ARCHIVES
of
FOUNDRY ENGINEERING
Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (1897-3310)
Volume 7
Issue 1/2007
131 – 134

28/1

Hybrid foundry patterns of bevel gears

G. Budzik, T. Markowski, M. Sobolak[a,]*
[a] Machine Design Department, Rzeszow University of Technology, Al. Powstańców Warszawy 8, 35-959 Rzeszów, Poland
*Mailing contact: e-mail: gbudzik@prz.edu.pl, tmarkow@prz.edu.pl, msobolak@prz.edu.pl

Received 08.02.2007; Approved for print on: 12.03.2007

Summary

Possibilities of making hybrid foundry patterns of bevel gears for investment casting process are presented. Rapid prototyping of gears with complex tooth forms is possible with the use of modern methods. One of such methods is the stereo-lithography, where a pattern is obtained as a result of resin curing with laser beam. Patterns of that type are applicable in precision casting. Removing of stereo-lithographic pattern from foundry mould requires use of high temperatures. Resin burning would generate significant amounts of harmful gases. In case of a solid stereo-lithographic pattern, the pressure created during gas burning may cause the mould to crack. A gas volume reduction may be achieved by using patterns of honeycomb structure. However, this technique causes a significant worsening of accuracy of stereo-lithographic patterns in respect of their dimensions and shape. In cooperation with WSK PZL Rzeszów, the Machine Design Department of Rzeszow University of Technology carried out research on the design of hybrid stereo-lithographic patterns. Hybrid pattern consists of a section made by stereo-lithographic process and a section made of casting wax. The latter material is used for stereo-lithographic pattern filling and for mould gating system. The hybrid pattern process consists of two stages: wax melting and then the burn-out of stereolithographic pattern. Use of hybrid patterns reduces the costs of production of stereolithographic patterns. High dimensional accuracy remains preserved in this process.

Key words: Innovative materials and casting technologies, gears, rapid prototyping systems, stereolithography, lost-wax casting method

1. Introduction

Patterns for castings in precision casting method are more and more often made with the use of rapid prototyping techniques [1,2,3]. The most developed among rapid prototyping methods are the incremental methods permitting also the production of foundry patterns. They comprise, among others: the stereo-lithography (SLA), 3D printing (3DP) and laminated object manufacturing (LOM) [4,5,6,7].

Each of these methods provides a pattern of specific accuracy of dimensions and shape. The stereolithographic method belongs to the most accurate ones, therefore it may be applied to produce gear patterns.

Patterns made by individual methods have specific physico-chemical properties. These properties determine the course of the pattern-from-mould removal process [8,9,10].

In the SLA, 3DP and LOM methods the pattern removal is executed by burning it out at 700÷800°C.

The pattern burn-out process produces a large amount of gases. Their pressure may in some extreme cases cause a mold cracking or bursting. The application of hybrid patterns with the use of stereolithography and wax patternmaking permits a reduction in the quantity of gases produced during pattern removal from mould [11,12].

2. Research Methods

Making prototypes of gears with complex or atypical teeth is possible with the methods of rapid prototyping and precision casting.

The research method covered making of CAD patterns of bevel gears of design that enabled minimizing the volume of stereo-lithographic material while applying additional filling with wax. Pattern was removed in two stages. First the wax part of the pattern was melted out and then the stereolithographic part was burned out. Due to large hot-air contact surface with the stereolithographic part of the pattern its removal was facilitated.

3. Pattern of gear

3.1. CAD and SLT gear model

Patterns of gears with complex or atypical shapes of teeth can only be made with the use of suitable CAD patternmaking techniques. Fig. 1 presents an example of a gear used in the tests. It is a Gleason SGM bevel gear with circular-arc teeth.

In CAD environment a 3D model of gear may be built using teeth machining simulation techniques while utilizing the potential of solid-shape modelmaking and that of CAD programming. In case of objects of complex surfaces, as gears, especially the atypical ones, it is difficult to make a thin-walled solid-body model. Therefore, the volume of an element shall be reduced through separate modifications of a solid-body model. A model should ensure accuracy of teeth dimensions and shape, as well as enable removal of wax filling (fig. 2). Fig. 3 shows the CAD model of analyzed gear with a relief that reduces pattern volume [13].

