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CAD Geometrical Modelling of Hydraulic Gear Pump and Optimal Structural System for Assembling

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Abstract
An approach for design and design documentation of mechanical product in CAD medium is presented. A geometrical modelling of hydraulic gear pump is shown as illustration. On the base of the developed graph model of design elements in assembled unit is generated a 3D geometrical model of mechanical product. A proposal for the use of normative documents: Information system, graph of the links between the design elements and problem related to the planning of material requirements. The Material Requirements Planning (MRP) module enables to plan material requirements for a manufacturing or procurement process based on the re-evaluation of existing inventories, demands, and supplies on changing planning parameters. 3D geometrical models and virtual prototypes of basic and modified variants have been developed. The results show that the most important limitations are minimum price, work area of the automated system as well as the number of operators. The modified variant of hydraulic gear pump has low technological value, high rate of automation and increase productivity. A structural scheme for automated assembling of hydraulic pump by robot from UR3 family is developed. The results will be useful for students, PhD students in Robotic and Mechatronic fields.

Keywords
CAD, modelling, hydraulic, gear, pump, automated, optimal system, assembling, choice, robot

1. Introduction

High technologies like CAD/CAM/CAE/PLM/virtual engineering are more and more frequently used throughout contemporary industries [1]. Marketing requirements necessitate improvement of the products in order to increase their competitiveness and to the European for safety measures. These requirements also apply to the manufacture of hydraulic gear pumps. Technical requirements for input and output control of used types of steel as well as summary technological indexes concerning thermal treatment of soothing [2] are incorporated via an experimental research. The generated 3D geometrical model of the designed assembly unit contains elements related to geometrical and cinematic connections as well as it presents a prototype. A systematic approach is used to the end of constructional documentation. It is based on the usage of a graph of the connections between the constructional elements [3, 4]. In the integrated system for designing gear transmissions are use expert systems, method of finite elements [5]. Automated assembling of mechanical products is already widely used in order to introduce the Product Life Management technology. It demands training of technical and non-technical specialists that could contribute to the manufacture of high-tech products. To that end, all companies introduce automation and management of processes that match the requirements for energy management according to ISO 50001 by a Smart Factory certificate.

The purpose of this work is to test an approach for 3D geometrical modelling of a mechanical product (hydraulic gear pump) and assembly through an automated system for training students and PhD students in the field of robotics and mechatronics and the main goals are the following:

- Optimal design of a hydraulic gear pump;
- Development of 3D geometrical models of the component details;
- Development of a graph of the connections between the construction elements;
- Development of the geometrical model of a modified assembling unit;
- Selection of the most optimal approaches for automated assembling of the mechanical product.

In order to fulfil these main goals, we have used methods and approaches from CAD/CAM/CAE/PLM technologies that are utilized within the field of machine-engineering and manufacture. Also the graphics system Solid Works and its specific modules for testing of solidity by ANSYS.

2. Structural Modelling of Assembled Units

During the designing process, the constructors spend a lot of time for drawing activity. This necessitates usage of a system for information which is to contain data about the purposes of constructional documentation, manufacture of the product [3]. Table 1 represents a version of the structure of a similar system for information. Module 1 represents the data provision for the purpose of constructional documentation within the scope of a CAD environment.

Table 1. Structure of the system for information

1	Technical solution for the designing of a pump
2	Database
2.1	Constructions of gear pumps
2.2	Unified details
2.3	Standardized details
3	A geometrical model of the assembled unit and a graph-model of the connections
4	Geometrical models and 3D visualizations of the component details
5	A geometrical model of the assembled unit
6	Documents of construction and 3D visualizations of the assembled unit

In order to represent the assembled units via their comprising parts within a CAD environment, one has to use constructional elements which are to be represented by a computer made graphics containing descriptive properties. If the designer has already defined the cinematic scheme and the construction of the composite details of the pump, he already has the opportunity to design a graph-model of the assembled unit and the connections between the details. If the structures of the separate details are replaced by their constructional elements, one could have a graph of the connections between them as the graph could serve as a presumable version of a hydraulic gear pump [3]. For the purpose of determination of new solutions, figure 1 shows a graph of the connections between the constructional elements that relate to a modified version of a gear pump.

