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CONTENTS

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A REVIEW OF OPTICAL CHARACTER RECOGNITION SYSTEM

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Abstract: Optical character recognition (OCR) has been a topic of great interest for many years. It is a system that permits us to convert various types of documents into machine encoded/computer-readable text. It consist of steps like image acquisition, pre-processing, segmentation, feature extraction, etc. The purpose of this work is to summarize the researches performed in the OCR field. It provides an overview of different aspects of OCR and discusses corresponding proposals aimed at resolving problems of OCR. A practical OCR problem is also investigated.

Keywords: *OCR, image acquisition, pre-processing, segmentation, feature extraction*

1. INTRODUCTION

Optical character recognition (OCR) is a system that allows us to convert various types of documents (PDF, BMP, TIFF, JPEG, PNG) into machine computer-readable text. It has become one of the most outstanding applications of technology in the domain of artificial intelligence and pattern recognition. Contrarily to the human brain which has the power to recognize easily the characters/text from an image, machines are still far to reach the human level to perceive the information available in image. Consequently a large number of research efforts have been put forward that attempts to convert efficiently a document image to format understandable for machine.

OCR is a sophisticated problem because there is a lot of variables that can affect the detection of the text/characters such the diversity of the languages, styles, and fonts in which text can be written also the environmental light that is difficult to control, etc. Therefore, techniques from different disciplines of computer science are employed to address different challenges.

This paper is organized as follows. In section 2, the different types of optical recognition systems will be studied. The components of the OCR will be shown in section 3. A practical problem is analyzed in section 4. Finally, some conclusions are given in the last section.

2. TYPES OF OPTICAL CHARACTER RECOGNITION SYSTEMS

There has been plenty of directions in which investigation on OCR has been achieved. This part review different types of OCR systems that have appeared as outcome of these researches. We can classify these systems based on character connectivity, font-restrictions, image acquisition mode, etc. *Figure 1* classifies the character recognition systems.

According to the type of the input, the OCR system can be classify as machine printed character recognition or handwriting recognition. The former is relatively simpler problem because characters are usually of uniform dimensions, and the positions of characters on the page can be predicted [1].

Handwriting recognition is arranged into two types as on-line and off-line character recognition. Off-line handwriting recognition includes automatic conversion of text into an image into letter codes which are applicable within computer and text-processing applications. Off-line handwriting recognition is harder, as a lot of people have different handwriting styles. But, in the on-line system, on-line character recognition deals with a data stream which comes from a transducer while the user is writing. The typical hardware to collect data is a digitizing tablet which is electromagnetic or pressure sensitive. When the user writes on the tablet, the successive movements of the pen are transformed to a series of electronic signals which is memorized and analyzed by the computer.

There have been numerous online systems usable because they are easy to develop, have good accuracy and can be integrated for inputs in tablets [2].

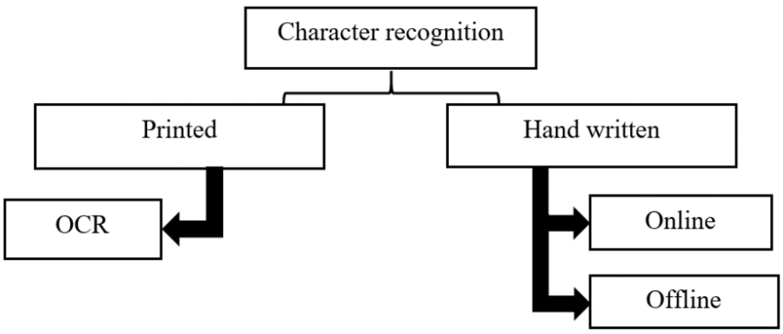

Figure 1. Types of character recognition system

3. COMPONENTS OF AN OCR SYSTEM

The principal notion in automatic recognition of patterns is first to train the machine which class of patterns that can appear and what they look like [3, 4]. In OCR patterns are numbers, letters and several special symbols like slash, exclamation, etc. The machine training is achieved by displaying to the machine examples of characters of all different classes. Based on these examples the machine builds prototype or description of each class of characters. Throughout recognition the unknown characters are matched to previously obtained descriptions and assigned to class that gives the best match.

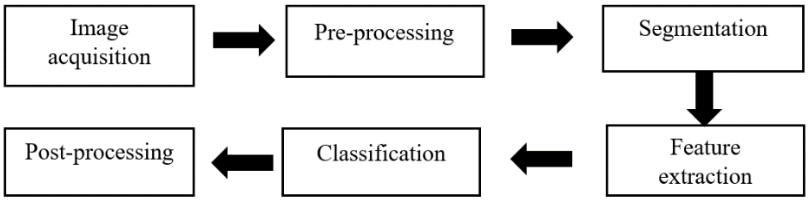

Figure 2. Components of an OCR-system

An OCR system is composed of many components as exposed in *Figure 2* [3, 5]. The initial step is to digitize analog document using an optical scanner. When regions consisting text are discovered each character is extracted by segmentation process. The obtained characters are pre-processed, removing noise to simplify feature extraction. The identity of each character is detected by matching extracted features with descriptions of character classes obtained by a previous learning phase. Lastly contextual data is used to rebuild numbers and words of the initial text. These steps are shortly given in *Figure 2*.

3.1. Image acquisition

Image acquisition is the first step of OCR system that involves getting a digital image from an external source like scanner or camera and converting it into appropriate form that can be easily processed by computer. This can include compression as well as quantization of image. A special case of quantization is binarization it converts an image of up to 256 gray levels to a black and white image. Generally, the binary image is sufficient to characterize the image. An overview of various image compression techniques have been provided in [6].

3.2. Pre-processing

Once the image has been acquired, different preprocessing steps can be performed to improve the quality of image and to make it suitable for recognition. A typical OCR system may use the following techniques for image enhancement:

- Filtering: The aim of it is to remove noise and diminish spurious points usually introduced by poor sampling rate of the data acquisition device and uneven writing surface. The main idea is to convolute a predefined mask with the image to assign a value to a pixel as a function of the gray values of its neighboring pixels. Various filters have been created for thresholding, smoothing, removing lightly colored background and contrast adjustment purposes [7, 8].
- Skewed correction: The camera captures images may suffer from skew and perspective distortions. This effect is due to improper image capture technique

like the angle of the camera with the object or the lens of the camera. The horizontal text may suffer rotation at some degrees. The calculation method for rotation of the image has been described in reference [9].
- Thinning: Is the process of reducing the width of the foreground pixels. While thinning, it is necessary to maintain the form of the characters on the image. Thinning is done on the basis of neighborhood of a pixel, e. g., if a line on an image is of 3 pixels width, the thinning function will change the border pixels of the line and the output image will consist of line of one pixel width.

3.3. Segmentation

Segmentation is a process that defines the components of an image, and its task is to isolate the characters or words from the back ground of the picture or the document. The segmentation can be done explicitly or implicitly as a byproduct of classification phase [10]. Most of optical character recognition algorithms segment the words into isolated characters which are recognized separately. Normally this segmentation is achieved by isolating each connected component that is each connected black area. This technique is easy to implement, but problems appear if characters touch each other or if characters are fragmented and consist of various parts.

3.4. Feature extraction

The aim of feature extraction is to catch the main characteristics of the characters/symbols, and it is usually admitted as one of the most difficult problems of pattern recognition. The right way of describing a character is to use the actual raster image. Another approach is to extract some features that still characterize the characters/symbols but without taking into consideration the unimportant attributes. The technics for extraction of such features are usually split into three principal groups where the features are found from:
- Structural analysis.
- The distribution of points.
- The distribution of points.

3.5. Classification

It is described as the process of classifying a character into its correct class. The basic approach to classification is founded on links present in image components. The analytical approaches are based on the usage of a discriminate function to arrange the image. Some of the statistical classification approaches are Decision tree classifier, Bayesian classifier, Neural network classifier, etc. Finally, there are classifiers based on syntactic approach that assumes a grammatical approach to compose an image from its sub-constituents.

3.6. Post-processing

After the classification of the character, there are several approaches that can be adopted to enhance the preciseness of the OCR results. One of the paths is to utilize several classifier for the classification of the image. The classifier can be used in parallel, hierarchical or cascading fashion. The results of the classifiers can then be united using several approaches. For a better OCR results, contextual analysis can also be executed. The geometrical and document context of the image can aid in decreasing the chances of errors. Lexical processing based on Markov models and dictionary can also help in improving the results of OCR [11].

4. A PRACTICAL PROBLEM

In this part, we will show you an experiment that have been performed using iRvision system that is a ready-to-use robotic vision system which requires no additional hardware except for a camera or sensor and cable. It provides a 2-D or 3-D robot guidance and/or error proofing tool to accomplish part location, presence detection, and other operations that normally require special sensors or custom fixturing. In our case the experiment will use the iRvision system to recognize successfully scratched numbers. It should be mentioned that in the teaching process of the system a non-scratched numbers were used. The laboratory is located in University of Miskolc, at Robert Bosch Department of Mechatronics. iRVision consists of the following components (see in *Figure 3*):

- Camera and lens, or three-dimensional laser sensor.
- Camera cable.
- Optional multiplexer (contained in the robot controller).
- Setup PC ... *.
- Communication cable ... *.

Note: The components marked with an asterisk (*) are necessary only for setting up iRVision and can be removed during production operation.

