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RAPID PROTOTYPING OF CYCLOID DISC

ABSTRACT: Rapid prototyping technology is present in various industrial areas, because many benefits witch these technologies offers today. Over time, these technologies evolved from the technology for the production of prototypes future product to technology for the production of finished products ready for the market. A key element cycloid drives both, from the aspect of the complexity of the geometry and from the aspect of loads is cycloid disc. Teeth profile of cycloid disc is equidistant of shortened epitrochoid, and it is very complex curve. The characteristic of the cycloid drives directly depends from the quality and accuracy cycloid disc of production. This paper is based on a 3D model cycloid disc, which is used in various rapid prototyping technologies, and couple of physical models has been made. The influences of certain parameters on the properties of prototyping cycloid disc are analysed.

KEYWORDS: rapid prototyping, cycloid disc, 3D model, 3D printing

INTRODUCTION

The development of CAD technologies and 3D product modelling enabled the rapid advancement and automation of production processes [6, 7]. In recent decades, there appeared a completely new technology that has fundamentally changed the way of product development and its production. This technology is named *Rapid Prototyping*. In the beginning, this technology is used in development of new products, while today more used for the production of high quality final products. Rapid Prototyping technology extremely reduces the product development time of new ones by enabling the introduction of changes in the structure in the early stages of product development.

Cycloid drive the mechanical transmission system which is now more used in industry due to a very favourable operating characteristics, [2,4]. The key component of the cyclo drive is the cycloid disc. The cycloid disc profile is very complex curve lines - equidistant of shortened epitrochoid. The quality and accuracy of making the cycloid disc profile have a very large impact on the performance of cycloid drive.

Based on the experience available in the literature [1-3,8]application of CAD / CAM technology first is developed a 3D model of a particular cycloid disc and then a several physical models is made. Researches are performed in *Centre for Testing and Calculation of Machine Elements and Systems – Vera Nikolić-Stanojević*, at Faculty of Engineering, University of Kragujevac.

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PARAMETRIC MODELING OF A CYCLOID DISC

Parametric modelling of cycloid drives is done in Autodesk Inventor software. [5]. Basic input parameters are: radius of the rolling circle R_a, radius of the fixed circle R_b, radius of the pitch circle of the central stationary gear r, transmission ratio u_{CR}, eccentricity e and radius of the cylinder stationary central gear q. To simplify the process of parametric modelling, Assembly environment is used, so along with cycloid disc other elements of the cycloid drive are automatically generated which are in the contact with cycloid disc. Input definition of cycloid drive parameters is shown in Figure 1.

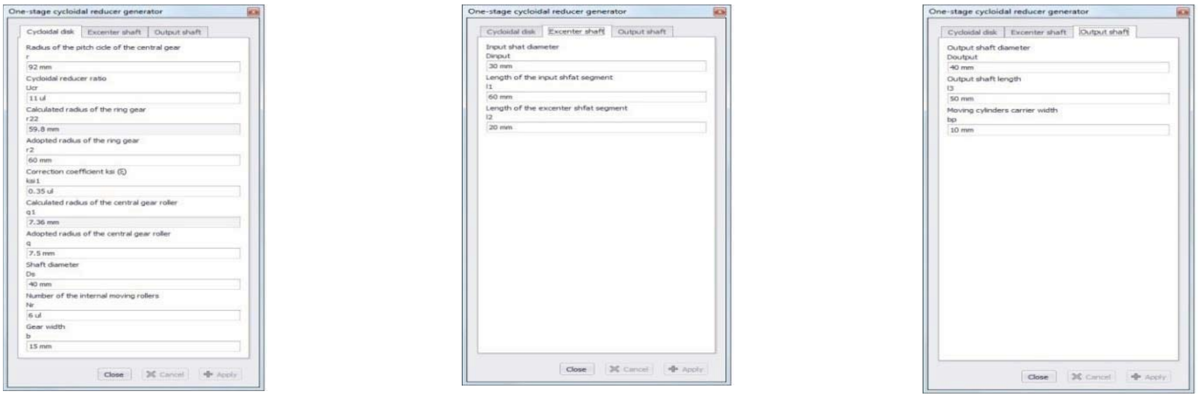


***Figure 1** Parameters definition cycloid disc*

Next step is calculation of dependant geometric parameters required for generating of cycloid drive parametric model, Figure 2.

