverse head construction (checking the flow of the material inside the head),
- simulation of plastic flow at high temperature,
- analysis of fluid properties after the nozzle outlet.

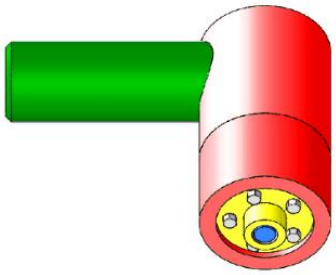


Fig. 5. Construction of an transverse extrusion head

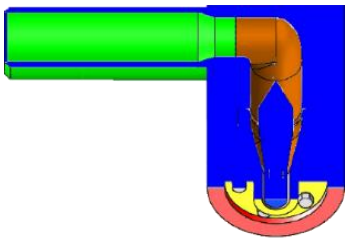


Fig. 6. Cross-section of an transverse extrusion head

3.2. Plastic materials

Two polymer materials were selected for the tests: Polypropylene (PP) under the trade name MoplenEP440G from Basell Orleni and Low Density Polyethylene (PE-LD) under the trade name Malen E FGAN 23-D006 from Basell Orlen. The properties of the materials used during the simulation are shown in Table 1.

Tab. 1. Properties of plastics used in the simulation process

Properties	Polypropylene	Polyethylene	Unit
Density	900	925	kg/m^3
Specific heat	1700	2200	J/(kg K)
Thermal conductivity	0.4	0.45	W/(m K)
Mass flow index	1.3	0.75	g/min
Melting point	150	114	°C

The parameters and variables used in this work for extrusion simulation are shown in Table 2.

Tab. 2. Parameters the extrusion simulation

Evaluated parameters	– Temperature of the material in the nozzle – Material temperature after outlet from the nozzle – Plastic pressure in the nozzle – Plastic pressure after the nozzle outlet
Variable parameters	– Temperature – Flow speed
Fixed parameters	– Temperature of the material at the inlet to the cylinder – Pressure – Flow rate – Curosity of walls – Cooling at the outlet – Load

3.3. Simulation of plastics flowing in the cylinder

The cylinder model described in the test program was used to analyze the flow of plastic in the cylinder to analyze the temperature distribution. In order to properly define the flow of selected materials in the cylinder, boundary conditions were given:

– temperature of the material at the inlet (25°C),
– wall temperature in the heating zone (185°C, 205°C, 225°C),
– wall temperature in the cooling zone (15°C, 25°C, 35°C),
– flow speed (10 m/s),
– wall roughness (2 μm).

The temperature distribution during heating and cooling is shown in the cross-section drawing, on which points were placed along a radius of 4.5 mm, defining the internal temperature of the fluid, the core temperature and the external temperature of the liquid, respectively (Figure 7).

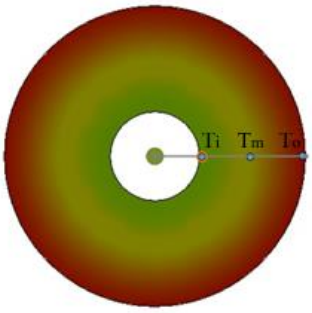


Fig. 7. Distribution of points along the diameter of the cross-section.
T_i – Inner temperature, T_m – Middle temperature, T_o – Outer temperature

For each of the points placed on the radius at a distance from the point of the cross-section, the values of the fluid's temperature along the length have been generated using the Point parameter tool:

- Ti, at a distance of 1.5 mm from the center point,
- Tm, at a distance of 3.0 mm from the center point,
- That, at a distance of 4.5 mm from the center point.

3.4. Simulation of the mini-tube extrusion process

In order to simulate the extrusion of mini-tube through the heads, the basic boundary parameters for and for polyethylene were generated. The flow was defined as laminar, internal, and isothermal for non-Newtonian liquids at temperatures of 240°C for polypropylene, and 200°C for polyethylene, respectively.

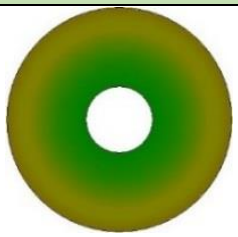
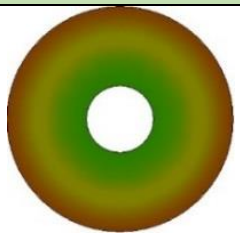
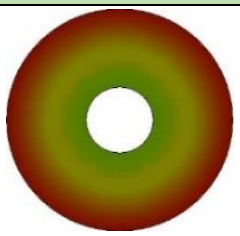
In order to a more accurate analysis of the simulations, the following boundary parameters were given:

- wall temperature (200°C, 240°C),
- inlet load (22 N),
- flow speed (10 m / s)
- wall roughness (1.2 μm),
- cooling at the outlet (25°C).

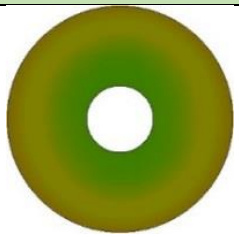
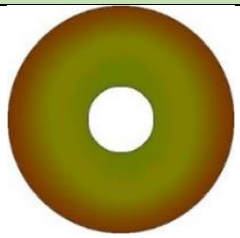
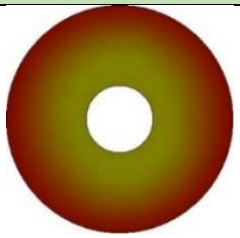
4. RESULTS AND DISCUSSION

The temperature distribution of polypropylene and polyethylene during the heating process are depicted have been calculated the results are depicted in Tables 3 and 4, respectively. We have simulated a series of three different temperatures: 185, 205 and 225°C. As it was expected the temperatures T_o, T_m and T_i increase with the increasing temperature. It is interesting to note that in every case, the polyethylene samples show a higher temperature than the analogue simulation of polypropylene due to the higher conductivity of the polymeric matrix.

Tab. 3. Temperature distribution during heating for polypropylene (PP)

185°C			205°C			225°C		
								
T_o	T_m	T_i	T_o	T_m	T_i	T_o	T_m	T_i
180.20	142.19	121.75	199.65	155.85	132.85	219	173.45	148.33

Tab. 4. Temperature distribution during heating for polyethylene (PE-LD).

185°C			205°C			225°C		
								
T_o	T_m	T_i	T_o	T_m	T_i	T_o	T_m	T_i
181.83	156.22	141.91	205.02	169.86	158.11	222.03	189.02	169.90

In Figure 8, we have also presented the temperature distribution of our samples during the heating process. In agreement with the previous results, the temperature distribution of polyethylene is more uniform in comparison to polypropylene and higher values of Ti are reached for PE-LD when polymers are heated.

