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PARAMETRIC MODELING OF GEAR TRANSMISSIONS IN CAD SOFTWARE WITH DEFINABLE SHAFT AXIS POSITIONS

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Abstract: This paper presents a practical example of using current CAD software solutions for improved modeling of geared power transmissions. The parameterization process used is for creating individual models, elements and assembly models of transmissions. The assembly model parametrically defines the correlation between elements of the assembly and defines the position of the shaft axis. This approach presents an automation of the modeling process, a quick and effective approach to forming and changing technical documentation. The suggested approach forms a basis for automation of the complete design process for geared power transmissions. This paper also presents models of practically applicable geared transmissions which verifies the quality and efficiency of the development process, compared to a conventional approach. Practical examples also show ways of creating models and use of development processes. Models are developed for two-stage and three-stage geared power transmissions.

Key words: Parametric modeling, CAD, geared transmission, shaft axis

1. INTRODUCTION

The use of CAD software is quite wide spread today and is practically unavoidable in engineering practice. A very attractive and frequent use of CAD software is for the automation or the design process. Automation in CAD software implies automated modeling of families of similar components of a certain product and even whole products. Automated modeling is based on modeling parts, subassemblies and assemblies of complete structures automatically by defining parameters, which are previously determined. Defining parameters and their relations is done mathematically

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before the development of an automated model in CAD software.

Parameterization and automation of the design process represents an active theme, which it is possible to prove with a review of literature. In paper [1], the methodology of attaining a parametric model is shown. In this paper a parameterization and optimization of one type of transmission has been given. Parameterization in paper [2] was done using the criteria of bearing size and their deformation. The derived parameterization and automation of helicopter transmission [3], represents a very good optimization solution for a decrease in the transmission mass. Wind-generators [4], have been analyzed based on the criteria of structural optimization. In paper [5], a parameterization of a transmission with a large number of components has been shown. Paper [6], shows the parameterization of a turbine, which has been developed using artificial intelligence. In paper [7], a multistage parameterization of modeling parts has been presented.

The motivation behind this research comes from the need for a more efficient modeling process for geared speed reducers with parallel shaft axes. Putting into action the automation of modeling these drives will be done according to input geometry parameters. This type of modeling automation, to a great extent, increases design process efficiency compared to the conventional methods in CAD software design. For the purposes of this research, a parameterization of a geared speed reducer has been made in CATIA V5 R20.

2. PROBLEM DESCRIPTION

Challenges in modern design and engineering imply a need for an increase in efficiency of all development processes and the improvement of operational characteristics of the designs and production processes themselves. In an attempt to increase efficiency, CAD software is used more and more, however due to a large number of possibilities which the development process has to offer the process itself becomes exhaustive and time consuming. Aside from this, similar processes, which are repetitive, but have a lot of similarities are done separately, therefore providing room for speeding up development and production processes.

Through the automation by parameterization of modeling, efficiency is increased to a great extent as well as achieving an improvement in performance by decreasing the possibility of human error.

Parametrically solving problems in CAD software implies generating models from a family of parts, assemblies and entire products by inputting parameters. This paper shows a parameterization of a dual-stage and a three-stage conventional geared speed reducer with parallel shaft axes. The parameterization given covers the following four cases:

1. Dual-stage conventional geared speed reducer with shaft axes in the same plane;
2. Dual-stage conventional geared speed reducer with shaft axes in different planes;
3. Three-stage conventional geared speed reducer with shaft axes in the same plane.
4. Three-stage conventional geared speed reducer with shaft axes in different planes.

Input parameters for the first and third case are: number of teeth, gear module, and gear widths. For the second and fourth case, aside from these three parameters, more are added. Those parameters are the angles between axes in relation to the horizontal plane. These angles define in which position the shaft axes will be placed in the transmission housing.

The second and fourth cases are derived for the following benefits:

- Smaller overall dimensions of the transmission housing,
- Decrease in the mass of the transmission (by decreasing the mass of the housing),
- Material savings,
- Less oil needed to lubricate gears.

In all four cases gears, shafts and transmission housings have been parametrically defined. The values which have been used as examples for all four cases have been taken from real existing examples.