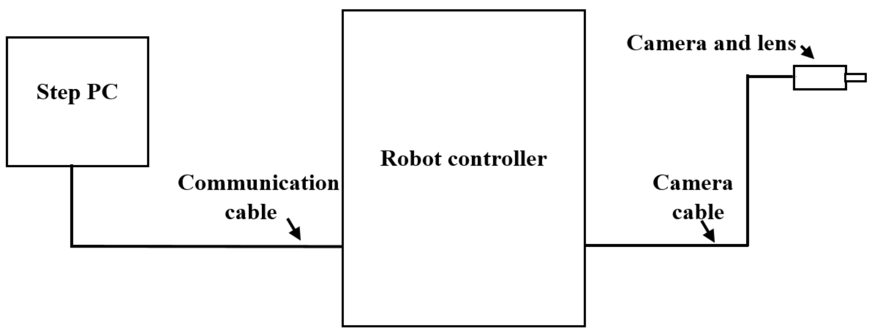

Figure 3. The iRVision System

After teaching our iRvision system to recognize number 3, we created some scratched number that was written in a piece of paper A4 and this scratches varied from big to small one. Then iRvision system was applied to verify if it can recognize the scratched numbers successfully in such cases when changing some parameters like score threshold, contrast threshold, scale, orientation. Consequently these parameters increase the necessary time for recognition. The application of the solution is shown in the *Figure 4*. Environment light was used in this experiment.

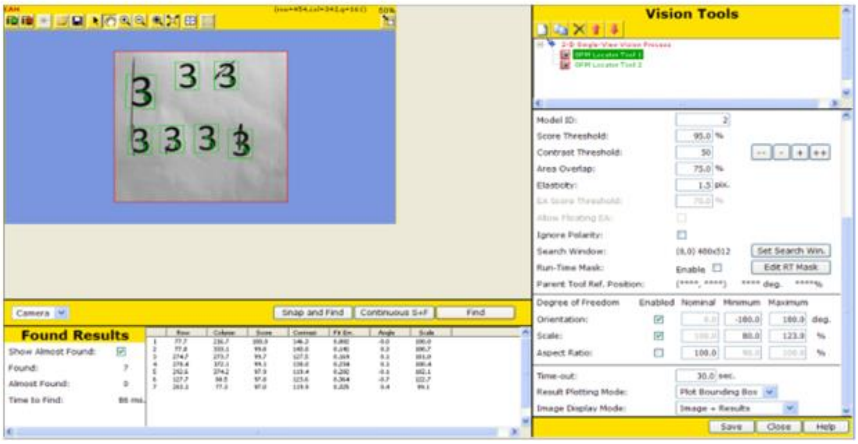

Figure 4. Results of the iRvision system

All the scratched numbers were detected successfully but in the Found Results section there are some parameters which are different from each other:

- Row and Column: Coordinate values of the model origin of the found pattern (units: pixels).
- Score: Represent how similar the pattern found in the image is to the model pattern. It is ranging from 0 to 100 points. If the pattern fully matches, it gets a score of 100 points. If it does not match at all, the score is 0.
- Contrast: This value represents "how clearly the pattern found in the image can be seen". The value of contrast ranges from 1 to 255. The larger the value, the clearer the pattern.
- Angle and scale of the found pattern: The Angle of the found pattern indicates the degree of rotation with respect to the model pattern. The scale of the found pattern shows the value of how many times it is expanded with respect to the model pattern.
- Fit error (Fit err.): Deviation of the found pattern from the model pattern (units: pixels).

There is a lot of system which performs better like Cognex system. Using thus system allows us to apply morphological operation to remove noises from the image and make it easy to be detected.

5. SUMMARY

An overview of several techniques of OCR has been discussed in this paper. An OCR is not a single process, however it includes several stage like acquisition, preprocessing, segmentation, feature extraction, classification and post-processing. Each steps is reviewed in this paper. Using a combination of these techniques, a powerful OCR system can be developed as a future work. The OCR system can also be used in several functional applications such as smart libraries, number-plate recognition and various other real-time applications used in the industry.

6. ACKNOWLEDGEMENT

The described article/presentation/study was carried out as part of the EFOP-3.6.1-16-2016-00011 "Younger and Renewing University – Innovative Knowledge City – institutional development of the University of Miskolc aiming at intelligent specialization" project implemented in the framework of the Szechenyi 2020 program. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

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DESIGNING OF ROBOTIC DOUBLE-FUNCTION FINGERTIPS

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Abstract: This paper presents the design of robotic end-effector fingertips for precision assembly work. The fingertips are used to assemble four different elements of a battery package top cover. The workpieces have got complex shapes therefore double-function fingertips are essential in order to perform the four independent operation steps via an industrial robot. A Fanuc LRMate 200iC robot with a servo gripping mechanism are used to accomplish the assembling operations.

Keywords: *gripper, fingertips, robot, grasping*

1. INTRODUCTION

Robots can perform high repeatability and accuracy therefore it can be used to assemble workpieces [1], [2], [3]. Not only recently, robotic assembling [4] are a widely investigated area, especially for industrial purposes [1], [5]. Changing from manual assembly to robotic one may can rise serious difficulties because robots are controlled kinematically without force feedback. When workpieces are not matching due to their bad orientation the system cannot correct the motion of the end-effector.

There are a great number of commercially available grippers, which are actuated by, e.g., pneumatic air supply, electrical servo motors. However available fingertips usually have flat surface shapes [1], [6]. Using such fingertips to grasp a workpiece it will not be in a well determined orientation and position of the coordinate system of the end-effector. Therefore these fingertips cannot be used for a precision assembling. This drawback can be improved by applying three-finger gripper [7] but many cases this is not a perfect solution.

A better solution is the task specific fingertips, which have surfaces compatible with the geometries of gripped workpieces. However such fingertips may fit only to a specific type of workpieces. Since industrial robots usually have 6 DoF, the end-effector can be rotated to an arbitrary orientation. In many cases this gives the possibility to design the fingertips fitting to more than one workpiece. Naturally it depends on the geometry of the workpieces.

The purpose of this paper to design double-function gripper fingertips, which can be used for a battery package assembly process. There are four workpieces each of them having complex geometry. Well defined positions and orientations of the workpieces are required for the precision assembling. In order to satisfy this condition the surfaces of the fingertips and the corresponding workpieces must be compatible.

Further requirement is to apply as few robots as possible, which can be fulfilled by multipurpose fingertips. The present paper deals with double-function fingertips, which are applicable to assemble four workpieces.

The remainder of the paper is organized as follows. In section 2, the assembling strategy of the top cover workpieces are described and the scheme of the working area is also given. The 3D modelling of the fingertips are given in section 3. Autodesk Inventor 2016 software was used to create the model and the technical drawing of the fingertips. The summary and concluding remarks are presented in section 4.

2. WORKPIECES TO BE ASSEMBLED

The top cover of the battery package consists of four workpieces, i.e., steel spring, black plastic stick, red plastic button and top cover (see *Figure 1*). Four steps are needed to perform their assembling. Step I: the spring is attached into the hole (Ø $1\ mm$) of the black plastic stick. Step II: the black stick is inserted into the plastic top cover element. Step III: the red pushbutton is snap-in to the top plastic cover. Step IV: the ready-made workpiece is placed to the next assembling stage.

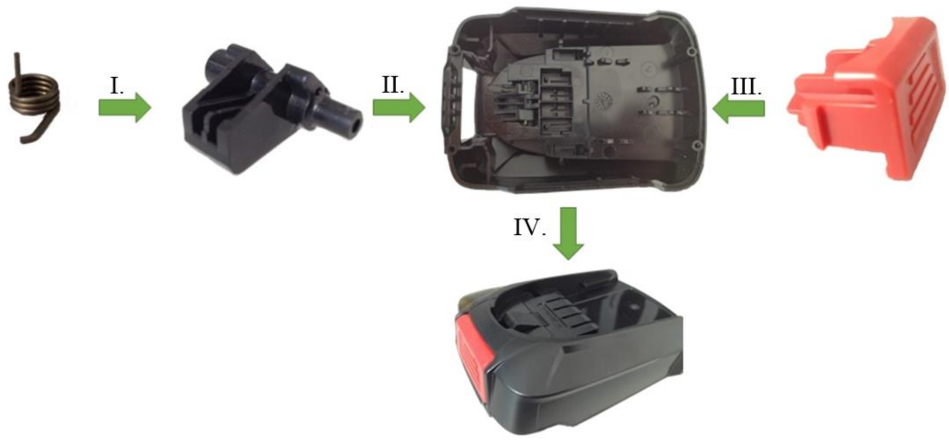

Figure 1. The assembling sequence of the top cover

In order to perform the assembling by robot the base positions and orientations of the workpieces must be well defined. Furthermore the working area of the robot must be considered, i.e., all of the workpieces and the assembling process must be placed within this area. A test bench was designed to perform the assembling of the four workpieces, the arrangement of the working area is shown in *Figure 2*. The sequence is denoted by arrows with numbers. A Fanuc LRMate 200iC industrial robot is applied to execute the assembling process.

The robotic assembling can be performed by the following sequence:

- The end-effector is moved from the base position to grasp the plastic stick.
- A steel spring is inserted into the hole of the stick and kept in this position by a magnet.
- This stick subassembly is put to a temporary place.
- Then the end-effector is moved to the top cover to grip it.
- The stick subassembly is taken away from the temporary position and snap-in to the top cover.
- Also a snap-in process is performed to fix the red pushbutton into the top cover temporarily.
- Then the red button is pushed to its final position.
- Finally the end-effector is moved to the end position where ready-made workpiece is stored.