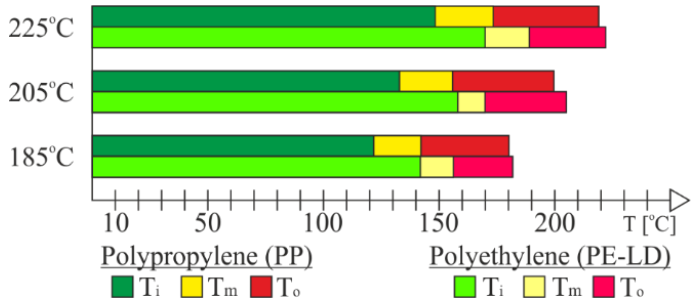
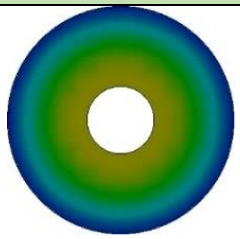
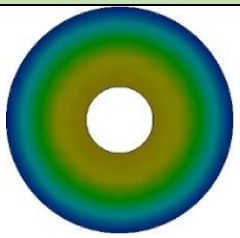
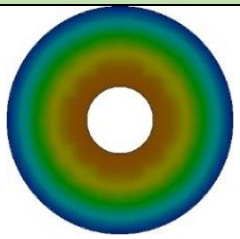
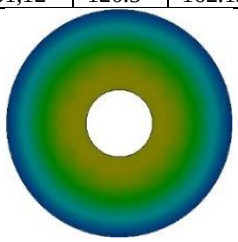
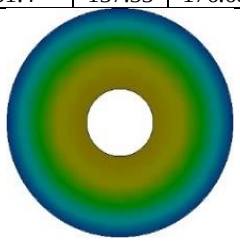
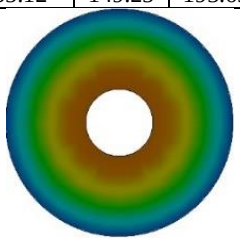
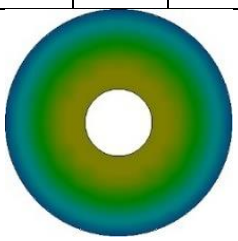
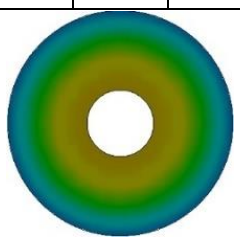
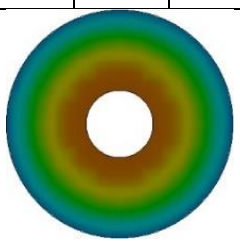


Fig. 8. Temperature graph in measuring points, for PP and PE-LD, during heating

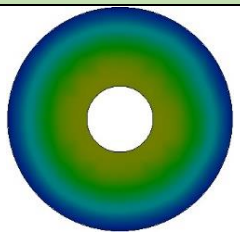
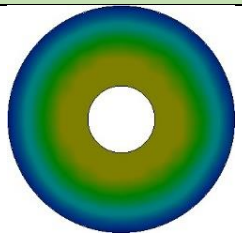
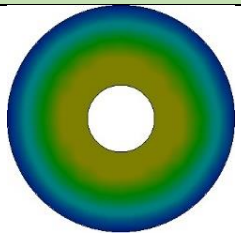
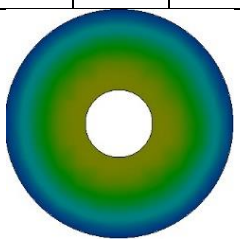
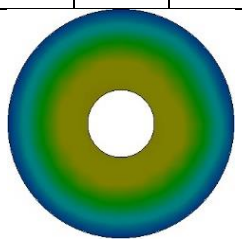
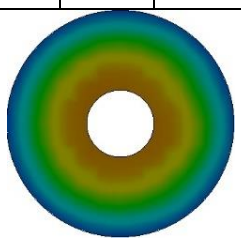
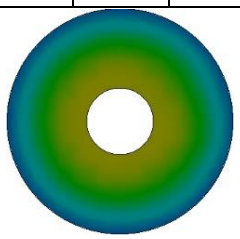
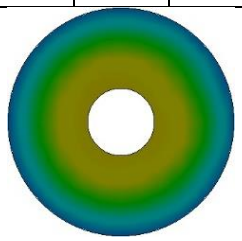
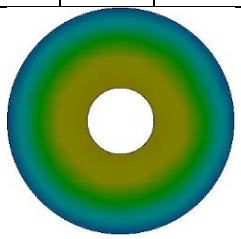
We have performed an analogous study with our samples during the cooling process in the extrusion. The results of the simulation of the temperature distribution during cooling for polyethylene and polypropylene are presented in Tables 5 and 6. Three different cooling temperatures have been evaluated (15, 25 and 35°C) for the three heating temperatures studied in the previous section. As expected, the cooling temperature has a big impact on the values of To. With the decrease of the cooling temperature, lower To values are calculated. In the case of PP, the values of To are slightly lower compared to PE-LD. Regarding the values of Ti for PE-LD, the lower values of cooling temperature decrease significantly the values of Ti as it was expected due to the conductivity of this polymer. Interestingly, the values of Ti are not affected by the cooling temperature for the PP samples. As it was shown in Table 1, the thermal conductivity of PP is 0.4 W/m·K and 0.45 for PE-LD. This small difference in this parameter generates a very different behavior of the temperature in the inner layer of the extrusion profile during the cooling process.

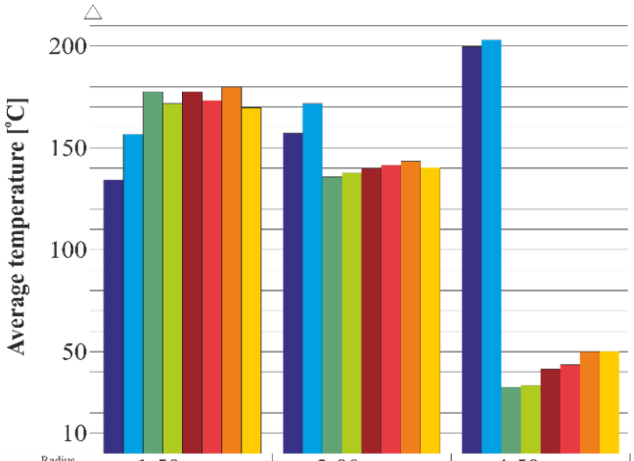
In addition, we have studied the influence of the length of the radius (measuring point) on the temperature distribution. All these data are collected in Figure 9.

Tab. 5. Temperature distribution during <u>cooling</u> for polypropylene (PP) at temperatures of 15°C, 25°C, 35°C.

