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INFLUENCE OF OPERATING PARAMETERS OF THE VEHICLE ON THE ROLLING RESISTANCE SIZE WITH THE VARIABLE DIAMETER OF THE TEST ROLLER

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Abstract:
The paper on the theme "how the tire pressure, vertical load upon wheel, and driving velocity influence the rolling resistance during the measuring cycle on the roller test stand with various roller diameters" is focused on the selected parameters (tire pressure, vertical load upon wheel, and driving speed), which exert, under certain circumstances, more or less significant influence on the rolling resistance at measuring of the performances, consumption rates and/or pollutant emission rates on the road vehicle roller tester. These roller testers, however, may be equipped with rollers differing in diameter, which is the significant parameter that influences the tire rolling resistance and must be taken into account whenever a roller tester is under design.

Key words: *roller tester; rolling resistance; vertical load.*

INTRODUCTION

Road vehicles and their operation have a significant impact on human health. Therefore, vehicles are approved for road safety and environmental friendliness. Both new and in-service vehicles are approved. New vehicles are approved during homologation tests and vehicles in use during inspection tests that replace demanding homologation tests in service.

Roller dynamometers are used for homologation tests of road vehicles and generally for detailed tests. The use of roller dynamometers simulates road traffic in laboratory conditions. Using the dynamometer, the vehicle's operating parameters are then evaluated, such as emissions, both in the form of particulate matter and in the form of gaseous components, and the fuel consumption is evaluated *(Damanik 2018, Kaya 2018, Aydin 2015)*. Tests such as the NEDC test-New European Driving Cycle *(Wu 2019, Mera 2019, Dimitrakopoulos 2019),* WLTP World-Harmonized Light-Vehicle Test Procedure *(Massaguer 2019, Park 2019, Solouk 2019),* JC08 Japan Cycle *(Umihara 2018, Kim 2018, Hagino 2016)* etc.

In order to assess the impact on human health, the technical condition of vehicles in operation is also monitored. As it turned out, it is difficult to describe the technical condition of the vehicle correctly and to identify its shortcomings. Therefore, roller testers designed for inspection measurements are being developed, but also for routine service workplaces.

The design of the roller testers remains essentially the same, and the rollers used, in particular their size, change. The usual diameter of the test roller is between 170 and 250 mm (Maha Consulting, Bosch etc.), there are also test benches with a diameter of 400 mm, and recently test rollers with a small diameter of around 100 mm (Actia) have appeared. The realization of a small roller test room has much less space and thus less demand for input investment. The use of such a wide range of test roller testers means that the tire rolling problem on the test bench rollers is well and correctly solved. In practice, the issue of rolling agricultural tires *(Derafshpour 2019, Farhadi 2018)*, or on rolling flat tires *(Greiner 2018, Lee 2011)* or on large diameter rollers, which are considered straight road simulations for laboratory tests, are often addressed (*Ejmont 2018*). The issue of rolling on small-diameter rollers in vehicle test rooms is not addressed in detail in the literature.
The aim of the paper is to analyze the influence of the size of the rollers of the vehicle roller testers on the rolling resistance, which is significantly reflected in the measurement accuracy. The analysis is

performed on a 165/70 R13 tire at 1.9 bar and the variables are the vertical tire load, the tire peripheral speed, and the test roller diameter.

MATERIALS AND METHODS

The rolling resistance measurements have been taken on test equipment shown in fig. 1. Its main part is the test roller (the diameters used 90, 110, 170, 220, 320 and 400 mm), against which the tire (165/70 R 13) is pressed by action of a hydraulic system. Powered by the frequency converter the electric drive is responsible for the roller rotation speed. The output power values necessary to overcome the rolling resistance have been established as watt-meter readings.

