Cezary GRABOWIK[*], Krzysztof KALINOWSKI

Institute of Engineering Processes Automation and Integrated Manufacturing Systems,
Faculty of Mechanical Manufacturing, Silesian University of Technology, Gliwice, Poland
[*]cezary.grabowik@polsl.pl

A REVIEW OF RAPID TOOLING TECHNOLOGIES IN TECHNICAL PRODUCTION PREPARATION – A VACUUM CASTING PRACTICAL EXAMPLE

Abstract: In the paper a practical example of vacuum casting technology application in the technical production preparation (TPP) of a gear transmission body is shown. All stages of TTP process starting from a gear transmission body CAD preparation to a mould casting are presented. Same aspects of rapid prototyping with fused deposition modelling (FDM) are also included. The problem of tessellation in STL file is disused.

1. Introduction

The choice of a gear transmission as an example of an application of vacuum casting technology was dictated by its broad application in industry [2]. Thanks to application of rapid prototyping (FDM) in a process of a positive mould cavity preparation and vacuum casting technology in a tooling process it was possible to prepare a gear transmission upper body faster than in traditional way. Fast accessibility of a model prototype allows manufacturing products well matched to a client demands. In the figures 1 and 2 CAD models of gear transmission body prepared in Autodesk Inventor 2011 are shown [3].
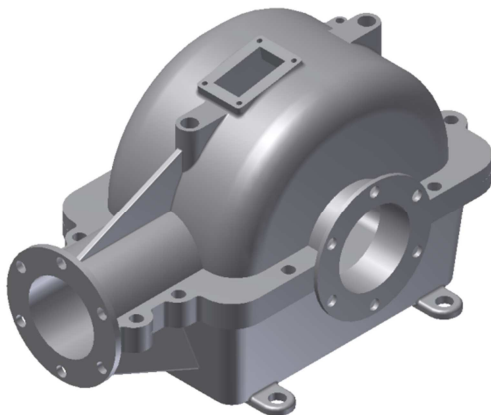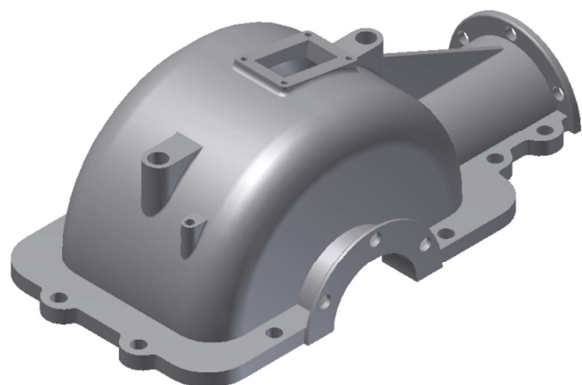

Fig.1. The CAD model of a gear transmission body

Fig.2. The upper part of a gear transmission body

2. **Transformation of a CAD model into STL a file**

Having the CAD model of the upper part of the gear transmission body done this model has to be transformed into an STL file. The STL file format was worked out by 3D Systems Company for translating a 3D model geometry for SLA technology but currently is widely used in other rapid prototyping technologies. Nowadays almost each CAD system have its own STL file translator. The idea of STL file format is based on 3D model tessellation process. During the tessellation process a model surfaces are approximated by a grid of triangles – facets. This process allows for further division of a model geometry into particular layers (each layer contains one model outline) which are parallel one another. After the tessellation process the STL file contains information about vertexes location, in the global Cartesian coordinate system, and also about the normal vector to a facet [1]. The STL file can be represented either in text format or binary one. A model translation into an STL file causes that some faults and surface imperfections might appear. The most common fault is a chord fault which is measured by the shortest distance from a chord to approximated triangle. The idea of a chord fault in the figure 3 is shown.
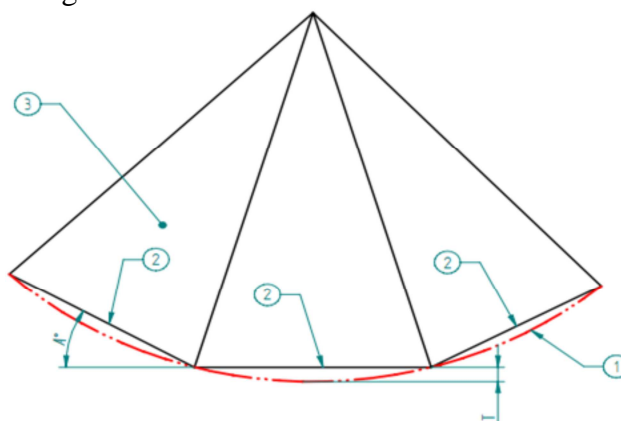

