The Design and Construction Process of a Test Stand for Casting the Power Steering’s Housing with the Use of the Pdcpd Material

M Sobek¹, A Baier¹ and Ł Grabowski¹

¹Silesian University of Technology, The Faculty of Mechanical Engineering, Institute of Engineering Processes Automation And Integrated Manufacturing Systems, ul. Konarskiego 18a 44-100 Gliwice, Poland,

Abstract. The use of new technologies and materials in various industries is a natural process that is directly related to the very high rate of development of these technologies. Certain industries decide to much faster introduce new technologies and materials. One of such branches is the automotive industry, whose representatives are very energetically looking for both financial savings and savings resulting from the vehicles mass reduction. An economically justified approach to construction materials is leading the search for new solutions and materials. The use of a modern material such as the two-component PDCPD composite shows hitherto unknown possibilities of producing subassemblies of many different constructions. The possibility of using a modern composite material with parameters comparable to that of metals and significantly lighter, can be an excellent alternative in the selection of materials for many parts of motor vehicles. The potentiality of precise casting of tolerated surfaces will allow to reduce the operations related to machining process, which is an indispensable part of the production process of elements that are cast of metal. This article describes the process of designing and building a test stand for precise positioning of power steering gear components at the stage of casting their housing. The article presents the principle of operation of the test stand and the process of preparation for the casting and the cast itself will be rudely described. Due to the implementation of research as part of a research project with an industrial partner, the article will only describe some operations. This is related to the confidentiality of the project.

1. Introduction

Analyzing the development of individual branches of the market a very clear advantage of the automotive market over other markets can be noticed. This development is related to the definitely increased demand for motor vehicles in recent years. Increased safety requirements, production economics and economics of car use force manufacturers to look for savings at the stage of constructing new car models. This drives directly to the development of research and development (R&D) sectors responsible for searching for new solutions. These solutions not only deal with mechanical issues. They are also often related to the issues of the materials used. Replacement of a construction element made of metal alloy with an element of comparable strength, but made of a composite material, is very often associated with a significant reduction in the mass of such an element. Therefore, it is not strange, that producers try to replace as many components as possible with elements made just in composite technology. An additional advantage of composite technologies is the fact that the production process usually comes down to a few simple steps. The implementation of the complicated shape of a metal alloy is usually associated with the subsequent machining process. From the point of view of economics, it is necessary to reduce the stages in the production process in order to reduce the total cost of a particular subassembly. The possibility of making a composite
element in a relatively simple casting process of a composite material would reduce the costs of both making this part and the subsequent operating costs resulting from weight reduction. [1, 2, 3, 4, 5]

![Figure 1. Block diagram of a test stand [1]](image)

The aim of the research and development project's activities is to examine the possibility of replacing the power steering gear metal body. Currently, such systems are made in the technology of metal casting, mainly aluminum. This material is characterized by relatively good mechanical parameters. Unfortunately, after the casting process, the element made of this material is not suitable for assembly. It is due to the necessity to adjust the surface of mechanical elements that require maintaining appropriate dimensional tolerances. For this purpose, machining is usually used, which involves the extension of the entire part production process. [1, 2, 10]

In result the innovative approach used in the project and then patented was to reorganize the production stages in such a way as to avoid the machining step. To achieve this, a test/production stand was designed to allow the production stages to be completed in the assumed order. The stand was designed in the Siemens NX10 environment and then the actual model was build. [1, 2, 6, 7, 8]

The stand is used in the process of casting the power steering gear housing from a material such as PDCPD (Polydicyclopentadiene). This material, thanks to the use of an innovative reaction that is metathesis, allows to obtain a durable element in a relatively short time. The reaction takes place between two components, one of which is a catalyst. By controlling the ratio of individual formulation components, it is possible to control process parameters. Thanks to this, there is the possibility of control the reaction time which has a direct influence on the temperature during the reaction. Adjusting the appropriate process temperature allows to control the shrinkage of the material in a way allowing to obtain a satisfactory surface quality, even for elements requiring dimensional tolerance. [1, 2, 4, 9].

2. Design and Construction of the Test Stand
The main assumptions of the construction of the of the test stand were as follows:
- adjustable position of the power steering transmission components
- the type of steering gear used is equipped with a worm gear
- the ability to verify the correct positioning of the elements relative to each other
- possibility to mount the injection mold on the test stand (after modification of the test stand)

Such formulated conditions allowed for the creation of a block diagram of the test stand.
(Figure 1), which was expanded with motor and measuring elements. The basic elements of the test stand are the following elements:

- four mounting brackets (supports)
- three-phase motor with measuring sensors
- power inverter with measuring card
- belt transmission
- test object

It has been decided that the individual elements of the worm gear were supported in specially made supporting brackets. In order to establish a precise position between the elements of the worm gear it was decided to use the front support with the possibility of positioning the axis of the worm wheel in the vertical direction. In order to the positioning process run as accurately as possible, a 1 μm clock gauge was attached to the support. Such a procedure allows to establish appropriate conditions for cooperation between the components of the worm gear transmission. Verification of determining the proper position consists in driving one of the elements of the worm gear by means of a three-phase motor through the belt transmission and then testing the value of the current drawn by the motor. This test is performed using data acquisition equipment. The current value is proportional to the torque caused by the worm gear system. This value is used to assess the correctness of the position of the elements relative to each other. The first iteration of the station was made in accordance with the principles of the block diagram and is shown in the figure (Figure 2a, Figure 2b).