	185°C			205°C			225°C		
15°C									
	T_o	T_m	Ti	T_o	T_m	Ti	T_o	T_m	Ti
	31,12	120.5	162.12	31.4	137.33	176.68	35.12	149.25	193.65
25°C									
	T_o	T_m	Ti	T_o	T_m	Ti	T_o	T_m	Ti
	39.11	128.02	160.66	41.21	138.97	177.53	44.02	152.34	194.36
35°C									
	T_o	T_m	Ti	T_o	T_m	Ti	T_o	T_m	Ti
	48.12	131.21	164.01	49.89	142.89	179.11	52.13	156.19	196.24

Tab. 6. Temperature distribution during cooling for polyethylene (PE-LD), at temperatures of 15°C, 25°C, 35°C

	185°C			205°C			225°C		
15°C									
	T_o	T_m	Ti	T_o	T_m	Ti	T_o	T_m	Ti
	31.15	124.21	156.01	34.11	137.05	170.98	34.86	152.03	188.21
25°C									
	T_o	T_m	Ti	T_o	T_m	Ti	T_o	T_m	Ti
	40.85	128.21	157.17	44.12	141.97	173.44	45.71	154.2	189.12
35°C									
	T_o	T_m	Ti	T_o	T_m	Ti	T_o	T_m	Ti
	49.87	132.32	158.5	52.34	145.44	175.11	48.12	142.92	175.32



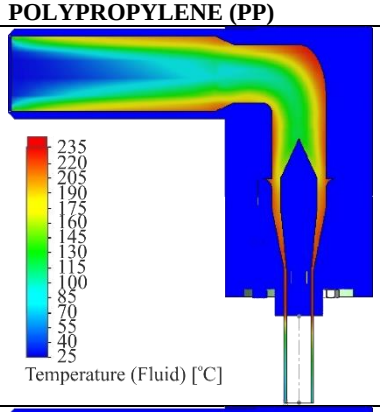
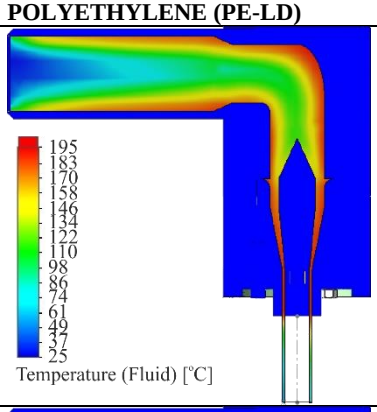
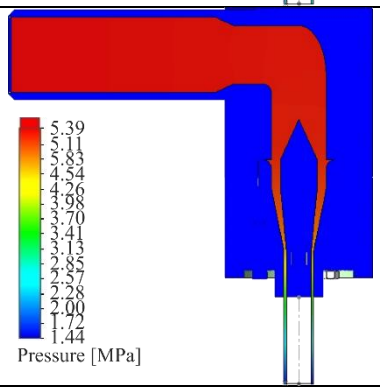
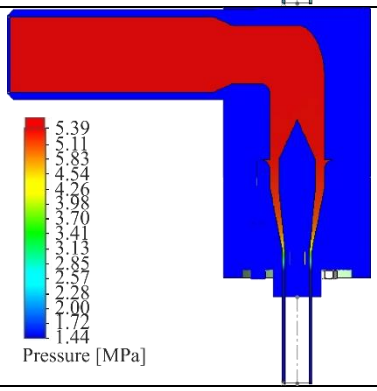
Process & material / Radius	1.50 mm	3.00 mm	4.50 mm
HEATING			
Polipropylene (PP)	134.31	157.16	199.62
Poliethylene (PE-LD)	156.64	171.70	202.96
COOLING 15°C			
Polipropylene (PP)	177.48	135.69	32.55
Poliethylene (PE-LD)	171.73	137.76	33.37
COOLING 25°C			
Polipropylene (PP)	177.52	139.78	41.45
Poliethylene (PE-LD)	173.24	141.46	43.56
COOLING 35°C			
Polipropylene (PP)	179.79	143.43	50.05
Poliethylene (PE-LD)	169.64	140.23	50.11

Fig. 9. Average values of the temperatures of the inner layer, the core and the outer layer.

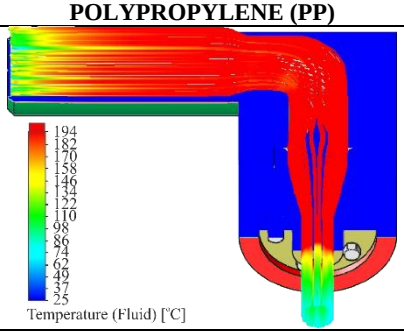
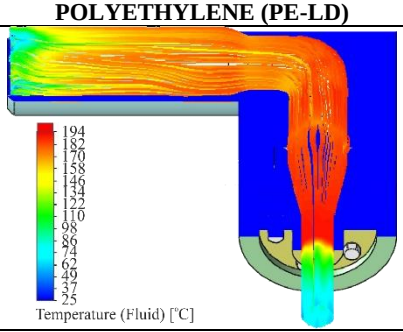
It can be seen that increasing values of the radius provokes higher temperatures in the heating zone and lower temperatures in the cooling zone regardless the material and extrusion conditions studied. In the heating area, the differences between PE-LD and PP are decreased at longer radius. Our hypothesis is that for such a long distance the thermal conductivity values of 0.4 and 0.45 W/m·K are not able to induce a different behavior in the flowing material. In agreement with this statement, the cooling temperature is a parameter with a remarkable impact on the temperature profiles at large values of radius.

Finally, based on the conducted simulations of the polymer extrusion process, using the transverse head for extruding mini-tubes, the pressure and temperature distribution values were read out during the flow of the material through the tool and the distribution of the flow trajectory was illustrated. The final results of the extrusion simulation of polypropylene and polyethylene are presented in Table 7 and Table 8.

Tab. 7 . Temperature and pressure distribution for polypropylene and polyethylene

	POLYPROPYLENE (PP)	POLYETHYLENE (PE-LD)
TEMPERATURE		
PRESSURE		

Tab. 8. Distribution of flow trajectory for polypropylene and polyethylene

	POLYPROPYLENE (PP)	POLYETHYLENE (PE-LD)
EXTR. HEAD		

5. SUMMARY AND CONCLUSIONS

In this paper we have shown that numerical simulations are a basic tool for solving many problems in various technical fields, specifically in the flow conditions of plastic extrusion. We have proved that basic simulation software such as Solid-Works and MOLDFLOW allows us to rapidly evaluate the extrusion conditions for different kinds of polymers, heating and cooling temperatures and extruding heads. In our case, we have evaluated the influence of these extruding conditions on the processing of polyethylene and polypropylene in order to manufacture mini-tubes. The outer, core and inner temperature has been calculated for three different heating temperatures (185, 205 and 225°C) and cooling temperatures (15, 25 and 35°C). The higher thermal conductivity of PE-LD provokes higher inner temperatures compared to PP in the heating zone. In the cooling zone, the temperature affects more significantly the values of the outer temperature. Surprisingly, the values of Ti of PP do not change with the cooling temperature, however, there is a big impact on Ti values for PE-LD. When the length of the radius (measuring point) is evaluated, we have demonstrated that with larger values of radius the thermal conductivity barely affects the average temperature in the heating zone, however in these conditions the cooling temperature is a relevant parameter which must be taken into account in the design of the extruding process.