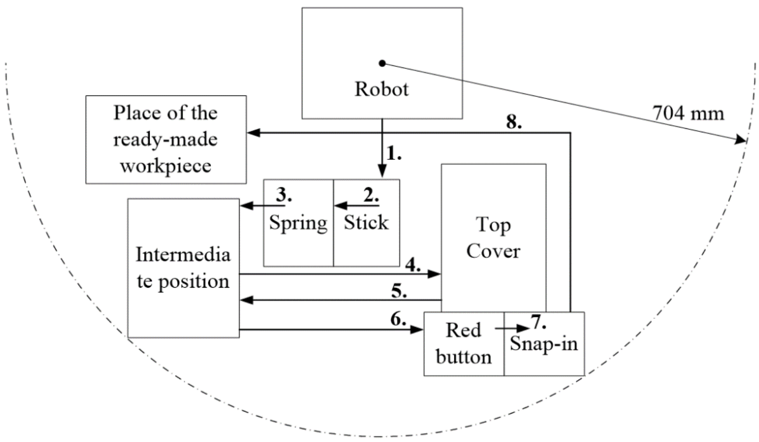

Figure 2. The block scheme of the robotic assembly

It is an economical solution if double-function fingertips are used for the above assembly process because one robot is enough to complete all of the operations. Due to the different shapes of the workpieces double-function fingertips are needed.

3. CAD MODEL OF THE FINGERTIPS

The model of the fingertips are created by the use of Inventor CAD software. The 3D models of the units are shown in *Figure 3* and *Figure 4*. The inside surfaces of the fingertips are shown in *Figure 3 (a)* and *(b)* the corresponding workpiece, which fits to it can be seen in *Figure 3 (c)*. The gripping surface of the stick and the corresponding tool surfaces are marked by blue circles [see *Figure 3 (a)–(c)*]. Red circle denotes the middle range of the stick, which fits to the fingertip [see *Figure 3 (a), (c)*]. A neodymium magnet is placed into the hole of the fingertip denoted by red circle shown in *Figure 3 (a)*. The function of the neodymium magnet is to keep the spring together with the stick.

In order to use also the same end-effector for grasping the battery cover, the outer sides of the fingertips are shaped to fit it. The outside surfaces of the fingertips and the battery cover are displayed in *Figure 4 (a)–(c)*. The orange ellipses show the fitting surfaces of the top cover and the fingertips.

The black stick can be grasped by closing the fingertips and by opening it will be released. Before grasping the top cover the fingertips are closed then at an appropriate position by activating the opening command the fingertips will grip the top cover.

There are two counter bores to mount the fingertips onto the end-effector of the robot [see *Figure 3 (a), (b)*].

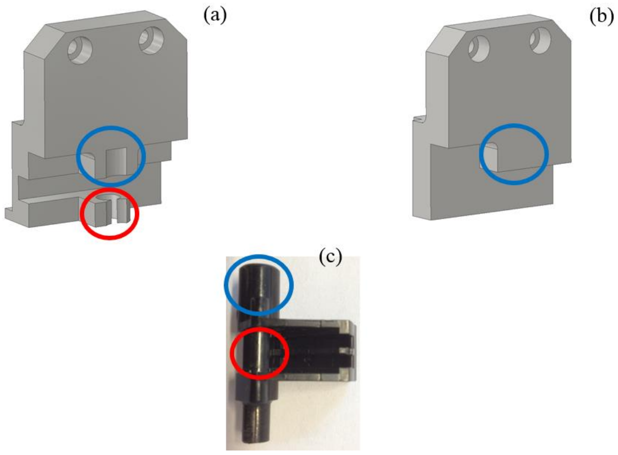

Figure 3. Inner shaped surfaces of the fingertips and the picture of the stick

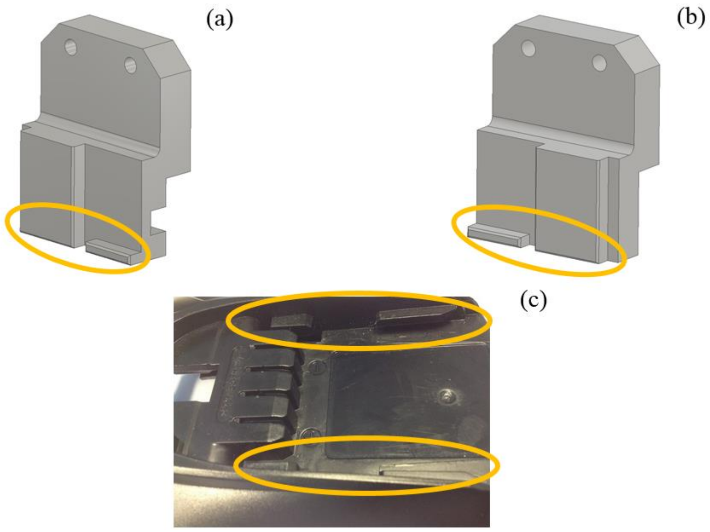

Figure 4. Outer shaped surfaces of the fingertips and the picture of the top cover

The technical drawings of the fingertips were created under Inventor CAD software and shown in *Figure 5* and *Figure 6*. The material of the gripper fingertips is aluminium alloy. The given geometry of the fingertips can be manufactured by milling machine. The general chamfers of the surfaces are 0,5 × 45°.

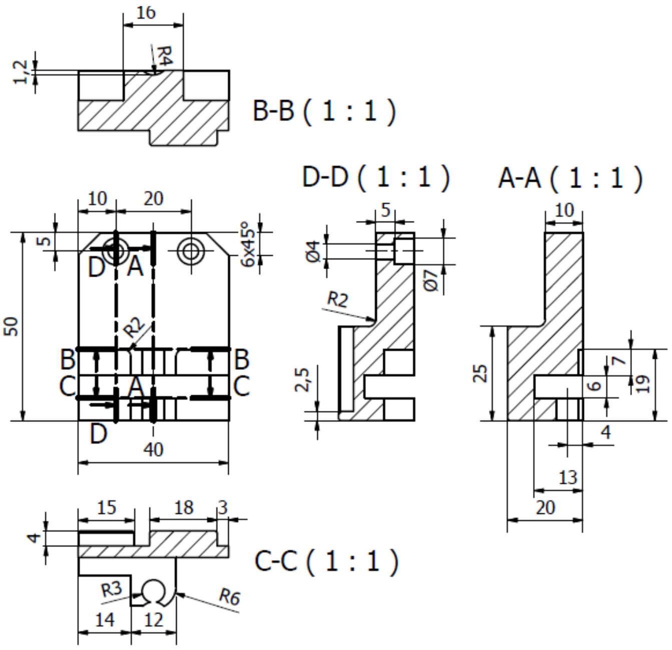

Figure 5. Technical drawing of the first fingertip

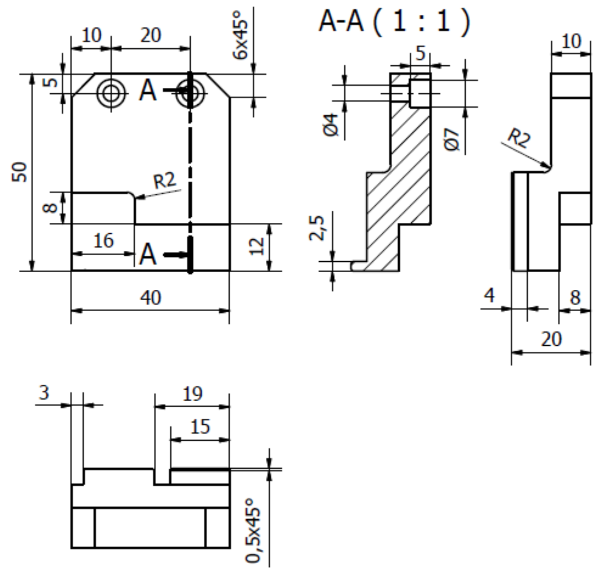

Figure 6. Technical drawing of the second fingertip

4. SUMMARY

Special purpose double-function fingertips have been designed to assemble four workpieces. The fingertips can grasp via inside surfaces a plastic stick together with a steel spring. The outer surfaces of the fingertips capable to grip a plastic top cover in order to perform three assembly steps. Though both the plastic stick and the plastic top cover are having complex geometry their positions and orientations in the coordinate system of the end-effector are precisely determined. This fact is essential to perform precision assembling via robot.

The assembly process was performed properly. This experiment validated the above proposed geometries of the fingertips. The robot can assemble the workpieces less than 1 minute. Thereafter the assembling process of the battery pack can be continued from the position of the ready-made top cover.

The presented case study is a good example that robotic assembly is applicable for such a complex assembly process, which was originally worked out manual assembly.

5. ACKNOWLEDGEMENT

The described article/presentation/study was carried out as part of the EFOP-3.6.1-16-2016-00011 “Younger and Renewing University – Innovative Knowledge City – institutional development of the University of Miskolc aiming at intelligent specialisation” project implemented in the framework of the Szechenyi 2020 program. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

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APPLICATION POSSIBILITIES OF 3D SCANNING AND PROTOTYPING IN THE MANUFACTURING OF PACKAGING TOOLS – CASE STUDY

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Abstract: In this paper authors describe the results of an industrial based work. The task of the work was to make new packaging tools for different chocolate hollow figures. The packaging machine was manufactured in the former East Germany and new tools are not available now. Two types of packaging tools were made in this project. One type was "poli-shing trough", the other type was lifting/pushing tool. In this paper the whole production of the mentioned tools are introduced from the design to the manufacturing.

Keywords: *prototype milling machine, CAD, 3D scanning, packaging tools*

1. INTRODUCTION, AVAILABLE INFORMATION

Our Institute was asked by one of our industrial partner to make new packaging tools to replace their old ones. Their packaging machines were made in the former East Germany. They cannot order new packaging tools because of the original manufacturer is not existing anymore.

