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TESTING A FINAL DRIVE FOR A TRACKED VEHICLE

Abstract. The final stage of the design process of final drives of tracked vehicles comprise bench tests that reflect the actual operating conditions. During the tests the set parameters (torque M and rotational speed n) are similar to the parameters resulting from the conditions of vehicle use. The paper presents research methodology, verification and evaluation of the wear of components, which provide a basis for making the necessary structural changes in final drive (transmission) components. In addition, a schematic diagram of the verification test stand is presented and the obtained test results are discussed.

Keywords: tracked vehicles, final drive, bench tests, gear transmission.

1. INTRODUCTION

Before launching a new product the following subsequent implementation stages are necessary:

- construction of a model,
- fabrication of a prototype,
- running a pre-production batch,
- starting series production.

The purpose of these mentioned stages is to eliminate errors and optimize the design of the new product. In order to ensure high reliability and to lower operating costs, various methods are sought and certain procedures are developed to verify the design of the device prior to its releasing to production.

The dynamic development of IT tools allows design engineers to employ virtual techniques that support 3D design. Today, modern 3D CAVE systems allow for spatial visualization of an object, machine or assembly, enabling modification of geometric interdependencies in real time.

Structures designed to operate under load are verified by the finite element method (FEM) calculations. Advanced computational techniques allow, among other things, to reduce the weight of the structure without compromising its strength.

The methods of proceeding listed above do not complete the design process. Complex structures require verification of the design of the machine, device or assembly using experimental methods, under laboratory, test stand and field conditions. In this paper the method of design verification is described using the example of bench testing that checks the correctness of the designed final drives of a tracked vehicle.

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2. SUBJECT OF THE STUDY

Publication [4] presents the process of designing final drives, emphasizing the most important aspects of designing a new structure, including the critical structural units.

During the design of the final drive of a land vehicle carried out at OBRUM's Construction Office 3D SOLIDWORKS virtual prototyping techniques were used, which allowed the final drive (transmission) model to be built in the further design development phase.

The whole process of structure development in the modelling phase is based on the construction of the model and on a detailed experimental study. The results provide a basis for design optimization. If tests are not successful, the procedure calls for making appropriate corrections to the transmission design.

3. PURPOSE AND SCOPE OF FINAL DRIVE BENCH TESTING

The purpose of the conducted tests was to check a number of important transmission parameters, such as:

- smooth transmission operation: occurrence of irregularities, e.g. caused by increased dynamic stimulation and vibrations, etc. may indicate lack of alignment of bearings, shafts or gears, which may result in transmission failure during its operation,
- uniform heating of the transmission: temperatures in individual kinematic joints should be similar. If in one of the points the temperature would be significantly increased, it may indicate a problem with insufficient lubrication of individual joints, incorrectly selected tolerances of bearing mounting diameters, or faulty shaft journals, or lack of axial alignment of bearing seats in the transmission housing;
- transmission tightness: leaks may indicate poorly matched seals, manufacturing faults; no leaks indicates that the design is correct;
- stable operation under load: this is the main stage of final drive testing, allowing to draw conclusions about the correct operation of the transmission under conditions similar to the operational ones.

4. EXPERIMENTAL SETUP AND PROCEDURE

Tests were performed on a test stand which comprised the following components:

- dynamometer (drive element),
- transmission operating as a reducing gear with a gear ratio $u = 3$,
- transmission operating as a reducing gear with a gear ratio $u = 5$,
- water brake SCHENK D900,
- temperature recorder UPM 60 with type J thermocouples.

Tests were split into two stages:

1) No-load tests.
   During the tests, the final drive was connected via a reducing gear with gear ratio u = 3