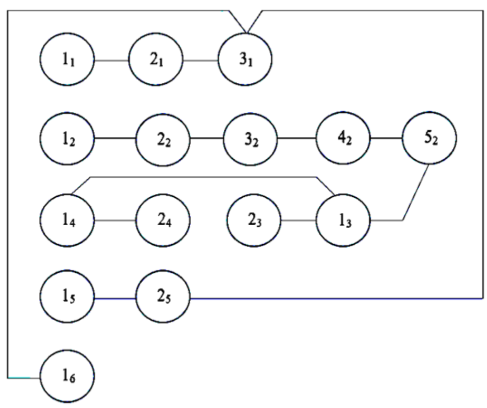


Fig. 1. Graph of the connections between the constructional elements

These parts play the role in terms of determination of the composition of the connections within the assembled unit. The relation to the size structure is performed by establishment of limitations and an algorithm based on the rule 'condition-action' [3]. Technological solutions are also utilized as they allow the exclusion of some composite details like sealing, linking elements, etc. A suitable approach on the basis of the 'down & up' rule would definitely help for the purpose of creation of a 3D geometrical model of the assembled unit. This particular approach is preferable since the models of the composite details are prematurely known and structuralized on the basis of the already virtually created models. Throughout the application of this approach, one could use a system for information which is to contain database about the purpose of constructional documentation of the manufactured product as the system is based on a conducted analysis. If there are issues occurring during the generation of the assembled unit that could be due to discrepancies in the geometrical parameters within the composite details, has the option to overcome them by setting limitations of the size of the details. It is also important that the designer should observe the obtained results and the optimal parameters [6].

Figures 2 and 3 show 3D geometrical models of assembled units and prototype component details for two variants hydraulic gear pumps. The developed 3D geometrical models of the designed mechanical product (and the other documents of construction) will be used later in order to create program-based provisions and development of criteria for designing of systems for automation of assembling [7]. Figure 4 show some of geometrical models of nonstandard details for modified pump.

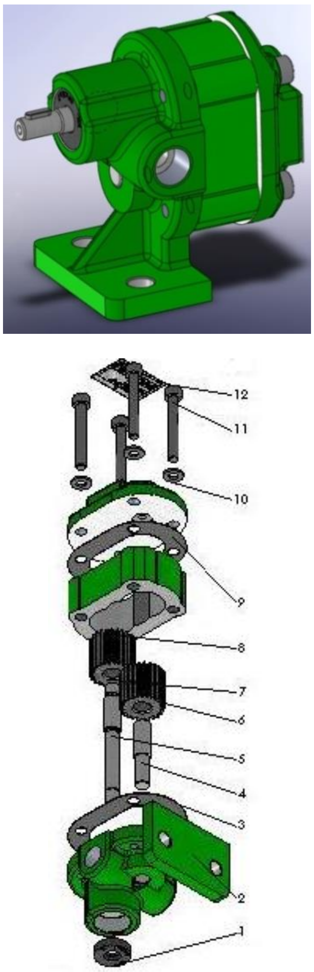


Fig. 2. Base variant

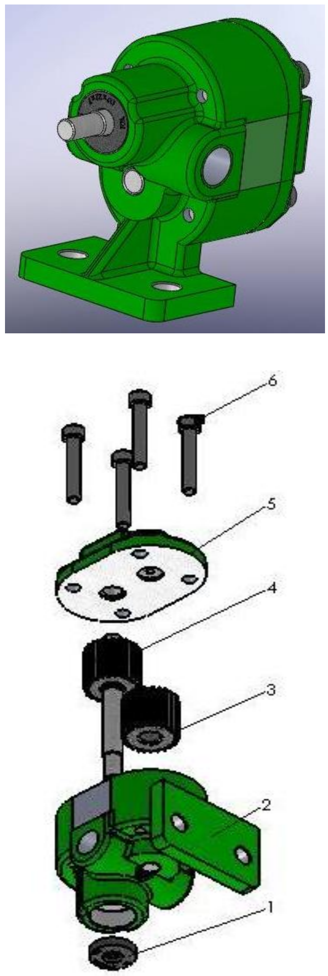
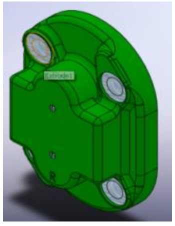


