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GENERATIVE MODEL OF SPUR GEARING

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Abstract: Generative design is a branch or a concept in the field of designing that typically uses codes, patterns, and algorithms to create some product that can be generated as CAD model in various designs. In spite of the fact that gearing in gearbox is not most typical part of a car that is appropriate for creation of its generative model, it cannot be ignored in designing of cars.Therefore, in this paper spur gearing in gearbox is being solved as parametric model with some features of generative model.
Keywords: generative design, gearing, parametric model

1. INTRODUCTION

Engineering design culture is being considerably changed in last decade. Nowadays is design process understood to be as close flexible connection between designs and implementation in existing environment.In spite of many aspects leading to conclusions, that engineering design methods development is concluded, there are many fact coming to light, that destroy this presumption. One of new and sophisticated design methods namely available in automotive industry is generative design.

A generative design uses a parametric modelling, i.e. models controlled with specified parameters resulting in various variants of design. It can be easily transformed in technological tools because it uses transforming rules that can be easily written in algorithms. The main advantage of parametric design is a possibility to redesign a model by changing of its parameters. But the generative design is method of higher level than parametric design. It provides an unconventional methods and philosophy that reflects a process dynamics connected with conceptual product development. This philosophy is based on nature phenomena and processes (DNA as base of organism heterogeneity). The diversionism and adaptability of life on earth represents analogy and potential that allows processes of designing to over cross a horizon of classic engineering design and to create diversified models from relative simply components. The generative design offers the whole complex of information about a new product which has not only a deterministic, but also heuristic nature [1]. Application of generative design methods leads to modifications and rules creation that help to generate design variants automatically. The role of engineer however remains in centre of design process.

2. GENERATIVE DESIGN WITH CATIA PROGRAM

To enable an effective automation of the design tasks the implicit knowledge in terms of product information, standardisation documents etc., has to be made explicit. This process, where knowledge will be reused for product design, is called Knowledge Based Engineering - KBE.

The basic task of KBE is to built-in an „intelligence“ to digital product model to save and reuse it with help of parametric systems tools that help to degrade routine work and save time of designer for creativity. The model with built-in intelligence is *generative model*. The essence of generative model is in fact, that the logic of model and design process (product knowledge) is described in a way that allows generating a variety of solutions of the same product automatically.

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Nowadays the CAD systems are not more only replacement of drawing board and a paper drawings. The modern CAD system is based on modelling kernels that can process the self-controlling of CAD and can detect its errors, manufacturability and function. As a typical example of contemporary knowledge based engineering application is KBE module in CATIA programme – Knowledgeware workbench. The geometric kernel of CATIA system protects the CAD model against to data corruption. Designer can explore geometrical possibilities of model together with CATIA Knowledgeware module for processing and saving knowledge.

A generative model can be created by:

- ✓ direct use of CATIA Knowledgeware tools
- ✓ creating a programming interface that uses functions of Knowledgeware

The first way is on Figure 1 displayed.

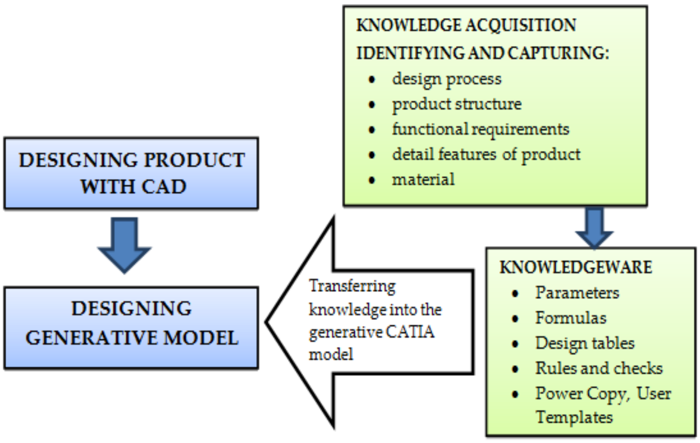

Figure 1.Generative model creation in Catia knowledgeware workbench

3. GENERATIVE MODEL – BACKGROUND

The role of designer is to correctly identify, structure and use of important information in design process, so that he must be able to determine the boundary conditions of generative model. This means the following:

- ✓ to define design problem and to find a relevant design specifications and characteristics,
- ✓ to find information from database of PLM system,
- ✓ to use various methods and tools to discover which information are useful,
- ✓ to transform information to data embedded in design,
- ✓ to create a codified design parameters and build them into the CAD model.

