AN ALTERNATIVE DESIGN OF TESTING BENCH FOR DYNAMIC WHEEL CORNERING FATIGUE TESTS

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Abstract: *Worldwide test laboratories use complex equipment with high level of automated testing processes due to the larger quantity of samples processed. In order to facilitate the testing of products in domestic, accredited test laboratories, the Center for IC Engine and Vehicles of Vinca Institute developed a testing bench adapted to requirements of the domestic producers. This article presents an examination device designed for cornering fatigue testing of wheels in laboratory conditions. Furthermore, this testing bench allows testing of a wide range of elements and systems associated with the wheel, e.g. hubs, bearings, screw connectors, axles etc. Upon construction, the test bench was evaluated through a number of tests of various wheel specimens. The obtained results confirm the pertinence of this method in the development of the vehicle suspension systems.*

Keywords: WHEELS, CORNERING FATIGUE TEST

1. Introduction

Testing of vehicle elements and assemblies is one of the unavoidable stages in the development of automotive industry, whereby this activity is given a special attention. In Şerbia, a number of vehicle elements is produced, among which are wheels, which require verification in terms of meeting the quality, i.e. harmonization with relevant world standards in this field.

Worldwide test laboratories use complex equipment with high level of automated testing processes due to the larger quantity of samples processed. In order to facilitate the testing of products in domestic, accredited test laboratories, the Center for IC Engine and Vehicles of Vinca Institute developed a testing bench adapted to requirements of the domestic producers.

Apart from the aforementioned primary purpose, this testing bench allows testing of a wide range of elements and systems associated with the wheel, e.g. hubs, bearings, screw connectors, axles etc.

Technical solution of this test bench was evaluated through a number of tests of various wheel specimens and obtained results confirm the pertinence of this method in the development of the vehicle suspension systems.

2. About wheel testing

The problem is in what way to maximally speed up the dynamic wheel testing by incurring minimum costs. Solutions are usually sought either in the increase of wheel load or in the frequency of load change. Testing conditions need to be true to realistic exploitation conditions, which imposes certain limitations, especially when the wheel testing is performed with a tire where the overload capabilities are of limited nature. An alternative to this is an increase in the wheel rpm up to velocities of close exploitation maximum, which, when the lateral strength of the wheel is concerned, is most easily achieved by affect of load of centrifugal force. Most often, the wheel axis is placed vertically to reduce the effect of gravity on the elements that transmit the lateral force. One of those solutions, such as the one shown in Figure 1 (CFT-5 testing bench [4]), although it possesses the best characteristics in terms of centrifugal force effect on the wheel load, is still not ideal since the weight of the shaft coupled with additional load (axial load on the wheel) is the cause of deviation from the real conditions when exploiting the wheel.

Fig. 1 *CFT-5 testing bench with a detailed overview of the rotating weight*

When performing wheel testing on commercial vehicles, it is not easy to implement a solution together with a vertically postioned testing bench axis due to high testing installation height complete with all the accompanying effects such as high vibrations, which require massive stands or some other adequate mechanism.

3. Some shared experiences as regards wheel testing

In a number of countries, wheel testing has already been regulated in the adequate standards (such s USA[3], Japan, UK) and as such has mainly been based on the dynamic wheel testing performed either under lateral or radial load conditions. Apart from the abovementioned tests, tests such as torsional strength and testing of resistance to lateral impact are also present.

The stiffness testing by means of radial load is carried out on the wheel on which the recommended tire is mounted and and which rolls on the roller either on the outside or inside, or perhaps on several smaller rollers that simulate a flat surface. The surface on which the wheel is placed must reflect a smooth road as realistically as possible due to reduced deformations of tires. This kind of dynamic testing entails an overload (up to 70%) in the radial direction, which significantly reduces the lifespan of a tire.

Rollers of various diameters are used for wheel testing in commercial vehicles, but the most common value that we come across is d = 1.7m (SAE), which is also common when performing tire testing. In case when the wheel sits on the inside of the roller, diameter of roller is only slightly bigger compared to a wheel diameter.

Stiffness testing through application of lateral force is carried out either with or without a wheel fitted with a tire. When performing tests on a complete wheel, the load is usually achieved by changing a wheel slope compared to its supporting surface, but this is also possible in a number of different ways. Figure 2 shows the ZWARP testing bench of MAKRA company [5] with a variable wheel tilting point that sits on the drum on the inside.

Fig. 2 *ZWARP testing bench by MAKRA company*

Wheel testing without tires is most often used when applying lateral force, for which reason only two types of construction, shown in the Figures 3 and 4 below, are mainly used. The first picture shows a testing bench with a turning wheel attached to the rotating stand. A simulation of the lateral force (torque) is achieved by placing weights or in some other way.

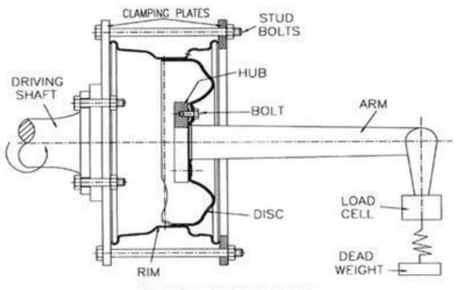

Fig. 3 *Cornering fatigue test*

Figure 4 show a more frequently used testing bench that is based on the principle of using centrifugal force that is generated by rotation of eccentrically arranged mass. The wheel is fixed to the stand, whilst the load change reaches the frequency of up to 100,000 changes per hour. In this way, the testing in question lasts significantly shorter.