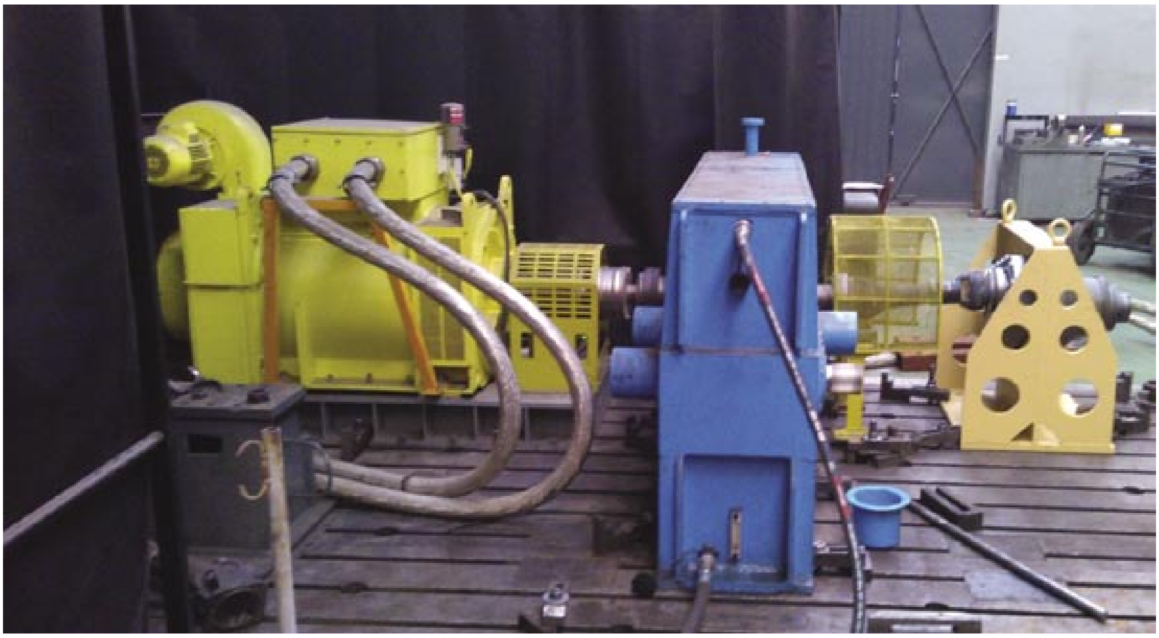

Fig. 1. Final drive test stand with no working load

2) Load tests.

Fig. 2. Part of test stand for testing under load

The left-hand and right-hand final drives were placed in a proper stand corresponding to the final drive location in the vehicle. Temperature recording was effected using J type thermocouples connected to a UPM 60 recorder (Fig. 4).

Fig. 3. Arrangement of temperature measurement points

The seven thermocouples, marked with symbols 00 to 06, were placed on the final drive casing (Fig. 3), on its main structural points (drive output, bearing mounting location).

Fig. 4. UPM60 temperature recorder

The UPM60 temperature recorder enables recording the temperature simultaneously on multiple channels at a given time step. A 1-second measurement step was adopted, allowing for accurate tracking of temperature increase and quick response in case of any irregularities (sudden temperature rise), avoiding transmission damage.

5. DESCRIPTION OF THE FINAL DRIVE TESTING PROCESS

5.1. Evaluation criteria

The final drives were tested upon adopting the following criteria:

- smooth transmission operation,
- temperature range of transmission operation,
- transmission tightness.

If there was no smooth operation and lubricant leaks were observed, the elements would be dismantled and causes would be identified. Then, after removing these malfunctions, tests would be run again. Much more complex is the temperature measurement. The temperature values in all critical measurement points (selected structural units) should be comparable. Under assumed tolerance ±10°C.

5.2. Preliminary tests

Preliminary tests of the final drive were carried out in two stages:

Stage 1: no-load tests.

The no-load tests consisted in checking the correctness of the installation of the transmission components and in checking the temperature at the minimum torque resulting only from the interaction of the transmission structural units.

Tests commenced at 600 rpm, and the speed was continuously increased to 2500 rpm. At this speed the test was completed. Figs. 6 (right-hand drive) and 5 (left-hand drive) show temperature graphs recorded during the tests.

Stage 2: testing under load.

The tests under load were carried out in the OBRUM propulsion laboratory. Variable load was applied, which simulated driving in different gears. The load was applied by means of the SCHENK D900 water brake.

Figs. 7, 8, 9 show temperature graphs for the selected points recorded during tests under load.