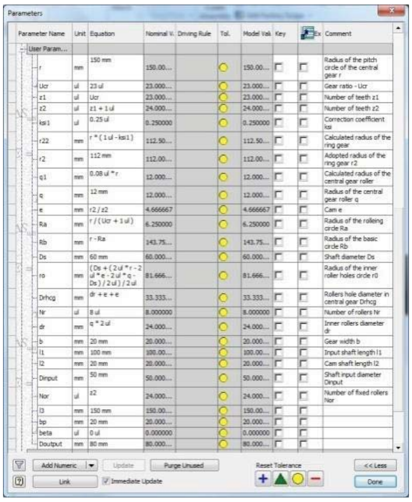


***Figure 2** Calculation of* dependant geometric parameters *required for cycloid drive* generation

After defining parameters, individual files of the assembly parts were created: cam shaft, cycloid disc, stationary roller axels, stationary rollers, output shaft assembly, and moving roller axels with rollers. The most complex part of cycloid drive in this entire assembly is cycloid gear. Its profile is created using the parametric function drawing based on cycloid curve equations. The generated cycloid drive assembly is shown in Figure 3.

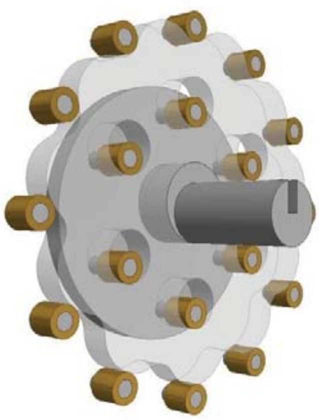


***Figure 3** Parametric model of cycloid drive assembly*

RAPID PROTOTYPING OF CYCLOID DISC

Production of cycloid disc models is performed in *Centre for Testing and Calculation of Machine Elements and Systems – Vera Nikolić-Stanojević*, at Faculty of Engineering, University of Kragujevac. Available Centre equipment is used(3D printer *Maker Bot Replicator 2* and milling machine *Roland MDX-40A*), figure 4.

a) b)

Figure 4 *Used equipment: a)* 3D printer Maker Bot Replicator 2, b) milling machine Roland MDX-40A

Production of cycloid disc using the3D printing method

3D printing technology is one of the methods of using the principle of application of the melt material in the space and be bonded in layers, followed by forming the desired object. For 3D printing various types of plastic are used in different colours. Most often there are used ABS and PLA plastic. ABS resins are obtained from petroleum products (as well as most of the plastic polymers), while the PLA materials made of starch and biodegradable in the slightly acidic range compost at a temperature of 60° C. In 3D printing are also used and other thermoplastics (LDPE, HDPE, PP, PVC, PMMA ...).

To create a physical model of the cycloid disc on a 3D printer, it is necessary to create a 3D model cycloid disc from the software Autodesk Inventor exported in STL format. Accompanying software of MakerBot Replicator 2 is used for preparing the 3D printing, Figure 5.Followed by the simulation of the design process, in order to determine tuning parameters of printing time required for the model is shown in Figure 6.In this 3D printer precision of the 3D printing is in the range of 0.05 to 0.5 mm, and the printed model density can be adjusted in the range of from 5 to 100%.By increasing the density and accuracy, increased is printing time, as well as price. When the certain temperature is reached, plastic wire melts and in the form of thin threads is applied layer by layer. For 3D printing of this model it is used a precision of 0.1 mm and a density of 5%.3D printing of cycloid disc lasted 25 minutes in Figure 7.

Figure 5 *Loading models cycloid disc*

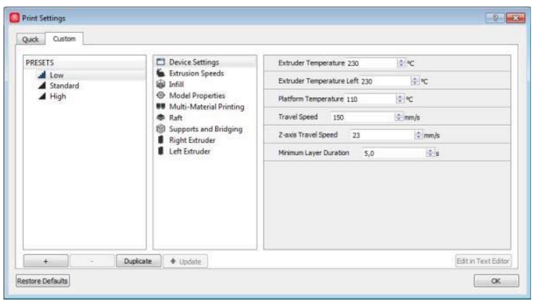


Figure 6 *Setting the parameters printing*

Figure 7 *Cycloid disc printed on a 3D printer MakerBot Replicator 2*

Production of cycloid disc using the 2D milling process

Production of the cycloid disc using a 2D milling process on a milling machine Roland MDX-40A, requires the usage of software Autodesk Inventor HSM Pro. The model is produced from a PMMA material (extruded XT) having from 6 to 17 times the resistance to breakage related to glass thickness of 1.5 to 15 mm. In case of breakage, this material is broken up into small pieces without sharp edges, which greatly reduces the risk of injuries. The process of preparing cycloid disc production using a 2D milling is shown in Table 1.

