UNIVERSITY OF ZIELONA GÓRA
FACULTY OF MECHANICAL ENGINEERING
in association with the Design Society

THIRD INTERNATIONAL SEMINAR AND WORKSHOP
10th - 12th October 2002
Zielona Góra - Łagów
POLAND

ENGINEERING DESIGN IN INTEGRATED PRODUCT DEVELOPMENT
Design Methods that Work

CAD 3D SYSTEMS IN MODELING OF HYDRAULIC COMPONENTS ON EXAMPLE OF GEAR PUMP

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Keywords: CAD, modeling, hydraulic components

Abstract: *This paper presents some aspects of using CAD systems in modeling of hydraulic components on example of gear pump. The way of using different CAD system was presented. Not only geometry modeling was presented but also a strength analysis using FEM. On basis of this analysis was carried out an optimization and results of FEM analysis were set as constrains. After optimization obtained the pump body geometry what allows pump to work with higher working pressure.*

1. INTRODUCTION

Solid modeling is often used in designing of hydraulic components. A lot of packages for this purpose is available offering various possibilities. Some of them are very advanced and allow to realizing complex tasks, some are simpler usually used for particular taks. Taking full advantages of the first one usually requires a long term learning, furthermore some tasks are still very difficult to realize in such systems. The usage of simpler CAD systems is easier and that is why many users eagerly combining theirs individual possibilities in order to achieve assumed goals.
In this paper the authors wanted to share theirs experiences gained during modeling hydraulic components what is presented on example of gear pump. During modeling the following packages were used: SolidWorks, SolidEdge, Pro/Engineer, MSC Nastran which are used for education in Cracow University of Technology.
The main aim of the work was to strengthen the pump body so as to raise its working pressure. Firstly the existing body was checked but rising working pressure was not possible because of too large displacements. There was necessity of improving the body in case of using higher working pressure.
To perform this task several CAD systems were used on particular stages. Data among them were transferred in the way presented in Fig. 1.

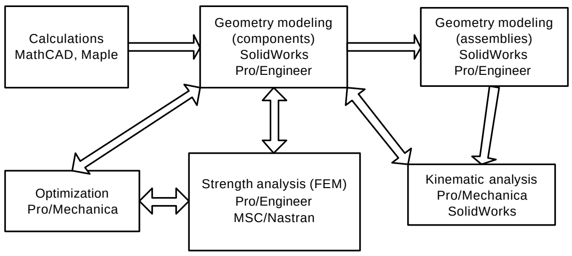

Fig. 1. *The way of transferring data among CAD systems during modeling geometry of gear pump*

2. COMPONENTS MODELING

Nowadays modeling is conducted by the use of solid modeling techniques based on features. It allows to obtaining hierarchic structure of the model and further easily modify existing model. Such a structure is presented in Fig. 2 on example of the gear pump body with feature tree on the left.

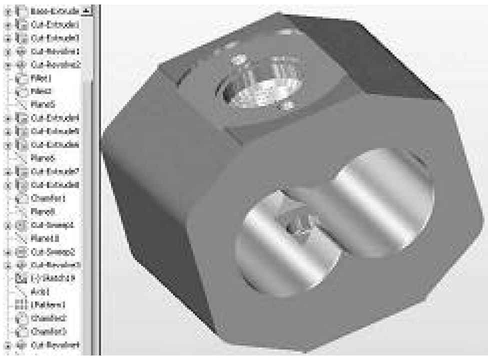

Fig. 2. *Model of the gear pump body*

In body modeling at first the main solid had been performed and next some material has been removed. This methodology is particularly useful in modeling complex geometry what was presented on example of pump cover (Fig. 3) where was necessary to perform complicated ducts.

Fig. 3. *Model of the pump cover*

In modeling of gear teeth to generate their profile is necessary to use special curves. In case of impossibility generating this profile directly in CAD system it might be calculated in mathematical packages. It was presented in Fig. 4 where is shown sketcher with tooth profile calculated in MathCAD. In Fig. 5 and 6 are shown models of driven and driving gear respectively.