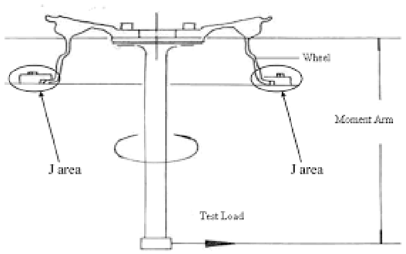

Fig. 4 *Centrifugal force testing*

When testing a wheel with no tire on it, a real-life simulation of workloads on the wheel disk is enabled, but not on the entire wheel. Knowing the fact that fractures occur almost exclusively on the central disk, this method provides a quality assessment in terms of wheel endurance relative to lateral forces.

The determination of the load by applying a bending moment is, for example, performed according to formula below (SAE J267):

$M= L*(r_{st} * \mu + d)* K$

Where:

M – means a bending moment

L– means a vertical wheel load

r_{st} – means a static wheel radius

μ – means an adhesion coefficient (0.7)

K – means a testing velocity coefficient (1,1 – 1,6)

d – means a wheel disk eccentricity

The requirement of the mentioned standard is that cracking may occur, naturally depending on the material used, only after a certain number of cycles (most often 60,000). Allowed variation of the bending moment totals +/- 3%.

4. Explanation of essence in the proposed solution

When we tried to tackle this technical solution, the key task was to make a testing bench for the lateral force of wheels of various dimensions, as well as for other associated elements (hubs, bearings, screws, etc.), with the maximum use of existing assemblies, which proved impossible in commercial solutions. We also decided to implement the lateral force over the course of testing, which is one of the main causes of wheel damage.

The essence of the technical solution is to simplify the testing installation in terms of using universal large mass surcafe for dynamic loads without substantially affecting the variation of a wheel bending moment. A relatively simple calculation suggests that when using the centrifugal force of rotational mass (n = 1440 rpm), we can avoid complicated solutions to testing benches for special purposes with vertical positioning of wheel rotation axis. The analysis further suggests that the following load ratio of weights and centrifugal force is as follows:

$F_g/F_{cf}= m*g/m*r*\omega^2=0.3\%$

Where:

- r=150mm
- $\omega=n*\pi/30=150s^{-1}$

The influence of the weight of other elements in the system (shaft, articulated joint, etc.) can be minimized by an optimal selection of dimensions for each sample being tested, but it is easy to see that the moment change is within the allowed +/- 3% (SAE J267) .

Effectively measured values indicate that deviations in the bending moment occur due to lateral force that appears during the cycle at the level from 1 to 2% (when testing a wheel of a commercial vehicle rim size 16“, therefore the torque variation is 5daNm).

Figure 5 shows a schematic drawing of a testing bench used for examining the impact of the lateral force on the wheel where the rotation axis is set horizontally. The key elements of the testing bench are as follows:

1 – electric motor drive

2 – articulated joint

3 – centrifugal weights ($F=m*r*\omega^2$)

4 – rotary shaft with bearings

5 – wheel stand

6 – tested wheel

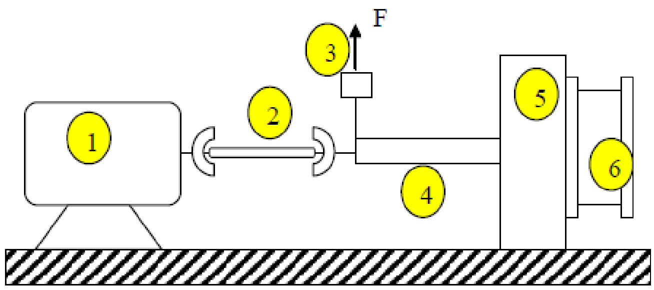

Fig. 5 *Schematic drawing of the test bench*

When appliying solutions based on the use of the effects of the centrifugal force, special attention should be paid to safety systems (see Fig.6) that provide an immediate stoppage in the event of enlargement of diameter in a rotating mass (once the cracking occurs).

Fig. 6 Position of load weights and automatic shutting down system in the event of increased amplitudes of oscilation

5. Detailed description of technical solution

As already mentioned, a universal large mass stand on elastic supports was used (see Fig 7) as a basis for the testing bench. The wheel itself is positioned over an adequate stand, which is intended for a nominal wheel diameter of up to 24 ", attached to six points.

Fig. 7 Testing bench for wheel testing complete with measurement-control unit

Testing device consists of the following below:

- Base structure complete with the supporting elements

The basic construction has a purpose to fix the testing objects (a wheel). At the same time the construction serves as a carrier of motor drive. The very construction is of a dismantling type, therefore it is possible to provide transfer and repositioning onto another location should the need occur.

- Measuring and control equipment

The measurement of the bending moment on the wheel is done by using strain gauges mounted on the rotary shaft (the "half-bridge" circuit), and whose calibration is performed by implementation of HBM U1 force transducer (see Fig. 8) that operates on the weight carrier. The signal is closely monitored, digitized and stored on a portable computer over the course of testing bench operation by means of a SK6 slip-ring and "HPSC 3502" amplifier of carrier frequency.

Fig. 8 Calibration of strain gauges in the shaft using HBM force transducer

Figure 9 shows a typical fracture detected over the course of wheel testing performed on a delivery vehicle of domestic production.

Fig. 9 *Typical fracture on a wheel disk*

6. Conclusion

The described testing bench technical solution with horizontal direction of rotation axis intended for wheel cornering fatigue tests, meets the requirements of the relevant standards and can be successfully used for vehicles and trailers wheel testing. It can also be widely used when testting other wheel elements such as hubs, shafts, screw connectors, etc.

7. References

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