Figure 1. 9 g Hollow Figure gypsum sample

Part of our work was to find the right technology for the manufacturing of packaging tool to be fit the old machines. The client made available some gypsum samples of that type of chocolate hollow figures that should be packaged with new tools. A sample of a 9 g figure can be seen in *Figure 1*.

Packaging tools we made can be divided into two groups. One of them is the polishing trough; the other one is lifting/pushing tool. Polishing troughs are used at the end of the packaging process. Lifting/pushing *(Figure 2)* tools are used at the beginning of the packaging process.

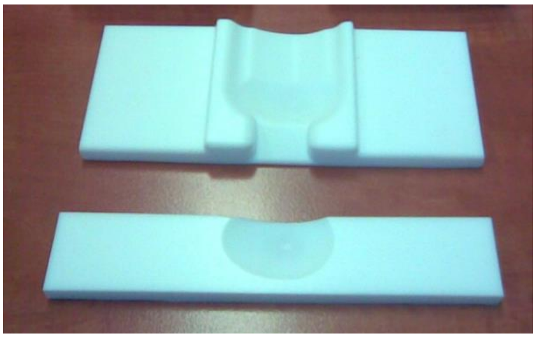

Figure 2. Lifting/pushing tools for 17.5 grams chocolate hollow figures

The task of the lifting/pushing tools is to lift up the product into the packaging machine and push the product into the right position. The finish of the packaging process happens in the polishing troughs. The packaging machine bowls the figure trough the polishing trough *(Figure 3)*, which presses the aluminium foil to the hollow figures. We can use this kind of packaging when the figures are rotationally symmetric.

Figure 3. Polishing trough for a 9 grams hollow figure

We had opportunity to see the old and worn-out packaging tools. It was a good basis to solve the problem.

2. Scanning the samples

We started our work with scanning the gypsum samples of hollow figures the client gave us. We digitalised the samples with a Roland PIX4 type touching scanner *(Figure 4)*.

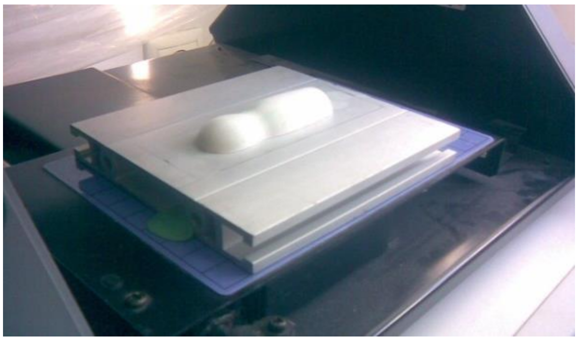

Figure 4. Scanning the gypsum sample of the 9 grams hollow figure with Roland PIX4 scanner

We could see the created surface in the controller software *(Figure 5)*. The scanning was made with 0.3 mm subdivisions in all the three directions.

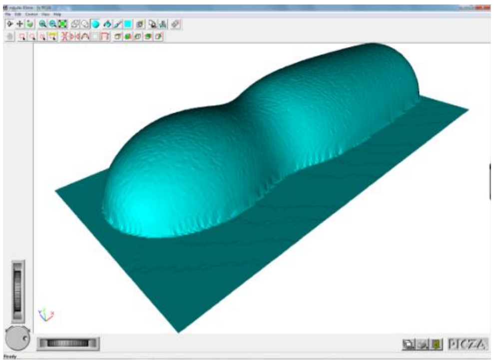

Figure 5. The scanned shape in the Picza software

The controller software can export the digitalized data to several file formats CAD systems can read (for example: step, igs, stl).

Figure 6. The manufactured sample with Roland MDX650A (left) and the original gypsum sample (right)

We chose stl format to use in our further work. This file format can be read by the CAD software (Solid Edge ST5) we used. Furthermore, the prototype printers can print directly from this file format. We made a sample from the scanned data, without any modification. The manufacturing of this sample was made with MDX 650A prototype milling machine. Our aim was to compare the dimensions of the original gypsum sample and the manufactured sample *(Figure 6)*.

3. MEASURING THE DIMENSION ACCURACY OF THE SCANNED SURFACES

We compared the originally gypsum sample and the manufactured sample. We choose easily measurable dimensions to examine the dimension differences between gypsum sample and manufactured sample. The chosen dimensions were the length and the height of samples. In the next two figures *(Figure 7, 8)* the measuring of the length can be seen. We made the measuring with digital calliper.

Figure 7. The length of the manufactured sample

Figure 8. The length of the gypsum sample

We got 0.52 mm differences between the two samples (average of multiple measuring). This difference is the 0.88% of the original length. We measured the height of the gypsum sample (9.66 mm), and the manufactured sample (9.8 mm) too. The difference was 0.14 mm. This is 1,4% difference. We had to validate the two differences on the contour of the tools. We decided to use just one modification value in both directions, 1%. We made an offset operation on the contour of the polishing trough to reduce the dimensions to approximate the contour of the original gypsum sample *(Figure 9)*. Several publications pay attention to the dimension differences of scanning geometries, [2] for example.

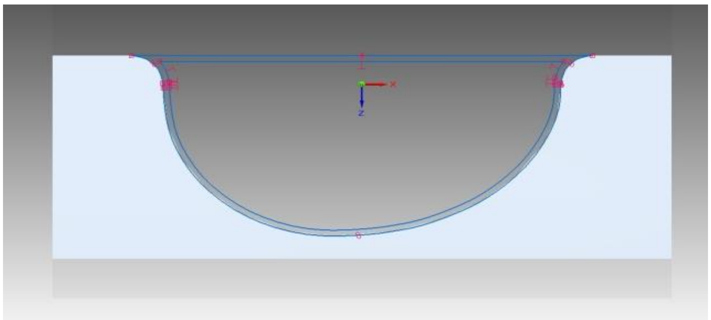

Figure 9. Offset of the contour

4. Design of the packaging tools and manufacturing testing samples

After checking the dimensions and determine the modification we could begin the designing process of the packaging tools. We started the design process with the determination of the polishing trough contour. We had to pay attention to the thickness of the padding which is in the polishing trough. The padding has two layers. A 4 mm thick rubber foam is connected to the trough and a 0.9 mm thick plastic textile is connected to the rubber foam. We considered the 4.9 mm distance of the contour with an offset. We made the offset movement of the contour to decrease the cross section of trough. We made an 80 mm long piece from steamed beech material. This length of the piece is long enough to make at least one revolution with the gypsum-sample. The next step was to glue the rubber foam and the plastic textile into the trough. We had to make two gluing between two different materials twice. We had to glue wood to rubber and rubber to plastic. In conjunction with the client Pattex Palmatex contact glue was chosen.

Figure 10. The short version of the trough (form and press)

To make perfect gluing, we had to grant the fat free and solid surface. To get a perfect connection between the elements we had to press them. The strength of the gluing greatly depends on the magnitude of the pressing force [1]. The pressure has to affect the whole surface of the trough.

To solve this task, we designed a pressing tool. We determined the dimensions of the pressing tool, on the basis of the ready size of the polishing trough. It can be seen in *Figure 10* in the vice of the prototype milling machine. The one in the left is the body of the trough the one in the right is the pressing tool. We made the gluing on the short version of the trough and the pressing tool. The glued and pressed elements can be seen in the *Figure 11*.

Figure 11. Gluing and pressing of the short version of the trough (for 17,5 g chocolate egg)

The short version of the trough was examined by the client with a chocolate figure if the aluminium foil is tight enough on the figure. The answer was positive.

5. MANUFACTURING THE PARTS OF THE FINAL VERSION OF PACKAGING TOOLS AND ASSEMBLING THEM

After the client accepted the final version of the tools' profile, we could start to make the body of the packaging tools. We had to choose such material for the body of the tools that can be glued.

Figure 12. Parts of the packaging tool made from PA6

It was necessary to glue the parts of the tools, because the length of the tools was 750 mm, but our milling machine can manufacture just 530 mm long parts (because of the limitation of working area). We chose the PA6 material for the body of tools, without glass fiber strengthening. We had to find glues with that PA6 materials can be glued to each other and the rubber foam can be glued to the PA6. To choose the right type of glues we asked for help from the Henkel Magyarország Kft. They recommended the Loctite 401 for the PA6 material, for the rubber foam and the plastic textile they suggested the Pattex Palmatex. We had to make some rework on the parts to connect them perfectly to each other. The parts of the packaging tools that were made with MDX-650 milling machine can be seen in *Figure 12*.

We milled the outside surfaces of the parts to reach the prescribed dimensions; parts were turned face-to-face to each other *(Figure 13)*. The manufacturing was made by a Wemomill FUS32 type milling machine, which is equipped with linear encoder.

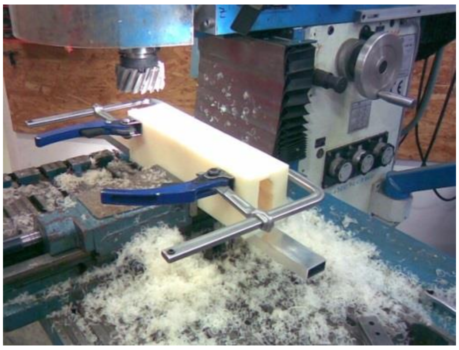

Figure 13. Manufacturing of the parts of the trough with milling machine

After the parts were ready, we started to glue them to each other. Parts were laid down to a planar surface (ILSE T-slot table) to provide the right connection of the profiles. We degreased connecting surfaces with pure alcohol then glued them to each other with Loctite 401 type glue *Figure 14*.