5.2.1. No-load test results

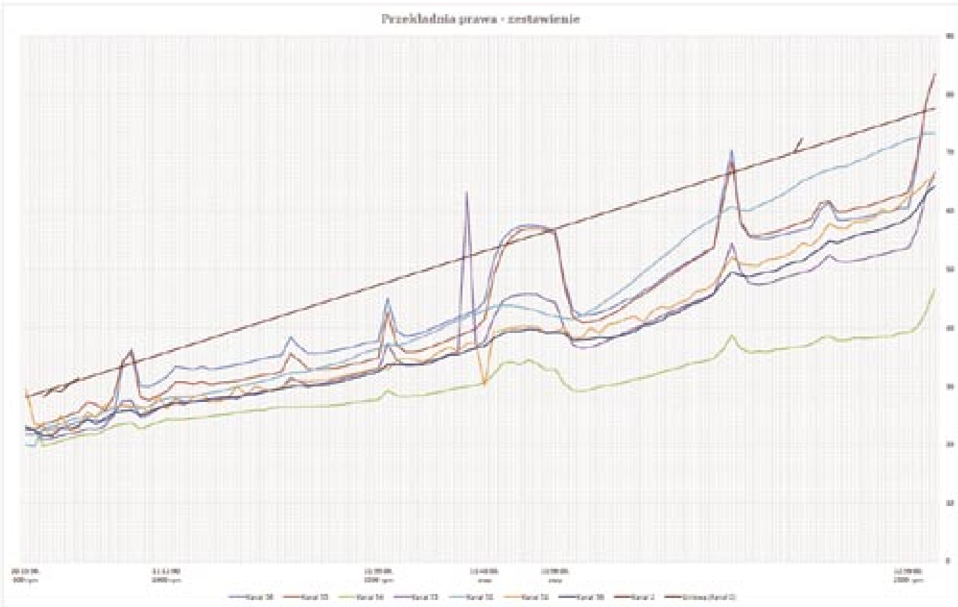

Fig. 5. Temperatures recorded at measurement points of the left-hand final drive tested under no load

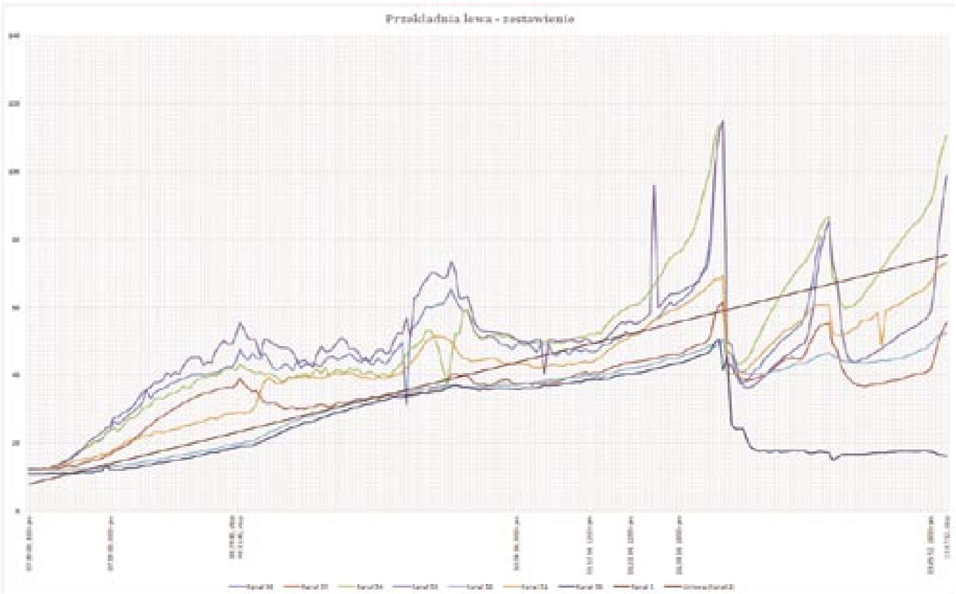

Fig. 6. Temperatures recorded at measurement points of the right-hand final drive tested under no load