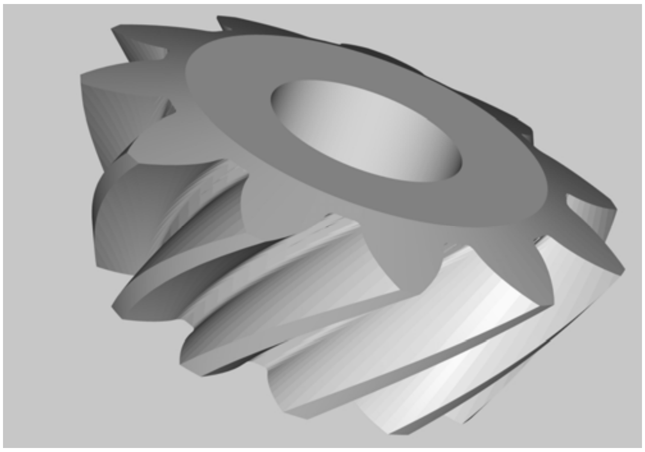

Fig. 1. CAD model of the entire gear

Model volume for the entire gear is 86,3 cm^3. A modification of CAD model permitted a reduction of gear volume to 45,9 cm^3 (fig. 2).

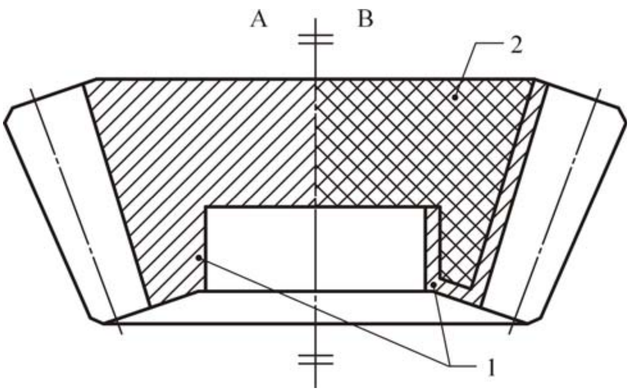

Fig. 2. Cross sections of analyzed gear: A – full pattern, B – hybrid pattern; 1 – resin, 2 – casting wax

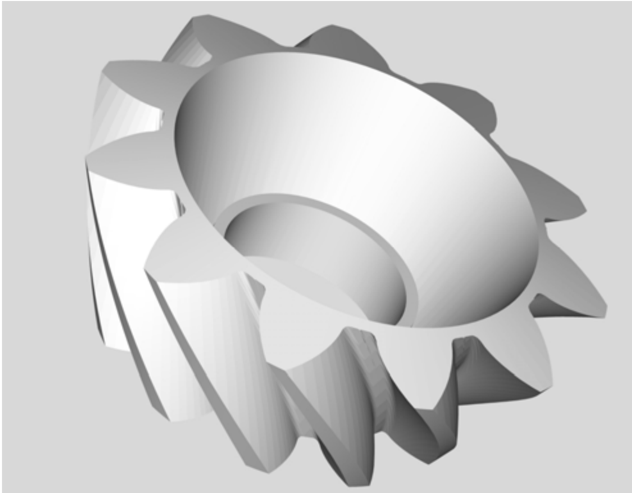

Fig. 3. CAD model of gear with a relief

On the basis of the CAD model, a model in STL format was generated.

Fig. 4 presents the STL model of analyzed gear. Compared to CAD model, model accuracy was 0,001 mm. Then the 3DLightyear program was used to prepare the process of model manufacturing on the 3D Systems SLA-250 apparatus (fig. 5).

The program enables a modification of automatically generated process supports, which is necessary in case of the model under consideration. In the 3D Lightyear program the control codes for stereolithographic apparatus were generated [14,15]. The thickness of a single layer of SLA model was assumed as 0,1mm. The model consisted of 335 layers. The modelmaking period was 380 minutes. For comparison, the time for making an entire model is 525 minutes.