With this study, we have the opportunity to evaluate the main parameters of the processes that occur inside the extruder, including the head itself. This allows us to optimize the design of the tool in order to get the most accurate reproduction of the extrudate. Correctly performed numerical simulations, together with a reliable interpretation of results, allow to avoid errors during the design of both the tool and the process (including parameters) of extrusion leading to a reduction of time and costs.

Acknowledgments

The authors acknowledge the Ministerio de Economía, Industria y Competitividad (MINECO, Spain), the EU FEDER Program (Grant # MAT2017-85130-P), "Este trabajo es resultado de la actividad desarrollada en el marco del Programa de Ayudas a Grupos de Excelencia de la Region de Murcia, de la Fundación Séneca, Agencia de Ciencia y Tecnología de la Region de Murcia (Grant # 19877/GERM/15) ".

REFERENCES

Garbacz, T. (2012). Structure and properties of cellular thinwalled cable coatings. *Polimery*, *57*(11–12), 865–868.

Garbacz, T., & Sikora, J. (2012). *Przetwórstwo tworzyw polimerowych, ćwiczenia laboratoryjne, część 1*. Lublin: Wydawnictwo Politechniki Lubelskiej.

Githuku, D., & Giacomin, A. (1993). A Spectral Element Simulation of Gravitational Flow During Plastic Pipe Extrusion. *Journal of Engineering Materials and Technology*, *115*, 433–439.

Jachowicz, T., & Klepka, T. (2012). *Przetwórstwo tworzyw polimerowych, ćwiczenia laboratoryjne, część 2*. Lublin: Wydawnictwo Politechniki Lubelskiej.

Klepka, T. (2001). Parameters characterizing optotelecommunication cable and its innerduct interaction. *Polimery*, *46*(2), 192–201.

Klepka, T., Jeziórska, R., & Szadkowska, A. (2015). Thin wall products made of modified high density polyethylene. *Przemysl Chemiczny, 94*(8), 1352–1355.

Koutelieris, A., Kioupi, K., Haralampous, O., Kitsakis, K., Vaxevanidis, N., & Kechagias, J. (2017). Simulation of extrusion of high density polyethylene tubes. *MATEC Web of Conferences 112*, 04004.

Pielichowski, J., & Pruszyński, A. (1998). *Technologia tworzyw sztucznych*. Warszawa: Wydawnictwa Naukowo-Techniczne.

Rabek, J. F. (2008). *Współczesna wiedza o polimerach*. Warszawa: Wydawnictwo Naukowe PWN.

Rauwendaal, Ch. (2014). *Polymer Extrusion.* Munich: Hanser.

Rydzkowski, T. (2011). Properties of recycled polymer mixtures obtained in the screw-disc extrusion process. *Polimery, 56*(2), 135–139.

Sasimowski, E., Sikora, J., & Królikowski, B. (2014). Effectiveness of polyethylene extrusion in a single-screw grooved feed extruder. *Polimery, 59*(6), 505–510. doi:10.14314/polimery.2014.505

Sikora, J. (2008). *Design of Extrusion Heads.* Lublin: Wydawnictwo Politechniki Lubelskiej.

Sikora, R. (1993). *Przetwórstwo tworzyw wielocząsteczkowych*. Warszawa: Wydawnictwo Edukacyjne.

Sikora, R. (2006). *Przetwórstwo tworzyw polimerowych. Podstawy logiczne, formalne i terminologiczne.* Lublin: Wydawnictwo Politechniki Lubelskiej.

Sykutera, D. (2012). *Wspomaganie komputerowe w procesach przetwórczych – materiały wykładowe*. Bydgoszcz: UTP Bydgoszcz.

Tor-Świątek, A., Garbacz, T., & Jachowicz, T. (2016). Quantitative Assessment of the Microscopic Structure of Extruded and Injected Low-Density Polyethylene Modified with Microspheres by Image Analysis. *Cellular Polymers, 35*, 67-84. doi:10.1177/026248931603500202

White, J. L., & Potente, H. (2003). *Screw Extrusion. Science and Technology*. Munich: Hanser.

Wilczyński, K., Garbarski, J., Nastaj, A., & Lewandowski, A. (2009). Model komputerowy procesów wytłaczania i wtryskiwania. *Czasopismo Techniczne. Mechanika, 106*(1-M), 367-373.

Wytłaczanie - linia technologiczna (n.d.). Retrieved August 6, 2018, from http://www.tworzywa.pwr.wroc.pl/pl/dydaktyka/linia-technologiczna

Applied Computer Science, vol. 14, no. 3, pp. 96–106
doi:10.23743/acs-2018-24

Submitted: 2018-08-20
Revised: 2018-09-08
Accepted: 2018-09-24

medical imaging, 3D reconstructions, orthopaedic trauma surgery

Przemysław KRAKOWSKI[*], *Robert KARPIŃSKI*[**], *Marcin MACIEJEWSKI*[***]

APPLICATIONS OF MODERN IMAGING TECHNOLOGY IN ORTHOPAEDIC TRAUMA SURGERY

Abstract

Orthopaedic trauma surgery is a complex surgical speciality in which anatomy, physiology and physics are mixed. Proper diagnosing and based on that planning and performing surgery is of crucial matter. This article briefly summarizes available radiological modalities used for diagnostics and for surgical planning. It focuses on utility of rapid prototyping process in trauma surgery. Moreover, a case study in which this technique was used is described. Rapid prototyping proved its usefulness and in future it may become a modality of choice for planning complex trauma procedures.

1. INTRODUCTION

Orthopaedic surgery can be easily called a mix of anatomy, physiology and physics. Every day orthopaedic surgeons deal with complex fractures, limb malalignments or developmental disorders that influence axis of the limbs. Bones are connected with soft tissues which put strain on the structure of the bone and in case of fractures, they generate fracture distraction and malalignment. The same forces act on musculoskeletal system in developmental diseases or posttraumatic axis alterations. Therefore, in planning complex surgical procedures, surgeons have to

* Orthopedic Department, Łęczna Hospital, Krasnystawska 52, 21-010 Łęczna, Poland
** Department of Machine Design and Mechatronics, Faculty of Mechanical Engineering, Lublin University of Technology, Nadbystrzycka 36, 20-618 Lublin, Poland, r.karpinski@pollub.pl
*** Institute of Electronics and Information Technology, Faculty of Electrical Engineering and Computer Science, Lublin University of Technology, Nadbystrzycka 36, 20-618 Lublin, Poland

take under consideration various forces, which will affect the bones. The complex 3D structure of bones is often hard to reconstruct. Meticulous surgical planning is of great importance to successful performing a complex surgery. Therefore, orthopaedic and engineering society seek methods that could enhance planning of complex surgical procedures. A wide variety of imaging solutions is available for usage of orthopaedic surgeons including plain X-rays, ultrasound, (US), computed tomography (CT) or magnetic resonance imaging (MRI). Every of these modalities has its unique features, advantages and disadvantages. However, even having such a wide variety of imaging solutions, orthopaedic surgeons often come to a point where these modalities are not capable of providing adequate data concerning complex fractures or limbs deformities. Even having a 3D reconstruction of bone, which is to be operated, in some instances is not sufficient to fully understand the complexity of the bone geometry. A solution to that problem might be 3D printing based on CT scans of the affected limb (Mulford, Babazadeh & Mackay, 2016). This article was written to show possible future paths to improving medical imaging techniques.

