EAN 2019
57th conference on experimental stress analysis

Optical analysis of low-floor tram drive motions

HAVLÍČEK Martin [1,a], DUB Martin [1,b] and LOPOT František [1,c]

[1] CTU in Prague, Faculty of Mechanical Engineering, Department of Designing and Machine Components, Technická 4, 166 07 Prague 6, Czech Republic

[a]martin.havlicek@fs.cvut.cz, [b]martin.dub@fs.cvut.cz, [c]frantisek.lopot@fs.cvut.cz

Keywords: Shift, Rotation, Gearbox, Traction electromotor, Optical analysis, Qualisys

Abstract: This paper is focused on special method for observation relative motions of bodies in space thanks to the optical analysis. In this case, relative motions are measured between the gearbox and the traction electromotor of low-floor tram. These components are marked by special markers. During the drive regime markers create trajectories, which are captured by cameras. All data is processed by system Qualisys. Each component gets own cartesian coordinate system and from them were found relative shifts and rotations between gearbox and traction electromotor.

Introduction

Trams are one of the most popular means of public transport, which are used worldwide. Due to this fact, specific needs are required. The main requirement is reliability. It means that the tram can work without any failures as long as possible. It is very complex to design tram traction electromotor because it challenges a lot of different types of loads. One of them are dynamic loads, which occur due to acceleration, deceleration, quality of the rail track and curves. These loads have a big impact on wearing of drive unit´s parts, e.g. gears, bearings etc.

The goal of this experimental measurement is to find out the relative motion between the traction electromotor and the gearbox. In case of a partly-sprung drive the traction electromotor is fully-sprung mass and gearbox is a partly-sprung mass due to its connection with the wheelset. These movements of a drive unit were measured by an optical cameras connected to system Qualisys.

Instrumentation

This experiment was realised by Qualisys. Qualisys is an optical system which can capture and analyse motions of bodies in space. This system was used to capture relative motion of the gearbox to the chassis and to the motor. To capture these data, at least three optical cameras are required. In this case, six cameras were used, divided into two groups. The first three of them were stationary and settled in the pit in the ground. The second group is composed of three optical cameras, which were bolted by special holders to the bottom of the tram. Both groups were calibrated and synchronized. To create the reference plane and cartesian coordinate system (see Fig.1) on objects which were monitored, three special spherical markers were put on the gearbox and three of them were put on asynchronous motor (see Fig.2). One spherical marker was attached to rotating shaft to determine speed of tram and synchronize time data.

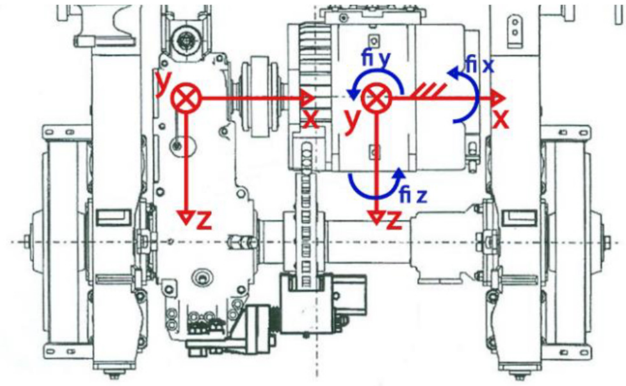

Fig. 1: Cartesian coordinate system of drive unit Fig. 2: Positions of markers on objects

Measurement

This measurement took place at testing loop in Prague. Three main drive regimes were measured: maximal acceleration, maximal deceleration and normal drive. A lot of data was obtained because of these three regimes. After these measurements, all the data were processed by Qualisys software and from this data can be found relative shift of asynchronous motor to the gearbox in all axis. Relative rotation of the gearbox to the asynchronous motor round all axis were obtained too. This paper focuses closely on maximal acceleration regime.

Maximal acceleration regime

One of the regime that was measured, was maximal acceleration. This means that the tram accelerated from zero speed as much as possible. In Fig.3 there is shown torque of the traction electromotor during acceleration. It can be seen that the tram started to accelerate from 2nd second with approximate torque 1000 Nm. This acceleration lasted till 10th second, at this time the tram started to break.