Figure 14. Gluing the parts of the polishing trough

The strength of the gluing can be increase by pressing the parts of the trough to each other. Pressing was made on a planar surface *(Figure 15)*.

Figure 15. Pressing the parts of the trough

After the curing process the pressing was unlocked and the trough was ready *(Figure 16)*.

Figure 16. The glued polishing trough

We made the pressing tool for the polishing trough as well. We chose steamed beech for the material of the pressing tool. The pressing tool operates after gluing, during curing process. A prototype of the trough and a pressing tool can be seen in *Figure 17* and *18* both made from steamed beech. Both of them were strengthened with aluminium sections.

Figure 17. The top view of the tools

Figure 18. The bottom view of the ready polishing trough and pressing tool. Aluminium strengthening can be seen here

6. Designing and manufacturing of pushing/lifting tools

Pushing/lifting tools work in the beginning of the packaging process of chocolate hollow figures. These tools directly touch the chocolate figures, so the material of the tools must suit to hard specifications. We had to choose a material that corresponds to 1935/2004/EK regulation, which is "on materials and objects intended to meet foodstuffs". Furthermore, the material corresponds to strength, cutting and clean-ability viewpoints. Think of the viewpoints, we chose the PTFE material. Tools have to hold precisely and firmly the chocolate figures; should not make any harm for the figures, but should hold chocolate figures in the right position. During pushing-in it is not allowed to rotate the chocolate figure except around its own axle. To reach the above mentioned requirements we designed sinks for the lifting and pushing tools. The shape of the sink is the same as the shape of the hollow figures (based on the gypsum sample). We made prototypes of the lifting/pushing tools of steamed beech, as you can see in *Figure 19–21*. The prototypes are tested in the factory.

Figure 19. Lifting tool made of steamed beech

Figure 20. Pushing tool made of steamed beech

After a short test, the client asked a little modification in the position of the sink. After modification we made the tools of PTFE material (Figure 2).

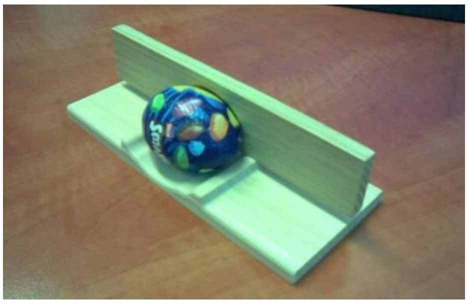

Figure 21. Pushing and lifting tools made of steamed beech and the packed chocolate egg

7. SUMMARY

In the process of designing packaging tools, we got result with the application of nowadays engineering methods (CAD, 3D scanning, prototype manufacturing). It is important to give the knowledge of these skills to the mechanical engineer students. It is not allowed to forget about the importance of mechanical drawing.

8. ACKNOWLEDGMENTS

Our colleague Attila Potyka had an important role in the design and manufacturing process. We are grateful to him.

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SIMULATIONS OF COSMETIC PRODUCTS MADE FROM BIODEGRADABLE MATERIAL

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Abstract: The environment pollution caused by polymer wastes is becoming more problematic. Dozens million kilogram polymers are thrown away every year, and they pollute not only the waters but the whole world. One of the solutions for this problem is the usage of biodegradable materials. With the application of biopolymers, the pollution of the environment can be reduced. This paper deals with the designing and simulations of environmentally friendly products. The injection molding simulation of a lipstick and a razor is introduced. Furthermore, the load capacity of the razor was examined by applying finite element simulations.

Keywords: *Biopolymer, injection molding, simulation, FEM, polymer pollution*

1. INTRODUCTION

We took part in an international multidisciplinary co-operation among JAMK University of Applied Sciences Jyväskylä, Universidad de Jaen and University of Miskolc. This project was a part of EU funded HEIBUS project that aimed to develop smart and innovative new methods including virtual implementation. In this project eighteen students were divided into three groups, two people from each country (Hungary, Finland and Spain). During the whole project, students had support of supervisors to solve real life problems using eco-friendly materials. All three groups worked independently on the same topic. The topic of the project was: *Reducing the environmental footprint through the development of new and biodegradable plastic products*.

This theme was given by Andaltec, which is a non-profit-making technological centre located in Southern part of Spain, Martos. The topic aimed at designing and developing sustainable, eco-friendly products, as alternative to disposable polymeric products that has great impact to nature. The group needed to decide the product to be developed thoroughly by using systematic tools and research methods. It was expected from teams to produce clear identification of the product and improved functionality using biodegradable polymeric alternatives. Material to be used was already limited to four 100% bio-based and biodegradable materials: PLA, PHA, TPS and Cellulose acetate. During the design CAD, FEM and CAM tools were needed to analyse, simulate and present the products. A final prototype was developed and manufactured using current plastic technologies such as FDM 3D Printing.

In the following sections we are going to introduce our part of the project work. First the 3D models of the chosen products were created, afterward injection molding simulations were used to determine the properties of the injection molded products. Finally, finite element simulations were made to define the appropriateness of the product.

2. Polymer pollution in the world

Each year around 300 million tons of plastic are produced around the world. 50% of this is disposable product. 4.6% of the annual petroleum utilization in the U.S is used up by the plastics manufactures. The energy which is consumed this way cannot be recovered. 34 million tons of plastic was disposed in the United States in 2008. 86% of this ended up in landfills [1].

Among the four islands of the Pitcairn Archipelago, the largest is the Henderson Island, which is on the UNESCO World Heritage List and one of the few parts of the world. The ecology of this island is virtually untouched by humankind. There are a number of unique biological attractions on the island, considering that it is only 3700 hectares, with 10 endemic plants and 4 bird species. The isolation of the island has protected this area from human activity until today. However, this island is packed with 18 tonnes of waste, which has the highest density of anthropogenic debris in the world. 99.8% of the waste is made up of plastics, which means 38 million plastic products. Most of the waste (about 68%) is not visible, as nearly 4,500 items per square meter are hidden up to 10 cm deep. Approximately 13,000 new wastes drift to the shore on a daily basis. Hundreds of crabs make their homes out of plastic debris, such as cosmetic tubes or bottle caps *(Figure 1)*. Thus, one of the most desolate islands is also the most polluted part of the world [2].

Figure 1. Henderson Island [2]

Examples show that the usage of the polymer materials causes huge damage in the environment. Therefore, new solutions are needed to reduce the ecological footprint. One possibility to solve this problem is the development of biopolymer products.

2.1. Biopolymers

Biopolymers are typically natural-based, renewable resources produced by polymers if they are placed in a biotic environment or soil-composite due to the enzymatic breakdown of bacteria, fungi or algae they break down to invisible particles without contaminating the environment. This can take a few month, perhaps a few year [3].

Figure 2 illustrates the categorization of polymers based on the biodegradability of the material and the basic composition. The three main material types are the oil-based, partially bio-based and 100% bio-based polymers. Those materials were chosen that are bio-based polymers and in the same time they are also biodegradable. This group contains the PLA, PHA, TPS and cellulose acetate.

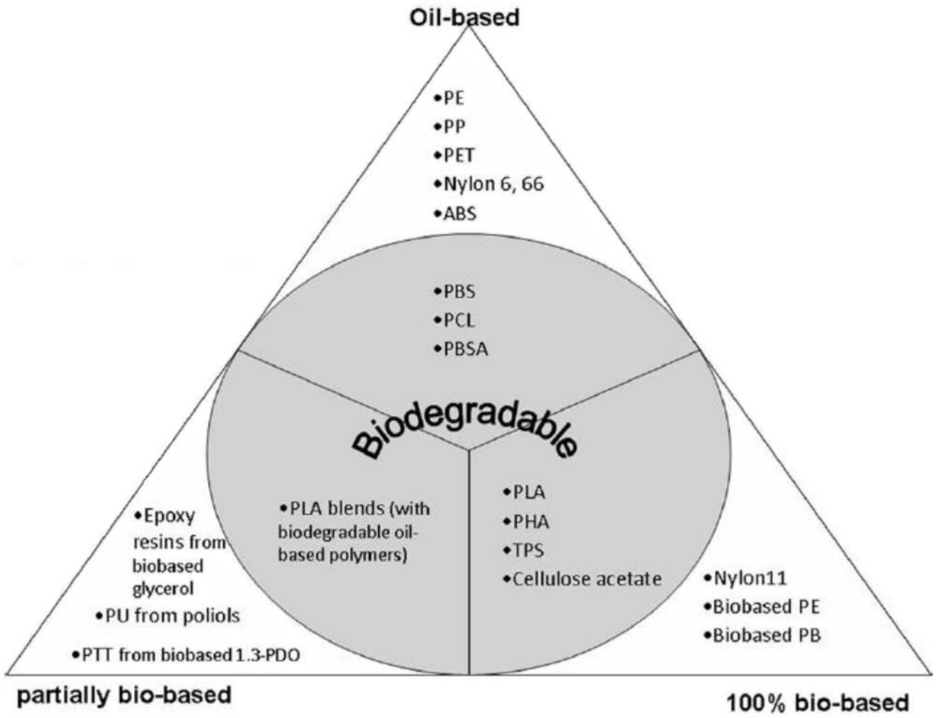

Figure 2. Categories of polymers based on the main material and biodegradability [4]

The chosen material of the products was the PLA. It is made from starch or sugar extracted from biological materials such as wheat, corn and sugar beet. As a first step, the starch or sugar is broken down into glucose by acidic hydrolysis. When fermented, lactic acid is formed from glucose in the presence of lactic acid bacteria. The PLA has good mechanical properties, its shrinkage is low, but it is brittle and the impact strength of it is small. It has a low heat resistance (55–65 °C), it is hydrophilic but not water-soluble, the resistance of it against grease and aroma is excellent. Furthermore, it is resistant to UV light and alcohols, but not to acids and alkalis.

