

The impact of various distance between axes of worm gear on torque value. Worm gear test stand

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Abstract. Transferring both rotational and translational movements in systems used in the automotive industry is a very important and complex issue. In addition, the situation becomes much more difficult and complicated when the design of the transition system requires a high precision of operation as well as a well definite and long operating life. Such requirements are imposed on all components of today's motor vehicles. However, particular attention is paid to the elements that directly or indirectly affect the safety of persons traveling in the vehicle. Such components are undoubtedly components included as parts of the steering system of the vehicle. Power steering systems have been present in motor vehicles for more than a century. They go through continuous metamorphosis and they are getting better and better. Current power steering systems are based on an electric motor and some kind of transmission. Depending on the position of the drive relative to the steering column, different configurations of the transmission are used. This article will cover issues related to tests of power steering gearing using a worm drive. The worm drive is a very specific example of a propulsion system that uses twisted axles. Normally, in this type of transition you can find two gear units with the axis mounted with a 90° angle between. The components of the worm drive are a worm and a worm gear, also called a worm wheel. In terms of the geometrical form, the worm resembles a helical spur gear. The shape of the worm is similar to the shape of a screw with a trapezoidal thread. A correct matching of these two components ensures proper operation of the entire transmission. Incorrect positioning of the components in relation to each other can significantly reduce the lifetime of the drive unit, and also lead to abnormal work, eg by raising the noise level. This article describes a test method of finding the appropriate distance between the axles of both worm drive units by testing the torque change during gear operation.

1. Introduction

The automotive industry today is one of the fastest growing industries. As a result of such fine developing branch the components manufactured for its needs are meeting higher requirements every day. Those requirements concern not only security but also many other areas. One of them is undoubtedly the product life management (PLM), which despite the general belief of consumers about the forced aging of the product is an important aspect taken into consideration during the design and construction process. In the automotive branch car's and car parts manufacturers are taking part in race of supplying best quality and best specified products. In the group of mechanical parts a huge attention is paid in terms of high working culture. It directly affects the comfort resulting from the use of the part itself, eg by not generating excessive noise levels during use.



In order to maintain the highest quality of the performance of the mechanical assemblies in the vehicle, the best fitted components should be provided. In order to do so, an extensive research of assemblies and each part of these systems are conducted. These studies are mainly aimed at:

- Partial analysis in terms of mechanical strength
- Analysis of phenomena and forces generated between individual components of component systems
- Study of work culture between components of parts assemblies
- The influence of long-term load on changing the parameters of the work of the elements
- Estimating the lifespan of an element and the entire assembly of parts on the basis of long-term studies with significantly overstated performance

Undoubtedly a very important element of the car, thanks to which the driver directly interacts with the vehicle is the steering and its system. For many years this element has been developed so that today it has undergone a metamorphosis even comparing to the systems used few years ago. Also undoubtedly, the greatest advancement in this area is the introduction of steering assistance through a variety of actuators (Power Steering). Because this element is coupled with the driver of the vehicle by the steering column it is very important that it acts flawlessly and guarantees travel built type and type of actuator:

- EPS-P - hydraulic system with electrohydraulic pump (Pump)
- EPS-C - electric system with engine mounted on a column (steering column)
- EPS-R - electrical system with engine mounted on steering gear (Rack)

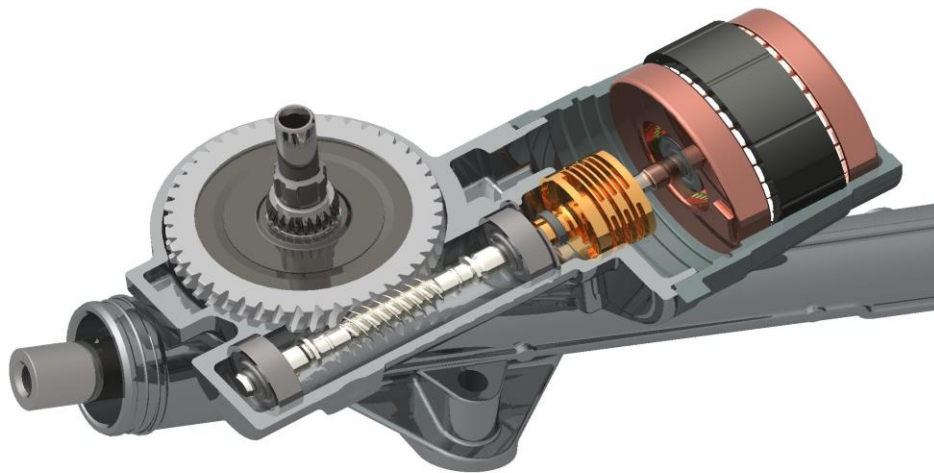


Figure 1. A cross section through the power steering mechanism [11].

