# Loading of the Axle Gearbox for Metro During Drive Simulation

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**Abstract:** During working of the rail vehicle the parts of the drive are dynamically loaded by the input torque on one side and by the roughness of the rail track on the other side. The axle gearbox which is used in partly sprung drive of the metro unit is placed in the test rig for dynamic loading in company Wikov MGI a.s. The stress states of the gearbox and the hinge are investigated during the dynamic loading by means of the strain gauge measurement. Reached results are verified by the analytical calculations and finite element analysis.

**Keywords:** Strain Gauge; Axle Gearbox; Hinge; Rail Vehicle; Partly Sprung Drive; Drive Simulation; FEM; FEA.

## 1 Introduction

During working of the rail vehicle the parts of the drive are dynamically loaded by the input torque on one side and by the roughness of the rail track on the other side. Those additional loads can be significant. It is necessary to describe the dynamic loads to design appropriate parts correctly. There are various methods to reach the quantities of those loads such as analytical calculations or finite element method (FEM). It is convenient to verify calculated results by means of experimental measurement to confirm the correctness of the assumptions.

This paper deals with the measurement during the testing of the axle gearbox for metro unit. There is used the partly sprung drive, which is consisted of asynchronous motor and one-stage gearbox. The axle gearbox is embedded on the wheelset axle. Moreover, it is supported by means of the gearbox hinge, which is there to catch the reaction force caused by the torque of the wheelset. The gearbox hinge can be conveniently used for the identification of the loads, especially of the torque [1], [2], [3].

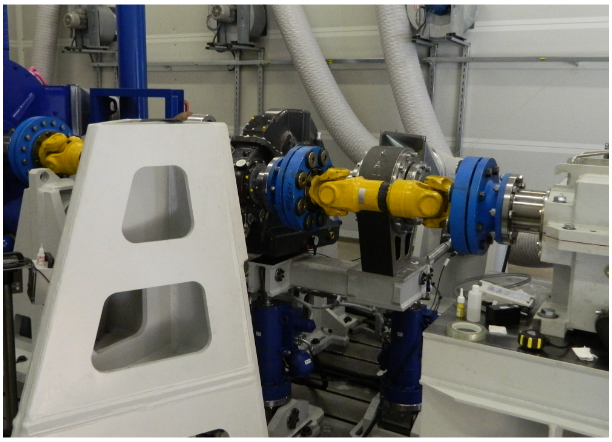

Fig. 1: The test rig with the one-stage axle gearbox.

## 2 Test Rig

The gearbox is placed on the test rig for dynamic testing of rail vehicle gearboxes in company Wikov MGI a.s., see Fig. 1. This test rig enables long–term runtime testing of the various types of gearboxes for rail vehicles, including testing of gears, [4]. It is possible to load the gearbox both by the torque in the closed loop and by the simulation of dynamic shocks. Those are generated by the set of hydraulic cylinders, which are installed in the triaxial arrangement, for more information see [5] and [6].

## 3 Measurement

The aim of the measurement is to verify quantities calculated by usage of FEM or analytically and also describe the behaviour of the tested gearbox during torque loading and during the dynamic shocks.


Fig. 2: Strain gauge rosettes installed on the gear box.

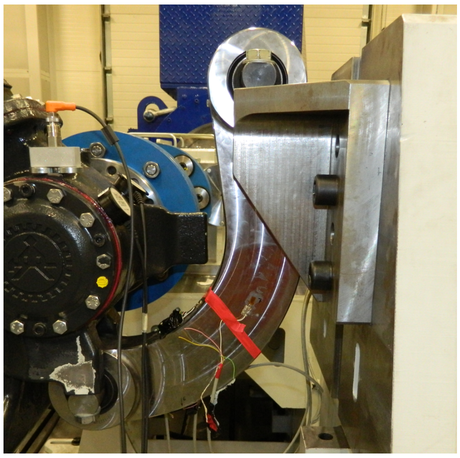

Fig. 3: Uniaxial strain gauges installed on the gearbox hinge.

### 3.1 Hinge Measurement

The gearbox is supported by the angled hinge, which is connected to the test rig frame, see Fig. 3. The hinge has to take the reaction force generated by the torque of the wheelset, but it has to allow some specific movements of the gearbox as well. The hinge is embedded into the test rig frame and into the gearbox by means of rubber–metal joints.

