APPLICATION OF CAD MODELLING IN PREPARATION OF A GRINDING WHEEL USED IN SHAPING OF A WORM THREAD OUTLINE

Zastosowanie modelowania CAD w przygotowaniu ściernicy używanej do kształtowania zwoju ślimaka

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DOI: 10.15199/160.2020.3.7

A b s t r a c t: This paper presents overall description of the cylindrical worm thread grinding process. The grinding wheel CAD model was developed by the use of Boolean operation in the CAD software. The model is universal and is a basis for dressing of a grinding wheel according to the chosen shape. The tools were prepared in the way that allow to grind any contours of the worm thread.

K e y w o r d s: CAD modelling, CAD software, worm thread shape, helical surface, cutting surface of the grinding wheel

S t r e s z c z e n i e: W artykule przedstawiono ogólny opis procesu szlifowania ślimaków walcowych przekładni. Model CAD ściernicy został opracowany przy użyciu operacji Boole'a w programie CAD. Model jest uniwersalny i stanowi podstawę do obciągania ściernicy zgodnie z wybranym kształtem. Narzędzia przygotowane w sposób pozwalający na szlifowanie dowolnych geometrii zwoju ślimaka.

S ł o w a k l u c z o w e: modelowanie CAD, program CAD, kształt zwoju ślimaka, powierzchnia śrubowa, powierzchnia tnąca ściernicy

Introduction

Advanced CAD/CAM (Computer Aided Design/ Computer Aided Manufacturing) software is nowadays one of the most significant tools of the digitalized manufacturing industry. Regardless of they function as independent software or modules of extended CAx platforms, they have become important tools of manufacturing environments. In reference to a worm gear, CAD systems, are particularly useful if a worm thread characterized by an unusual outline, is shaped. The same applies to the geometry of the tools, which are used in machining of gear wheel teeth. Modelling of complex shapes of the grinding wheel's cutting surface is one of the most difficult design issues, especially if teeth are shaped in envelope milling. For tools characterized by a simple shape, such as straight-line, the modelling process is not challenging. In this case, the standard approach in CAD software concerns the use of revolve function with reference to the appropriate sketch. The issue is complicated when the outline shape is defined by the shape of a worm thread outline. In such case, the issue is complex and requires an individual approach. It concerns the revolved curve enabling to obtain the required shape of a worn thread by the use of envelope grinding. One of the solutions is an analytical model of the grinding wheel outline, developed on the basis of a mathematical model. The scope of their application is limited by computational complexity and workload.

The tailor-made computer programs have been developed for their effective use [9, 17, 18]. Another solution concerns the machining process simulation in CAD environment, which allows to generate a tool's outline. Advanced functions regarding solids, using Boolean operation, make it possible to create to the grinding wheel shape based on the worm thread's outline. It is a kind of reverse-engineering. The task defined as a description of tool's outline on the basis of known and nominal outline of worn thread surface may be named as a reverse task, because envelope methods have been used so far in which the outline of a tool defines the shape of a worm thread. Different approaches focused on using CAD modelling in the development of worm threads grinding processes are presented in publications [1–8, 10–22]. It should be noted that solids or surface models are very often the basis for other works in engineering practice, e.g. as comparative standards in measuring systems, for geometric or strength simulation using FE-based numerical methods. This paper presents the method and results regarding the development of a grinding wheel's outline in grinding of the defined worm thread. The proposed approach enables modelling of grinding wheels geometry, which is applicable in grinding of worms characterized by various thread outlines.

Methodology of grinding wheel model development

The modelling method of a grinding wheel, characterized by complex geometry, concerns the simulation in a CAD environment. In order to complete the mentioned modelling tasks, a CAD model of a worn thread must be developed in advance. Modelling work was performed by the use of the SolidWorks software.

The investigations were completed using the worm thread defined by the following parameters:
m = 4 – axial module
z = 1 – number of start thread
q = 10 – diameter rate
γ = 5,71° – lead angle
α = 20° – axial outline angle
d = 40 – pitch diameter of worm
p_z = 12,56 mm – axial pitch
h_a = 4 – tooth head height
h_f = 4,8 – tooth foot height