This paper will focus on the research of the ability to adjust the power steering elements to achieve the best performance of the entire assembly. Research methods have been developed for research purposes, and a research station has been designed and constructed. Due to the confidential character of the research conducted, some descriptions of elements and schemes had to be replaced by substitutable replacement elements. The research in this area is still ongoing.

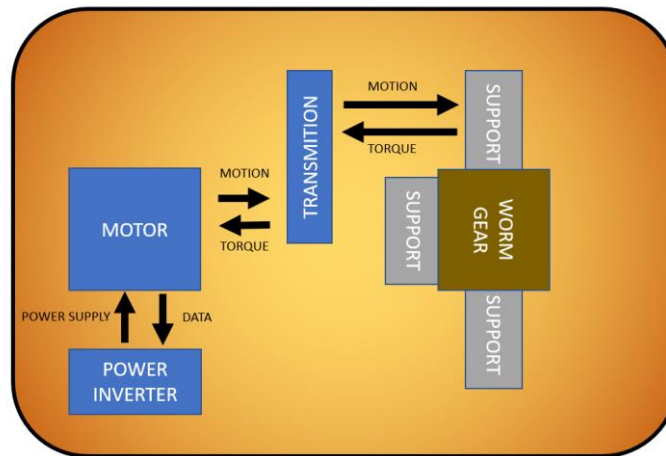


Figure 2. A block diagram of the test stand.

2. Laboratory research part

The laboratory research was carried out at a specialized test station for measuring the parameters of gearing with axial gear transmission with an angle of 90° to each other. The test stand in the form of a block diagram is shown in figure 2. The basic elements of the station are the following elements:

- Four mounting brackets
- Three-phase motor with measuring sensors
- Power inverter with card
- Belt transmission
- Test object

The study was conducted as follows. A standardized element was placed in the mounting brackets. This made it possible to pre-align the individual axes with respect to each other. The standardized element was then dismantled and replaced with the worm gear components so that the spacing between the axes corresponded to the previously mounted pattern.

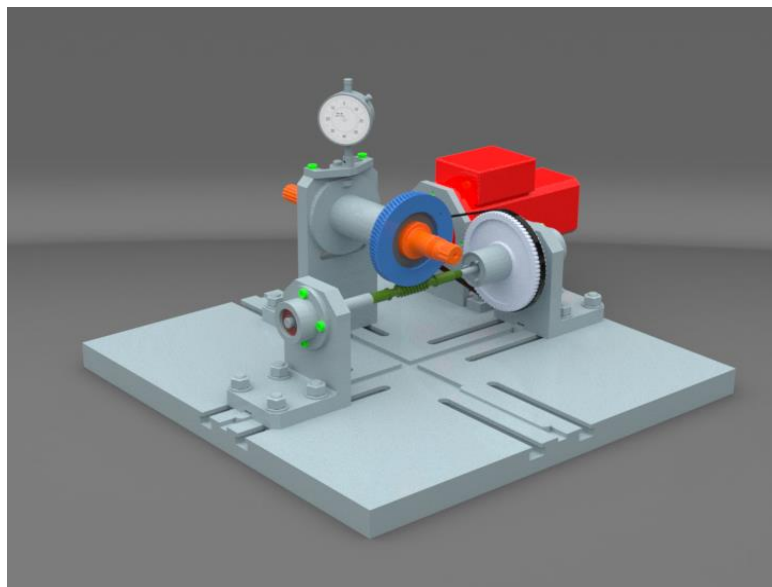


Figure 3. 3D model of the test stand.

The study consisted of rotating one of the worm gear components and then testing with the data acquisition instrumentation the basic parameters related to movement and resistance. To observe the effect of the distance change between the transmission axes, one of them was moved away from the other with the fixed axis. These shifts were done in the range of $\pm 20\mu\text{m}$ every $10\mu\text{m}$. The offset values were determined with a precision of $1\mu\text{m}$ by a precision dial gauge. After each offset of one of the transmission axes, the measurement was performed several times. The direction of rotation of the motor was clockwise.