![Figure 2](image)

**Figure 2.** First iteration of the test stand. a) CAD model; b) the actual test stand with reference housing mounted [1].

### 3. Modification for the Needs of PDCPD Injection

Positive results of torque measuring tests carried out on the stand influenced the decision to modify the test stand. The current position of the test stand elements, which are supports, did not allow placing the mold elements around the fitted parts of the worm gear. Modifications to the site began with the change of the CAD model and consisted of adding precision linear drives (Figure 3). In case of worm, on the trolleys placed on the drives there are supports that from now on have been able to perform a translational movement along with the axis of the worm. After the modification, the worm wheel support gained the possibility of translational movement in two directions - vertical and in along with the axis of the worm wheel. After the modification was introduced, the stand was not only prepared for injection, but thanks to movable supports it is possible to use it for testing gears with different distances between axes and also allows the use of molds of various sizes. At this stage, a model simulating the shape of the injection mold was added to the CAD model (Figure 3). After verifying the correctness of the CAD model of the modified version of the test stand, changes were made to the actual device.
4. Results and conclusions
In order to summarize the carried out tests and to verify the progress in project, the process of injection a composite housing began. For this purpose, an appropriate amount of both components of the composite PDCPD material was prepared (the volume of the housing calculated on the basis of the CAD model was about 600cm\(^3\)). The material used was placed in a specialized dispenser and mixed in a 1:1 ratio using disposable mixing heads. The reaction time for the formulation used was about 60 minutes. During the tests, a series of castings was made taking into account various environmental parameters, e.g. mold temperature.

The injection process was considered successful when at least 90% of the volume of the target housing was obtained and full functionality of the worm gear was obtained (Figure 4). By placing the body in the test stand it is possible to verify any changes in the gear unit work by examining the value of the torque before and after casting the housing. The casted housing was then subjected to tests to confirm the validity of the use of PDCPD material in highly exploited elements and exposed to long-lasting loads.

Figure 4. Fully functional housing casted with PDCPD material with the use of the designed and built test stand.
5. Final Conclusions
After analyzing all the results and conclusions drawn from the observations during the test, it can be clearly stated that designed and built test stand allowed to obtain many important information about the state of worm gear components in the power steering system during its operation. The modification made to the test stand significantly increased the its functionality.

The tests carried out allowed concluding that the use of the reversal methodology comparing to classical approach for the production of systems, i.e. the power steering system is possible.

In the case of tolerated surfaces, it is possible to use a cast element made of a material such as PDCPD. The obtained surface works in a satisfactory manner with mechanical elements.

Further tests and performed attempts of casting PDCPD material will allow refining the results and tuning the values of torque between the power steering with the casted housing and the reference housing.

6. Acknowledgments
The work was carried out under the project number PBS2/A6/17/2013 realized as a part of the Applied Research Program, funded by the National Research and Development Centre

7. References
[1] Sobek M, Baier A and Grabowski Ł 2017 the impact of various distance between axes of worm gear on torque value. Worm gear test stand. IOP Conference Series; Materials Science and Engineering; vol. 227 1757-8981
[2] Sobek M, Baier A and Grabowski Ł 2017 Molding of strength testing samples using modern PDCPD material for purpose of automotive industry. IOP Conference Series; Materials Science and Engineering; vol. 227 1757-8981
[3] Sobek M, Baier A and Grabowski Ł 2016 Fatigue test of a fiberglass based composite panel. Increasing the lifetime of freight wagon. IOP Conference Series; Materials Science and Engineering; vol. 145 1757-8981
[4] Baier A, Majzner M, Sobek M and Grabowski Ł 2016 Composite materials molding simulation for purpose of automotive industry. IOP Conference Series: Materials Science and Engineering vol. 145 (2), 022023
[5] Sobek M, Baier A, Buchacz A, Majzner M and Grabowski Ł 2015 Carbon fiber based composites stress analysis. Experimental and computer comparative studies. IOP Conference Series; Materials Science and Engineering; vol. 95 1757-8981
[6] Grabowski Ł, Baier A, Buchacz A, Majzner M and Sobek M 2015 Application of CAD/CAE class systems to aerodynamic analysis of electric race cars. IOP Conference Series; Materials Science and Engineering; vol. 95 1757-8981
[7] Baier A, Baier M, Dusik D, Sobek M, Papaj P and Grabowski Ł 2014 Computer aided Process of designing the mechatronic Silesian Greenpower electric car, Advanced Materials Research vol. 1036 (2014) pp. 674-679, Trans Tech Publications, Switzerland
[8] Baier A, Baier M, Dusik D, Grabowski Ł, Miera A and Sobek M 2013 Computer aided Process of designing the mechatronic Silesian Greenpower electric car, Selected Engineering Problems, Number 4, Gliwice
[9] Niedworok A and Baier A 2015 Numerical Modeling of the Phenomena of Frictional Coupling Between Wheel and Rail to Describe and Verify the Operation of Surface Condition Detector, Solid State Phenomena Vols. 220-221 pp. 251-256, Trans Tech Publications, Switzerland
[10] Buchacz A, Baier A, Świder J, Placzek M, Wróbel A, Herbuś K, Ociepka P, Banaś W, Sobek M, Grabowski Ł, Majzner M 2016 Analytical and experimental tests and determination of characteristics of components working as assemblies of innovative structures of repaired freight cars.Monograph vol. 643, Silesian University of Technology