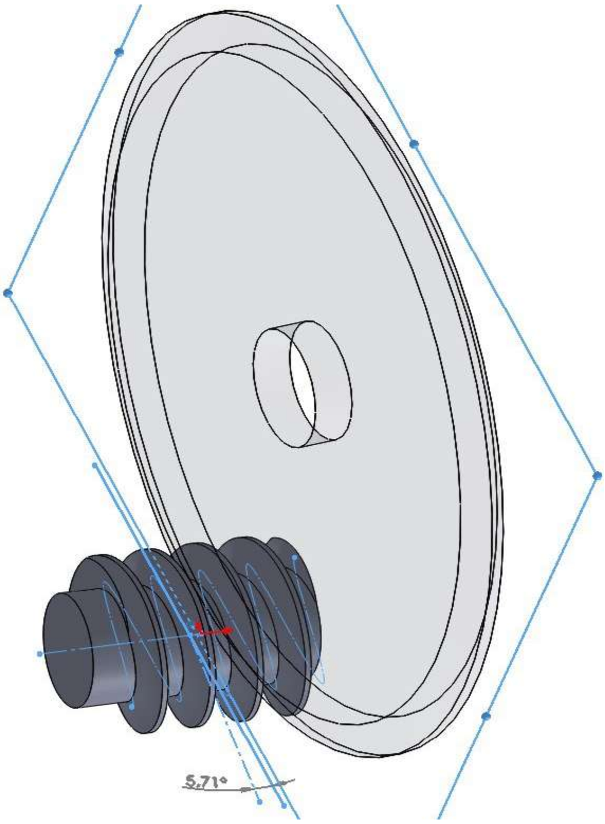

Fig. 1. Grinding wheel – worm thread setup

Preparation of a stock of grinding wheel is also necessary. It is used to create the required outline. Diameter and width of grinding wheel are important. These dimensions should correspond to the real dimensions. The shaped worms will be characterized by the concave outline of thread and their radiuses are as follows: R_1= 30, R_2 =50 mm. The machining process will be performed by the use of grinding wheels which diameters equal D_1 = 200 mm and D_2 = 150 mm. Both models must be properly positioned in the modelling space. The proper orientation of grinding wheel and worm thread's axis is crucial. The first step is to set up the grinding wheel model in a worm's hob correctly using the defined lead angle. This was done by using an additional reference line related to the structural element of the screw model. The structural element is a line which is tangent to the helix projected onto the plane forming the thread. The point of tangency is fixed on the axis of worm. This ensures that the reference line is correctly positioned, (Fig. 1). Based on the pitch diameter of worm and the thread height, the nominal diameters of grinding wheel were pre-defined as follows D_{N1} = 192 mm and D_{N2} = 142 mm. According to the worm threads machining technology with the use of enveloped tool, the nominal diameter of grinding wheel, must be tangent to the pitch diameter of worm. The tangent points were determined in the research model using the auxiliary sketches.

In the next step, the grinding wheel was transferred from the center of the hob towards the thread's surface. Monitoring of the penetration depth of models enables to determine the "cutlayer" of grinding wheel (Fig. 2). Similarly, the cut-outs will be defined on the other side of the grinding wheel using another model of worm. This approach will let obtain the tool's symmetry and determine its width, including the nominal one (Bn).

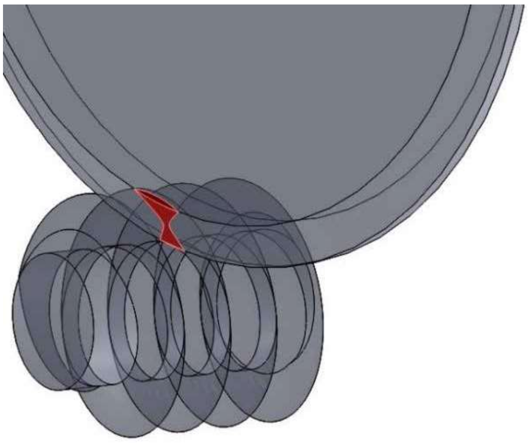

Fig. 2. The position of the grinding wheel shaped with the use of a worm

In comparison to the kinematic system of the machine tool such as thread grinders, the presented approach requires worm turning around wheel's perimeter. As a result, the contact of the grinding wheel with the thread is simulated during its rotational movement (Fig. 3). At this stage, the worm models "penetrate" the grinding wheel. The outline of the cutting surface is obtained by subtracting these worms by means of a function, which is