Table 1 *The process of preparing development model cycloid disc 2D milling*

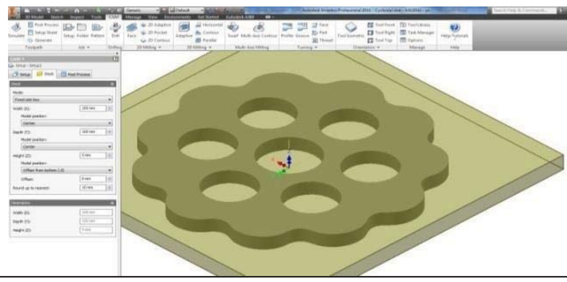
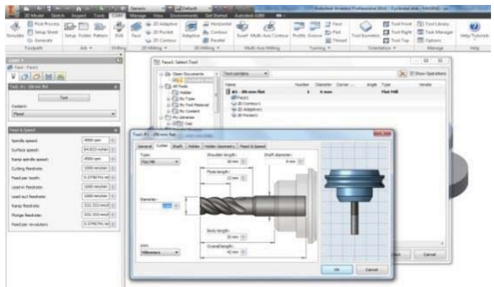
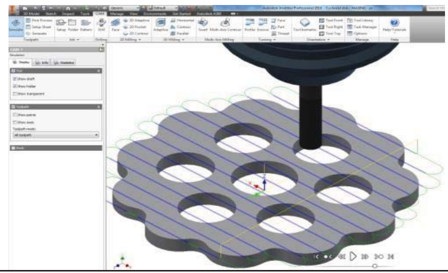
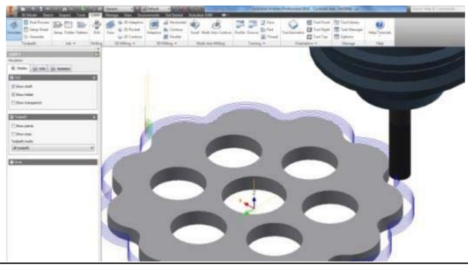
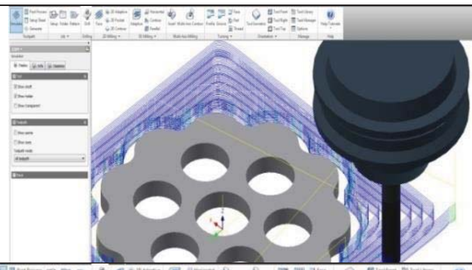
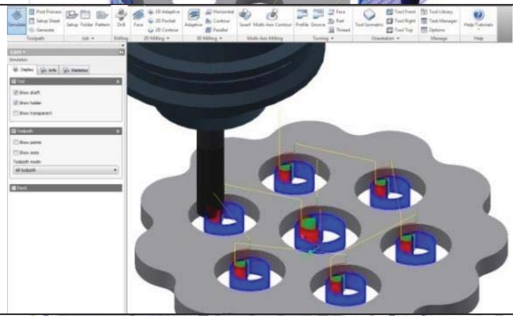
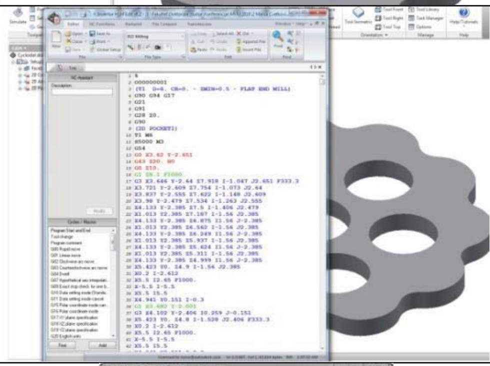
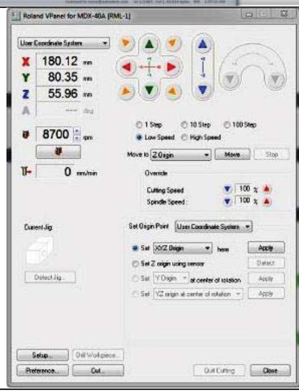
Step 1 *Preparation model*	Z axe of preparation is directed towards the top of the tool. Preform dimension 5x100x100. Fixing of preparation is done on down side with adhesive tape.	
Step 2 *Simulation alignment surface*	For all operations the same milling parameters is used	
Step 3 *Processing simulation*	Using a single tool (milling tool ϕ6 mm) enables the development of models cycloid disc in a single clamping with one NC code	
Step 4 *Simulation of machining contours*	Determination of the number of passes for processing contours	

Table 1 *(Continued)*

Step 5 *Simulation clean contours*	Adaptive cleaning of cycloid contour	
Step 6 *Simulation of drilling holes*	In the model it is necessary to create the centre hole as well as six holes for output rollers	
Step 7 *Generating NC code*	Before milling machine is in the operation, it is necessary to generate NC code. The generated NC code is loaded into milling machine via Roland V Panel software.	
Step 8 *Connect CAM software and milling machine*	Linking Autodesk Inventor HSM Pro with milling machine trough Roland V Panel	

The method of cycloid disc models production on the milling machine Roland MDX-40A is shown in Figure 8, while the resulting model is shown in Figure 9.

