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OPTICAL TYRE TESTING AS A TOLL FOR QUALITY AND DYNAMIC PROPERTIES DETERMINATION

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ABSTRACT

The paper introduces two - cameras optical system, based on stereovision, nowadays used in tyre testing laboratory in dynamic regime. With a help of this non-contact optical system it is possible to determine a sidewall displacement of a tyre at different velocities.

We have tested the same type tyres with different internal construction and defined the best properties with the rolling resistance measurement.

Keywords: tyre, dynamic, displacement, simulation

1. INTRODUCTION

1.1 Tyre testing

The rolling resistance is defined like the energy used up for a length unit of trajectory during moving of tyre. A viscoelasticity effects energy dissipation like heat. Hysteretic losses, resistance of aerodynamics and friction in contact location of road and tyre have influence on a car moving. With decreasing of rolling resistance value is possible to decrease of fuel consumption. Values of rolling resistance are in relation to velocity, loading, temperature and pressure [1].

The rolling resistance of a vehicle on the road is larger than that which can be attributed to the tyre rolling resistance measured on a smooth drum. It is thought that there are three mechanisms by which the road profile roughness causes energy loss in addition to that produced by steady rolling on a smooth surface:

- excitation of vehicle vibration by road roughness leads to energy dissipation in the suspension, particularly in the dampers and through friction in the mechanism,
- dynamic vertical deflection of each tyre causes hysteretic losses in the tyre material and frictional losses in the contact patch due to micro-slip. This force leads to additional deformation of the tyre and consequent energy loss,
- envelopment of road roughness features by the tyres causes hysteretic losses in the tyre material and further frictional losses in the contact patch due to micro-slip.

Rolling resistance is primarily due to viscoelastic heat dissipation in the rubber. Aerodynamic drag, friction in the contact patch, and friction with the rim also contribute to the total rolling resistance [2].

Rolling resistance is affected by many factors, both in tire design and operating conditions: tire mass, rubber formulation, inflation pressure, speed, tire temperature, applied drive torque, surface roughness and steer angle and camber. The rolling resistance power Fx increases with decreasing of the tyre inflation.

1.2 Rolling resistance

The test of rolling resistance is performed at laboratory temperature with defined measurement conditions of a tyre inflation, loading and speed. Before the measurement it is necessary to do a condition (tyre relaxation) for three hours at laboratory temperature. A testing time is given by standard. After condition it is necessary to do tyre stabilization one hour at 120 km/h. To follow is again condition for six hours. In our case the run-in stabilization inflation was 300 kPa and the loading was 7800 N.

The rolling resistance is the power which effects against the movement. This power is expressed by relation

$$F_R = F_x\left(1+\frac{r_d}{R}\right), \qquad (1)$$

where r_d is dynamic radius of tyre and R is the radius of testing drum.

The coefficient of rolling resistance is defined by relation

$$C_x = \frac{F_r}{9{,}81.Q_R}. \qquad (2)$$

This relation presents the ratio of rolling resistance and radial load Q_R. The total rolling resistance ratio is defined by an average value of RR coefficients at different velocity.

The aim of the test is the determination of rolling resistance ratio Cr on a big rolling drum (Fig.1) at 50, 90, 120, 150 and 180 km/h according to standards VW and ISO.

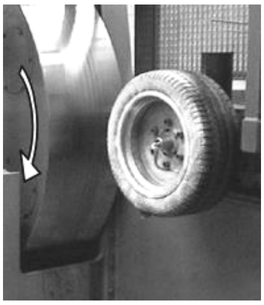

Figure 1. Testing drum and prepared tyre with a pattern

Figure 2. Optical system Aramis

In the year 1999 was introduced a new techniques for surface deformation of objects under temperature, stress and humidity effect [3]. The work [4] illustrates a random pattern for correlation coefficient calculation. The pattern is made by white spray. The displacement gradients are determined by comparison of images created before and after deformation of object. The method presented in [5] show dynamic characteristics of a sidewall optical measurement, which can be used for new tyre type development. The introduction of images processing taken from CCD cameras is very important in this testing area [6].

By using of non-contact optical system Aramis (Fig. 2) it is possible to study tyre behavior at different velocities.

1.3 Steel belt optimization

The steel belts are produced of cord material in a rubber. They are bedded under the acute angle. They limit the function of tyre. We have focused on multi-ply steel belt, which generally optimized directional stability and rolling resistance. It is made of steel cords embedded in rubber compound. The breaker is the most important tyre radial part. It consists of two layers and its steel cords are crossed under 23° angle mostly. They are placed symmetrically to vertical central plane of a tyre (Figure 2). The cords are made of compact steel wires coiled of filaments. We have modified the cords angle – 20, 23, 25 and 27°.

2. THE MEASUREMENT CONDITIONS

2.1. Aramis Measurement

The two cameras system measurement is based on grey scale range differentiation in facets in non – deformed state and deformed state. The facet is a square defined by finite number of pixels. The measured surface has to be mat and it can't be reflected. The starting point from left camera image is automatic searched in the left camera image. The calibration is based on white points scanning of calibration cross or calibration plate. The apparatus consists of two cameras, PC, external trigger and flesh. This system is synchronized with testing machine with a rolling drum. A control is done by software. The axial or radial displacement can be determined with images comparison of reference image done at 10 km/h with other ones at different velocities.

