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COMPUTER AIDED MACHINING OF SIMPLISTIC WORM WHEEL TEETH PROFILE

Abstract

Creating a simplified worm wheel profile leads to approximating it through the use of sections. The worm gear notch created through approximation is inaccurate and does not ensure proper meshing. However, this method is commonly exploited because of economic reasons such as the use of universal milling machines and tools. In summary, machining worm wheel teeth with a simplified tooth profile is less complex thus less time consuming.

1. INTRODUCTION

The traditional method of machining worm wheel teeth is worm gear hobbing. Worm gear hobs or cutters mounted on shafts are the most used tools for this machining operation. Subsequently, there is a need to prepare and set a tool end with specific geometry after each machining operation because each tool can only be used to cut one type of worm gear. Achieving the desired worm wheel profile and accuracy depends on how well the CAD model is prepared as well as the placement of tool paths on the side walls of the teeth.

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Currently, worm drives are designed through the use of simplified worm tooth profiles in many devices. This approach is suitable for devices that do not require a high level of infallibility nor accurate meshing. These transmissions are used in household appliances and simple agricultural equipment.

The complex shape of the side surface of worm wheel teeth completely depended on the convolution shape, that works with worm gear, because of this the correct machining if the teeth requires the use of special tools and machine. This ensures the right contact between gear teeth, which directly influence its properties of exploitation. There are a few methods of worm wheel teeth machining in industry, which allow the meeting of requirements [1–4]. Their choice dependent on many factors, which may include: machine wheel parameters, its precision, production size etc. Contemporary developments of computer techniques grant new possibilities in a field of worm wheel teeth machining. This concerns CAD/CAM software as well as CNC machines. There are many machining possibilities of these systems, which allow for the shaping of worm wheel teeth. It should be noted that this is possible through the use conventional machines and equipment, without a doubt this is positive feature of this method [5]. We usually apply hobbing methods for the execution of wormwheels. A wormwheel executed in this manner has the full tooth outline. In order to apply a different method of execution, we simplify the tooth geometry. It shall be remembered that a gear executed in this way will have lower power train capability. However, in case of certain products, it is permissible to reduce durability parameters of gears, taking into consideration the benefits of simplistic component machining.

2. THE PROCESS OF CREATING WORM WHEEL MODEL

In order to create a simplistic wormwheel model, full wormwheel model needs to be first determined, and then simplified. It shall be stressed that a wormwheel model does not have to be accurate. In order to create a full wormwheel model, we may use the treatment simulation method, or analytic derivation presented in the literature [2, 5]. It shall be stressed that the important thing is not the selection of the method, but the determination of basic wormwheel gear geometry. The information provided in the source may serve for this purpose [1, 2]. This article presents the application of the treatment simulation method, because the tooth outline in a wormwheel is a component with a high level of complexity. One of the difficulties with modelling the shape of a tooth results from profile changes along the width of a wheel. The simulation method is based on repeating specific operations of Boolean algebra. Such operations in CAD software allow for determining the sum, difference and product between solids. In the considered case, our activity consists in immersing the tool in the properly prepared wheel envelope and performing the difference operation. This process is performed multiple times, with changing positions of the tool and the treated wheel. The result of our activity will be discreet surface, i.e. consisting of elements of actual surface. The process of cutting wormwheel teeth using the simulation method with the application of Boolean algebra is presented in picture 1.

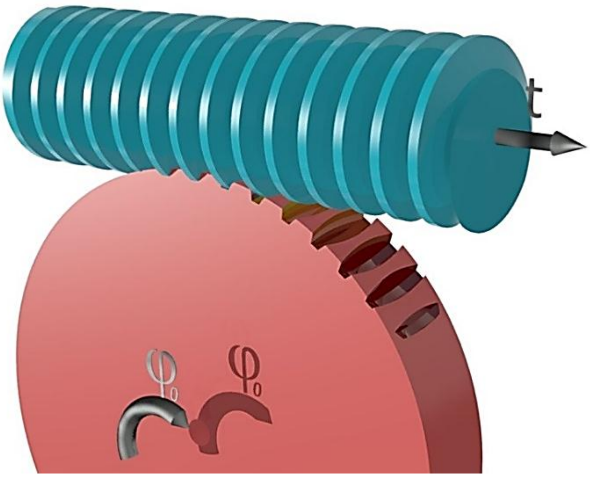

Fig. 1. The process of cutting wormwheel teeth using the simulation method with the application of Boolean algebra [source: own study]

The above picture presents the types of changes in consecutive steps and values of particular changes concerning rotation and translation of solids. In this case, the change of positions involves wormwheel rotation and worm displacements.

$$t_o = \frac{p_o}{2} \tag{1}$$

where: $t_o[mm]$ – elementary displacement,
$p_o[mm]$ – axial scale;

$$\varphi_o = \frac{360°}{2z_2} \tag{2}$$

where: $\varphi_o[°]$ – elementary angle of rotation,
z_2[-] – number of wormwheel tooths;