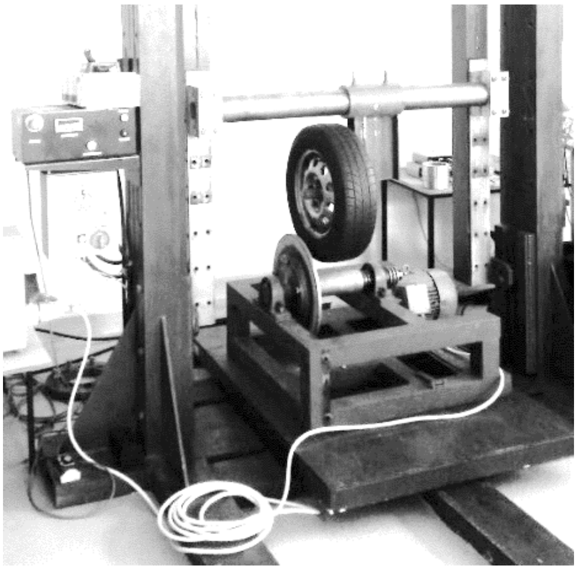

Fig. 1 Testing equipment

Because of the fact that it is the motor input what is actually measured, it is necessary to gradually eliminate other resistances that can influence the measurements, with power losses due to tire air resistance, those attributable to the tire hub bearing, to the roller supporting bearings, to the rotating roller air resistance, to the driving belt slippage, to the motor bearings rolling resistance, to the motor air resistance (ventilation losses), and due to motor electromagnetic efficiency. The output power necessary to overcome the tire-on-roller rolling resistance is the result.

Elimination of these associated losses is realized by measuring the roller without any tire pressed against it and by running out of the separate (not pressed against) tire at such a speed at which the measurements themselves would be taken. Fixed measurement conditions:

- summer tire (165/70 R13) used – temperature range 40–60 °C
- roller diameter (90, 110, 170, 220, 320 and 400 mm),
- vertical load settings (200, 260, 330, 400 kg),
- roller circumferential speed (10, 15, 20, 25, 30, 35, 40, 50, 60, 70 km.h^{-1})
- air pressure is constant inside the tire, not being varied during the measuring session (1.9 bar).

An example of how the resistances can be eliminated is shown in fig. 2. During the measuring session (roller loaded with tire) the output power measurements were taken, shown in utmost grey. The lowest positioned values reflect the situation when the roller alone is in motion, but with no tire pressed against it. They pose most included losses. The lower loss values are attributable to the bearing on which the tire is seated and to the related ventilation losses. They are the values lying just below the zero axis. The black points and the black line represent the rolling resistance resulting values.