The PLA can be processed with conventional polymer processing technologies (for example: injection moulding, vacuum forming). The degradation of it produces water, humus and carbon-dioxide, thus it does not pollute the environment. It is compostable and the process goes through in a few months, it is not degradable in biotic environment [3], [5].

3. 3D MODELLING OF PRODUCTS

Product ideas were gathered by brainstorming sessions. After narrowing the view using different tools we chose the lipstick and the disposable razor. We wanted to make the design to look like an organic plant to draw attention for the fact that the product is eco-friendly. A bamboo theme was chosen as final concept. They work as a reminder of our environmental stage and offer good stand for effective design in all the simplicity. In the following the geometry of the two products is shown.

3.1. The razor

The geometry of the razor was made with Creo Parametric 2.0 Software. We focused on the design of the handle part instead of the blade, because the blade should be metal, and the handle can be eco-friendly polymer. One of the main principles in designing was to provide shapes that support injection moulding. To use less material in the making of the razor we lighted it. The first version of the lightened razor can be seen on *Figure 3*.

Figure 3. First version of the razor

The result of the different kind of finite element simulations showed that the handle had a lot of unnecessary material, therefore with a new geometry the razor was lighted further. The final geometry is shown in *Figure 4*.

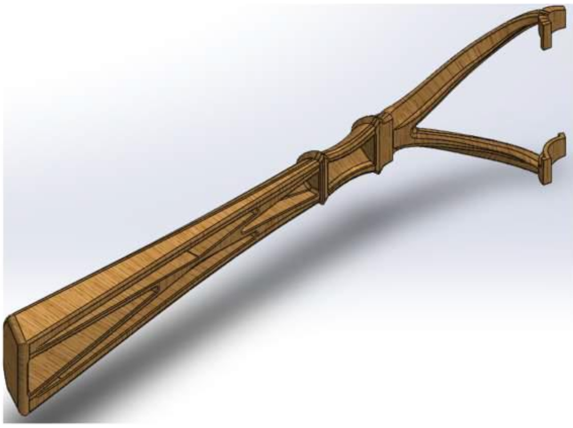

Figure 4. Final version of the razor

3.2. The lipstick

The lipstick has a simple mechanism which is of the rising system of the substance. The mechanism was impossible to do with a single part, so assembly was demanded. In case of the inner components the goal was to achieve a good functionality. The outer part needed to offer good grip and look like a bamboo. The geometry of the lipstick was made in SolidEdge ST5 software and the appearance and the sectional view can be seen on *Figure 5*.

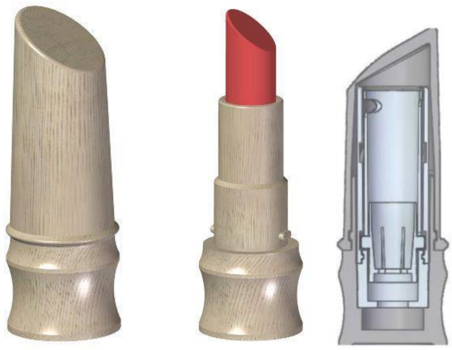

Figure 5. Geometry of the lipstick

4. INJECTION MOULDING

Injection moulding is the easiest method to produce a polymer product. Using injection moulding the products can be produced relatively fast and in large quantities even with complicated geometries. The system can be automatized; however the equipment and tools require high investments with a large amount of processing waste. During injection moulding the plastic is melted then it is pressed into the closed cavity, which shapes the product. After the plastic is solidified, the tool is opened, and the finished product is removed. In a full injection moulding simulation, there are four main sections: filling, packing, cooling and warpage. In the filling section the melt is filled in the form on a given temperature. From this information about the filling time, the melt front temperature, the air drops (little air bubbles inside the product) and the welding lines are gotten. In the cooling part the ejection time is shown.

4.1. Process of the injection moulding simulation

The process of the injection moulding simulation is presented through the simulation of the razor. The same steps were performed in case of the lipstick parts too.

The Moldex3D software divides the injection moulding simulation in two parts. The first module involves the geometry and mesh generation of the cavity, runner and cooling systems, definition of the material and creation of the simulation files, while in the second module – the process parameters setting and the results of the simulation. The first module is the Moldex3D Designer. It consists of two solution modes, the eDesign and the Boundary Layer Method (BLM). The first solution generates the 3D mesh automatically, but in case of the BLM mode the user sets the parameters of the mesh and the program makes the mesh denser near the surfaces as the most important changes accrue here during the injection moulding.

At the next stage, the location of the gate has to be selected. The gate is a designed small opening where the melted polymer is injected into the mould cavity; a successful gate design is determined by the gate type, the dimensions and the location. The position of the gate is influenced by the thickness of the geometry: the gate has to be at the thicker part in order to have steady filling.

With the position of the gate the length/thickness ratio can be checked. If this value exceeds 200, then the injection moulding of the product cause difficulties more gates are recommended to be used. The calculation method of this ratio can be seen in *Figure 6*.

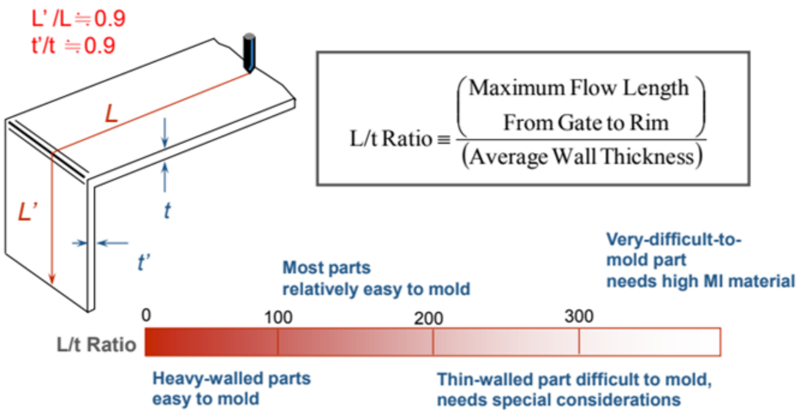

Figure 6. Calculation of the flow length and the wall thickness ratio [6]

The next task is the sizing of the mould base. The exact values of this component were not known, thus the default dimensions provided by the program were used. One of the steps in establishing the settings of the simulation is the design of the cooling system. In this case a simplified version was made to make the calculation time short. The layout of the cooling system can be seen in *Figure 7*.

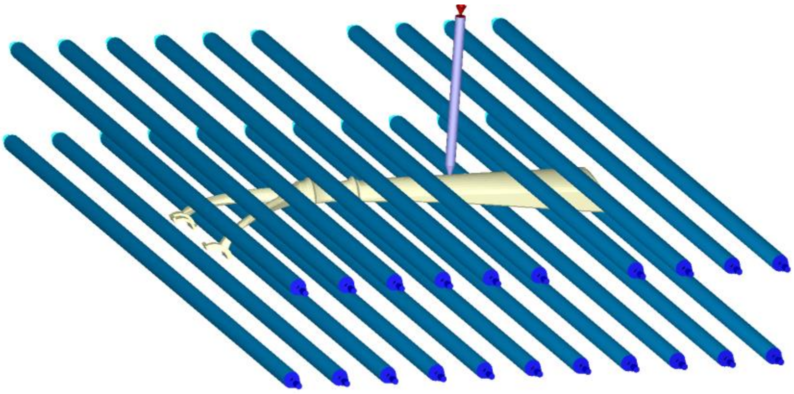

Figure 7. Layout of the cooling system

The final step involves the mesh setting. The previously described BLM method was selected, and three layers were defined near the surface. Application of too many layers in the skin increases the number of elements in the mesh, and the computational time would be extended too. A section of the completed mesh is illustrated in *Figure 8*. Enlarged view shows well that near the surface and around the gate the mesh is denser. This way the calculation will be more accurate.

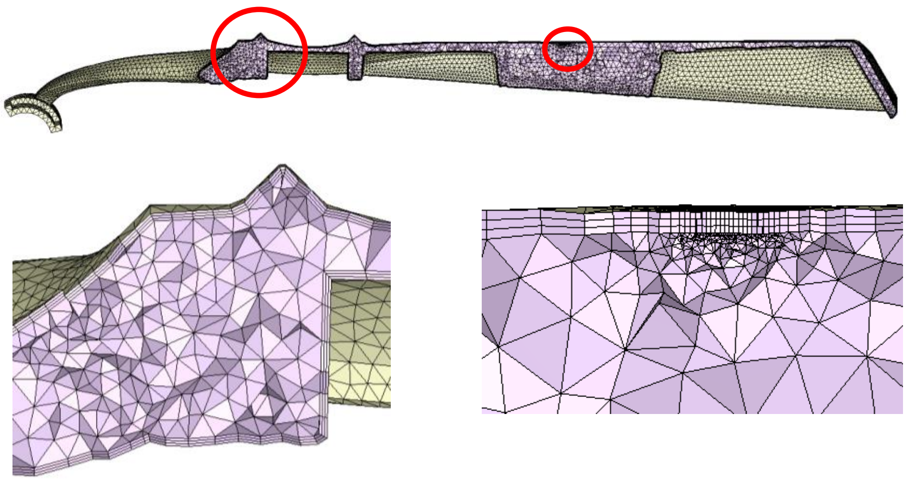

Figure 8. Meshed geometry

The additional parameters have to be adjusted in the second module of the program. It includes for example the setting of the melting temperature, the packing pressure, the cooling temperature.