3. PARAMETERS

For parameterization of all four cases it is necessary to understand basic gear parameters and their relations. Basic parameters of all gears are module *m*, number of teeth *z*, and gear width *b*. These two parameters define the gear diameter *d*. Their relation is given by the following formula:

$$d = m \cdot z \tag{1}$$

Defining the gear diameters defines the distance between axes. It is constant and is calculated as a half sum of diameters:

$$a = \frac{d_1 + d_2}{2} \tag{2}$$

The value of the distance between axes plays a role in the parametric restrictions of the geared transmission model assembly. Depending on the power it transmits and working conditions, gear width is variable. Gear width influences the change of the axel length. Gear width is adopted using the ψ_{bd} coefficient. This coefficient represents the ratio of the gear width and diameter. *Ut* is adopted for the driving gear from suggested values in literature depending working conditions and input power. For the purposes of this research, a parameterization of a geared speed reducer has been made in CATIA V5 R20.

In this CAD software Part Design and Assembly design have been used in the parameterization process. In the Part design environment parameters of individual shaft and gear parts have been created and their dependencies have been set. There, based on three input parameters a gear’s complete solid geometry is created.

In assembly design, parameters for managing the assembly and housing have been created. In this environment parameters for defining the angle between shaft axes relative to the horizontal plane have been defined. Aside from that a relation between all elements of the assembly has been created so as to have further parameter changes influence the change of the entire assembly. This way the automation of the design process has been achieved and the possibility for creating a family of transmissions with various parameters and technical specifications within the provided set.

For further increase of efficiency a table of part families has been created which can be used to directly influence on creating a model. All parameters can be changed from an MS Excel table. This table is directly linked to the CAD software. All changes to the parameters in the table can be seen in the CAD software upon refreshing the model.

4. RESULTS

When all the connections between the parameters are defined parameterization can commence. Parameterization of the first case is solved in one of the papers of author [8], for the case when shafts are located in one plane. In the first case the drive has paralleled shaft axes which lie in one plane.

The second case has a parameterized shaft position. Parameterization of the shaft axes is done by angle parameters which define the position of the shafts relative to the horizontal plane. Angle change is done so as to achieve a minimal housing volume.

The third case a three-stage reducer with parallel shaft axis which lies in the same plane has been modeled. This case differs from the first in that it has an additional transmission set, and therefore an additional shaft. This model is created so that all shaft axis of the drive lie in the same plane, actually parameters which define angles in relation to the horizontal plane have a value of zero.

The fourth case has the most similarities with the second model. Shaft axes form an angle relative to the horizontal plane. The complexity of this case is in the requirements for a larger number of parameters, defining one more angle value and a larger number of constraints.

The values used for the created examples covering the four cases this paper covers are given in table 1.

These example values have been previously calculated to suite the requirements of set transmission ratios and input power.

Table 1. *Editorial instructions*

<table>
<tr><td>No</td><td>Trans.</td><td colspan="4">Parameter values</td></tr>
<tr><td colspan="2"></td><td colspan="2">Stage 1</td><td>Stage 2</td><td>Angles</td></tr>
<tr><td>1.</td><td>P1</td><td colspan="2">m1=2 mm, z1=20 mm, z2=83 mm, b1=35.6 mm</td><td>m2=3 mm, z3=23 mm, z4=67 mm, b2=30 mm</td><td>angle1=0 deg, angle2=0 deg</td></tr>
<tr><td>2.</td><td>P2</td><td colspan="2">m1=2 mm, z1=20 mm, z2=83 mm, b1=35.6 mm</td><td>m2=3 mm, z3=23 mm, z4=67 mm, b2=30 mm</td><td>angle1=30 deg, angle2=-60 deg</td></tr>
<tr><td colspan="2"></td><td>Stage 1</td><td>Stage 2</td><td>Stage 3</td><td>Angles</td></tr>
<tr><td>3.</td><td>P3</td><td>m1=2 mm, z1=24 mm, z2=110 mm, b1=76.4 mm</td><td>m2=3 mm, z3=24 mm, z4=84 mm, b2=116 mm</td><td>m3=4.5 mm, z5=23 mm, z6=56 mm, b3=140 mm</td><td>angle1=0 deg, angle2=0 deg, angle3=0 deg</td></tr>
<tr><td>4.</td><td>P4</td><td>m1=2 mm, z1=24 mm, z2=110 mm, b1=76.4 mm</td><td>m2=3 mm, z3=24 mm, z4=84 mm, b2=116 mm</td><td>m3=4.5 mm, z5=23 mm, z6=56 mm, b3=140 mm</td><td>angle1=30 deg, angle2=-60 deg, angle3=30 deg</td></tr>
</table>

For the first case, transmission P1, by entering the values from table 1 into the file, the program automatically creates the model, shown in three views in figure 1.