Relationship [1] and [2] allow for determining the size of displacement in the function of angle of rotation. It is certainly possible to apply different translations and rotations of solids, but this requires deriving appropriate relationships:

$$\varphi_0 = \frac{\varphi_c}{l_k} \tag{3}$$

where: $\varphi_0[°]$ – elementary angle of rotation,
$\varphi_c[°]$ – total angle of rotation,
$l_k[-]$ – number of steps;

The process of rotation, displacement and difference should be performed with full meshing of wormwheel tooth and worm. On the basis of the achieved rotation, the number of steps necessary to generate the wormwheel groove outline shall be determined. In order to increase accuracy, the wormwheel angle of rotation and worm displacement should be reduced properly. The number of repetitions usually depends on various parameters. During the process of its selection, the required accuracy and time necessary for performing the iteration process shall be determined. The equipment capabilities may also constitute a significant factor, because the arising model is an element with irregular surface, generating high load during display. After performing all iterations, we cut the model along the central plane and project the resulting area against this plane. Then we create the curve outline. The lateral surface outline may be approximated to any number of sections. The number of sections depends on the method and time required for the execution of an element. This also provides information on how exactly the curve will be represented. Picture 2 presents the formed tooth profile curve.

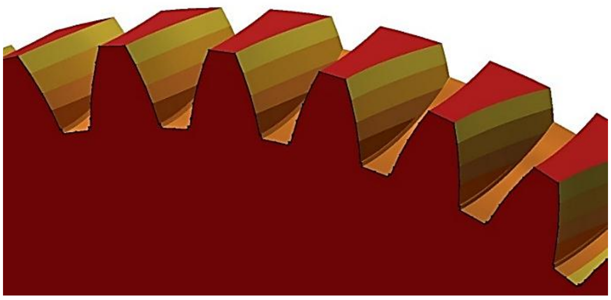

Fig. 2. Tooth profile curve [source: own study]

The following step consists in creating a full inter-tooth groove outline based on tooth thickness in characteristic section. For the purpose of appropriate deduction, the curve projected on tooth reference cylinder and inclined by an appropriate angle shall be derived (Picture 3). Helix can also be derived instead of a curve.

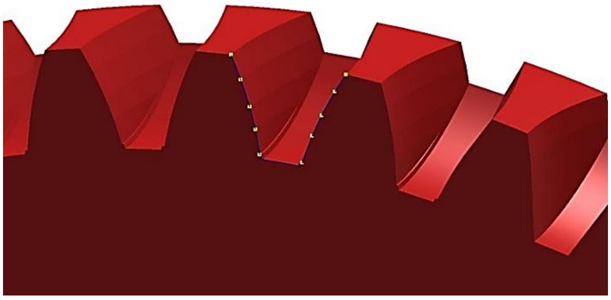

Fig. 3. Approximate shape of tooth space with characteristic point [source: own study]

The final element consists in executing the previously created outline dragging, formed along the leading curve, taking into consideration the guide surface. Picture 4 presents a finished model of simplistic wormwheel.

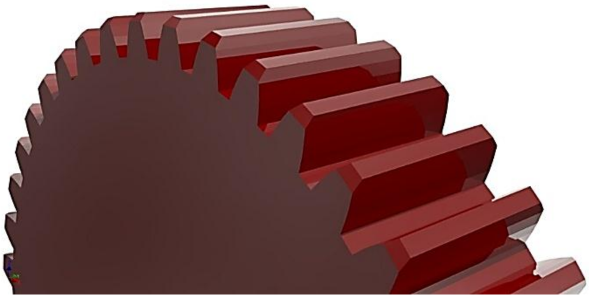

Fig. 4. Simplistic wormwheel model [source: own study]

Tooth outline executed in this manner is a simplistic representation. In order to achieve a full model of wormwheel, the dragging operation should be repeated in circular array.

3. MACHINING OF SIMPLISTIC WORM WHEEL TEETH PROFILE

In traditional machining methods, wormwheel tooths are shaped in the envelope manner. The applied tools are hobbing cutters or blades fastened in the rod performing circular motion. In order to ensure proper meshing of worm gear, the tool should be geometrically consistent with the worm in wormwheel machining. Therefore, it is required to prepare each time a tool with specific geometry, because only one type of wormwheel can be cut by means of one tool.

With the application of contemporary machining assistance CAD/CAM computer systems, the machining process of wormwheel tooths is entirely different from the above-described methods based on envelope treatment. The achievement of assumed shape and accuracy of the wormwheel depends on the correct preparation of CAD model and arrangement of tool paths on the lateral surface of tooths.

In traditional machining with the application of CAD/CAM systems, formation of tooths consists in roughing and finishing. The advantage of this type of machining is the application of universal tools, as well as four- and five-axis machine tools. This method is limited with regard to the possibility of using cutters for treatment of inter-tooth grooves, which requires the application of cutters with small diameters in small wheels. Finishing consists in lining tooth side with the application of ball end cutters. The disadvantage of this method is the machining time, which is long in this case, and the technology is not usable for serial applications.