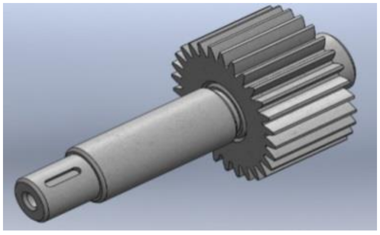
Fig. 3. Modified variant

Also from the point of view of achieving high economic efficiency, the factor for planning material resources is important. The Material Requirements Planning (MRP) module allows material requirements for a production process to be planned based on existing stocks, needs and deliveries of changing planning parameters (lead time, decision making, etc.). MRP calculates gross requirements for the highest level of materials (BoM) based on sales orders, purchase orders, production orders, forecasts, etc. This module must include the following information components in the planning: Demand Customer Forecast; Manufacturing Plans; Bill of Materials (BoM); Raw Materials Procurement; Inventory Records.

Gear



Cap



Pinion

Fig. 4. Non-standard components for a modified hydraulic gear pump

Table 2 represents the volume and the size of the component parts of the pump which are to be used throughout the automated assembling of the mechanical product.

Table 2. Weight and limit sizes

№	Name of part	Weight, kg	Sizes, mm
1	Seal	0.005	Ø22×5
2	Housing	0.300	24×58×73
3	Gear	0.070	Ø27×24
4	Pinion	0.120	Ø27×45
5	Cap	0.280	21×53×78
6	Screw	0.012	Ø10×45

These data are valuable during the designing process of pallets in accordance with the requirements for automated stream transport. All limitations are precisely regarded throughout the construction process, that is to say, the volume of the details in the pallets must not exceed 15 kg. Another limitation is that the number of details in the pallets must be equal with the pallets which contain a minimum number of details.

3. Selection of an Optimal Structural Version

Throughout the process of selection of a solution for the assembling of the product within the conditions of full automation by usage of a flexible cell for mounting and a robot for assembling, it is necessary to come up with a layout scheme [8]. Throughout the technological process of assembling of the product, the operations of assembling of each detail are to be reviewed as a partial function of the designed system. In this scenario, the general function of the designed system for assembling includes six partial functions that relate to the assembling of a type of modified housing, a gear, a pinion, a cap, screws and a type of sealing. During the process of selection of an optimal structural version, the relevant criterion is the effectiveness of the solved issue. On the basis of the preliminary investigation of these versions of hydraulic pumps, the scenario is characterized by the limitations of a minimal value, working space of the automated system and by the number of the operators involved [9].

The results from the performed analysis of various versions of assembling show that, in this scenario, a robot for assembling is the most suitable option. The optimal solution is to choose a FANUC SR-3iA model which is capable to assemble products with a weight capacity of 3 kg, a range of 400 mm, a value of motion of 200 mm and a working curve with a range of 360° with compact dimensions [10].

4. Conclusion

This was a presentation of an established structure of an integrated system appropriated for the purpose of constructional documentation during the designing process of hydraulic gear pumps. This system provides informational exchange which concerns team-based work along with all its stages of construction. It contains a database of both graphical and text information that refer to engineering analysis and computer-based graphics. A modified version of a hydraulic gear pump has been used for the purpose of the assembling procedures of a product within the environment of thorough automation by the utilization of a flexible cell for assembling and a robot for assembling. This option has the characteristics of a low technological value, a high rate of automation as it yields considerable increase of productivity. Energy effectiveness can also be increased by the use of the system of Material Requirements Planning. These factors give us a ground to establish a structural scheme for automated assembling of a hydraulic gear pump by the implementation of a robot from the category of UR3. The obtained results could be very useful for the purpose of training of students and PhD Students working in the field of 'Robotics and Mechatronics'.

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