Fig.3. The schema of chord fault arsing

In this schema: (1) the red line represents the original model surface, (2) represents the model surface after the tessellation process, (3) triangles made in the tessellation process, (T) chord tolerance it is the distance between a triangle and real model surface, (A^0) an angle between particular triangles. The chord fault has the greatest importance for models with considerable number of cylindrical, conical or spherical surfaces and in their case it might cause the big model imperfections. This fault can be minimised by reduction of a chord tolerance and also by increasing the number of triangles but in both cases it will make the STL file bigger and bigger. The model imperfection might be also caused by CAD system an internal STL file translator, so that the STL file is illegible for rapid prototyping machines. The most common fault generated by CAD translators results from inversion of a triangle normal vector sense caused by writing of triangle vertexes in improper order. If the triangle vertexes are written in improper order then a triangle orientation is also improper. Other model faults are lack of lines between particular triangle vertexes and discontinuity appearing in gaps between model edges. The STL model should be characterised by closed surfaces which explicitly describes its geometry. If any fault appeared in the STL model it would cause product failures. The STL for a consider upper part of the gear transmission model was

prepared in Autodesk Inventor 2011. In the figure 4 the STL conversion process parameters are shown, the figure 5 presents appearance of the CAD model after translation.
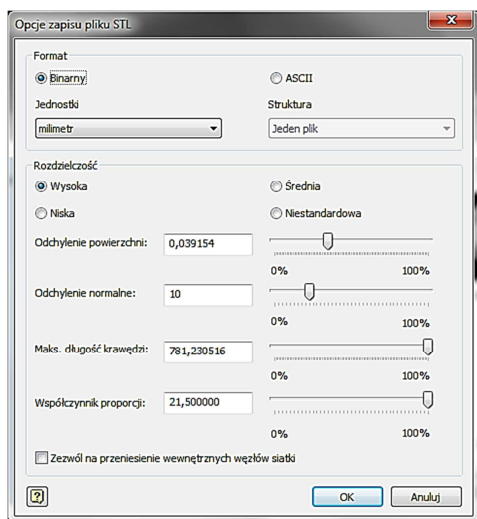
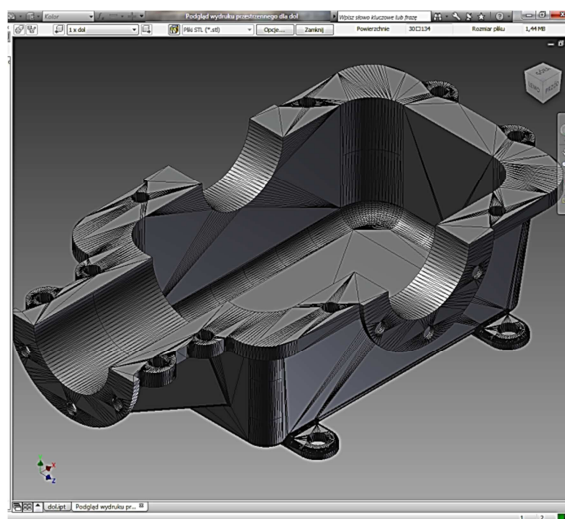

Fig.4. The STL conversion process parameters definition

Fig.5. The lower part of a gear transmission body after STL translation process

3. Printing of a positive mould cavity with fused deposition modelling

Generated in Autodesk Inventor 2011 STL model is further processed in the Insight programme. This programme is dedicated by the STRATASYS Company for FDM 360mc Small printing machine. The first step in the printing process relies on reading the STL model into Insight programme (see: the figure 6). Because of building chamber size limitation if the product model is to big for printing it has to reduced to appropriate size. In the next step the modeller parameters are being defined (see: the figure 7). The most important things in this step are proper selection of printing heads and proper selection of base and support material.
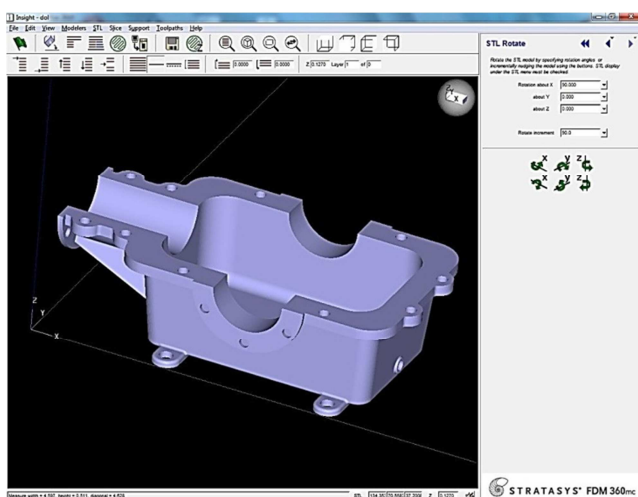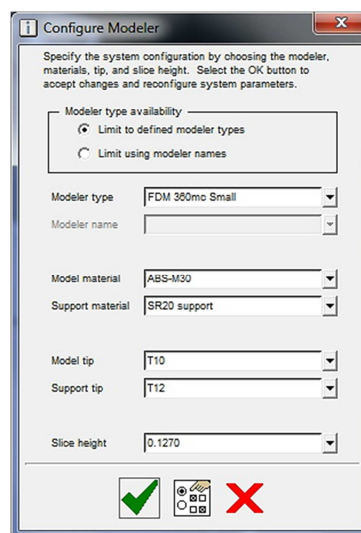