Machining of simplistic wormwheel tooth profile consists in generating tool paths for the machining of simplistic lateral surface of a tooth. The execution of tool paths for simplistic outline is significantly easier and less time-consuming than in case of outlines created by means of the simulation method. Machining of simplistic wormwheel consists in applying four-axis CNC machine tool and four-axis strategy of side cutter treatment. The arrangement of tool paths on tooth sides is presented in picture 5.

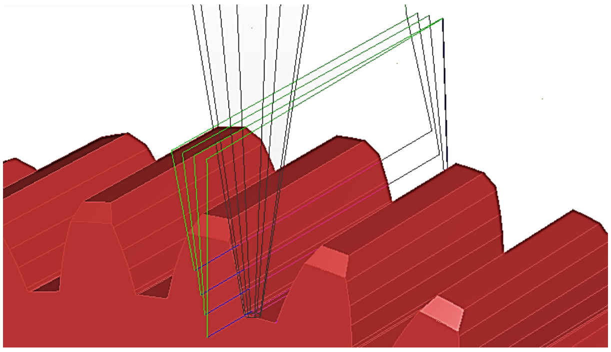

Fig. 5. Tool paths on tooth side [source: own study]

In the case of simplistic wormwheel tooth outlines, preparation of tool paths is very easy due to the simplified tooth side. Treatment time is much shorter than in traditional treatment methods. Such approach to designing and manufacturing is frequently applied in the case of low responsible gears. In treatment, most frequently applied are side and face shank cutters. The application of conic file cutters is a novelty presented in this article. Due to the diversity of shapes and blade geometry, these tools are becoming widely applied in CNC treatment.

An additional advantage of these tools is a wide range of sizes, which makes them outstandingly useful in the treatment of wormwheels of different sizes. These tools were widely described in item [6].

Each path is generated separately on each surface of simplistic side of wormwheel tooth. Picture 6a presents simulation of 3D machining of one wheel groove, picture 6b shows comparison between the cut groove and the model.

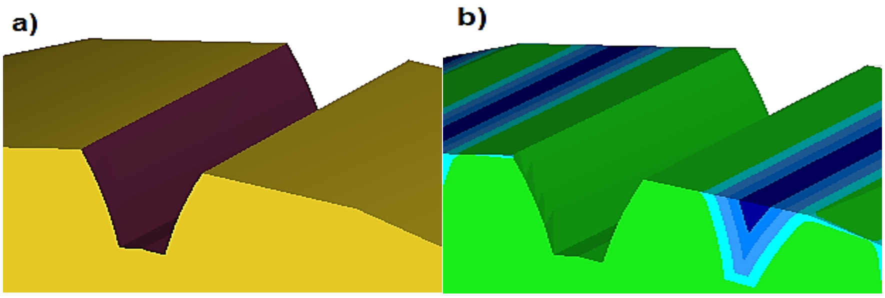

Fig. 6. Tooth space machining simulation a) tooth space after simulation, b) comparing tooth space before and after machining [source: own study]

Picture 7a presents simulation of machining in CAM system. Such simulation allows for detecting any collisions between the tool and the machine tool. Picture 7b presents the actual treatment of wormwheel on Haas VM3 machine equipped with a dividing head.

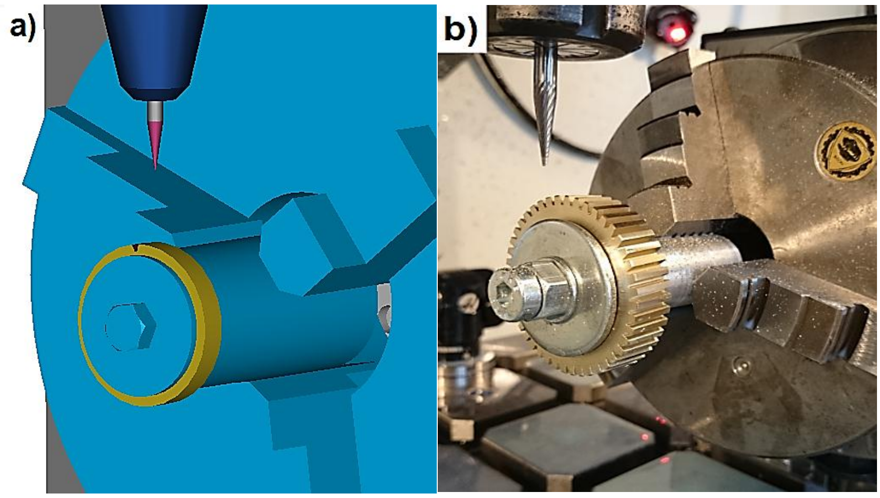

Fig. 7. Simplistic tooth space machining: a) CAM simulation, b) machining on machine [source: own study]

4. CONCLUSIONS

The main advantage of the presented technology of wormwheel machining is the maximum simplicity of the model outline and application of CAM systems for generating simple tool paths for conventional CNC machine tools and universal tools. The simplification of tooth profile is widely used by multiple manufacturers of different types of tools containing work gear units. Such approach is obvious from the economical perspective, because the manufactured devices are supposed to be cheap and they are designed for specific duration. However, from the consumer point of view, with certain degree of engineering knowledge, elements executed in this manner can be easily designed and performed.

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