Using 3D Modelling to Demonstrate the Device and Operating Principles of an Automotive Clutch

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Abstract. Modern production technologies, also known as 3D printing or additive manufacturing, have applications in diverse areas of human activity. These methods are characterized by accuracy and economy compared to traditional methods of manufacturing parts, components, and elements. These technologies are characterized by: low production costs, the ability to create complex and innovative models, flexibility in the materials used, and extremely fast production speed. Technological advances in this field are opening doors for the use of additive technologies in the academic and scientific sectors. In this regard, the emphasis in the publication is placed on the creation of a three-dimensional model for students' understanding of the main functional capabilities of dry, frictional, single-disc clutch in modern cars. This model can be used to create educational and scientific tools that facilitate learning and expand the scope of scientific research in this area, contributing to the improvement of the quality of scientific and educational activity.

Keywords: additive technologies, 3D printing, three-dimensional model, connection system.

1. INTRODUCTION

Nowadays, additive technologies are used more and more in various fields of human activity. This is easily explained by the fact that this technology is not relatively expensive compared to traditional methods of manufacturing certain details and parts. Additive technologies significantly support the work of modern companies and industries. Due to its many advantages, the scope of 3D technologies is quite wide. In the field of research and development, additive technologies are widely used (Antonova et al., 2017).

In the field of mechanical engineering and industrial production, additive technologies find application in the printing of prototypes. This is very convenient because it saves production resources for parts that may lose their qualities during experimental work. Through such models, the functionality and assembly of the prototype can be evaluated and design errors and flaws can be identified.

In the process of studying engineering disciplines in higher education institutions, the most important part of the learning process is the skills formed during laboratory practicums. In the course of their implementation, students develop work skills necessary for their future professional realization. Conducting experiments, gathering and analysing information, as well as planning are additional skills that students acquire during the educational process (Armaroli et al., 2019).

In this regard, the emphasis of the publication is placed on the creation of a three-dimensional model of a dry, frictional, single-disc clutch for students' understanding of the main functional capabilities of this type of clutch used in modern cars. The production of such prototypes has a high cost, and the parts can be very bulky, so not every educational institution

can afford it. Thus, additive technologies are taken as the basis of the thesis that place the question of optimization and reducing production costs for creating laboratory models and benches using 3D modelling (Pinto et al., 2020).

2. ANALYSIS OF EXISTING COUPLING DESIGNS

The most common type of clutch used in modern cars is a dry friction single disc clutch. This type of connector is easy to use, has a simple construction, low production cost, and good operational properties. The purpose of this type of clutches is to transmit torque from the engine to the transmission, without slipping, when the car starts and moves, and to cut it off when the gears are changed and the car comes to a complete stop. When the clutch pedal is pressed, the transmission of torque from the crankshaft to the transmission is stopped. Actuation of the arm fork, which moves the thrust bearing, is accomplished by means of mechanical levers, a string, a hydraulic system, or solenoids (Nerush et al., 2016). A model of a dry, frictional single-disc clutch and its components is shown in Fig. 1.

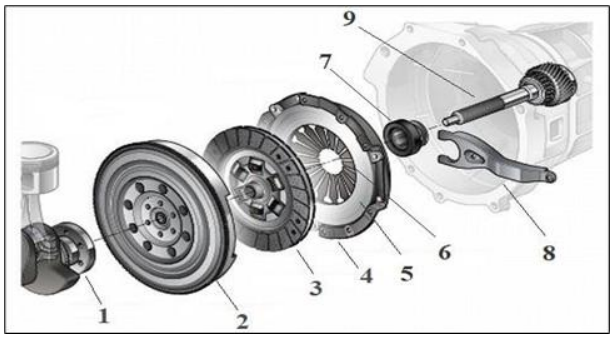

Fig. 1 Dry friction single disc clutch.
(1 - crankshaft; 2 - flywheel; 3 - friction disc; 4 - presser; 5 - mirror disc; 6 - diaphragm spring; 7 - axial bearing; 8 - shoulder fork; 9 - primary shaft)

Taking into account the purpose, the place in the scheme of transmission of power to the transmission of the vehicle, the design requirements for the clutches are: simple design, minimal dimensions and weight; manufacturability and low cost of production; cheap maintenance; low noise level.