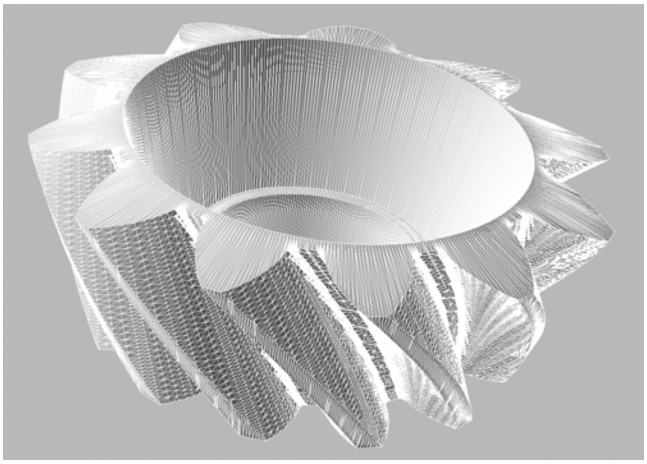

Fig. 4. STL model

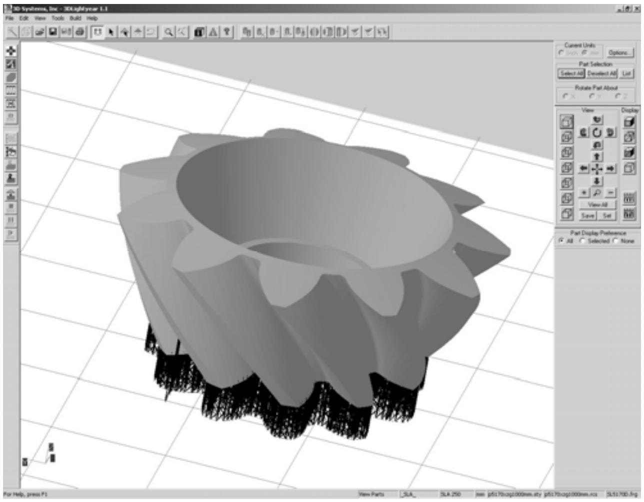

Fig. 5. Model on work platform (3D Lightyear software)

3.2. SLA gear model

A stereolithographic model was made with the SLA-250 apparatus available in the Laboratory of Stereolithography and Vacuum Casting in the Machine Design Department at Rzeszow University of Technology.

The SLA-250 unit makes a stereolithographic model through laser beam curing of consecutive layers of photo-polymer. A reduction of volume of virtual pattern in the first stage causes a reduction in the quantity of resin necessary for pattern making. It is a significant plus because of a considerable resin cost. The number of layers remains the same as that of the entire model, because it depends on the model height and layer thickness. A shortening of the model making time is achieved through restricting of the cured surface of individual gear mode layers. Fig 6 shows a finished SLA model of gear.

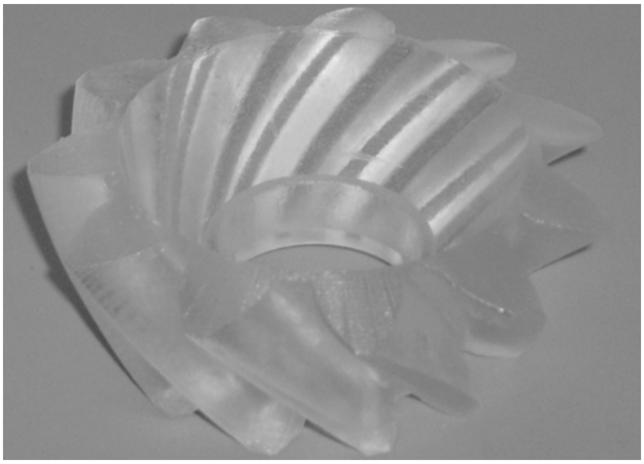

Fig. 6. SLA model of gear

3.3. Hybrid pattern

The next stage in the foundry pattern making is the filling of the remaining gear volume with casting wax as well as gating system making. For this, molten wax shall be prepared to fill the free space. After this operation a gating system may be added (fig. 7). Depending on the number of elements made, a simple or combined gating system is added.