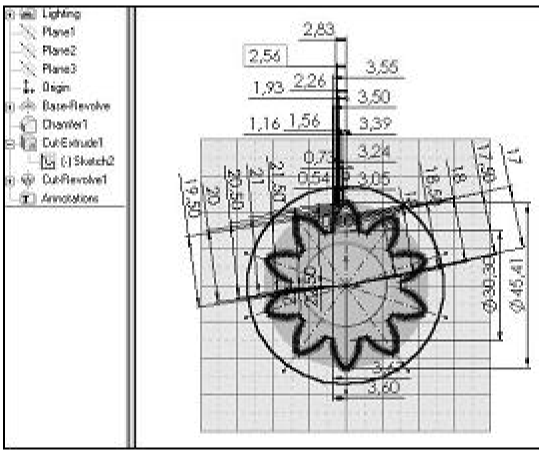

Fig. 4. *Determining of tooth profile based on an external data*

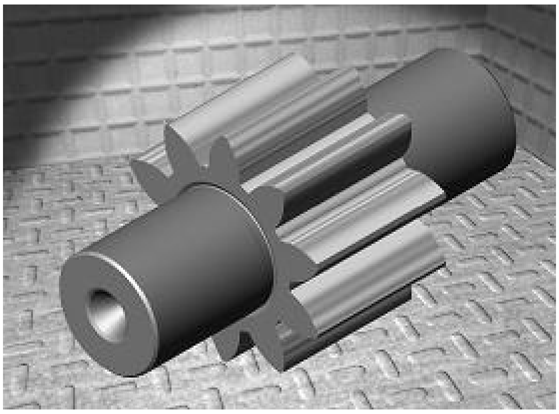

Fig. 5. *Model of driven shaft*

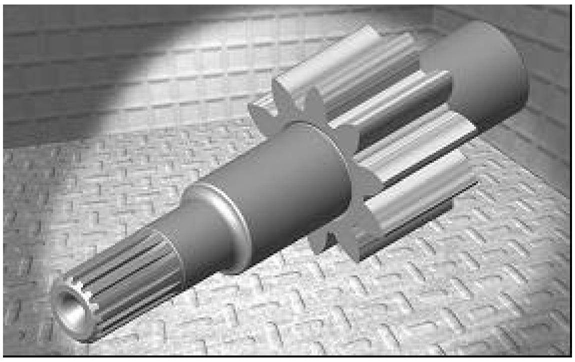

Fig. 6. *Model of driving shaft*

3. Modeling of assemblies

Assemblies modeling might be performed as appropriate connections of particular components by constraining them in a way allowing to analyzing their motion in function of defined input. As an example in Fig. 7 is presented the way of giving relations between gears where the axles of gears are parallel, teeth surfaces are tangent and rotation of driving shaft causes the rotation of driven shaft. It allows to visualizing and analysis of matting particular teeth.

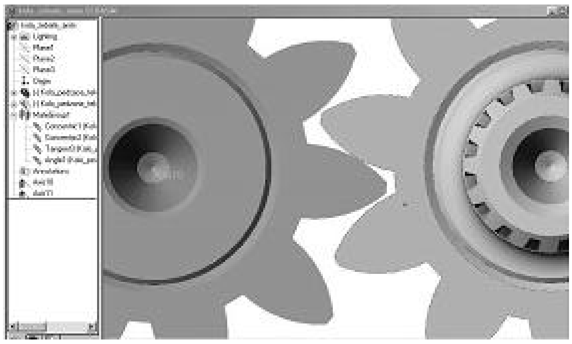

Fig. 7. *Analysis of teeth mating*

Assembly of the pump consisting of components performed beforehand is shown in Fig. 9. In dependency of needs some of components might be hidden.

For example hiding the gear body allows to presenting internal gear components.