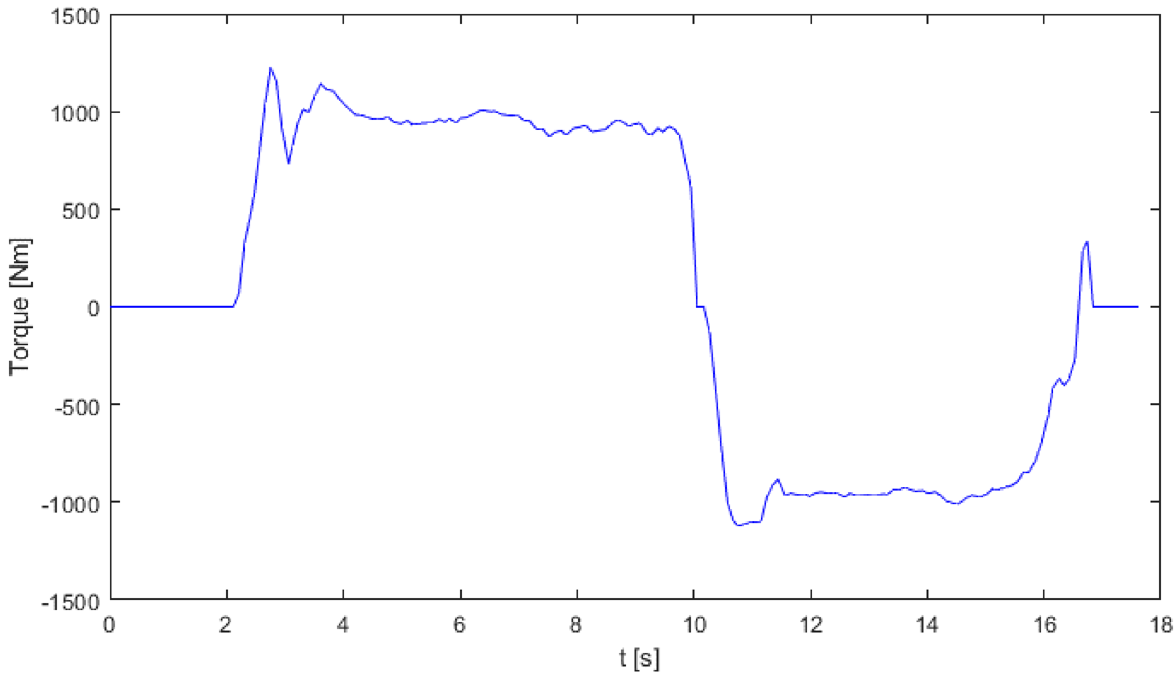

Fig. 1: Torque of traction electromotor during acceleration

In Fig. 4 there is shown relative shift in x-axis. From 2nd second it is seen that shift between the gearbox and the traction electromotor increased. From 10th second, the tram started to break and distance between bodies decreased. The values of relative shifts stayed in tolerance ±1 mm in comparison to zero speed.