Fig. 7. Hybrid pattern of gear with gating system

3.4. Mould structure and pattern removal

On a pattern, prepared as described above, foundry mould making may be started with.

Once the mould is made, the patter needs to be removed from it. Pattern removal is performed in two stages. The wax gating system and any pattern filling is to be removed first with temperature of about 150°C. Then the stereolitographic pattern is burned out at the temperature of 700÷800°C. Such process enables a complete pattern removal.

4. Conclusions

Application of hybrid patterns for gear prototype making permits a combination of the potentials of rapid prototyping techniques and wax pattern technique. The stereolithography method enables adequate making of gear teeth profiles. Application of wax filling reduces foundry pattern making costs considerably.

The cost reduction results from reducing of photo-polymer volume and from shortening of the stereolithographic model making time.

Quite important in the application of hybrid patterns is the reduction in harmful gas emissions from the pattern burn-out process.

Application of hybrid patterns permits a reduction in the amount of gases generated during pattern removal from mould and, consequently, a reduction of mould damage risk.

Acknowledgments

This research work is financed from the funds allotted for science in 2007-2009, as a research and development project titled „Developing of innovative gear boxes with atypical teeth”.

References

[1] R. Haratym, J. Tomasik, The influence of ceramic mould quality on surface geometry of Al investment casting, Archives of Foundry, Volume 6, N^{o}18 (2/2), (2006) 237-242 (in Polish)

[2] D. Myszka, J. Modzelewski, M. Leśniwski, A. Kerwiński, Introduction to titanium investment casting as implants use, Archives of Foundry, Volume 6, N^{o}18 (2/2), (2006) 237-242 (in Polish)

[3] R. Hartym, Dimensional Accuracy of investment casting for the burned pattern process, Archives of Foundry, Volume 6, N^{o}18 (2/2), (2006) 231-236 (in Polish)

[4] J.C. Feriera, E. Santos, H. Madureira, J.Castro, Integration of VP/RP/RT/RE/RM for rapid product and process development, Rapid Prototyping Journal Vol. 12 No. 1/2006, Emerald 2006, 18-28.

[5] S. H. Choi, S. Samavedam, Patternling and optimisation of Rapid Prototyping, Computers in Industry N^o 47/2002.

[6] N. Homburg, E. Wellbrock, Knowledge-based manufacturing strategy and methods for foundries, Conference and Exhibition for Rapid Technology, Erfurt 2006.

[7] A. Gebhardt, Rapid Prototyping, Carl Hanser Verlag, Munich 2003.

[8] K.L. Mak, H.Y.K Lau., S.T.W. Wong, An object-oriented prototyping tool for automated manufacturing systems, Computers in Industry 43 (2000) 43-60, Elsevier 2000.

[9] Y. Song, Y. Yan, R. Zhang, F. Wang, Manufacture of the die of an automobile deck part based on rapid prototyping and rapid tooling technology. Journal of Materials Processing Technology 120 (2002) 237-242, Elsevier 2001.

[10] D.Kochan, C.K.Chua, State-of-the-art and future trends in rapid prototyping and manufacturing. International Journal of Information Technology. 1, 1995, p.173-184.

[11] G. Budzik, D. Kozdęba, M. Sobolak, Rapid Prototyping method of investment pattern of blade in silicone mould. Archives of Foundry, Volume 6, N^{o}18 (2/2), (2006) 201-206 (in Polish).

[12] G. Budzik, D. Kozdęba, M. Sobolak, Rapid Prototyping technology using for investment casting process, Archives of Foundry, Volume 6, N^{o}18 (2/2), (2006) 207-212 (in Polish)

[13] S. Miechowicz, M. Sobolak, G. Budzik, The complex rapid prototyping STL free surface generation”, International Scientific Conference PRO-TECH-MA Rzeszów – Bezmiechowa, Oficyna Wydawnicza Politechniki Rzeszowskiej *(University Publishing House)*, Rzeszów 2005.

[14] 3D Lightyear SLA File Preparation Software - User's Guide 2001.

[15] Stereolithography Buildstation - 3D Systems Publications 2001