Choosing a design scheme for creating a three-dimensional model includes determining the type of clutch and drive, the number of driven discs, the type and number of compression springs, the dimensions of the friction plates and the value of the safety factor of the clutch. Based on these criteria, the 3D model will be of a dry friction single disc clutch with a mechanical drive.

3. CREATION OF A THREE-DIMENSIONAL MODEL IN CAD KOMPAS 3D

To create the 3D model of dry, frictional, single-disc clutch the CAD software product KOMPAS 3D is used. It allows solid modelling and exporting models in STL format. Building the model begins with the selection of a plane. In Fig. 2, the initial sketch of the hull of the presser on the selected plane. Using the Extrusion Element command, the parameters of the distance and the angle at which the part will be extruded are set (Jimenez et al., 2018).

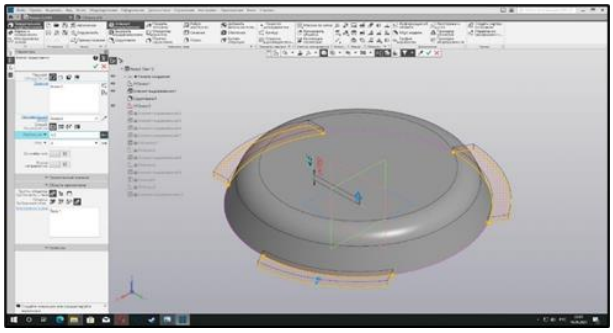

Fig. 2. Extrusion element.

Using the Cut Extrusion operation, holes are created for the fasteners, which are shown in Fig. 3. The Shell command is used to remove unnecessary material inside the part. The next steps of the modelling process is related to selecting the face, direction and thickness of the part.

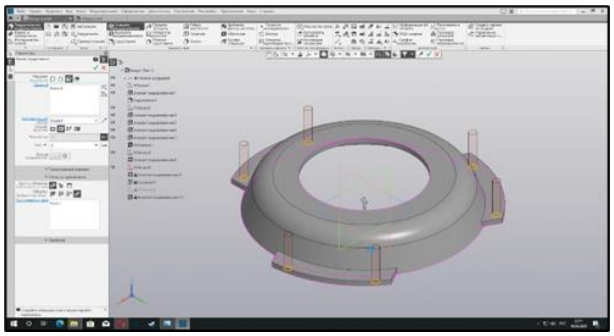

Fig. 3 Extruding holes.

To insert the diaphragm spring, it is necessary to cut a hole using the "Extrude" operation. Holes are also required for the diaphragm spring retaining ring shown in Fig. 4.

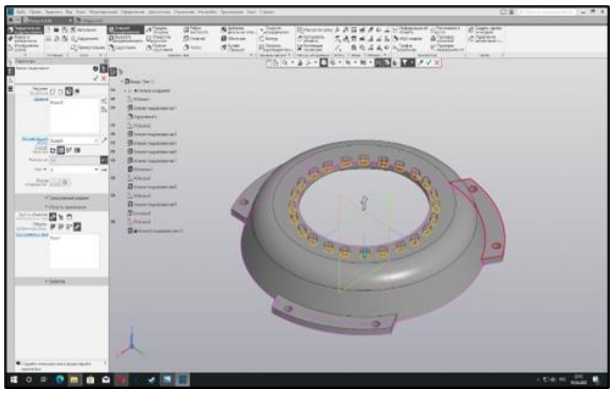

Fig. 4 Retaining ring holes.

The other parts of the clutch are created in a similar way. The mounting part is shown in Fig. 5.

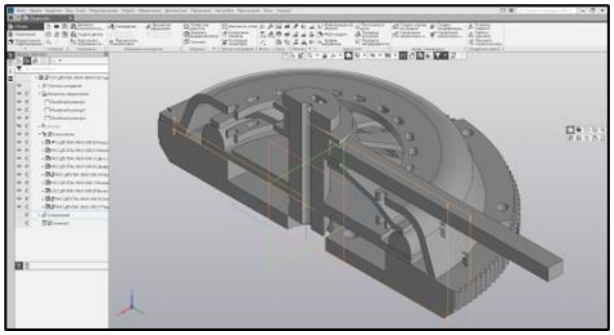

Fig. 5 3D connector model, isometric view, section.