2. IMAGING TECHNIQUES

The inventor of X-rays was Wilhelm Röntgen, who published his first paper in 1896 (Röntgen, 1896). Before that, orthopaedic diagnostic was limited to simple observation of limb alignment or pathological movement on fracture site. The invention was introduced to everyday practice. Up to this day, plain X-rays are the work horse for trauma surgeons (The ATLS Subcommittee et al., 2012; Bégué, 2014). It is cheap, widely used and available in almost any trauma setting. In orthopaedic diagnostics usually 2 views are required in 90 degree rotation of the films. However, in some cases such as scaphoid fractures, around 25% of fractures can be overlooked on initial X-rays (Jenkins, Slade, Huntley & Robinson, 2008). Similarly in paediatric orthopaedics, fractures often are occult and not visible on first presentation on plain X-rays due to unique characteristics of the paediatric skeleton which can cause troubles with diagnosing the fracture (Segal & Shrader, 2013). Moreover, conventional radiographs show only flat image of 3D bone structure. Nevertheless, conventional radiography is the first method of choice in diagnosing traumatic lesions, due to its simplicity, cost-effectiveness and accessibility. As mentioned above, bones are a 3D structures, with multiple soft tissue attachments to its surface, which influence the bone behaviour during trauma or other diseases. Therefore planning a complex procedure on simple X-rays is often hard and inadequate in details, which can impair surgical outcome. Therefore introduction of CT was of great importance for orthopaedic surgery.

CT is a routinely used imaging method since 1972 when the first commercial CT scanner was introduced (Richmond, 2004). Since that time the use of CT increased intensively (Berrington de González et al., 2009). It uses X-ray beams which are passed through a body and produce a set of data which can be manipulated in order to demonstrate various organs based on their ability to capture X-ray beam. Modern CT scanners and its software are capable of creating images in transverse, sagittal and coronal planes. Moreover, the data collected during scanning can create a 3D image of the affected bone with some adjacent soft tissues such as peroneal tendons in calcaneal fractures (Ohashi et al., 2015). The sensitivity for diagnosing peroneal dislocation was similar to the findings based on MRI evaluation. CT has also the advantage of diagnosing even small osteochondral fractures, which are usually occult in plain X-rays. CT is therefore, routinely used in intra-articular fractures, where up to 31% of depression fractures are missed by conventional radiography (Dale, Ha & Chew, 2013). Moreover, with technical advancement creating a intraoperative CT scanners was possible, which can be used in intraoperative control of reposition and fixation of complex fractures like foot or pelvis (Cunningham, Jackson & Ortega, 2014; Kemppainen, Pennock, Roocroft, Bastrom & Mubarak, 2014).

Magnetic resonance was introduced in 1973 (Lauterbur, 1973) by Paul C. Lauterbur. Its medical use was slowly increasing since early eighties. Images are acquired due to high concentration of water in tissues. When introduced into a magnetic field hydrogen atoms emit radio frequency signal which is measured by receiving coil, and then the data is processed in order to create an image. Since MRI is capable of imaging soft tissues which contain water, it has wide range of use in orthopaedic surgery. The most common use of MRI is in diagnosing soft tissue and cartilage lesions in joints (Puig, Kuruvilla, Ebner & Endel, 2015; Rosas, 2014; Shindle et al., 2006). Magnetic resonance imaging has the highest sensitivity in detecting cartilage and soft tissue lesions reaching 91% for structures like meniscus (Crawford, Walley, Bridgman & Maffulli, 2007) and 94% for cartilage lesions (Wong, Han, Wong & Lee, 2017). MRI has also high sensitivity in detecting other lesions and diseases of musculoskeletal system. MRI is one the most sensitive imaging modalities in detecting bone marrow oedema which is main symptom of stress fractures, tumors or trauma (Shin, Morin, Germany, Jones & Lapinsky, 1996; Silva Jr. et al., 2013). Nevertheless, all these modalities has their own limitations, and frequently are not reliable in planning of the surgeries.

3. COMPUTED NAVIGATION

Orthopaedic surgery is one of the most demanding specialities when performing complex procedures. Due to 3D construction of bones, one must be prepared to re-create the length, axis and rotation of the bone that is to be treated. In case of fractures soft tissues bone attachments create forces that displace

fracture fragments. In total hip (THR) and total knee (TKR) replacements recreating of proper axis to facilitate painless and smooth movement of the joint is of vital importance. Also tumorous resections require sophisticated planning in order to reconstruct the bone and overlying tissues. For this reason, computer-assisted orthopaedic surgery (CAOS) was introduced. Since the end of XX century more and more applications of CAOS were proposed. Before the advent of computed tomography the main source of information for orthopaedic surgeons were plain 2D X-rays, which were susceptible to errors resulting from magnification of X-ray or malpositioning of the patient during radiography. CT is free from these potential errors. Therefore, it can be used for proper planning of the surgery. Different methods of assisting the surgery were implemented including robots (Taylor et al., 1999) which perform crucial steps of the procedure. Also during total knee or total hip replacements, surgeons can use patient-specific guides. The guides are prepared on basis of MRI or CT of individual patient. It was shown that using patient-specific guides facilitate better limb alignment in complex joint replacement cases (MacDessi, Jang, Harris, Wheatley, Bryant, & Chen, 2014). Even though computer-assisted navigation has its benefits, it is hard to implement in everyday practice in operating room. The main obstacles in implementing CAOS in OR are: operating room setup, maintaining the correct alignment, or surgery time (Rahmathulla, Nottmeier, Pirris, Deen & Pichelmann, 2014). Guiding systems were found to have lover complication rate in spinal surgery (Rahmathulla et al., 2014). It was also shown that main weaknesses of the CAOS based on surgeons opinions were: intra-operative glitches, unreliable accuracy, frustration with intra-operative registration and line-of-sight issues (Zheng & Nolte, 2015).

