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Methods of Testing Gearboxes of Rail Vehicles

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Abstract. The article deals with the various methods of testing gearboxes of rail vehicles such as tram, metro, suburban unit EMU (Electric Multiple Unit). Further deals with determination of the load test parameters, the methodology for measuring of monitored magnitude and result evaluation. Some gearboxes have been designed for extreme operating temperatures ± 40°C. In the article are described the main types of tests performed on gearboxes of rail vehicles and their results on specific types of gearboxes. Tests include the following methods: verification of assembly accuracy, sealing test against leak of oil, sealing test against ingress of water (water fog) at runtime of gearbox, sealing test gearbox against ingress of water under pressure at rest, long duration test on-load (runtime test) with variable load spectrum, test in mode "Cold climate test", contact pattern – gears (application of modification).

Introduction

In the article are described the main types of tests performed on gearboxes of rail vehicles and their results on specific types of gearboxes. Nominal power on one gearbox (in the bogie) is for metro (0 – 100) kN, tram (100 – 150) kN, EMU (180 – 500) kN, locomotive (500 – 1 600) kN and max. input speed (3 000 – 4 500) rpm.

It is described the method of determining the load parameters of tests, measurement methodology and result evaluation of prototypes [1]. Some gearboxes have been designed for extreme operating temperatures ± 40°C. For these tests, it is necessary to carry out tests in these adverse conditions.

Type Tests of Gearboxes for Rail Vehicles

On gearboxes for rail vehicles are performed the following methods of measurements:

- Assembly verification (verification of assembly accuracy) – unloaded measurement.
- Sealing test against leak of oil (sealing test of labyrinth packing).
- Long duration test on-load (runtime test) with variable load spectrum.
- Test in mode "Cold climate test".
- Sealing test against ingress of water (water fog) at runtime of gearbox.
- Sealing test gearbox against ingress of water under pressure at rest.
- Contact pattern – gears (application of modification).

All of the above tests are described below.

Assembly verification (verification of assembly accuracy) – unloaded measurement

After assembling, is the gearbox placed on a test rig, where be verified the correctness of assembly, and imperfect of design solutions.

On the test rig is performed the test of gearbox no-load (unloaded). For the test is selected several levels of load spectrum (see Table 1). In the Table 1 are shown the measured noise levels per ISO 3740 and ISO 8579-1.

Table 1. Example of load spectrum for EMU gearbox.

Part of Load Spectrum	*Input speed [rpm]*	*Time [min] / max. noise [dB(A)]*	*The measured noise level [dB(A)]*
1	1 660	60 / 80	76
2	2 027	30 / 97	79
3	4 055	10 / 105	90

On the gearbox are measured all important temperature nodes by temperature sensors (see Fig. 1). At the bearing points, after 60 min run, temperature mustn't be higher than 65°C above ambient temperature (T). After end of testing, temperatures mustn't be higher than 80°C above the ambient temperature (T). Examples of the temperature characteristic is shown in Fig. 2. Also are checked, the leak tightness of all dividing planes, flanges, covers and shaft seals (labyrinth packing).

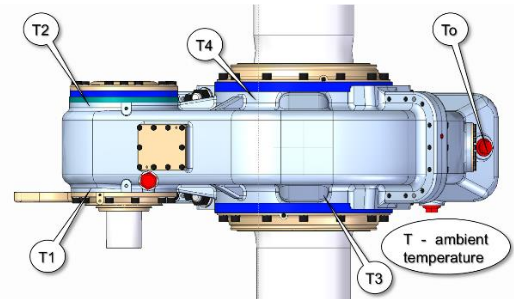

Fig. 1. Example of the location temperature sensors on EMU-gearbox.