Four uniaxial strain gauges are used for the strain and stress measurement of the hinge. Those strain gauges were installed on each side of the rectangular cross–section of the hinge. Two of them are placed in plane perpendicular to the axle axis (strain gauge 5 and 6) and two are placed in the plane parallel to the axle axis (strain gauge 7 and 8), see Fig. 6. Both the hinge and the gearbox were tested in various load regimes. Those regimes consists of the combination of torque loading and dynamic shocks in chosen directions. In Fig. 4 and 5, there can be seen that strain gauges 7 and 8 are completely unloaded. Further, the stress level due to the torque loading remains unchanged in both types of loading. From the Fig. 5 can be analysed the response to the shock loading.

### 3.2 Gearbox Measurement

The cast gear box is loaded through the bearing loads and also by the reaction force of the hinge. To investigate desired strains and stresses the strain gauge measurement is designed. There are used strain gauge rosettes because of complex stress state of the gear box. The reduced stress could be calculated from obtained stresses afterwards. The strain gauge rosette installed on the gear box is shown in Fig. 2. The temperature measurement of the gearbox during load test is also carried out. This measurement was carried out to compare obtained data with results from FEA. That has been done internally in the company and the results are not available.

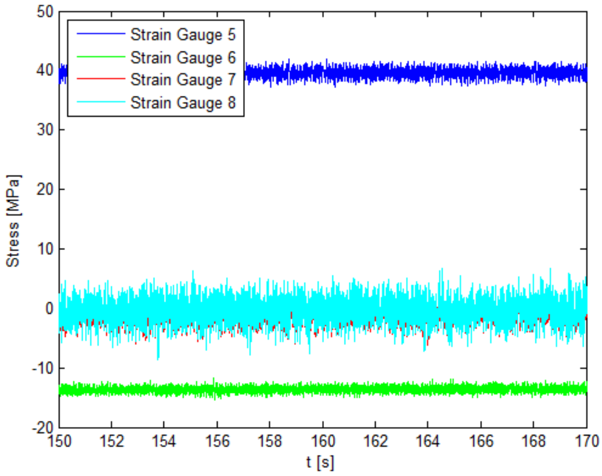


Fig. 4: Stress response of the hinge to the pure torque loading.

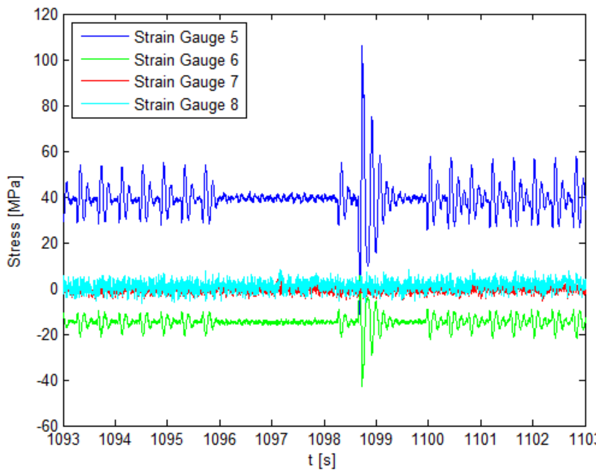


Fig. 5: Stress response of the hinge to the combination of torque loading and shocks.

## 4 FEA Verification

As a verification of measured stresses the FEM calculation is carried out. From known parameters of the gearbox power, torque, etc. and available 3D CAD model of the hinge the FEM model can be created. The reaction force in the hinge can be calculated analytically. For the one–stage gearbox (two gears) the reaction force $S$ can be calculated according to the 1, [2].

$$S = \frac{M_M\,(i_c + 1) - J\ddot{\psi}}{n} \tag{1}$$

$M_M$ is the torque of the asynchronous motor, $J$ is the moment of inertia of the gearbox without the big gear, $\ddot{\psi}$ is angular acceleration of the gearbox sway round the axle of the wheelset (i.e. the second derivative of the rotation angle of the gearbox round the axle of wheelset), $n$ is the perpendicular distance from the hinge to the axle (output shaft axis), see Fig. 6, and $i_c$ is the total gear ratio of the gearbox. If the dynamic contribution to the reaction force $S$ is neglected, the desired value of the reaction force $S$ for the torque loading test regime can be calculated as follows:

$$S = \frac{M_M\,(i_c + 1)}{n} = \frac{1.8e6\,(5.\bar{5} + 1)}{406.5} = 29028\ \mathrm{N} \tag{2}$$

This force is used as a loading force in the FEM. The comparison to measured data is carried out for the pure torque test regime (Fig. 4) and it can be seen in Tab. 1. Desired quantities are read in two test points SG 5 and SG 6, which are designated in Fig. 6. The FEA results can be seen in Fig. 7. On this figure there is shown von Mises stress distribution, although for the comparison with measured data the stress in strain gauge longitudinal direction is used.