The basic elements of every CAOS system are: the virtual object which is defined as representation of structures which allow surgeon to plan procedure. Virtual objects can be acquired prior to surgery or intraoperatively. In the beginning of CAOS all data was collected prior to surgery, however this approach had its limitations such as changes in bony anatomy between planning and performing surgery. Therefore, usage of intraoperative CT has been proposed (Jacob, Messmer, Kaim, Suhm, Regazzoni & Baumann, 2000). However, intra-operative usage of CT exposes medical professionals and patient to great level of radiation. Moreover, creating a space for intra-operative CT in the setting of operating room requires large investments in the infrastructure. Due to limitations of CT intra-operative usage new modalities were introduced including 3D fluoroscopic image data which proved to provide adequate information (Rajasekaran, Karthik, Ravi Chandra, Rajkumar & Dheenadhayalan, 2010). The next important part of CAOS is registration method which enables displaying the current location of the tool based on data collected previously. The techniques implemented in registration are surface matching (Bargar, Bauer & Börner, 1998; Bächler, Bunke & Nolte, 2001), 2D and 3D fluoroscopic images (Zheng, Kowal, González Ballester, Caversaccio & Nolte, 2007), also usefulness of ultrasound was proposed in registration (Oszwald et al., 2008). When data is processed it is possible to use so called navigators,

which can be specialized trackers (Meskers, Fraterman, van der Helm, Vermeulen & Rozing, 1999) or robots (Honl et al., 2003). However, usage of robots in trauma cases was mostly studied in laboratory settings (Oszwald et al., 2010). Moreover, trauma cases are more complex and more individualized approach is needed. One definition of a fracture is that it is a severe injury to the soft tissues with loss of continuity of the bone. The definition explains why fracture treatment is so demanding and unpredictable. Common surgical approaches have to be modified in trauma setting, moreover the time between injury and treatment is often limited, therefore preparation of individualized computer assisted navigation for the cases is very hard to obtain.

4. RAPID PROTOTYPING

In recent years there is growing interest in process called rapid prototyping. Especially trauma surgeons can benefit from such modality in complex cases due to problems regarding traumathology mentioned above. The process can be simply described as creating a 3D model of the structures from source image data. In medical field the data is collected mostly by CT. It is known that based on CT scans some physical properties and detailed geometry of the bone structure can be visualised (Falchi & Rollandi, 2004). The greatest benefit of rapid prototyping is the possibility to re-create surgical steps prior to the actual surgery. This include choosing the best surgical approach, sequence of fracture elements reposition and method of definite fixation.
Such a visualisation process usually requires a few steps:

- Properly establishing the region of interest, or ROI,
- Acquisition of a series of flat slice images of the ROI, often using CT,
- Recombining the images into a three-dimensional object,
- Post-processing of the object to remove any possible artefacts,
- Preparation for 3d printing,
- Printing and optional post-processing of the physical object.

Depending on the complexity of the model and printing time, the process can take even a few days. Some cases require high resolution of CT scans to preserve crucial detail, which often results in long processing and conversion times. Very complex, three-dimensional objects that result from such a process can sometimes require introduction of additional mechanical supports into the model. Lack of such supports can cause the physical representation to be brittle and of limited use to the team. Very complex objects will sometimes require dividing into multiple parts for easier printing, assembly or visualisation of the ROI. Another problem originates in subtle model errors, which can sometimes be challenging and time-consuming to find and make printing impossible.

Choosing the proper 3D printing technology for a particular case is very important, as different methods give different results at a different cost. The most widely used methods include:

- Stereolitography, or SLA, which is a method based on laser-hardening of special type of light sensitive resin in a layered fashion. This method produces very fine detail and is relatively cheap but takes a long time.
- Digital Light Processing, or DLP, which is similar to SLA but uses arc lamps or other sources of light and a liquid crystal panel.
- Fused Deposition Modeling, or FDM, which is the most widely used method in personal 3D printers. The machine builds the object by depositing heated material, which then forms thermally fused layers. It is very cheap and can be quite fast while maintaining moderate quality. Also, various materials can be used giving the object different properties like density, hardness or colour. In more advanced printers more than one material can be used to print, resulting in more advanced and complex objects, like a bone with soft, transparent tissue covering it. One of the main drawback of this method is needing support material for floating elements or overhangs.
- Selective Laser Sintering, or SLS. This method uses a high power laser that heats parts of a layer of powdered material. After processing one layer, another one is deposited and sintered until the object is complete. This method can produce objects made of plastics or metals, is fast and accurate, but quite expensive, as it requires a large amount of powdered material.
- Selective Laser Melting, or SLM, which is similar to SLS. The difference is that the material is fully melted, resulting in a stronger bond.

The methods mentioned above can provide different results and levels of detail even for the same object. That's why it is important to optimize the model with desired precision and ROI in mind. By implementing multimaterial printing techniques it is possible to create an object that can imitate the structure of the tissue in the ROI. The synthetic tissue can be touched and felt by the surgeon. It is impossible to imitate such an experience with even the best simulation software using just rendered images.

5. CASE PRESENTATION

A male age 40 was admitted to the hospital due to multifragmentary fracture of proximal tibia due to fall while driving a quad. The fracture was diagnosed as Schatzker type V fracture-dislocation of the proximal tibia. Gross impaction of tibial plateau was recognised at initial X-rays (fig. 1).

Fig. 1. Preoperative X-ray

CT of the affected joint was obtained. Due to severe swelling of the soft tissues surrounding the fracture site, the patient was immobilised in bed with traction of 8 kg. Based on the CT scans rapid prototyping model was accustomed prior to the surgery in technique described above. The object was printed using Creality CR-10S with a 0,3 mm nozzle, 40% rectilinear infill, with 0,2mm layer thickness and with support material enabled. The filament was 1,75 mm PLA. After the swelling reduction surgery was performed. Day before the planned procedure, the main surgeon was able to practice the fracture reduction of the 3D replica (fig. 2). The The object during the printing process was shown in Figure 3.

The model gave a great insight into the necessary monouvers during the surgery. Moreover, due to large posterior extension of the medial tibial condyle fracture, the medial surgical approach was modified to enable adequate exposure of the fracture site. Implants could be adequately measured and prepared in advance. In surgeons opinion the utility of the 3D replica shortened the surgery time, and facilitated better reduction of the fracture, while it was known prior to the surgery that additional supporting screws will be necessary to obtain satisfactory reduction and fixation. After surgery a continues passive motion was introduced, and walking with ground contact. The patient regained full painless range of motion and returned to off-road quad riding.

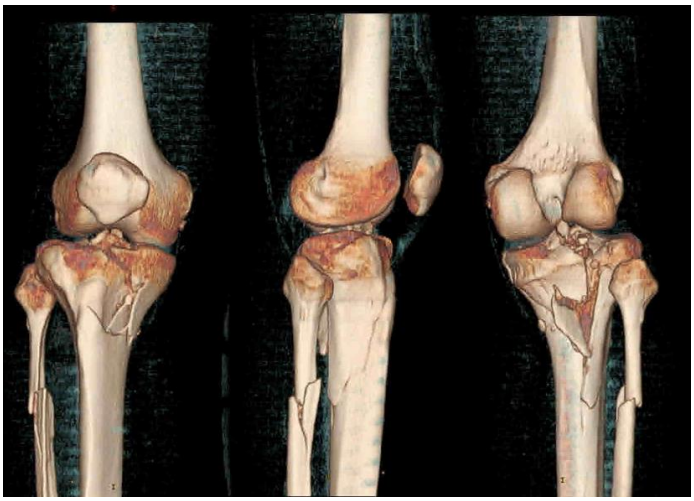


Fig. 2. 3-D reconstruction of fractured tibial plateau with visible multiple fracture lines