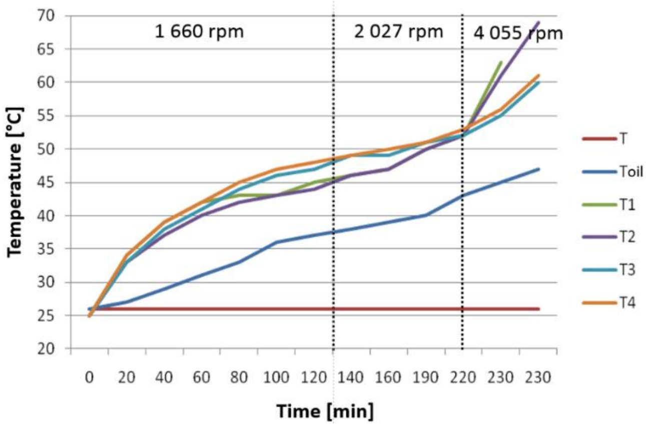

Fig. 2. Temperatures behaviour of the EMU-gearbox during increasing of the operating speed.

Sealing Test against Leak of Oil (Sealing Test of Labyrinth Packing)

The aim of the test, is to check function of the labyrinth packing for sealing the hollow shaft and the input pinion, during change of the oil level, which is given by tilting of the track structure and driving dynamics. The maximum deflection of the oil level (when standing) for a maximum cross slope of tram track is 6°. The maximum deflection of the oil level (when driving on a curve R = 200 m, v = 60 km·h^{-1}) is 8°. The maximum deflection of the oil level (when moving off and braking) is 9°.

For load of gearing are selected different combinations of tilt (cross slope) and speed of electromotor. For a complete simulation of the dynamics driving in a curve would have to change tilt and speed at the same time (lower speed = less centrifugal force = less tilt levels), this can be replaced by non-linear simulations (low status).

If is detected a leak of oil from gearbox, then is necessary to adapt method of sealing (bolted connections, the contact surfaces, sealing element, labyrinth packing). If labyrinth packing aren´t leaked, then must be found reason of leak, and optimize design (e.g. by welding parts which disturb splash oil into unsuitable area).

Fig. 3. The test of the tram-gearbox at a cross slope 8°.

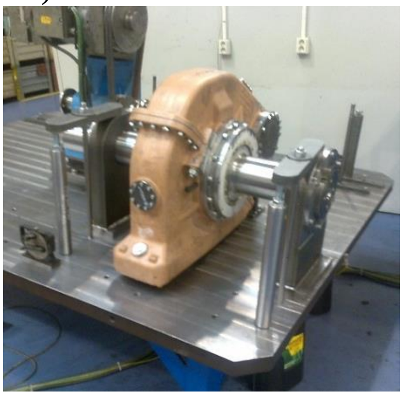

Fig. 4. The test of the EMU-gearbox at a cross slope 8°.

Long Duration Test On-load (Runtime Test) with Variable Load Spectrum

After the assembly verification and sealing test against leak of oil, when weren't detected the fundamental deficiencies on the gearbox, is tested gearbox in long duration test on-load (runtime test) with variable load spectrum. The test is performed until 50 000 km.

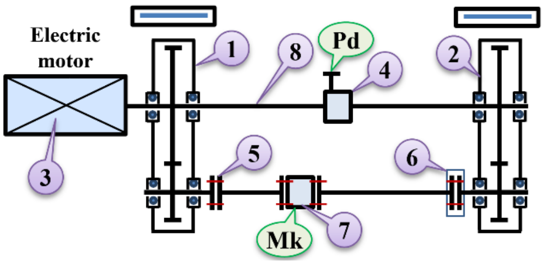

Fig. 5. Scheme for runtime test with variable load spectrum.

Fig. 6. The really assembled test rig with the location of temperature sensors (EMU gearbox testing in mechanically closed loop).