Fig.6. The product model in Insight programme

Fig.7. The window of modeller configuration

For a printing process the following printing heads were selected, T10 for base material and T12 for support material. Printing heads dentations mean as follows T10 – layer thickness 0,127 mm and T12 – layer thickness 0,178 mm. As base material ABS–M30 was selected whilst as a support SR20 material. The characteristic feature of SR20 material is that it can be dissolve in sodium hydroxide solution in temperature about 70^0 C. Having modeller parameters set the process of a model conversion can be done. During this process the following operations are being done: **Slice** – model is being sliced into horizontal layers, **Generate Supports** – supporting scaffold is being designed, **Write Boundary Curves** – bounding curves are being evaluated, **Generate Toolpaths –** toolpahts according to which printing heads move are being generated, **Write CMB File** – executable file is being for FDM printer is being prepared. Next the building chamber is heated up to temperature 95^0 C and printing heads are heated up to 320^0 C, the printing process on FDM 360mc small is started. The manufacturing time for simultaneous printing of the lower and upper parts of the gear transmission body was 32 hours and 36 minutes, material consumption for base material 103,78 cm^3 and 76,01 cm^3 for support material. In the figure 8 and 9 printed parts are shown.
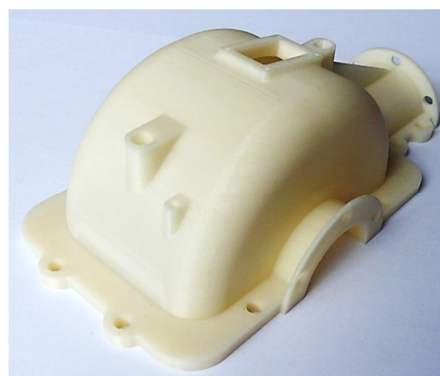

Fig.8. The lower part of the gear body

Fig.9. The upper part of the gear body

4. **Mould fabrication with application of Vacuum Casting technology**

Generally speaking the vacuum casting process starts with materials selection for a mould and manufactured part. In case of mould material the VTV750 silicone and CAT 740/750 catalyst were selected. Taking into account the mechanical properties of the final product for the part material SG95 resin was selected. This resin have similar properties to ABS material. SG95 resin consists of two components A and B which have to be mixed each other in a certain proportion. In the next step in vacuum casting process a moulding box is prepared. The moulding box has to made precisely in order to avoid of resin leakage during the cast operation. Usually the moulding box is made of wood or plastic material and its walls are stick together with a glue gun. Before casting a thin pressure– sensitive adhesive tape is stuck to a master model parting plane. Edges of the type should be marked with a felt–tip pen in order to make a parting plane more clear in the silicone mould. Having done this the master model is ready for adding a gating system, a degassing system and supporting frame. The gating and degassing systems can made from some kind of pipes. When the model is fixed in the moulding box steadily we can start the silicon mixing process. In the considered case 700g of silicone and 70g of catalyst were used. The mixing operation lasted 2 minutes whilst degassing 10 minutes. The casting operation should be preformed carefully in order not to