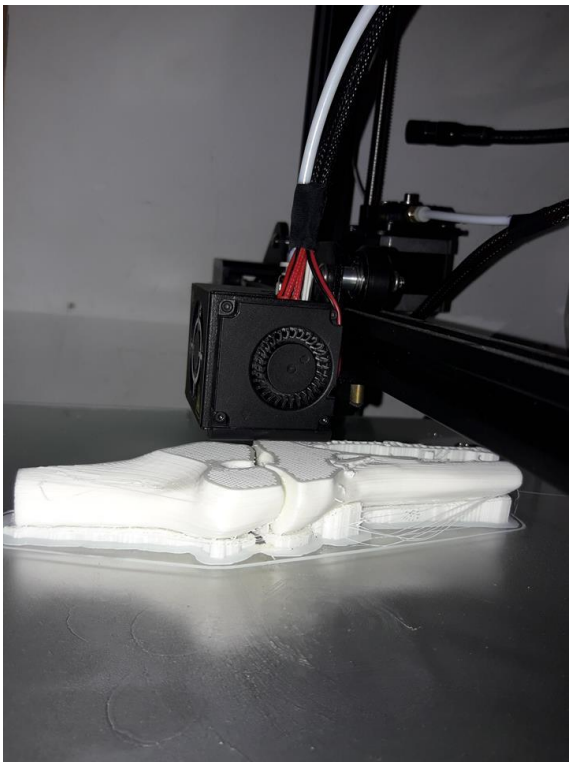


Fig. 3. The object during the printing process

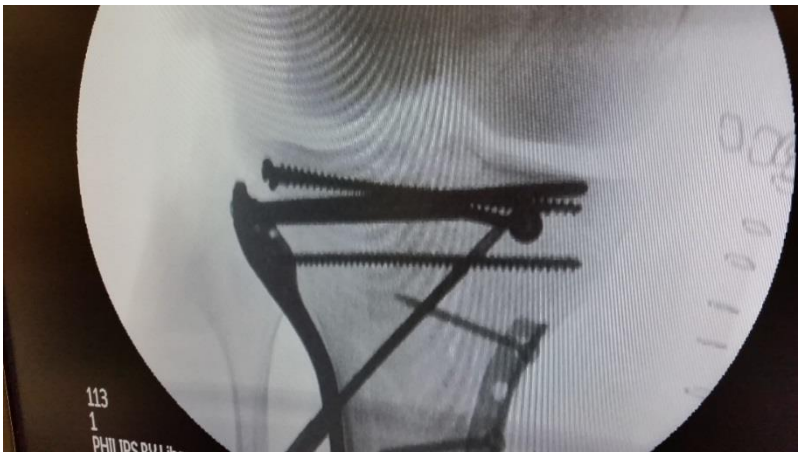


Fig. 4. Intra-operative fluoroscopic image of reconstructed tibial plateau

6. CONCLUSION

Trauma surgery is a demanding surgical speciality, due to close connection of anatomy, physiology and physics. Several modalities such as conventional radiography, MRI or CT were introduced in the past and widely used for diagnostic purposes. However, planning of trauma procedure is relatively hard and requires from the surgeon the ability to create imaginative 3-D model of the broken bone in order to re-create the bony anatomy during surgery. In simple fractures, this process is straightforward. However, complex intra-articular fractures with multiple fracture lines can be very difficult to fully understand the movements needed for restoring bony anatomy. Therefore, in complex trauma cases rapid prototyping might be useful as a assisting tool in surgery planning. The main advantage of these process is that surgeon can actually feel and see in 1/1 scale ratio the operated area, which influences surgical approach, technique and im-plants which are to be used. A pilot study wit a complex intra-articular tibial fracture showed its usefulness in planning and performing the surgery. We believe that in future more and more such applications will be used in everyday practice in orthopaedic surgery.

REFERENCES

The ATLS Subcommittee, American College of Surgeons' Committee on Trauma, and the International ATLS working group. (2013). Advanced trauma life support (ATLS): the ninth edition. *Journal of Trauma and Acute Care Surgery, 74*(5), 1363-1366. doi:10.1097/TA.0b013e31828b82f5

Bargar, W. L., Bauer, A., & Börner, M. (1998). Primary and revision total hip replacement using the Robodoc system. *Clinical Orthopaedics and Related Research, 354*, 82–91.

Bégué, T. (2014). Articular fractures of the distal humerus. *Orthopaedics & Traumatology: Surgery & Research*, *100*(suppl_1), S55–S63. doi:10.1016/j.otsr.2013.11.002

Berrington de González, A., Mahesh, M., Kim, K. P., Bhargavan, M., Lewis, R., Mettler, F., & Land, C. (2009). Projected Cancer Risks From Computed Tomographic Scans Performed in the United States in 2007. *Archives of Internal Medicine*, *169*(22), 2071–2077. doi:10.1001/archinternmed.2009.440

Bächler, R., Bunke, H., & Nolte, L. P. (2001). Restricted surface matching? Numerical optimization and technical evaluation. *Computer Aided Surgery*, *6*(3), 143–152. doi:10.1002/igs.1017

Crawford, R., Walley, G., Bridgman, S., & Maffulli, N. (2007). Magnetic resonance imaging versus arthroscopy in the diagnosis of knee pathology, concentrating on meniscal lesions and ACL tears: a systematic review. *British Medical Bulletin*, *84*(1), 5–23. doi:10.1093/bmb/ldm022

Cunningham, B., Jackson, K., & Ortega, G. (2014). Intraoperative CT in the Assessment of Posterior Wall Acetabular Fracture Stability. *Orthopedics*, *37*(4), e328–e331. doi:10.3928/01477447-20140401-51

Dale, J. D., Ha, A. S., & Chew, F. S. (2013). Update on Talar Fracture Patterns: A Large Level I Trauma Center Study. *American Journal of Roentgenology*, *201*(5), 1087–1092. doi:10.2214/AJR.12.9918

Falchi, M., & Rollandi, G. A. (2004). CT of pelvic fractures. *European Journal of Radiology*, *50*(1), 96–105. doi:10.1016/j.ejrad.2003.11.019

Honl, M., Dierk, O., Gauck, C., Carrero, V., Lampe, F., Dries, S., Quante, M., Schwieger, K., Hille, E., & Morlock, M. M. (2003). Comparison of robotic-assisted and manual implantation of a primary total hip replacement. A prospective study. *The Journal of Bone and Joint Surgery. American Volume*, *85-A*(8), 1470–1478.