If PLM system is connected with CAD system, then information in PLM database is already saved in structured form that is readable for CAD. The output information are design parameters embedded in model, representing its design, function and manufacture and accompanying product design in all phase (concept, analysis, detailing, drawing etc.).

The first question that should ask designer himself at designing a new product is:" Is that product proper to be designed as generative model?" The important factor for answer is "freedom" of shape modifications. The fact is that most of machine parts are limited by functionality, manufacturability and desired material properties that don't provide much space for shape freedom. In our department is being solved European structural project EŠF26240220076 „Industrial research of methods and techniques of generative design and knowledge based engineering for cars development". The main scope of research is to define an original methodology or design philosophy of structural units of cars so that all design process will be shortened and improved. The new methodology should be based on sample database of before designed, implemented and tested parts of car (generative models) so that new solutions are based (generated) from that generative models respecting a new conditions and limits.

4. GENERATIVE MODEL OF GEARING AND GEARBOX

The one of targets of our study was to create parametric design of spur gearing in gearbox so that gearing and also dimensions of other parts of the gearbox will be automatically generated after changing of axial distance. As the preliminary model and the first step to generative design wasone speed gearbox with spur gearing(at this time only with one speed) solved as parametric – generative model. Its parameters will change according with change of axial distance of gearing. The input parameters of gearing are in Table 1.

Table 1. Input parameters of gearing

parameter	pinion	wheel
number of teeth	z_1 (variable In DesignTable)	z_2
module	m = 5	m = 5
Gear ratio	i = 3,46	i = 3,46
axial distance	a(variable In DesignTable)	
base cylinder radius	$r_{b1} = r_1.\cos\alpha$	$r_{b2} = r_2.\cos\alpha$
pitch circle radius	$r_1 = m . z1/2$	$r_2 = m . z2/2$
outside circle radius	$r_{a1} = r1+m$	$r_{a2} = r2+m$
Pressure angle	α=20°	α=20°
root radius	$r_{f1} = r_1$-1,25m	$r_{f2} = r_2$-1,25m
Tooth feet radius	r_c = 0,38m	r_c=0,38m
Width	b_1 = b+m=55mm	b_2=50mm

Spur gear geometry is in the function of a few fixed parameters: teeth number *z*, module *m* and pressure angle *α*. We can generate every size of spur gear changing parameters *z* and *m*. The pinion and wheel ware designed in CATIA program with help of Knowledgeware tools. In construction of tooth face the equations of an involute were used as low (1), (2):

$$yd = rb * (sin(t * PI * 1rad) - cos(t * PI * 1rad) * t * PI) \quad (1)$$

$$xd = rb * (cos(t * PI * 1rad) + sin(t * PI * 1rad) * t * PI) \quad (2)$$

The grater the number of points is, the more accurately is involute curve created. In our case was selected 6 points (Figure 2).

After crating of the involute curve a symmetry profile was created and trimmed with head and foot circle. Using the join functions and circular pattern was thepinion and the wheel designed (Figure 3).

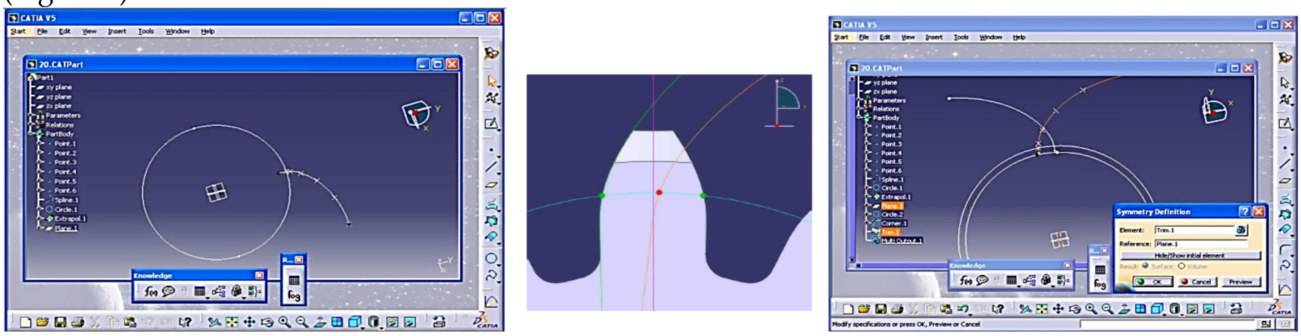

Figure 2. The points of involute (a), profile rotation (b) and symmetry profile of teeth (c)

Some other parts of gearbox was also designed (lower part of gear housing, shaft of wheel, bearings – Figure 4).