Test rig should be placed in noise-isolated box. On the test rig are tested two gearboxes connected "back to back", as is shown in Fig. 5 and 6. Gearboxes are possible testing into electrically closed loop [2] (see Fig. 7). In the Fig. 5 is shown the test gearbox (Item 2), which is over torsion element (item 4) connected by the output shaft of the wheel set (Item 8) with the same type of gearbox (Item 1). The gearbox (Item 1) is connected to the drive - electric motor (Item 3) by part of the output shaft of the wheel set (Item 8). Both gearboxes (item 1 and 2) are connected through a coupling (Item 5), torque sensor (item 7) and through safety coupling (item 6) to the input shaft (high speed). By using torsional element (item 4) to elicit a desired mechanical loads of gearbox [3]. The value of the torsional moment is evaluated by the differential pressure (Pb) and by the torque sensor (Mk).

Because during the test cannot be realized the real cooling of gearboxes, so, both gearboxes are cooled by ventilator, to prevent overheating. For the loading is selected a load spectrum according to where the gearbox will be moved in real life (moving off, brakes, max. speed, driving). During the whole test it's necessary to monitor temperature, operating characteristics (vibration and overall functioning) and especially noise, on which is given great emphasis. Max. noise levels for various levels of the load spectrum are given by the standard and by customer requirements.

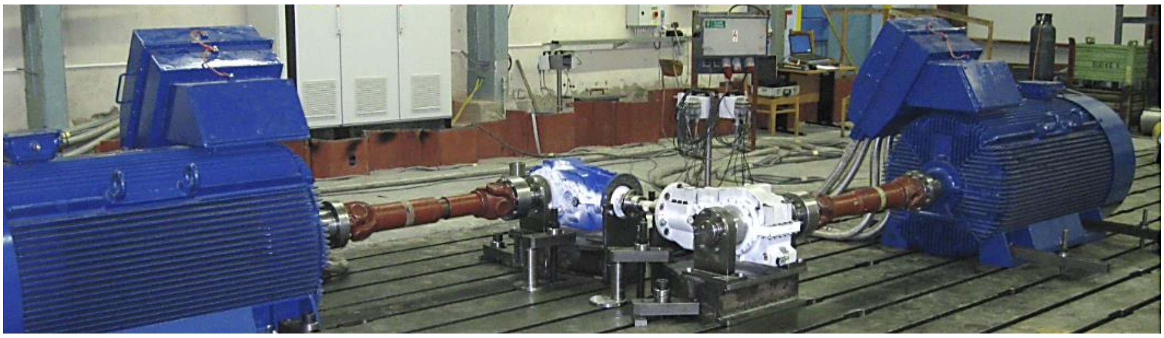

Fig. 7. Test rig (bevel-spur gearbox for 100% low-floor tram - electrically closed loop).

Fig. 8 and Fig. 9 are shown the resulting value of acoustic pressure level for the EMU-gearbox from real measurements. For the measurement is used function of weighing A, and the uncertainty of the gauge and measuring methods is 4 dB.

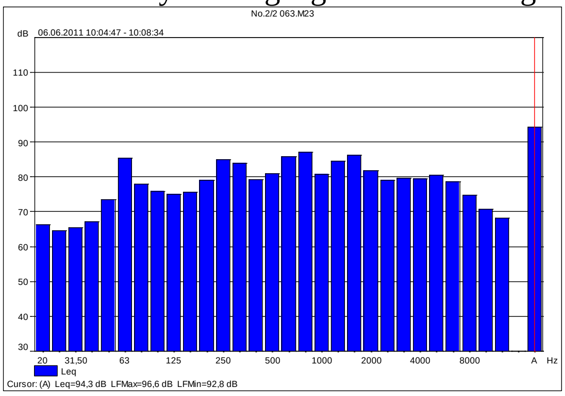

Fig. 8. Acoustic pressure during 4 055 rpm / 450 Nm (resulting value of acoustic pressure is 88.3 ± 4 dB (A)).