Jacob, A. L., Messmer, P., Kaim, A., Suhm, N., Regazzoni, P., & Baumann, B. (2000). A whole-body registration-free navigation system for image-guided surgery and interventional radiology. *Investigative Radiology*, *35*(5), 279–288. doi:10.1097/00004424-200005000-00001

Jenkins, P. J., Slade, K., Huntley, J. S., & Robinson, C. M. (2008). A comparative analysis of the accuracy, diagnostic uncertainty and cost of imaging modalities in suspected scaphoid fractures. *Injury*, *39*(7), 768–774. doi:10.1016/j.injury.2008.01.003

Kemppainen, J., Pennock, A. T., Roocroft, J. H., Bastrom, T. P., & Mubarak, S. J. (2014). The Use of a Portable CT Scanner for the Intraoperative Assessment of Talocalcaneal Coalition Resections: *Journal of Pediatric Orthopaedics*, *34*(5), 559–564. doi:10.1097/BPO.0000000000000176

Lauterbur, P. C. (1973). Image Formation by Induced Local Interactions: Examples Employing Nuclear Magnetic Resonance. *Nature*, *242*(5394), 190–191. doi:10.1038/242190a0

MacDessi, S. J., Jang, B., Harris, I. A., Wheatley, E., Bryant, C., & Chen, D. B. (2014). A comparison of alignment using patient specific guides, computer navigation and conventional instrumentation in total knee arthroplasty. *The Knee*, *21*(2), 406–409. doi:10.1016/j.knee.2013.11.004

Meskers, C. G. M., Fraterman, H., van der Helm, F. C. T., Vermeulen, H. M., & Rozing, P. M. (1999). Calibration of the "Flock of Birds" electromagnetic tracking device and its application in shoulder motion studies. *Journal of Biomechanics*, *32*(6), 629–633. doi:10.1016/S0021-9290(99)00011-1

Mulford, J. S., Babazadeh, S., & Mackay, N. (2016). Three-dimensional printing in orthopaedic surgery: review of current and future applications: Three-dimensional printing in orthopaedic surgery. *ANZ Journal of Surgery*, *86*(9), 648–653. doi:10.1111/ans.13533

Ohashi, K., Sanghvi, T., El-Khoury, G. Y., Ahn, J. M., Bennett, D. L., Geijer, M., Inaoka, T., Berbaum, K. (2015). Diagnostic accuracy of 3D color volume-rendered CT images for peroneal tendon dislocation in patients with acute calcaneal fractures. *Acta Radiologica*, *56*(2), 190–195. doi:10.1177/0284185114522224

Röntgen, W. C. (1896). On a New Kind of Rays. *Nature*, *53*, 274–276. doi:10.1038/053274b0

Oszwald, M., Citak, M., Kendoff, D., Kowal, J., Amstutz, C., Kirchhoff, T., Nolte, L. P., Krettek, C., & Hüfner, T. (2008). Accuracy of navigated surgery of the pelvis after surface matching with an a-mode ultrasound probe. *Journal of Orthopaedic Research*, *26*(6), 860–864. doi:10.1002/jor.20551

Oszwald, M., Westphal, R., Bredow, J., Calafi, A., Hufner, T., Wahl, F., Krettek, Ch., & Gosling, T. (2010). Robot-assisted fracture reduction using three-dimensional intraoperative fracture visualization: An experimental study on human cadaver femora. *Journal of Orthopaedic Research*, *28*(9), 1240–1244. doi:10.1002/jor.21118

Puig, S., Kuruvilla, Y. C. K., Ebner, L., & Endel, G. (2015). Magnetic resonance tomography of the knee joint. *Skeletal Radiology*, *44*(10), 1427–1434. doi:10.1007/s00256-015-2178-5

Rahmathulla, G., Nottmeier, E. W., Pirris, S. M., Deen, H. G., & Pichelmann, M. A. (2014). Intraoperative image-guided spinal navigation: technical pitfalls and their avoidance. *Neurosurgical Focus*, *36*(3), E3. doi:10.3171/2014.1.FOCUS13516

Rajasekaran, S., Karthik, K., Ravi Chandra, V., Rajkumar, N., & Dheenadhayalan, J. (2010). Role of intraoperative 3D C-arm-based navigation in percutaneous excision of osteoid osteoma of long bones in children: *Journal of Pediatric Orthopaedics B*, *19*(2), 195–200. doi:10.1097/BPB.0b013e328333997a

Richmond, C. (2004). Sir Godfrey Hounsfield. *BMJ*, *329*, 687. doi:10.1136/bmj.329.7467.687

Rosas, H. G. (2014). Magnetic Resonance Imaging of the Meniscus. *Magnetic Resonance Imaging Clinics of North America*, *22*(4), 493–516. doi:10.1016/j.mric.2014.07.002

Segal, L. S., & Shrader, M. W. (2013). Missed fractures in paediatric trauma patients. *Acta Orthopaedica Belgica*, *79*(6), 608–615.

Shin, A. Y., Morin, W. D., Germany, J. D., Jones, S. B., & Lapinsky, A. S. (1996). The Superiority of Magnetic Resonance Imaging in Differentiating the Cause of Hip Pain in Endurance Athletes. *The American Journal of Sports Medicine*, *24*(2), 168–176. doi:10.1177/036354659602400209

Shindle, M. K., Foo, L. F., Kelly, B. T., Khanna, A. J., Domb, B. G., Farber, A., Wanich, T., & Potter, H. G. (2006). Magnetic Resonance Imaging of Cartilage in the Athlete: Current Techniques and Spectrum of Disease. *The Journal of Bone and Joint Surgery (American)*, *88*(suppl_4), 27-46. doi:10.2106/JBJS.F.00614

Silva Jr., J. R., Hayashi, D., Yonenaga, T., Fukuda, K., Genant, H. K., Lin, C., Rahmouni, A., & Guermazi, A. (2013). MRI of bone marrow abnormalities in hematological malignancies. *Diagnostic and Interventional Radiology*, *19*, 393-399. doi:10.5152/dir.2013.067

Taylor, R. H., Joskowicz, L., Williamson, B., Guéziec, A., Kalvin, A., Kazanzides, P., Van Vorhis, R., Yao, J., Kumar, R., Bzostek, A., Sahay, A., Börner, M., & Lahmer, A. (1999). Computer-integrated revision total hip replacement surgery: concept and preliminary results. *Medical Image Analysis*, *3*(3), 301–319.

Wong, K. P. L., Han, A. X., Wong, J. L. Y., & Lee, D. Y. H. (2017). Reliability of magnetic resonance imaging in evaluating meniscal and cartilage injuries in anterior cruciate ligament-deficient knees. *Knee Surgery, Sports Traumatology, Arthroscopy*, *25*(2), 411–417. doi:10.1007/s00167-016-4211-1

Zheng, G., Kowal, J., González Ballester, M. A., Caversaccio, M., & Nolte, L.-P. (2007). Registration techniques for computer navigation. *Current Orthopaedics*, *21*(3), 170–179. doi:10.1016/j.cuor.2007.03.002

Zheng, G., & Nolte, L. P. (2015). Computer-Assisted Orthopedic Surgery: Current State and Future Perspective. *Frontiers in Surgery*, *2*, 66. doi:10.3389/fsurg.2015.00066