The graphs below show the percentage of the nominal torque of the motor in 2 seconds time. The signal was sampled at 1kHz frequency. The measurement has been made since the moment the motor has been started with a rising edge. Additionally, in order to observe the whole waveform, the value of the measuring buffer was determined before the motor was triggered. The time value of the buffer has been set at 0.2s before triggering the motor.

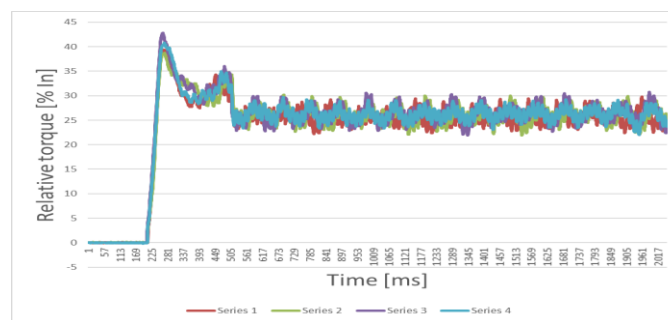


Figure 4. Percentage of nominal torque for standardized part.

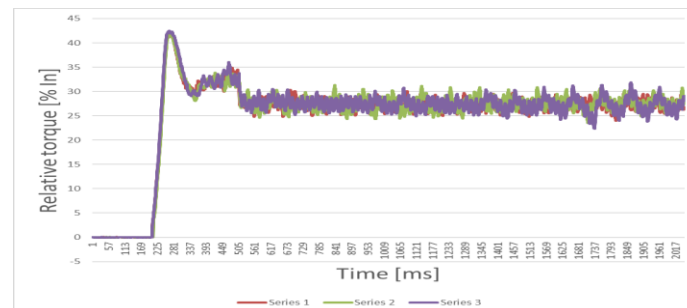


Figure 5. Percentage of nominal torque for distance between axes changed by $-10\mu\text{m}$.

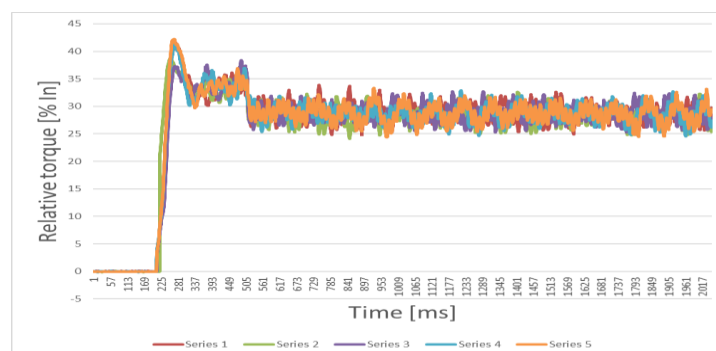


Figure 6. Percentage of nominal torque for distance between axes changed by $-20\mu\text{m}$.

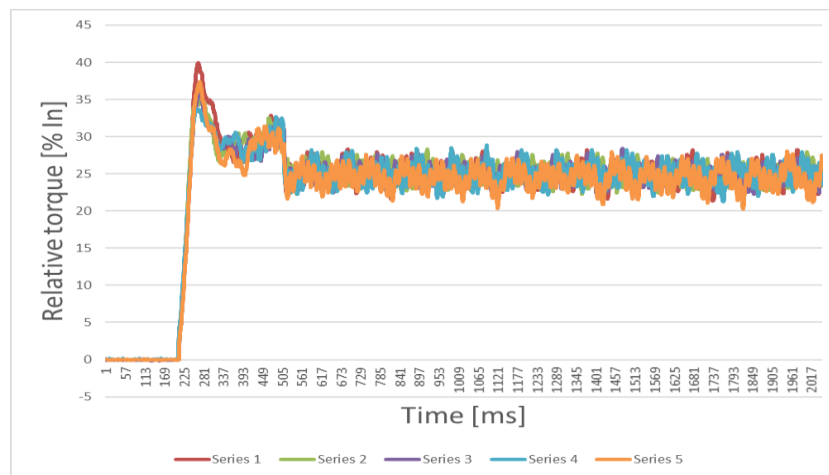


Figure 7. Percentage of nominal torque for distance between axes changed by +10 μm .