5.2.2. Working load test results

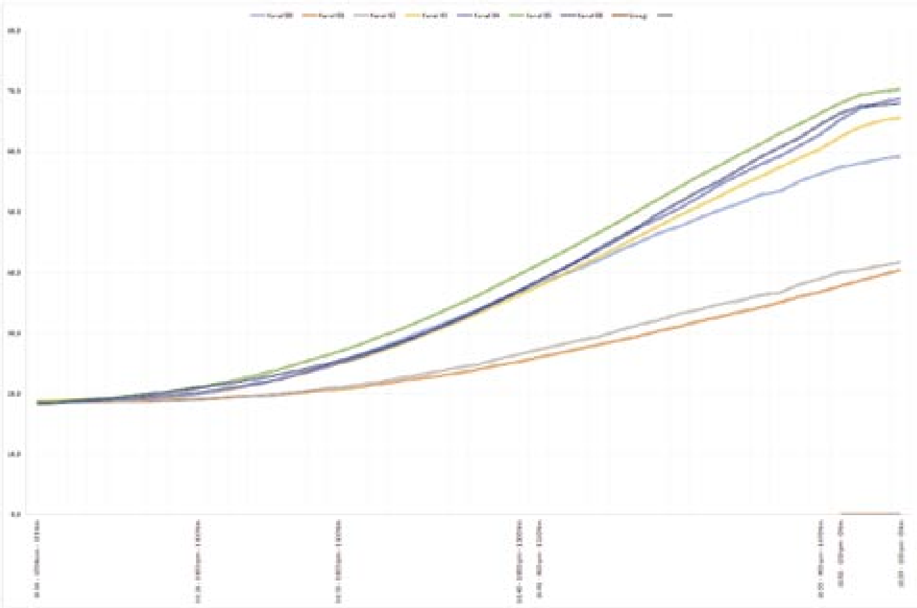

Fig. 7. Temperatures recorded at measurement points of the left-hand final drive tested under load

5.3. ANALYSIS

The tests conducted in the 1st stage revealed the transmission failure that occurred during the under no load and under load transmission tests. The temperature graphs presented show the distribution of measured temperatures in the following selected structural units of the final drive:

a) right-hand drive (Fig. 6) - sudden temperature increase to 115°C and an oil leak which indicated the imperfection of the seals, which resulted in discontinuation of the bench tests (no tests of the right-hand drive were carried out because of its failure);

b) left-hand drive (Fig. 5) - gradual increase in temperature, temporary high temperature increases as a result of the controlled cycle of interrupting the test stand operation in order to check for leaks;

c) left-hand drive (Fig. 7) - tests carried out under load showed a slight temperature increase.

5.3.1. Modifications

Tests conducted under load revealed a problem with seals and overheating of the bearing points of the cylindrical stage of the final drive. The basic units were re-analyzed, in particular those of the cylindrical gear bearing. Due to the heating to high temperatures, the sealing system was also analyzed.
Decisions were made to:

- replace the nitrile-butadiene rubber seals with fluoroelastomer (FKM) seals, much more resistant to elevated temperatures;
- change the tolerances of the openings for the tapered roller bearing mountings from transition fit to loose fit.

The result of the analyzes carried out after the tests revealed weak points of the final drive. It was therefore decided to make the aforementioned recommended changes in both the right-hand drive that has failed as well as in the left-hand drive that has passed the tests. The changes made also improved the quality of the final drive and significantly improved its resistance to high temperatures.

5.4. Verification tests stage

The verification testing phase was carried out after the modification of the final drive design described in the previous section. These drives, after re-starting and short operation under no-load conditions, were again tested under a load close to that of real operating conditions. The temperature graphs obtained in the tests are presented below.