The chosen material was the Ingeo 3251D PLA made by Nature Works. A few properties of it are shown in *Table 1*.

Table 1.
Properties of the material

Properties	**Value**
Young modulus [MPa]	3.5
Poisson ratio	0.36
Relative viscosity	2.5
Tensile strength [MPa]	62

The complete injection moulding simulation was performed, in particular the process of filling, packing, cooling, and warping.

4.2. Results of the simulations

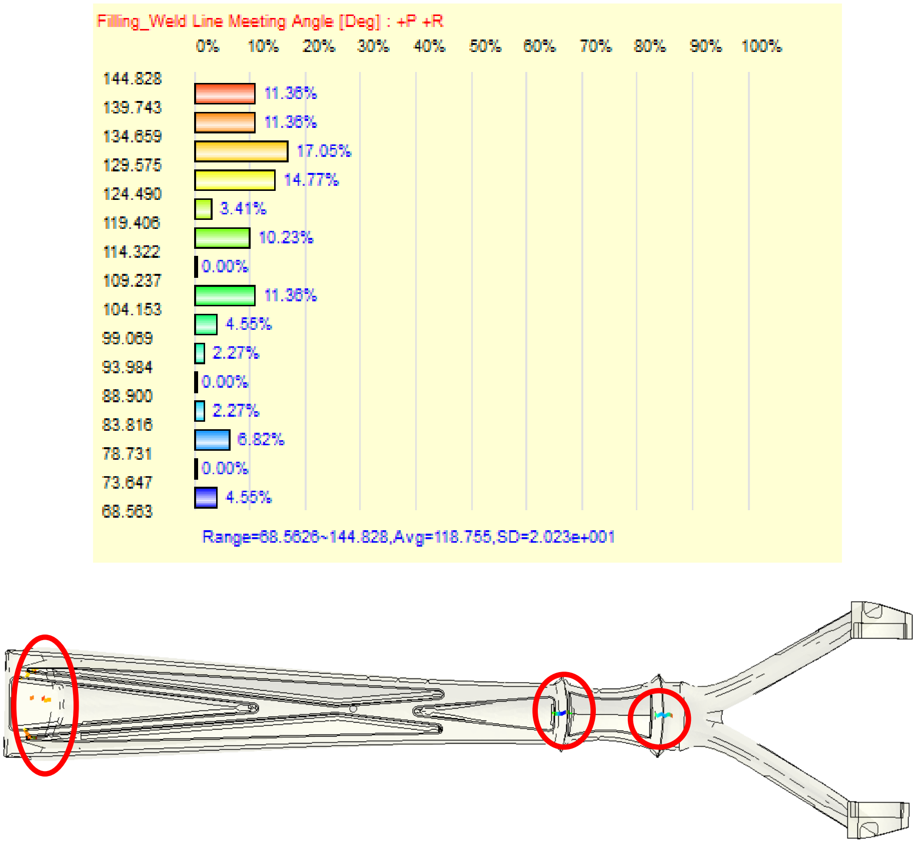

Figure 9. Position and meeting angle of the welding lines

Mainly the magnitude of warpage and the position of the weld lines were examined. Weld lines accrues when two melt fronts meet. These lines can cause huge deterioration in the mechanical properties of the product. This problem occurs when the angle between the melt fronts is smaller than 45°, otherwise the reduction is insignificant. The results about the welding lines are illustrated in *Figure 9*. It shows that the minimal value of the meeting angles is around 68° which is higher than the minimum limit value, thus the welding lines do not cause significant decrease in the mechanical properties.

One of the most important results of the injection moulding simulation is the warpage. The process of warpage is affected by the geometry (variation of the thickness or the direction of the flow), the process (variation of the melt temperature, mould temperature or the packing time), the shape (redesigning of the cooling channel or the gate) and the material. The result is presented in *Figure 10*. The maximal value of the warpage is around 1 mm and it occurs at the end of the razor. This displacement is too large because this connecting part has to be as accurate as possible. Further simulations are needed.

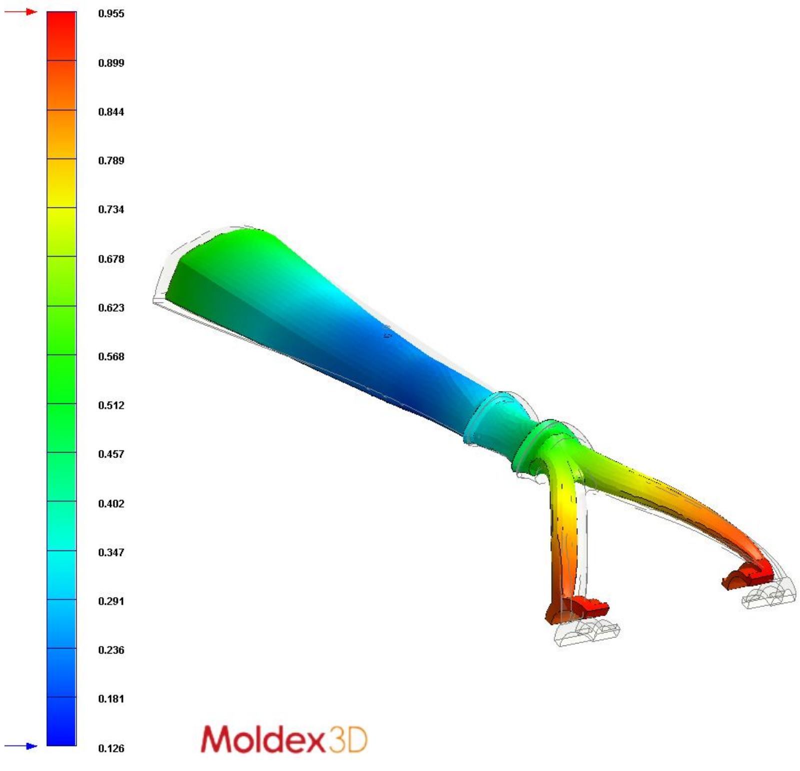

Figure 10. Warpage of the razor

The lipstick is built up from five different components therefore the simulation for every part was made. The main steps were the same as described with the razor. The meshed parts can be seen in the figure below. Several simulations were made however in the paper only the final results are shown.

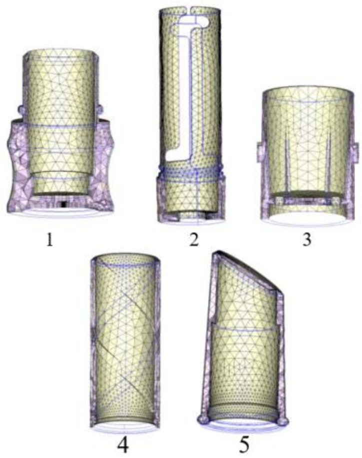

Figure 11. Meshed components

A few results are collected in *Table 2*. The L/t ratio of every component was well below the acceptable value, which is 200, thus only one gate was used to make the injection moulding of the parts.

Table 2.
Results of the different part of the Lipstick

	Part 1	Part 2	Part 3	Part 4	Part 5
L/T ratio	35.7	80.3	38.7	43.8	60.6
Filling time [s]	0.193	0,101	1.509	0.101	0.139
Cooling time [s]	34.813	6.366	6.366	6.06	12.942
Angle of the welding lines	–	143.908°	89.045°	144.141°	32.891°
Maximal warpage [mm]	0.201	0.128	0.0494	0.0942	0.367

The cooling time of the part 1 was reduced to the half of the previous simulations, however this value is still too large, therefore further changes have to be made. The solution can be the changing of the geometry or the cooling system. The angle of the welding lines only in case of the fifth part is problematic. As it was mentioned earlier the welding lines can cause huge deterioration in the mechanical properties of the product if the angle is lower than 45°. This problem can be solved with the changing of the geometry. Another solution can be the usage of more gates, because the direction of the flow will change.

The warpage of every component is lower than 1 mm. Received values are sufficient and modification is not needed. *Figure 12* illustrates the distribution of the warpage in case of the five components.

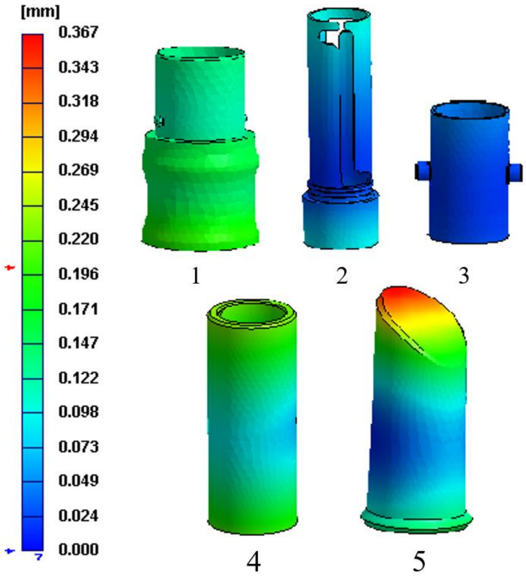

Figure 12. Warpage of the lipstick components

5. FINITE ELEMENT SIMULATION

The finite element simulation was performed using Marc software to check the load capacity of the razor. The simulation of many physical problems requires the ability to model a contact problem. This includes representing the friction between surfaces and heat transfer between bodies. In case of the razor only the forces and the friction between surfaces was taken into account. There are two types of contact bodies in Marc, deformable and rigid. In a contact analysis, a distinction is made between touching and glue conditions. In a structural analysis, a touching condition still allows relative sliding of the bodies in the contact interface. A glue condition suppresses all relative motions between bodies.