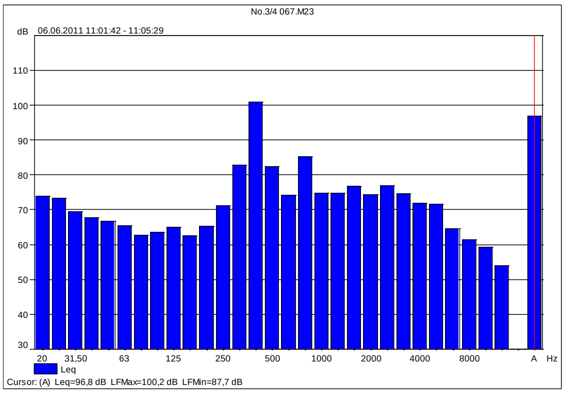

Fig. 9. Acoustic pressure during 1 137 rpm / 3 528 Nm (resulting value of acoustic pressure is 90.8 ± 4 dB (A)).

Test in Mode "Cold Climate Test"

This test is focused on testing of the train drive in conditions of low operating temperatures, when to start is occurred at -40°C and the oil isn’t preheated (see Fig. 10).

The test rig consists of a large cool box, compressor cooling unit, a supporting frame for the drive own construction and from the frequency converter.

Example of selection of load parameters for the tram of gearbox. Speed of the motor 890 rpm (corresponding to approximately speed of tram 20 km/h). Followed endurance at this temperature for 4 hours. Most importantly, that when undercooling of drive to the -40°C was a start-up of gearbox with the least resistance.

Fig. 10. Cold climate test of assembled gearbox with electro motor and coupling.

During the experiment is measured these physical quantities: ambient temperature in the freezer (Fig. 12); the surface temperature at several points of gearbox (Fig. 11, 12); temperature of the gearbox in place of oil level; housing temperature of traction motor; supply current to the motor.

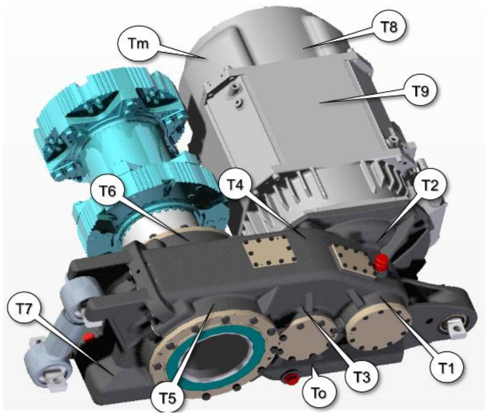

Fig. 11. Example of the location temperature sensors on the gearbox for 70% low-floor suburban trains.

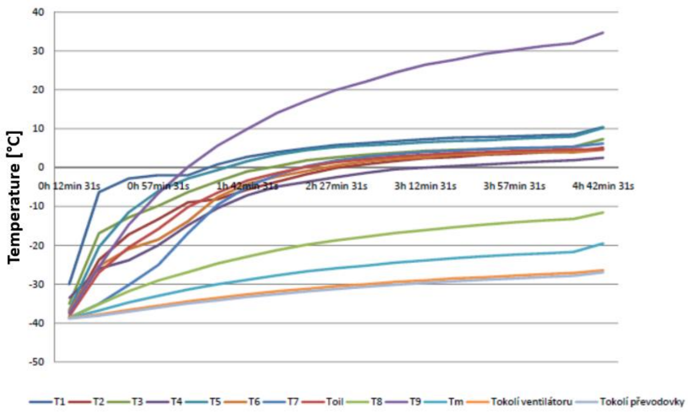

Fig. 12. Temperatures behaviour of the gearbox for 70% low-floor suburban trains and trams in a cool box (freezer) at -40°C.

Sealing Test against Ingress of Water (Water Fog) at Runtime of Gearbox

The aim of the test is to check function of labyrinth seals for sealing of the output shaft (train wheel set) and the input pinion against ingress of water into gearbox at runtime in the rain. During this test the gearbox is loaded at runtime with water fog, which have a different density (Fig. 13).

Gearbox is placed in the test box (Fig. 13), from which protrude the output shaft of gearbox, which it's driven. In the box are located 3 pieces of low pressure nozzles, which allowing to set the density of the water fog.