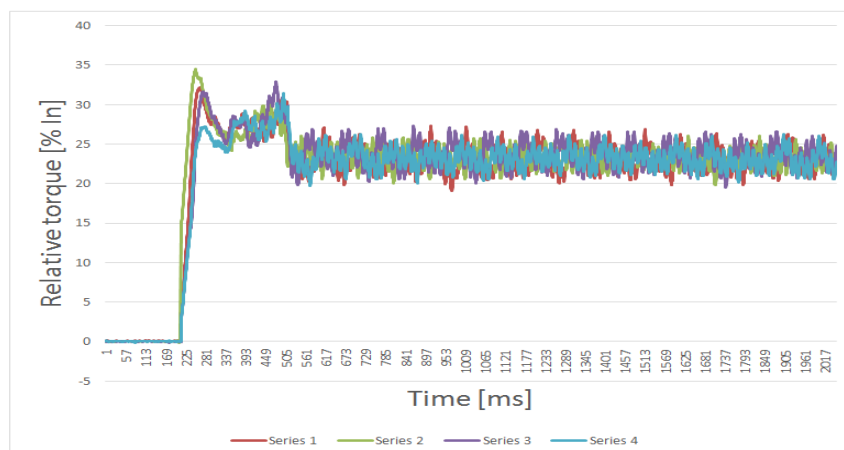


Figure 8. Percentage of nominal torque for distance between axes changed by +10 μm .

Table 1. Experimental results.

Distance [μm]	Max Torque [%ln]	Average Torque [%ln]
+20	34.47265625	21.27966583
+10	39.96582031	22.82814264
0	42.84667969	23.97089303
-10	42.48046875	25.13362964
-20	42.28515625	26.16900444

3. Results and discussions

Table 1 shows the average and maximum values of the torque for the tested objects recorded in all series. The tests carried out on the test bench have made it clear that there is a great influence of the worm gear axis distances on the torque read from the sensors installed in the engine. Unfortunately, only the movement resistance and torque changes of co-operating worm and worm gear make it unambiguously clear whether these components are correctly positioned. This is because of the linearity of the change in torque is relative to the change in distance between axes. However, with a reference system (reference worm gear), the correct operation of which has been investigated in

another study, it is possible to determine the distance between the axes so that the torque value is the same as that of the reference system by means of torque changes.

4. Conclusions

After analyzing all the results and conclusions drawn from the observations during the study, it can be clearly stated that in order to correctly select the distance between the cooperating elements of the worm gear, it is necessary to refine the process of examining the parameters accompanying the motion of that whole system. Further studies will be conducted on the same elements, however, a test stand will be refined to allow for other motion parameters to be investigated. As part of the improvement of the test stand, it is possible to test the noise level. In addition, long-term work in varying conditions and the change in friction force should lead to different values of thermal readings, which may also be measurement.

5. Acknowledgments

The work was carried out under the project number PBS3/B6/37/2015 agreement implemented under the Applied Research Program, funded by the National Centre for Research and Development."

6. References

- [1] Herbuś K. and Ociepa P 2016 Integration of the virtual model of a Stewart platform with the avatar of a vehicle in a virtual reality *IOP Conf. Series: Mat. Sci. and Eng.* **145** 042018
- [2] Herbuś K. and Ociepa P 2016 Determining of a robot workspace using the integration of a CAD system with a virtual control system *IOP Conf. Series: Mat. Sci. and Eng.* **145** 052010
- [3] Ociepa P and Herbuś K 2015 Strength analysis of parallel robot components in PLM Siemens NX 8.5 program *IOP Conf. Series: Materials Science and Engineering* **95** 012101
- [4] Baier A., Majzner M., Sobek M. and Grabowski Ł. 2016 Composite materials molding simulation for purpose of automotive industry *IOP Conf. Series: Mat. Sci. and Eng.* **145** (2) 022023
- [5] Sobek M. 2014 Badanie włóknistych materiałów kompozytowych na bazie tkanin węglowych. *Analiza wytrzymałości kompozytowej karoserii samochodu elektrycznego* Master's Thesis, Silesian University of Technology, Gliwice, Poland
- [6] 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 *Adv.Mat.Res.* **1036** 674-679
- [7] 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* **4**
- [8] 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* **220-221** 251-256
- [9] Majzner M and Baier A 2014 Computer Aided Design and Analysis of Composite Structure *Advanced Materials Research* **1036** 989-994
- [10] http://www.sae.org/dlymagazineimages/9131_10418_ACT.jpg.