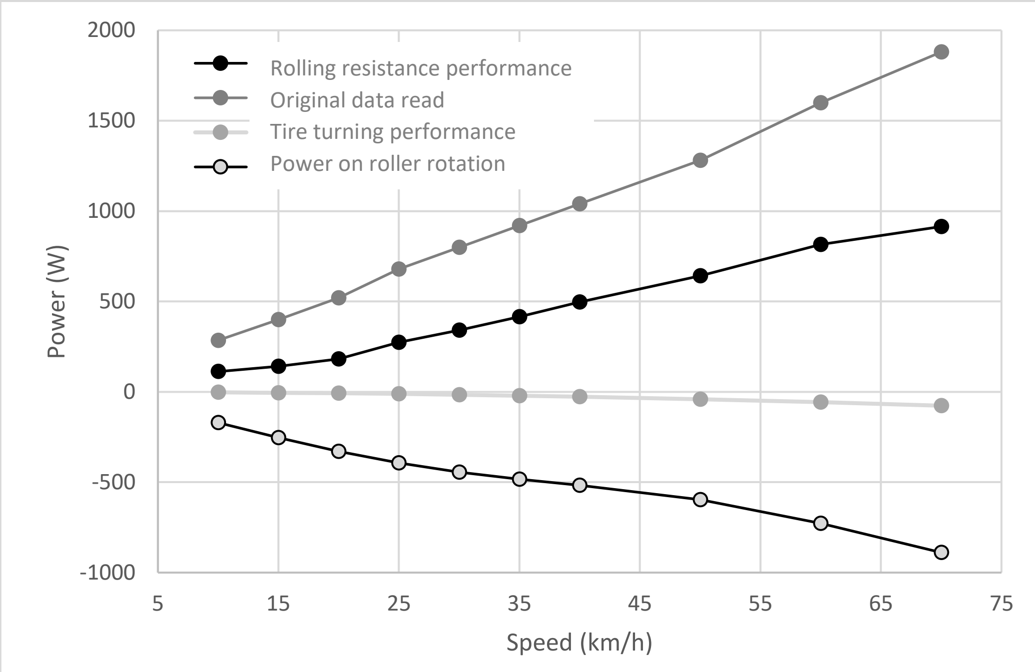

Fig. 2 Example of loss elimination (roller 170 mm, vertical load 205 kg)

RESULTS AND DISCUSION

Examples of the necessary rolling power resistance measurements for the mean vertical load of 205 kg acting upon the 165/70 R13 tire are shown in tab. 1. The watched vertical load upon tire in kg is shown in the first column, the test roller diameter in the second one, and the values of the output power in W, necessary to overcome the rolling resistance, in the following columns as function of speed in km.h^{-1}. The X symbols for the rollers having 90 and 110 mm in diameter at the speeds from 50 to 70 km.h^{-1} imply that no measurements have been taken here. Depending on the test equipment gears used this circumferential speed could not be achieved.

Tab. 1 Example of measured values of required rolling power for medium vertical load 205 kg, tire 165/70 R13

Power W		The circumferential speed of roller									
Load kg	Roller mm	10 km.h^{-1}	15 km.h^{-1}	20 km.h^{-1}	25 km.h^{-1}	30 km.h^{-1}	35 km.h^{-1}	40 km.h^{-1}	50 km.h^{-1}	60 km.h^{-1}	70 km.h^{-1}
203	90	227	296	478	550	622	839	1020	x	x	x
205	110	168	265	359	482	531	581	747	951	x	x
206	170	124	172	227	325	386	451	518	656	867	1010
207	220	119	156	214	252	322	372	445	596	670	862
204	320	101	135	188	230	292	334	386	482	609	738
205	400	103	123	183	231	269	316	364	478	572	646

As plotted against the stand roller diameter, circumferential speed and vertical load upon the 165/70 R13 tire, the curve of the necessary power to overcome the rolling resistance is shown in fig. 3. As widely known, the contribution of the circumferential speed has shown a quite unambiguous manifestation. The higher the tire circumferential speed, the higher is the power necessary to overcome the rolling resistance. As against their larger counterparts, smaller rollers show steeper growth in the power necessary to overcome the rolling resistance, given the growing circumferential speed.

In respect of the dispersal of the power values to overcome the rolling resistance at the individual speeds and vertical loads and with various rollers used the dispersal of the values can be said as lesser at lower circumferential speeds up to 40 km.h^{-1}. Hence the conclusion can be drawn that the roller size exhibits greater influence where higher levels of the test stand roller circumferential speeds are used.