2.2 Rolling resistance measurement

The aim of the test is the determination of rolling resistance ratio Cr on a big rolling drum at 50, 90, 120, 150 and 180 km/h. The test is performed at laboratory temperature with defined measurement conditions of a tyre inflation, loading and speed. Before the measurement it is necessary to do a condition for three hours at laboratory temperature. A testing time is given by standard. After condition it is necessary to do tyre stabilization (100 000 cycles) one hour at 120 km/h. To follow is again condition for six hours. In this case the time step duration of speed is 15 minutes a 50, 90, 120 150 and 180 km/h.

3. RESULTS AND DISCUSSION

We will analyze the changes of tread and sidewall displacement caused by changes of breaker angle of tyres with unchanged other construction or materials.

For the same tyres we tested also sidewall axial displacement changes for the same breaking angles. They were compared with those obtained by ABAQUS simulation. The results are in the Figures 3-6. It is possible to see good agreement among both simulated and measured curves. Differences occur at higher velocities for radial displacement. Nevertheless it is possible to state that the higher the breaker angle the higher the displacement is in axial and direction (the tyre growths).

The last experiment which has been done concerns the rolling resistance as a function of velocity. The experimental Cx versus velocity for different breaker angels is plotted in the

Figure 7. It is possible to see from that the smallest value of rolling resistance for 27° breaker tyre.

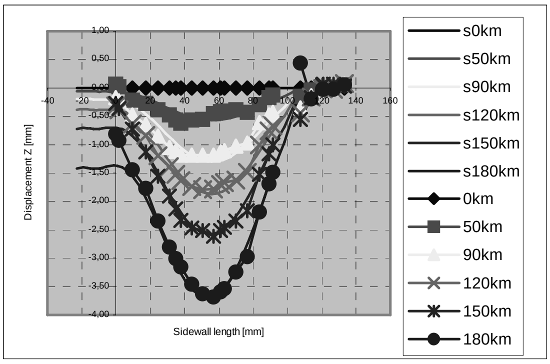

Figure 3. The axial displacement of the sidewall for 20° breaker angle (s-simulation, m- measurement)

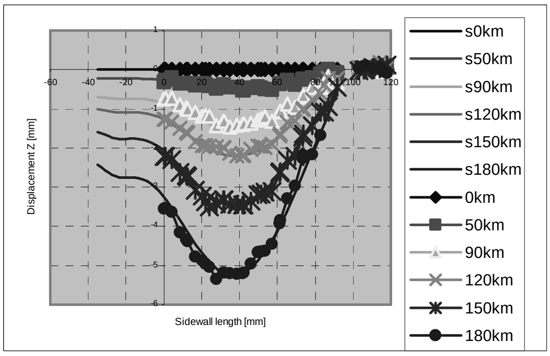

Figure 5. The axial displacement of the sidewall for 25° breaker angle (s-simulation, m- measurement)

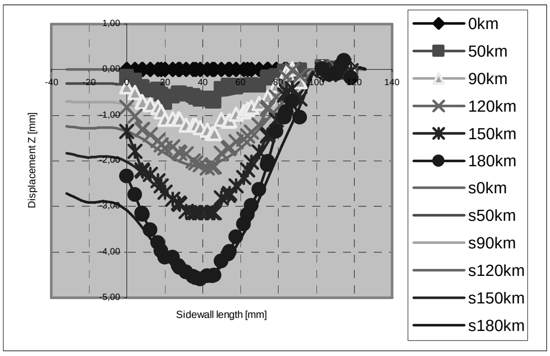

Figure 4. The axial displacement of the sidewall for 23° breaker angle (s-simulation, m- measurement)

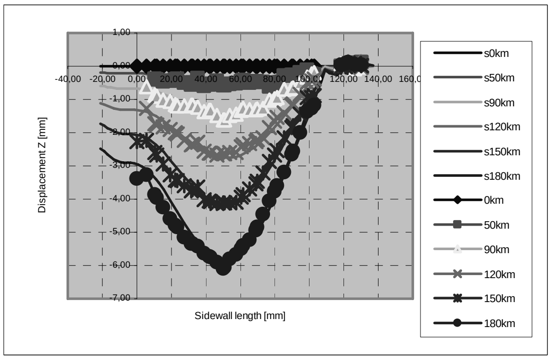

Figure 6. The axial displacement of the sidewall for 27° breaker angle (s-simulation, m- measurement)

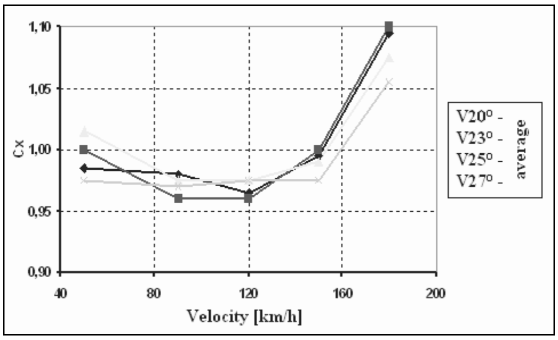

Figure 7. The experimental Cx versus velocity for different breaker angles

4. CONCLUSION

From presented experimental and simulated results we can conclude, that the best and the most expected results shows the tyre with 27° breaker. This confirms the rolling measurement results. The smallest value of rolling resistance coefficient has the same tyre at given conditions. It means for user of that tyre lower fuel consumption of a car and higher comfort.

But we have to remind, that for definitely enouncement of this work summary it is necessary to do other static and dynamic measurements in laboratory or on a road. The suitable could be the tyre with 25°breaker for given requests.

4. REFERENCES

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