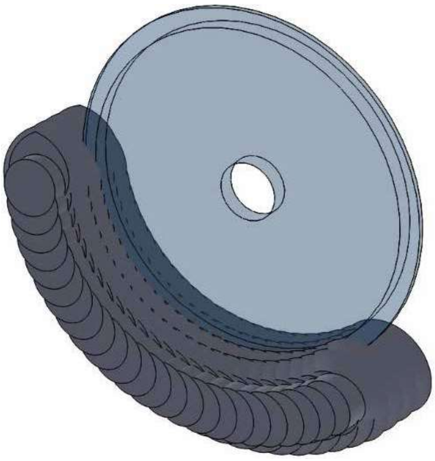

Fig. 3. The worms arranged on the perimeter of the grinding wheel

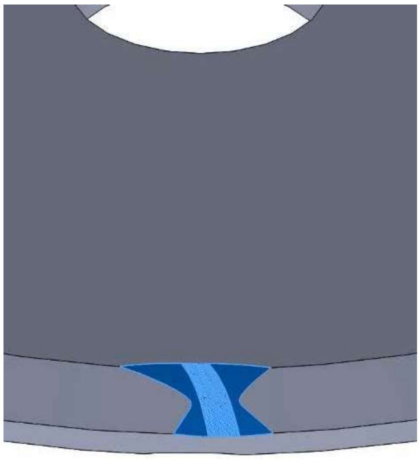

Fig. 4. The cutting surface of the grinding wheel obtained after the screw removal operation

based on the principle of Boolean algebra. The tool forming process is not continuous but discrete. The accuracy of the model is dependent on parameters of simulation, and more specifically – on the density of the distribution of the worm models on the circumference of grinding wheel. Visualization of the process was presented in Fig. 3. As the final result, the model of tool is created (Fig. 4). It will be used to prepare the NC (Numerical Control) program for a grinding wheel dressing process. Due to PC computational efficiency, the range of models which are used for creation of wheel's shape was reduced to the necessary area – needed to define outline.

Outlines of grinding wheels were obtained by the use of presented approach. It is presented in Fig. 5. Grinding wheel models were developed for worms with a concave thread outline. There are fragments of the cross-sections of the grinding wheels used in machining of a worm. The radius of R_1 = 30 mm is presented in Fig. 5a. whereas Fig. 5b presents a worm characterized by radius R_2 = 50 mm. The functionality of any CAD software allows to collect the dimensional data of model, e.g. in the form of a two-dimensional drawing. A fragment of such a drawing (Fig. 6) shows the outline of one of the grinding wheel with marked dimensions. The information on the outline geometry will be helpful in NC program development for further application on CNC (Computerized Numerical Control) machine tool, and in the measurements of outline of a fabricated grinding wheel.

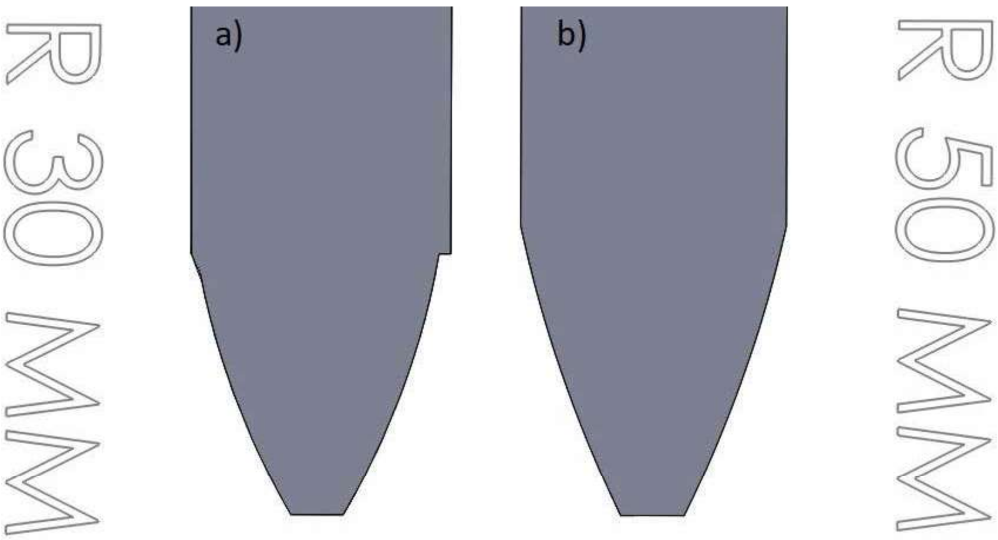

Fig. 5. The outline of a grinding wheel for a worm with the concave thread outline and the defined concavity radius: a) R = 30 mm, b) R = 50 mm