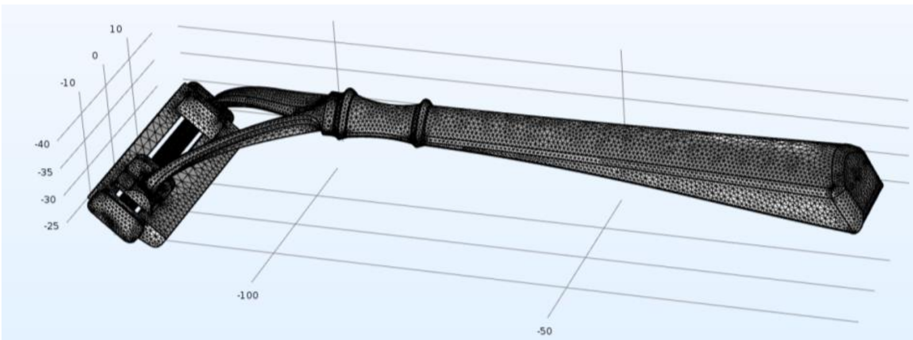

Figure 13. Generated mesh in Comsol Multiphysics

COMSOL Multiphysics program was used to make the mesh of the razor (see *Figure 13*), because the Marc Mentat built-in automatic meshing function was inaccurate. The following picture shows the different parts of the razor which include the blades, the head and the handle. The smaller parts were not taken into account during the finite element simulation.

Figure 14. Parts of the razor

After importing the mesh into the Marc Mentat the connections between the components were made. The blades of the razor were glued in the head therefore their movements were not permitted. Between the head and the handle touching was assumed just like in case of the head and the rigid surface. The following step was the setting of the boundary conditions. Usually the users hold the razor around the "neck" of the handle, thus the degrees of freedom of these nodes were tied. This and the placement of the rigid surface are shown in *Figure 15*.

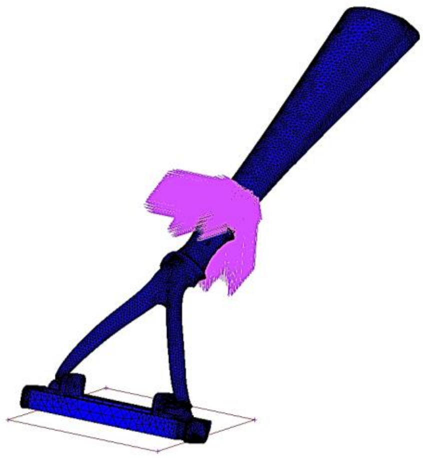

Figure 15. Placement of the surface and the fixed boundary condition

Two simulation cases were examined. In the first case the initial moment of the movements was simulated. It includes the moving of the razor and supervening of the contact between the razor and the surface, therefore the rotation of the head was not permitted. The load was put on the structure in more steps. The maximal von Mises equivalent stress was 8.34 MPa. This value is below the tensile strength of the material thus the razor can withstand this stress. Therefore, this maximal stress occurred around a stress concentration place, thus with the refining of the mesh this value would be lower. The distribution of the equivalent von Mises stress is shown on *Figure 15*.

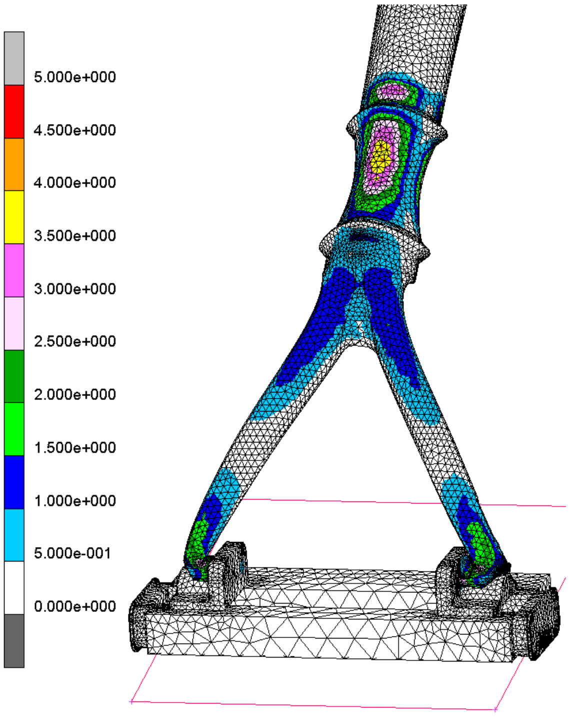

Figure 16. Distribution of the equivalent von Mises stress in case of the first geometry (first simulation)

In the second simulation besides the vertical loading the surface was rotated with 5°. In the first second of the simulation the load was put on the structure after reaching the given value the load stayed constant. In the first second the surface was not allowed to rotate, the rotation started in the second part of the simulation where the load was already constant. In this case the maximal equivalent von Mises stress was 10.81 MPa. This is also well below the acceptable value. This was one of the reasons that the lightening of the razor was taken into consideration, and finally it was changed to the new geometry, which is shown on *Figure 4*.

The same finite element simulations were made in case of the final geometry too. The process of the setting was identical therefore these steps are not introduced again. The maximal equivalent von Mises stress was 12 MPa. The razor can withstand this stress. It occurred at the "neck" part of the handle, which is circled on Figure 16. This part of the razor is a stress concentration place therefore with the refining of the location this value would be lower.

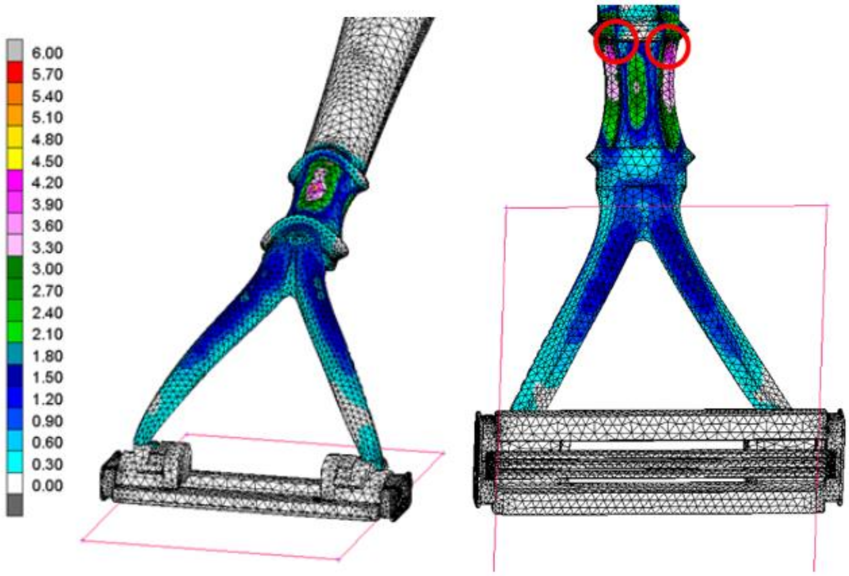

Figure 17. Distribution of the equivalent von Mises stress in case of the final geometry (second simulation)

6. SUMMARY

The above introduced products and the simulation of them proves that the razor and the part of the lipstick can be made from biopolymer. It can help reducing the ecological footprint. The following numbers prove this.

According to a survey, the American lipstick users were estimated to be around 135.99 million people. This data is from 2011 [7]. The weight of a lipstick is approximately 36.12 gram. Therefore, if every second American user would buy lipstick made from bio-friendly material then the polymer waste would be reduced by 2.4 million kilograms every year. The weight of the razor is around 9.6 gram, and the usage is wider thus this value is higher in case of the razor.

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PUBLICATION OF THE UNIVERSITY OF MISKOLC – A SHORT HISTORY

The University of Miskolc (Hungary) was founded by the Empress Maria Teresia in Selmecbánya in 1735. After the first World War the university moved to Sopron, where in 1929, it started the series of university publications with the title *Publications of the Mining and Metallurgical Division of the Hungarian Academy of Mining and Forestry Engineering* (Volumes I–VI). From 1934 to 1947 the Institution became the Faculty of Mining, Metallurgical and Forestry Engineering of the József Nádor University of Technology and Economical Sciences at Sopron. The publications got the title *Publications of the Mining and Metallurgical Engineering Division* (Volumes VII–XVI). For the last volume before 1950 – due to a further change in the name of the Institution – Technical University, Faculties of Mining, Metallurgical and Forestry Engineering, *Publications of the Mining and Metallurgical Division* was the title. For some years after 1950 the Publications were temporarily suspended. After the foundation of the Mechanical Engineering Faculty in Miskolc in 1949 and the movement of the Sopron Mining and Metallurgical Faculties to Miskolc the Publications restarted with the general title *Publications of the Technical University of Heavy Industry* in 1955. Four new series – Series A *(Mining)*, Series B *(Metallurgy)*, Series C *(Machinery)* and Series D *(Natural Sciences)* – were founded in 1976. These came out both in foreign languages (English, German and Russian) and in Hungarian. In 1990, right after the foundation of some new faculties, the university was renamed to University of Miskolc. At the same time the structure of the Publications was reorganized so that it could follow the faculty structure. Accordingly three new series were established: Series E *(Legal Sciences)*, Series F *(Economical Sciences)* and Series G *(Humanities and Social Sciences)*. The latest series, the Series H *(European Integration Studies)* was founded in 2002. *Design of Machines and Structures* (**HU ISSN 1785-6892 [Print], HU ISSN 2064-7522 [Online]**) first published in 2003 as a part of the Series C.