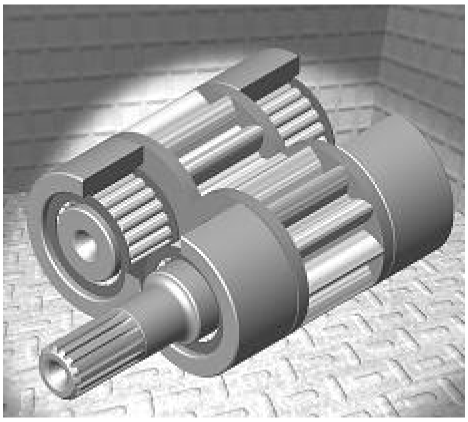

Fig. 8. *Model of gear unit with bearing*

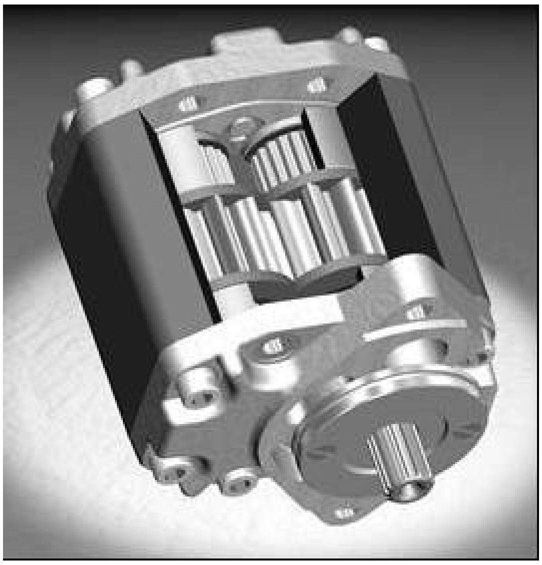

Fig. 9. *Model of the pump assembly*

4. Strength analysis

Hydraulic components in particularly pumps belong to one which works under high pressure what require carrying out strength analysis during designing. It allows to assess assumed geometry considering minimization of gaps and leakages. Using FEM analysis it possible to use geometrical models performed beforehand.

There is necessity of simplifying the geometry during FEM analysis. In case of pump body some of chamfers and fillets were omitted. The influence of other components on pump body was replaced by proper boundary conditions and loads. Covers also were taken into account in this analysis. FEM analysis was performed in Pro/Mechanica packages. Assuming symmetry of the pump body only one fourth of geometrical model was used in analysis. Remaining body parts was taken into account defining proper boundary conditions. Load to the body was set as it was shown in Fig. 12, pressure, influence of bearings and covers was taken into consideration. Pressure distribution is changeable and was set according to literature [2]. Preliminary analysis shown that for working pressure 25 MPa stresses occurring in the body remain below permissible values while displacement achieves value 0.8 mm in vicinity of outlet port (Fig. 10).

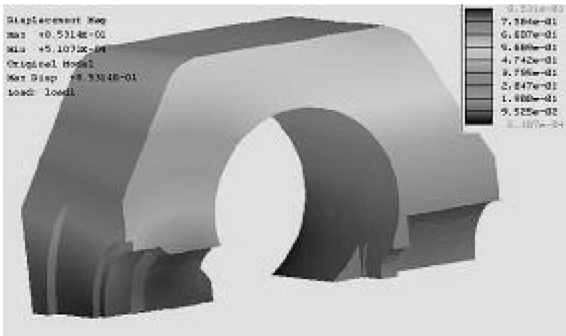

Fig. 10. *Displacement of the pump body*

In order to decreasing displacement occurring in the body an optimization task in Pro/Mechanica has been undertaken. For that purpose model of the body has been parameterized as it shown in Fig. 11. According to preliminary analysis boundary values have been determined which were next used in optimization process.