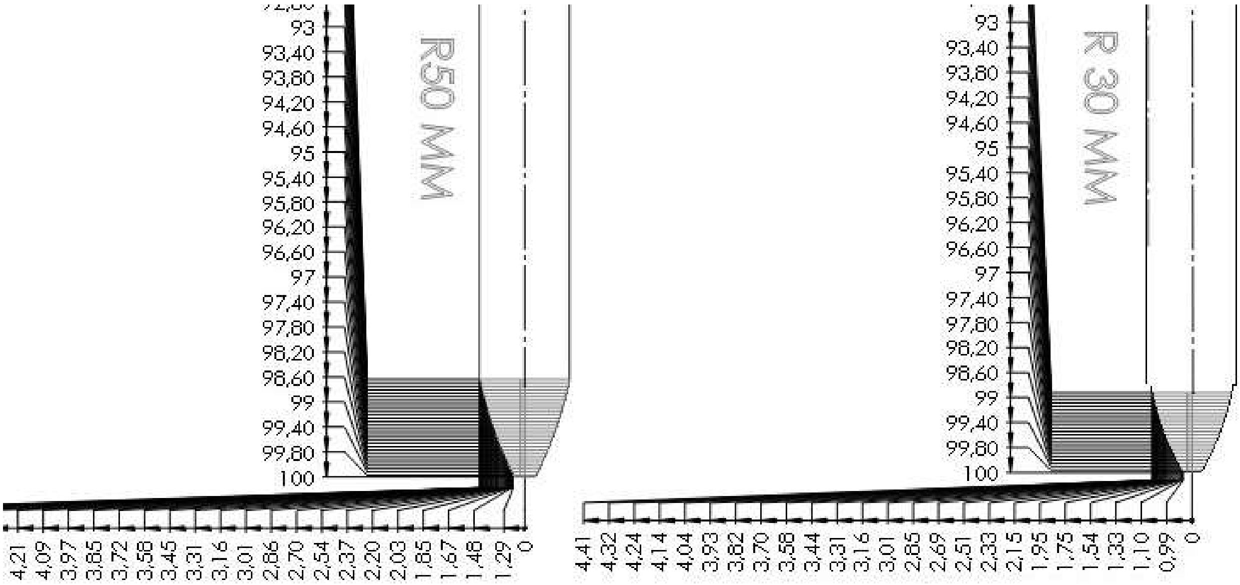

Fig. 6. The drawing of grinding wheel outline with marked dimensions

The outlines presented in Fig. 5 refer to a grinding wheel with the outer diameter of 200 mm. Preparation of a single tool model does not, however, end the design work. An active surface of wheel is subjected to natural wear during grinding. In order to retrieve the desired cutting properties of grinding wheel, it is necessary to dress it periodically. Subsequent dressings remove a certain layer of material. As the consequence of dressing process, a diameter of wheel decreases. This causes changes of its outline too. Due to the new diameter of grinding wheel which determines the new outline of active surface, the model must compensate these unavoidable changes in tool dimensions. A wear of diamond dressers is negligible. Therefore, the compensation of their dimensions can be skipped. On the basis of preliminary tests, the thickness of the abrasive layer, removed during dressing, is determined. This approach enables excessive loss of grinding wheel volume. An information concerning the expected diameter of a wheel after dressing may be used for program updates. It is also necessary to redefine the distance between the tool axis and the worm. Repeated Boolean operations generate a new shape of the active surface adapted to the new dimensions.

Summary

There are only few applications for development of the shape of selected element on the basis of a given model. The software developed by author of the publication [17], which is dedicated for modelling the outline of the thread worm and the cutting surface of the grinding wheel, is not commercial and is not easily accessible. However, it is possible to model these geometries using operations based on Boolean algebra available in CAD software. The abovementioned method was used for the aims of the study. A preliminary geometrical analysis of grinding wheel is hence enabled. The model is also the basis for a development of NC program which will be applied in dressing. The presented method allows to modify the outlines of the worms and ensure their "reflection" on the grinding wheel. It eliminates significant restrictions of envelope methods. These restrictions result from the lack of special tools with the required cutting edge. Roughing can be performed with simple tools (e.g. these which are generally available). Afterwards, it is possible to carry out finishing process using a properly prepared grinding wheel. The described modelling method allows to automate the grinding wheel design process and allows to control the correct preparation of the finished tool. The advantage of using CAD methods is a shortened design time. Grinding wheels, developed with the use of the presented method, will be research in the future.

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