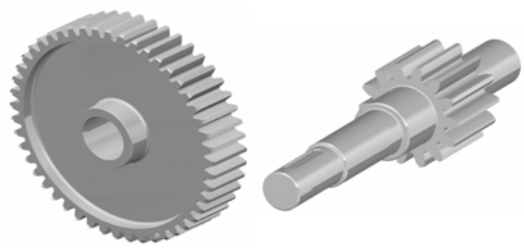

Figure 3. Parametric model of the pinion and the wheel

Based on assumption that all important design parameters of gearing and gearbox are dimensioned from input power of gearbox, we change now only the axis distance and number of pinion teeth. With change of variable parameters *a* and z_1 (Table 2) will change automatically the other parameters of gearing (z_2, the number, location and diameter of lightening holes of wheel), parameters of gearbox (location and thickness of gearbox wall and of ribs, distance of holes for bearing, length of box and also height of box. The values of axial distance were selected as shown in Table 2.

Tabel 2. The values of configurations of gearing

Configuration	1	2	3	4	5	6	7	8	9	10	11	12	13
Axial distance *a*	90	95	100	105	110	115	120	125	130	135	140	145	150
Number of pinion teeth z_1	13	14	15	16	17	18	19	20	21	22	23	24	25

Number of lightening holes is given by the rule in Knowledge ware where it is given as a function of parameter r_2. If the size of radius $r_2 \geq$ 150mm, number of holes is equal to 8, to the radius of the size lessthan 150 mm and more than 100 mm is number of holes equal to 6, otherwise there are no holes in wheel. This rule gives to parametric model some features of generative model.

5. CONCLUSION

However, the methodology proposed in this paper is mainly addressed for straight spur gears, as preliminary basic model. But this methodology provides references for the helical gears and also for planetary gear of car. We can conclude that CATIA V5 system offers not only possibility of creating of geometric product data associatively defined by relations between parameters but also possibility of rules definitions in Visual Basic programming language, that move parametric modeling to generative design.

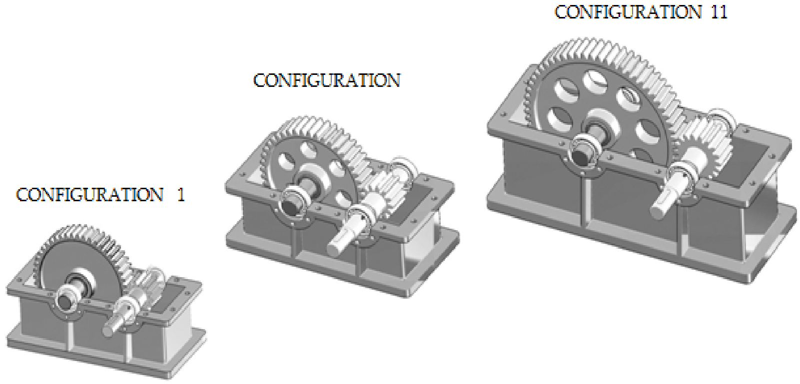

Figure 4. Some of automatically generated configurations of gearbox

Using Knowledgeware module in CATIA program can designer to generate more alternative design samples, concentrating his attention on design functional aspects, without consideration of details of elements of shape.

Finally generative design is finding its proper field in the next future. The revolution came from the generative approach theoretically and experimentally performed in the last 25 years. The vision of generative design strongly linked to real-time production is today widely available because of the technology of new 3D printers that the main printer companies are launching in the market.

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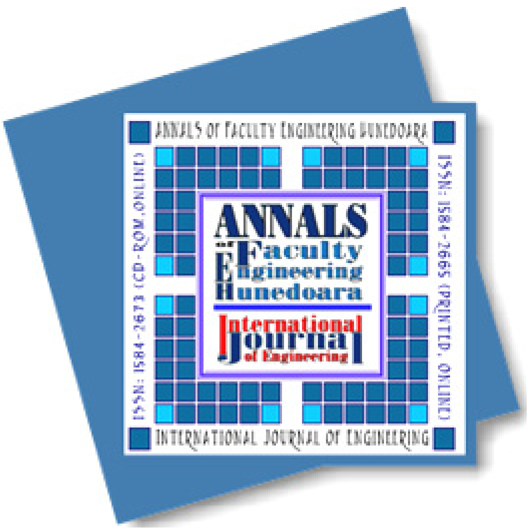

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