change the master model position in the moulding box. After casting operation the mould is degassed for 20 minutes in the vacuum system and next cured in temperature 70^0C for 2 hours. In the figure 10 the silicon casting process in details is shown.
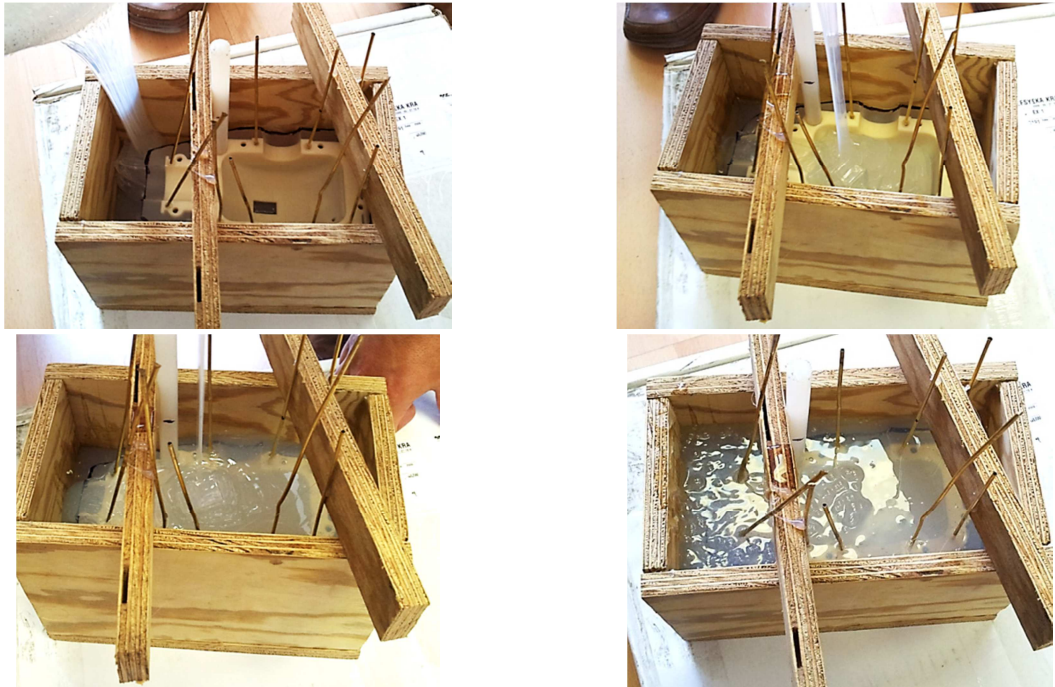

Fig.10. The process of the form preparing – silicon casting

Having the form cured, the gating and degassing systems are removed, the form is cut according to parting plane and the master model is removed (see: the figure 11). Before casting a new product the form is tapped with an adhesive type (fig. 12).

Fig.11. The master model taken out from the silicone form

Fig.12. The silicone form read for a casting of a new product

Before casting of a new product the internal surfaces of the form should be coated with thin layer of S3 spray in order to avoid sticking resin to silicon. It is necessary to remember that just before casting the resin and form have to be heated for about 4 hours. The resin is heated in temperature 40^0 C whilst form in 70^0 C. In the casting process 50g of A resin component and 75g of B resin component were used. It is also possible to add pigment but its amount can't exceed 2% in the mixture. Next the resin components and a form are placed in the vacuum chamber. The components are mixed and the form is casted. When the casting

process is finished the casted form is cured in the oven for 45 minutes in temperature 70^0 C. After curing the model is ready for removing and the next part can be casted. The durability of this form was evaluated for 20 parts.
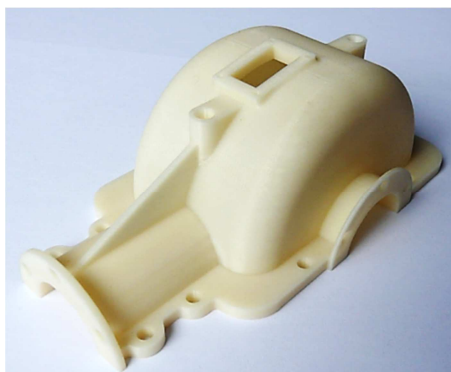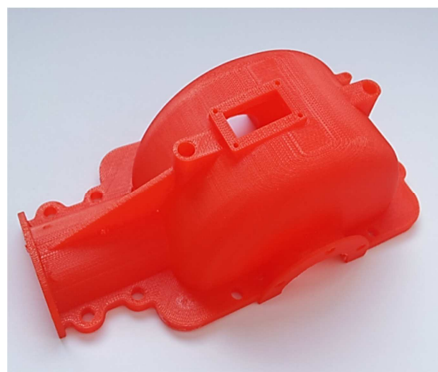

Fig.13. The master model

Fig.14. The casted part

5. Conclusion

The process of silicon form preparation in vacuum casting is quite easy but some skills and experience is needed. In VC process the following things are really important: calculation of components proportions and setting of proper mixing time. On the external surfaces of a silicon form some marks can be observed as a result of poor quality of wooden boards used for the moulding box preparation. In the form some air bubbles are present. They left in the form because the degassing process was difficult according to the moulding box size. The manufactured form was too small, so in order to let the air bubbles come out the moulding box should be bigger. The amount of resin used for casting was to big so a resin surplus left on the top of the form making the operation of the form opening difficult. Taking into account this it is important to calculate the volume of resin precise. The biggest advantage of this method is that it reproduce the master model surfaces very precisely, so the smallest details of the model are reproduced. Form master models with very smooth surfaces in vacuum casting it is possible to reproduce a fingerprint left by worker during the process of the silicone form preparation.

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