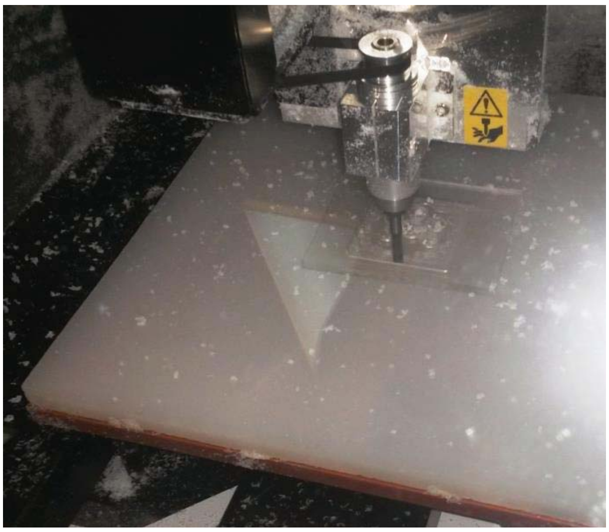


Figure 8 *The method of production the model cycloid disc using milling machine Roland MDX-40A*

Figure 9 *Cycloid disc produced on the milling machine 2Roland MDX-40A*

CONCLUSION

In this paper the process of cycloid disc models production using the method of 3D printing, as well as 2D milling is described. Both of these methods are still very present in the product development process. In this paper the cycloid disc is selected as objective of research, because it is a gear with very complex profiles where accuracy and preparation has a very important role on its performance (accuracy of the transmission ratio, capacity, vibration...).

The process of 3D printing is extremely fast. This method can perform very complex shapes. It is a great advantage and there is no waste material. The disadvantage of this process is the lack of making precision parts as well as the poor quality of the printed surface. This can be partially corrected by increasing the resolution (production quality), but in this way considerably increases the build time and price.

Method of 2D milling method belongs to the classical method of cutting. This treatment lasts considerably longer than with 3D printing. Additional software is needed. NC codes must be created. The treatment process is much more complex, but it is much more precise.

In future researching an analysis of the machining phases will be performed.

REFERENCES

[1] Bao, J., Weidong, H.: “Parametric Design and Efficiency Analysis of the Output-Pin-Wheel Cycloid Transmission”, International Journal of Control and Automation, Vol. 8, No. 8, 2015, pp. 349-362,

[2] Blagojević, M., Marjanović, N., Đorđević, Z., Stojanović, B., Dišić, A.: “A New Design of a Two-Stage Cycloidal Speed Reducer”, Journal of Mechanical Design, Vol. 133, 2011,

[3] Dascalescu, A., Ungureanu, M.: “CAD-CAM Programs Applied to the Cycloid Profile Wheels Processing”, Annals of the University of Petrosani, Mechanical Engineering, Vol. 12, 2010, pp. 65-70,

[4] Hsieh, C-F.: “Traditional Versus Improved Designs for Cycloidal Speed Reducers with a Small Tooth Diference: The Effect on Dynamics”, Mechanism and Machine Theory, Vol. 86, 2015, pp. 15-35,

[5] Petrović, N., Matejić, M., Kostić, N., Blagojević, M., Marjanović, N: “Parametric Modeling of a Cycloid Drive Relative to Input Shaft Angle”, The 3rd International Conference Mechanical Engineering in XXI Century, 17-18 September 2015, Faculty of Mechanical Engineering in Niš, pp. 157-160,

[6] Stanojević, M., Šljivić, M., Plančak, M., Đurđević, D.: “Advanced Investigation on Rapid Prototyping Techniques in Maxillofacial Surgery and Implanting Preparation”, Journal for Technology of Plasticity, Vol. 39, No. 1, 2014, pp. 11-20,

[7] Vučina, A., Obad, M., Rašović, N: “Design of Products Intended for the Production Using Additive”, Monograph, 2015, University of Mostar, Mostar,

[8] Weideng, H., Qi, L.: “Parametric Design and Dynamic Simulation of the Pin-Cycloid-Gear Planetary Reducer Used by Fast Moving Switch Machine”, International Conference on Computer Application and System Modeling (ICCASM 2010), 2010, Taiyuan, China, pp. 473-476.