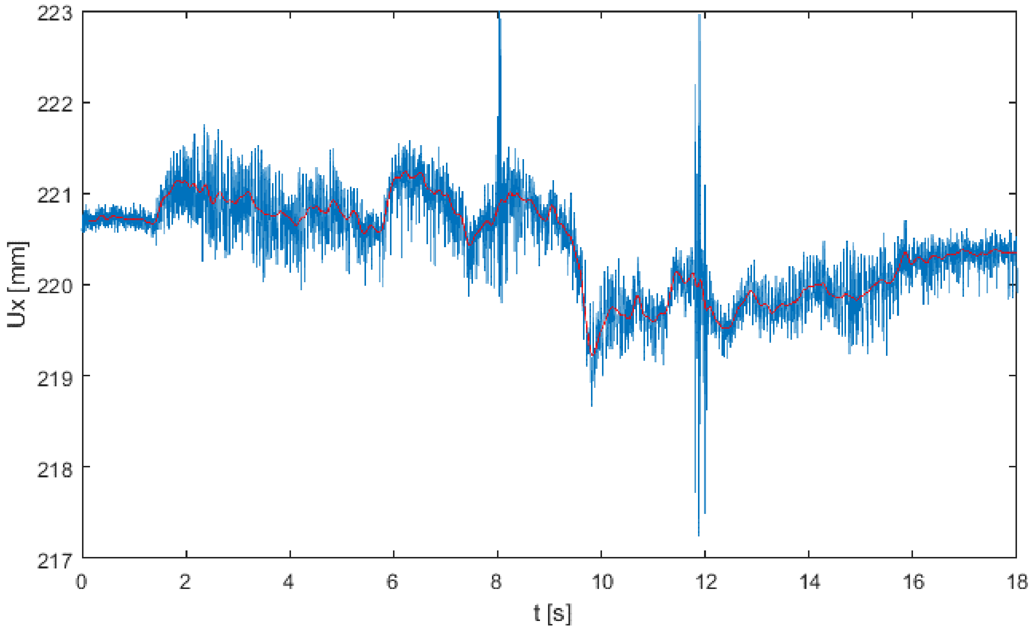

Fig. 2: Relative shift in x-axis

In Fig. 5 there is shown relative shift in y-axis. From 2nd second it is seen that shift between the gearbox and the traction electromotor increased. It is shown that this shift is affected by some oscillations. These oscillations increased during the acceleration and decreased during the breaking. These oscillations are probably caused by suspension of bodies. Traction electromotor is connected to bogie frame and gearbox is embedded to wheelset and its moment's support is catched by hinge connected to bogie frame. Gearbox is a partly-sprung mass and traction electromotor is fully-sprung mass. Total deflection of bodies was lower than ± 1,5 mm in comparison to zero speed.

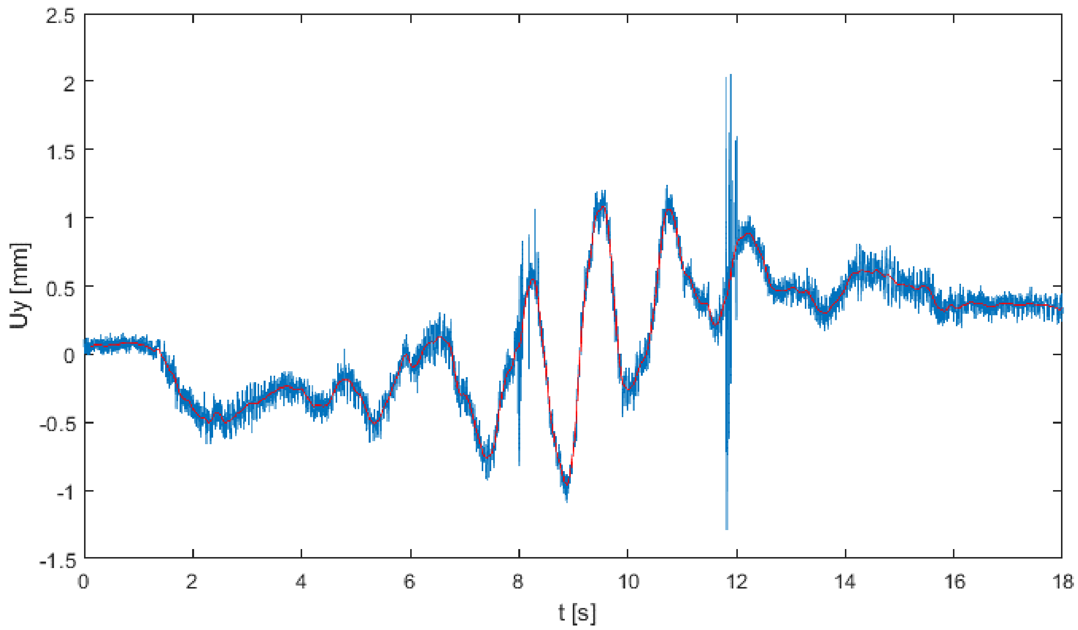

Fig. 3: Relative shift in y-axis

In Fig. 6 there is shown relative shift in z-axis. From 2nd second it is seen that shift between the gearbox and the traction electromotor increased. Deflection of the bodies was lower than ± 1 mm in comparison to zero speed.