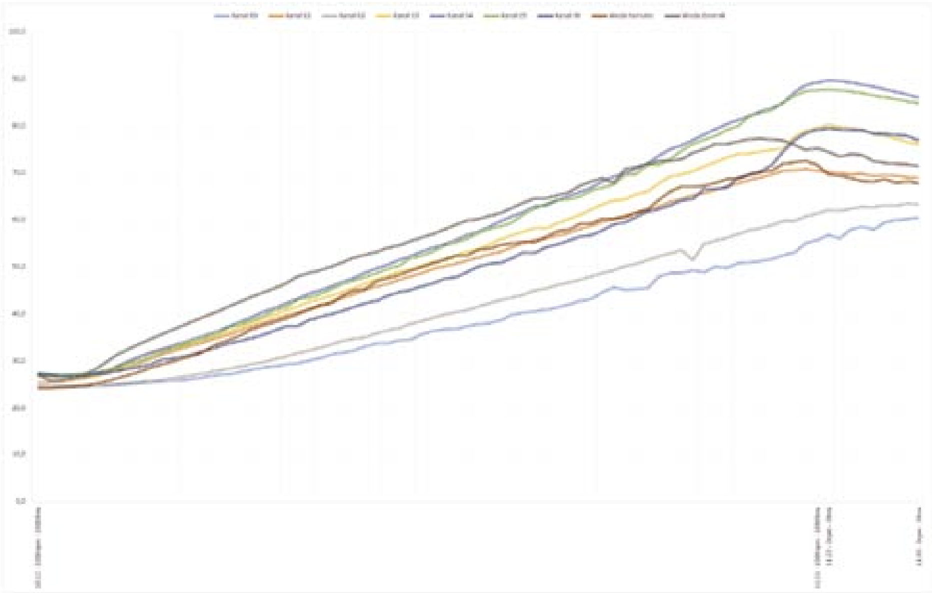

Fig. 8. Temperature changes recorded in the modified right-hand final drive

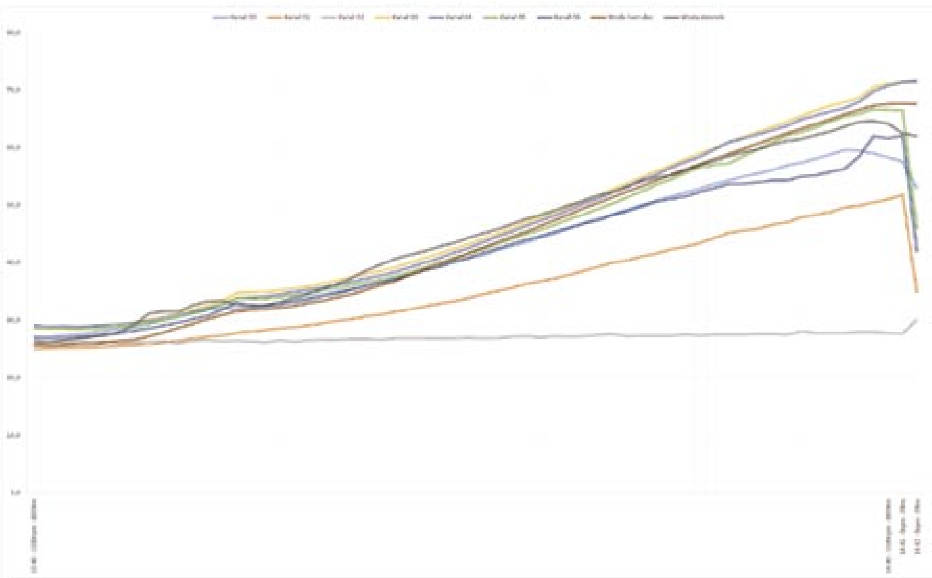

Fig. 9. Temperature changes recorded in the modified left-hand final drive

5.5. Analysis

The tests carried out after the modification of the original design showed a significant decrease in the thermal state of the drives determined by the temperatures in the designated measuring points. Neither leaks nor other irregularities were observed in both drives. The heating of the drives proceeded as expected. Temperatures in the individual structural units of the drives changed in a similar manner in the right-hand and the left-hand drive.

There was only a lack of stability in the temperature rise, which resulted from the short duration of the verification test.

6. SUMMARY

The obtained results show that bench tests, carried out under laboratory conditions and under near real-life conditions, are an indispensable step in the process of releasing a product (final drives in this case) to production. The elimination of discrepancies at the stage of bench tests will bring tangible benefits in terms of a smooth and uninterrupted process of factory and qualification testing of the complete product (tracked vehicle). Conducting the tests allowed to determine the necessary modifications in the final drive, in this case the change of seals and change in the tolerance of bearing mountings. The changes made significantly improved the operation of the final drive and reduced its operating temperature.

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