4. DETERMINING THE APPROXIMATE GEAR RATIO IN THE GEARBOX.3D MODEL OF A POWER SUPPLY UNIT

The gear ratio in a gearbox is the ratio between the rotational speeds of two meshed gears. Each gear has a gear of a different diameter which leads to a different frequency of rotation of the individual shafts. Changing the gear ratio is equivalent to changing the applied torque.

The gear ratio is determined by two methods: approximate and refined method.

4. 1. Approximate Gear Ratio

The approximate transmission ratio is determined by the ratio of revolutions of the input shaft to the output, that is, the number of revolutions of the crankshaft for one revolution of the output shaft of the gearbox and is calculated by the formula:

$$\textit{The transmission ratio} = n1/n2 = n; \quad (1),$$

- **n1** is the number of revolutions of the input shaft;
- **n2** is the number of revolutions of the output shaft.

To accurately measure the transmission ratio of a specific gear, the number of gear teeth in the mesh and the transmission ratios of the individual gear stages are determined by the formula:

$$U = Zn+1/Zn \quad (2),$$

- ***Zn+1*** is the number of teeth of the driven gear;
- ***Zn*** is the number of teeth on the drive gear.

The total gear ratio of a particular gearbox gear is determined by the product of the gear ratios of all gear pairs involved:

$$Ut = U1*U2*U3*\ldots\ldots Un \quad (3),$$

- U1 is the gear ratio of the gear box;
- Un is the gear ratio of pairs of gears in the gearbox stage.

The layout of the power supply unit is shown in Fig. 6.

Fig. 6 Layout of the power supply unit.

The rotary motion is produced by an electric motor mounted on the crankshaft pulley. A button with speed control depending on the force of pressing is installed for switching on. The electric motor drive required to power the model is shown in Fig. 7.

Fig. 7 Driving electric motor.

To optimize the calculation of the revolutions of the crankshaft and the output shaft of the gearbox, limit switches with a reader in the form of a calculator are used.

When changing gears, it is necessary to interrupt the transmission of the torque from the engine to the gearbox, by means of the clutch. Torque interruption is accomplished by moving the fork arm to the position shown in Fig. 8.

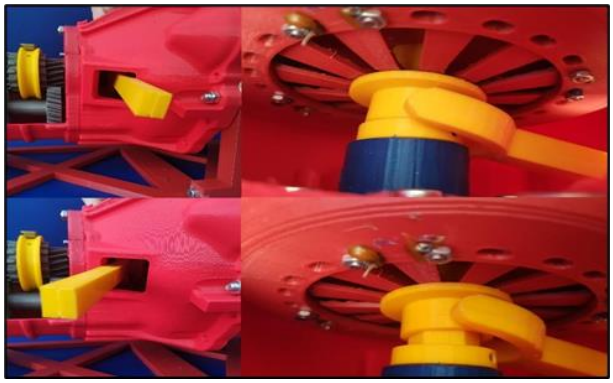

Fig. 8 Disconnecting the clutch.

5. CONCLUSION

Additive technologies enable the production of affordable and widely used component switch low cost in various sectors of the industry.

This production method is preferred over the known production methods, as it is characterized by the economical consumption of materials and means, the minimum spent time and practicality of the manufactured components intended for experimental work. The article is aimed at making a bench for laboratory work, which in turn is the subject of the study.

The basic concepts of 3D printing are covered in the course of the publication. The principle of operation of a dry, frictional, single-disc clutch and its device are presented step by step.

The article indicates the sequence of the conducted research, expressed in:

- automotive clutch design;
- demonstrating the transmission of torque from the engine to the transmission;
- torque break if necessary.

With the help of a stand printed on a 3D printer with an electric motor installed to it, the mock-up provides opportunities to carry out laboratory, research and experimental developments by bachelors and masters trained in the FTF at the Paisii Hilendarski PU.

ACKNOWLEDGMENTS

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