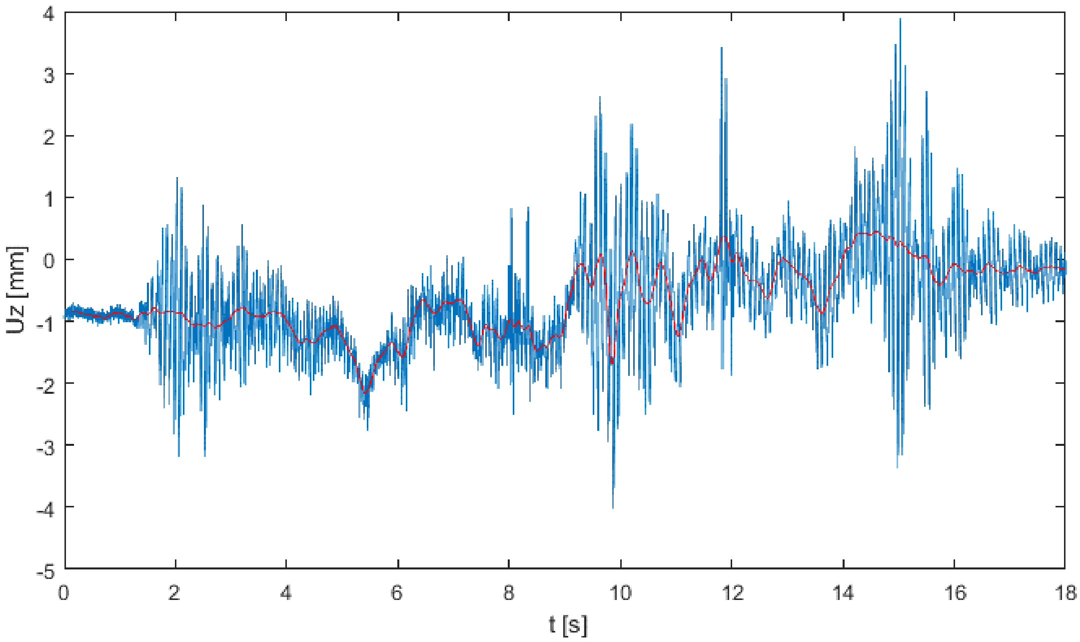

Fig. 4: Relative shift in z-axis

In Fig. 7, 8, 9 there are shown relative rotations round the x, y and z-axis. All these relative rotation between gearbox and traction electromotor have maximal deflection ±10° in comparison to zero speed.