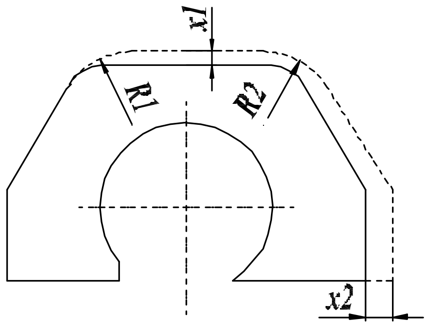

Fig. 11. *Parameters of the body*

The objective function was set as follows:

$$min \;\; f(x1, x2, r1, r2)$$

With the following constrains

- strength constrain:

$$ó \;\; ó_{max}$$

- stiffness constrain

$$u_r \;\; u_{rmax}$$

- constructional constrains:

$$0 \leq x_1 \leq x_{1max},$$
$$0 \leq x_2 \leq x_{2max},$$
$$10 \leq r_1 \leq r_{1max},$$
$$10 \leq r_2 \leq r_{2max}.$$

where:

$f(x_1, x_2, r_1, r_2)$ - mass of the body,

x_1, x_2, r_1, r_2 - model parameters, $ó$ - stresses, u_r - radial displacement in vicinity of outlet port

Optimization was carried out for the following values:

$ó_{max}$ =200 MPa, u_{rmax} = 0.5 mm, x_{1max}=5 mm, x_{2max},=10 mm, r_{1max} =20 mm, r_{2max} =20 mm.
Values of radius r_1 and r_2 are dependent on x_1 and x_2 arising from tangency of connecting surfaces. Values of maximal stresses and displacements ($ó_{max}$ and u_{rmax}) were set according to FEM analysis.
In Fig. 12 is presented parameterized model of the pump body used in optimization process. Symbols 1 to 6 indicate relation while arrows indicate loads.

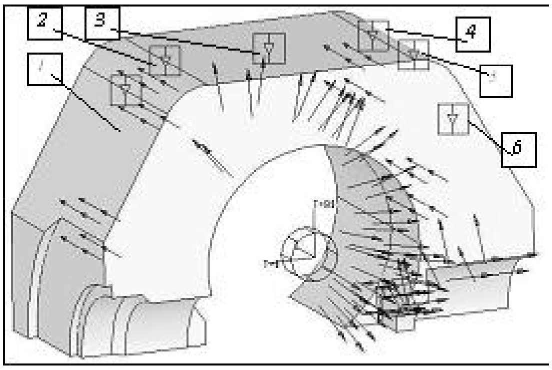

Fig. 12. *Model of the pump body with load and geometry parameters*

In a result of optimization for working pressure 25 MPa obtained body shape as is shown in Fig. 13. Particular parameters was changed in the following way: x_1 to 90% of x_{1max} ; x2 to 100% of x_{2max} ; r_1 to 25% of r_{1max} and r_2 to 80% of r_{2max}. Also maximal translation dropped about 25%, however, it causes an increasing overall dimension and mass of the body. Shape of the body after optimization was presented in Fig. 13.

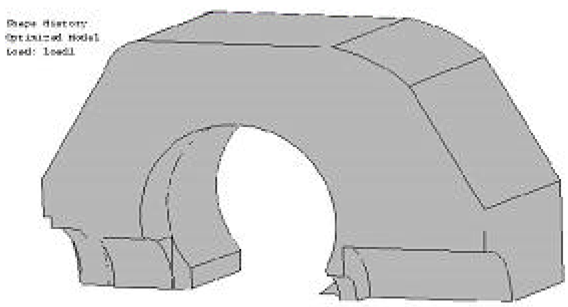

Fig. 13. *Shape of the pump body after optimization*

5. Summary

This paper presents selected problems of gear pump modeling using CAD systems. Three dimensional geometrical models of pump components as well as pump assembly were performed in SolidWorks. In pump model appropriate relations have been given, e.g. tangency between mating teeth what allows to carry out kinematics analysis. Components position in function of shift angle was investigated aimed at proper location of ducts taking away fluid from space between teeth.
Parallel with modeling of components geometry the strength analysis and optimization was carried out. This task was performed in Pro/Mechanica using parameterization body geometry. For assumed objective function and constrains obtained geometry with reduced displacements influencing on the quantity of leakage in pump.
Used in pump modeling CAD systems might be useful also in modeling others hydraulic components such as: motors, valves, etc.
The use parameterized models in solid modeling packages allowed to many modifications components geometry in purpose to testing different solutions.

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