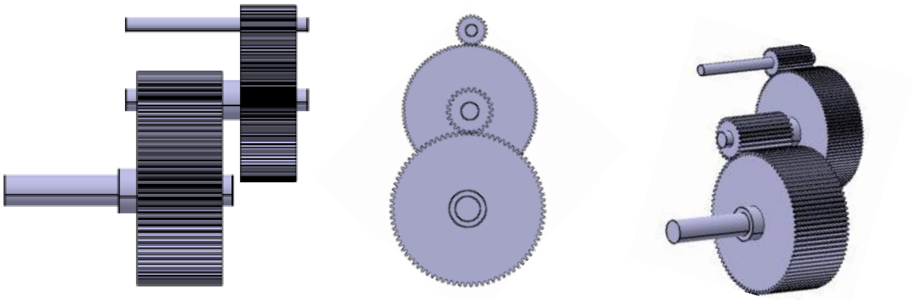


Figure 1. *Dual-stage conventional geared speed reducer with shaft axes in the same plane.*

For the second case, transmission P2, by entering the values from table 1 into the file, the program automatically creates the model shown in three views in figure 2. The angle parameters visibly change the size of the necessary housing in this case.

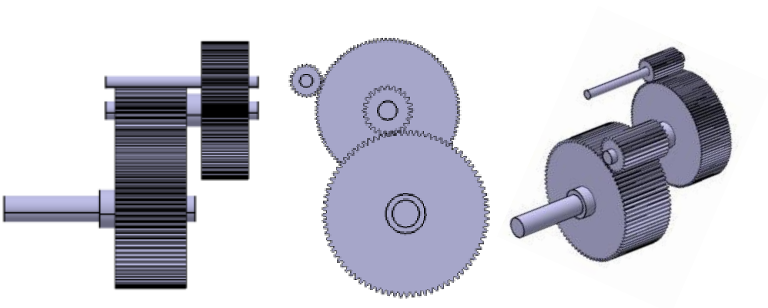


Figure 2. *Dual-stage conventional geared speed reducer with shaft axes in various planes*

For the third case, transmission P3, by entering the values from table 1 into the file, the program automatically creates the model of a three-stage transmission shown in three views in figure 3.

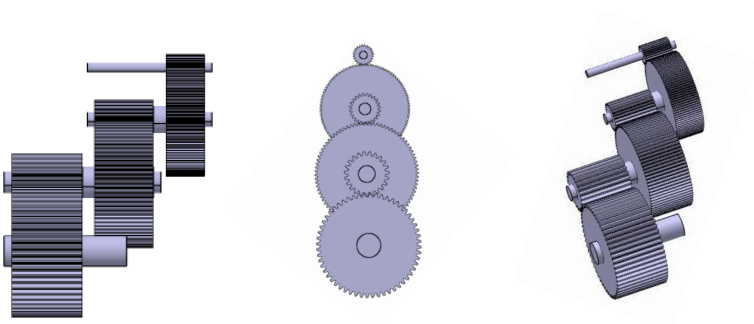


Figure 3. *Three-stage conventional geared speed reducer with shaft axes in the same plane*

The fourth transmission case, P4, is shown in figure 4. Compared to the positioning of axes in P3, a substantial difference can be seen in necessary housing size.