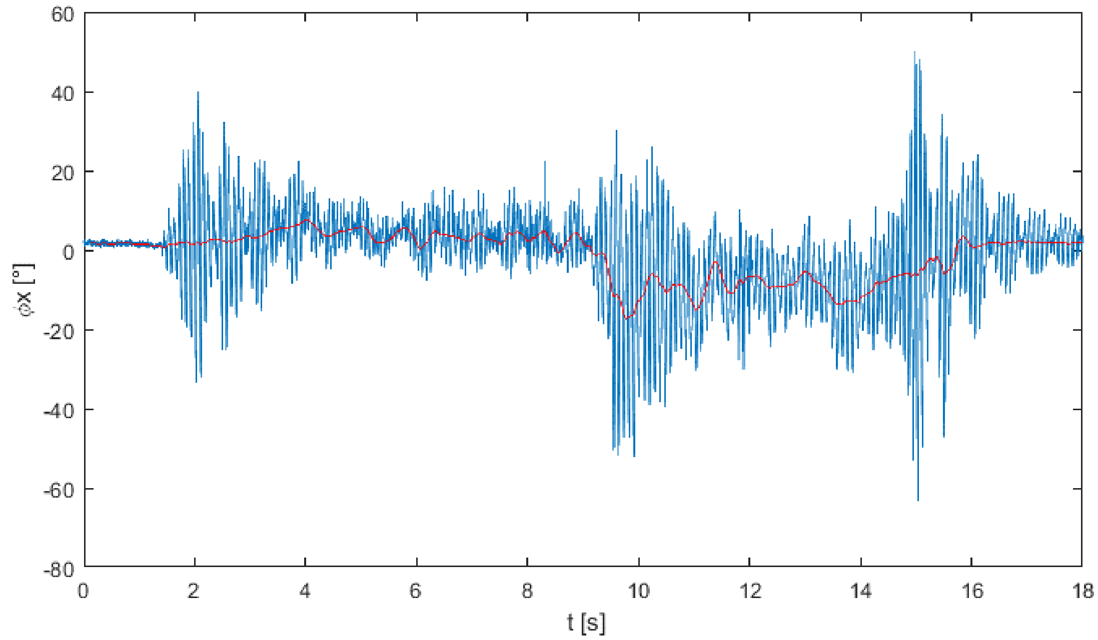

Fig. 7: Relative rotation round the x-axis

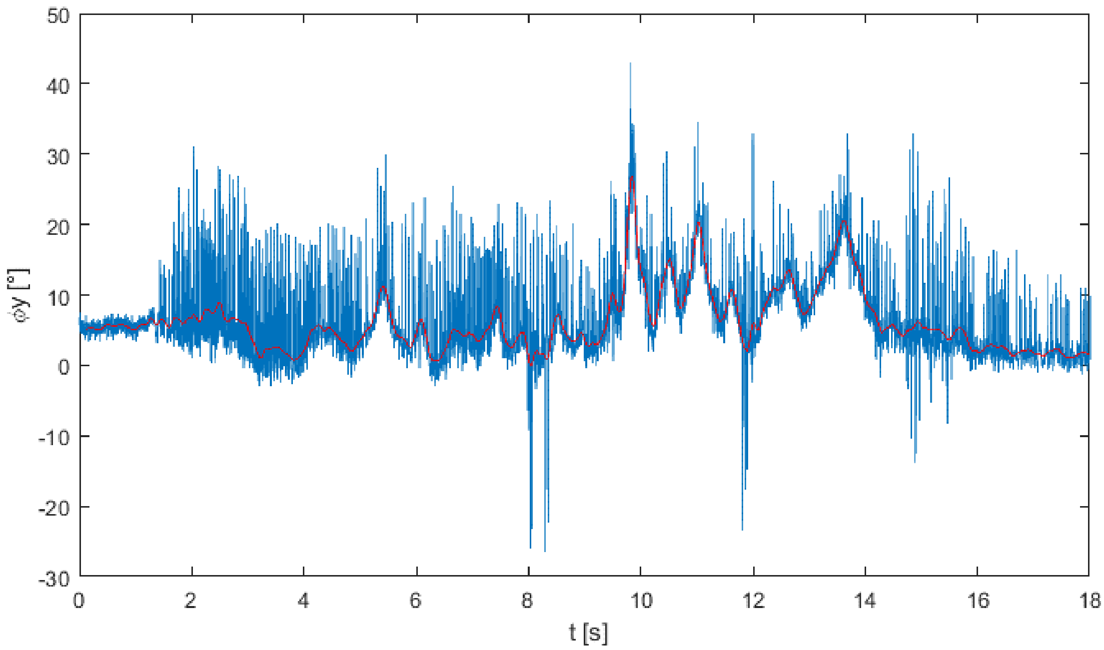

Fig. 8: Relative rotation round the y-axis

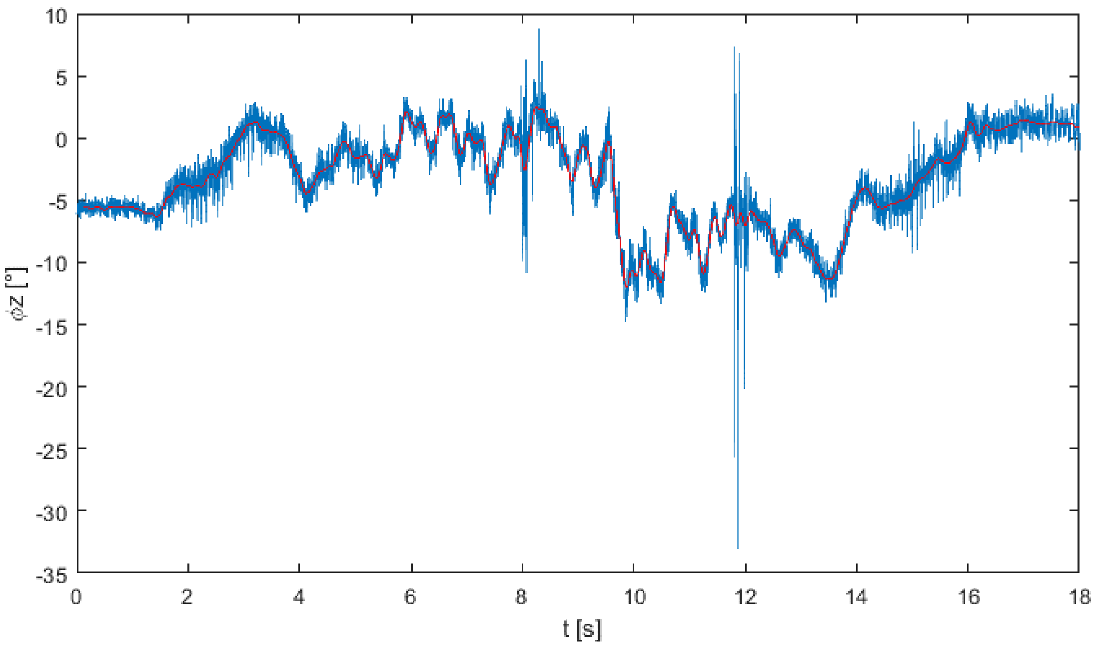

Fig. 9: Relative rotation round the z-axis

Conclusions

Thanks to this optical analysis there were analysed relative shifts of the traction electromotor to the gearbox in x-axis, y-axis, z-axis and relative rotations around x, y and z-axis. All results of the relative shifts had the maximal deflection ±1,5 mm in comparison to zero speed. Thanks to this analysis, there was found that the maximal deflections of the relative rotations are ±10° round all axis. This deflection is probably caused by different suspension of bodies. Traction electromotor is connected to the bogie frame and the gearbox is embedded to the wheelset and its moment's support is catched by hinge connected to bogie frame. It means that the gearbox is a partly-sprung mass and traction electromotor is a fully-sprung mass. The claw coupling that transmits torque from the traction electromotor to the gearbox is designed for relative rotation around 5° round y and z-axis. From these facts a hypothesis can be made. The relative rotation of the gearbox to the motor was higher than the allowed rotation of claw coupling and the coupling could not withstand this motion. In addition to this results were suggested two solutions which could help to remove this problem. Whereas the traction electromotor is fully connected to the bogie frame, the effort was concentrated to the connection of the gearbox. Gearbox is connected to the wheelset and moment's support is catched by hinge. This hinge is imposed in silentblock and the rigidity of this silentblock can be influenced by compression of hinge. If the rigidity of silent is higher, the motions of gearbox could decrease. Second solution is to use a different type of coupling.

References

[1] M. Dub, J. Kolář, F. Lopot, V. Dynybyl, O. Berka, Experimental Analysis of Stress State and Motion of Tram Gearbox Hinge, in: The 52nd International Conference on Experimental Stress Analysis, 2014.

[2] J. Kolář, F. Lopot, M. Dub, Vyhodnocení měření namáhání závěsky u nápravové převodovky tramvaje 14T, Technická zpráva ČVUT FS - U 12 120 - Z 14 - 01, 2014