Tab. 1: The comparison of measured and FEA results – uniaxial stress in the longitudinal direction of the strain gauges.

| Test Point | Measurement [MPa] | FEA [MPa] | Ratio [-] |
|---|---|---|---|
| SG 5 | 40.5 | 41.2 | 1.017 |
| SG 6 | -14.6 | -15.1 | 1.034 |

From the Tab. 1 there can be seen that the results from the FEA are in very good agreement with the measurement. Certain error is caused by the accuracy of test points positioning in FEA according to the experiment.

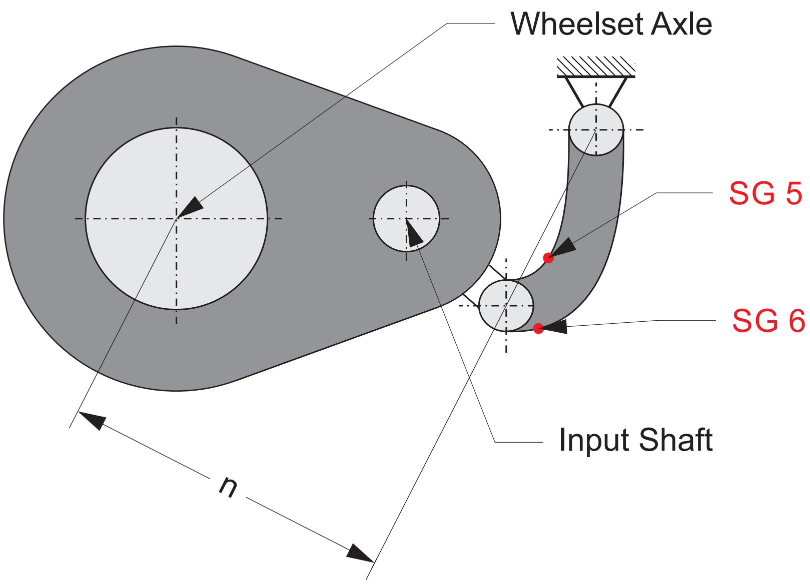


Fig. 6: Scheme of the partly sprung drive, strain gauges location.

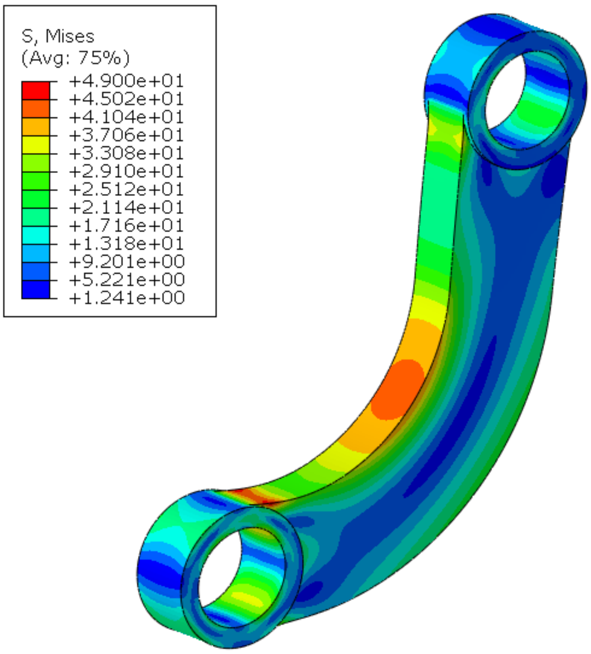


Fig. 7: Von Mises stress distribution in the gearbox hinge.

## 5 Conclusion

This measurement was carried out on the test rig for testing rail vehicles gearboxes. The response of the gearbox for rail vehicle and especially the hinge to the torque load and to the dynamic shocks was analysed. Those loads should simulate the real loading during working of the rail vehicle. The gearbox hinge proves to be useful and convenient object for the observation and analysis of the driving conditions and torque loading even during real drive. Loading by the torque was verified by the analytical calculation and FEA. Obtained results are in very good agreement with the measured data.

## Acknowledgement

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