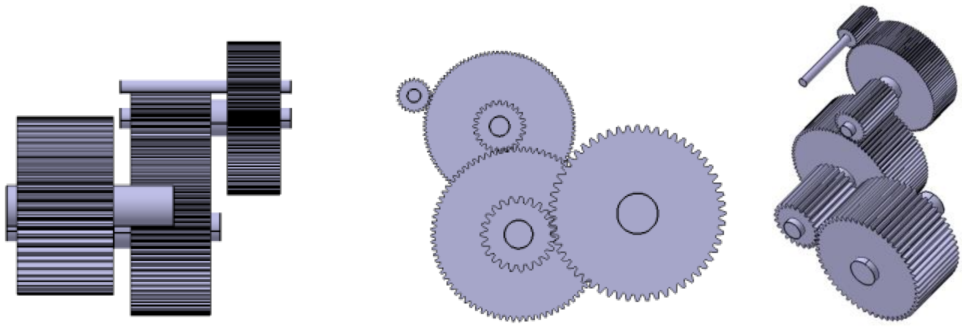
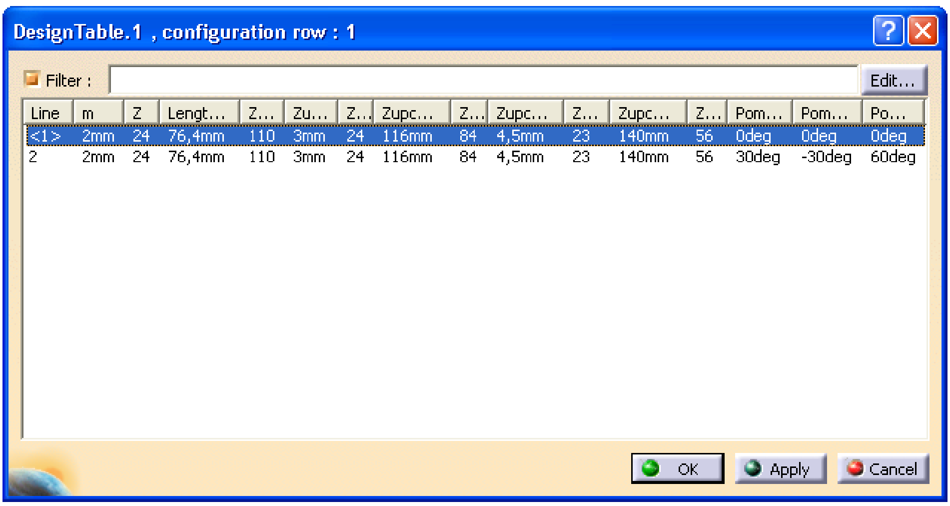


Figure 4. *Three-stage conventional geared speed reducer with shaft axes in various planes*

By changing the values of the parameters it is possible to directly, in the specification tree, create each model individually. To achieve additional efficiency a parts family table has been created in the Design Table command from the Knowledge tool palette. This way a table is created which enables the input of desired values and automated activation of parameter groups which result in model changes. The parameter group choice for creating models is presented in figure 5.



Line	m	Z	Lengt...	Z...	Zu...	Z...	Zupc...	Z...	Zupc...	Z...	Zupc...	Z...	Pom...	Pom...	Po...
<1>	2mm	24	76,4mm	110	3mm	24	116mm	84	4,5mm	23	140mm	56	0deg	0deg	0deg
2	2mm	24	76,4mm	110	3mm	24	116mm	84	4,5mm	23	140mm	56	30deg	-30deg	60deg

Figure 5. *Parameter group choice for automatically creating models*

The need for creating a transmission with a changeable value of angles between axes and the horizontal plane is reflected in the adaptability to working conditions, decreasing housing volume, thereby substantially decreasing the overall mass of the drive by saving on material.

5. CONCLUSUION

In this paper a parameterization of geared power transmissions has been achieved. A modern approach to CAD software has been presented and its possibilities to automate similar jobs. In other words an automation of the design process so that same type jobs can be automated for parts, assemblies, and various products. This achieves time savings, improves quality, lowers costs and decreases the possibility of human error to a minimum through the reduction of the number of necessary inputs.

This paper has shown the creation of four modeled drive assemblies. Dual and three-stage drives were created using specific parameter values as examples. Both models have been shown in two versions each, first with the axes angles being zero relative to the horizontal plane, and the other case being with various angle parameters. The three-stage model has an increased complexity due to the addition of another set of gears and an additional shaft which needs to be parameterized and constrained.

The next step in parameterization of conventional geared speed reducers could be an increase in the gear ratio, more precisely a parametric definition of the number of transmission stages and combining design and automation with optimization.

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NOMENCLATURE

Letter symbols

- *a* distance between axes, mm
- *d* gear diameter, mm
- *m* module, mm
- *z* number of teeth,

Greek symbols

- *ψ* bear width coefficient

Subscripts and superscripts

- 1 gear ordinal number, module ordinal number
- 2 gear ordinal number, module ordinal number
- 3 gear ordinal number, module ordinal number

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