For this test, it is necessary to select the load parameters. Example of load parameters could look like the following. The test may be run at a speed of 1 660 rpm during 4 hours in one direction and the same in the second direction. The same at higher speeds (e.g. 4 200 rpm). After finishing the test is necessary to check the water content in oil (oil analysis). Content of water must be less than 0.1 % of the oil.

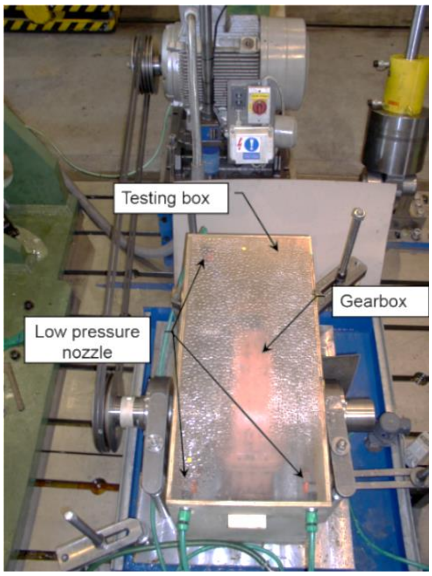

Fig. 13. Sealing test against ingress of water (water fog).

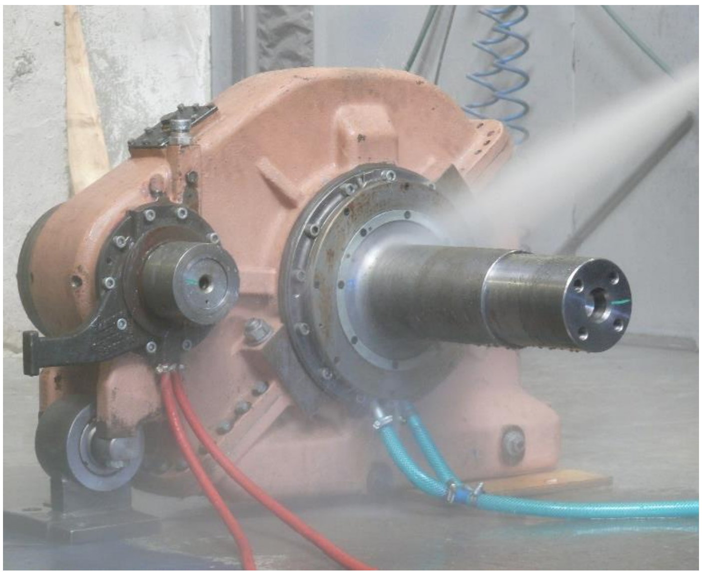
Fig. 14. Sealing test gearbox against ingress of water under pressure at rest.

Sealing Test Gearbox against Ingress of Water under Pressure at Rest

The aim of the test is to check function of labyrinth packing for sealing of the output shaft (train wheel set) and the input pinion against ingress of water into gearbox at rest, when the train bogie is washed with pressurized water (Fig. 14).

On the gearbox are mounted special covers, which are modified for attachment of outlet hoses. In outlet houses are retained water, which is allowed through labyrinth packing. On the gearbox is treated with pressurized water (Fig. 14) at a pressure 160 bar from a distance of 0.5 m for a period 5 minutes on each labyrinth packing.

Contact Pattern – Gears (Application of Modification)

When checking of gearing, by using colors applied on the flanks of the teeth, to detect the correct contact pattern. In the Fig. 15 and 16 are shown the print of meshing tooth in the length of a tooth and therefore gear-mesh is fine.

Fig. 15. Contact pattern (during assembly).

Fig. 16. Contact pattern after 50 000 km.

Summary

All the above described tests are carried out in various modifications for all the new gearboxes for rail vehicles. The results of these tests are not only important for the development, but very often also for the user (especially the noise parameters).

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