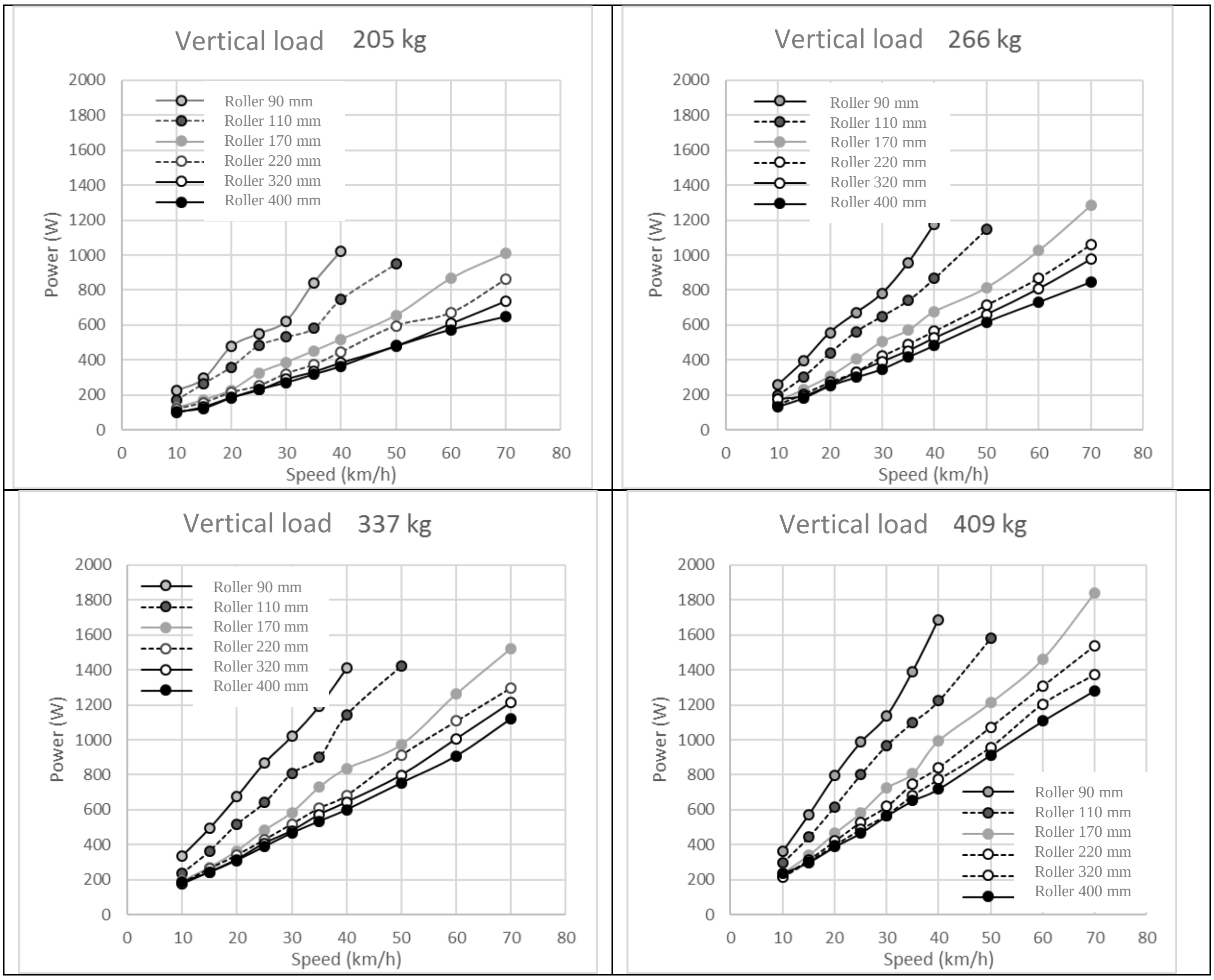

Fig. 3 Rolling resistance performance versus roller diameter, circumferential speed, and 165/70 R13 tire vertical load

For the load influence analysis see fig. 4, showing comparison of the power required to overcome the rolling resistance in per cents, while the 100 % level is to be understood as the measurements with the vertical load of 205 kg. The increase in vertical load to 266 kg can be said to raise the power necessary to overcome the rolling resistance to 128 %, the vertical load increase to 337 kg will raise this necessary power to 159 %, and the vertical load increase to 409 kg will result in this necessary power increase to 191 %.

A look at the dispersal of the power values required to overcome the tire rolling resistance (expressed in % in fig. 4) will reveal greater dispersal of the values at lower circumferential speeds than at higher speeds. Hence, the conclusion can be drawn that the roller diameter is the more significant factor at lower circumferential speed values than at higher ones.

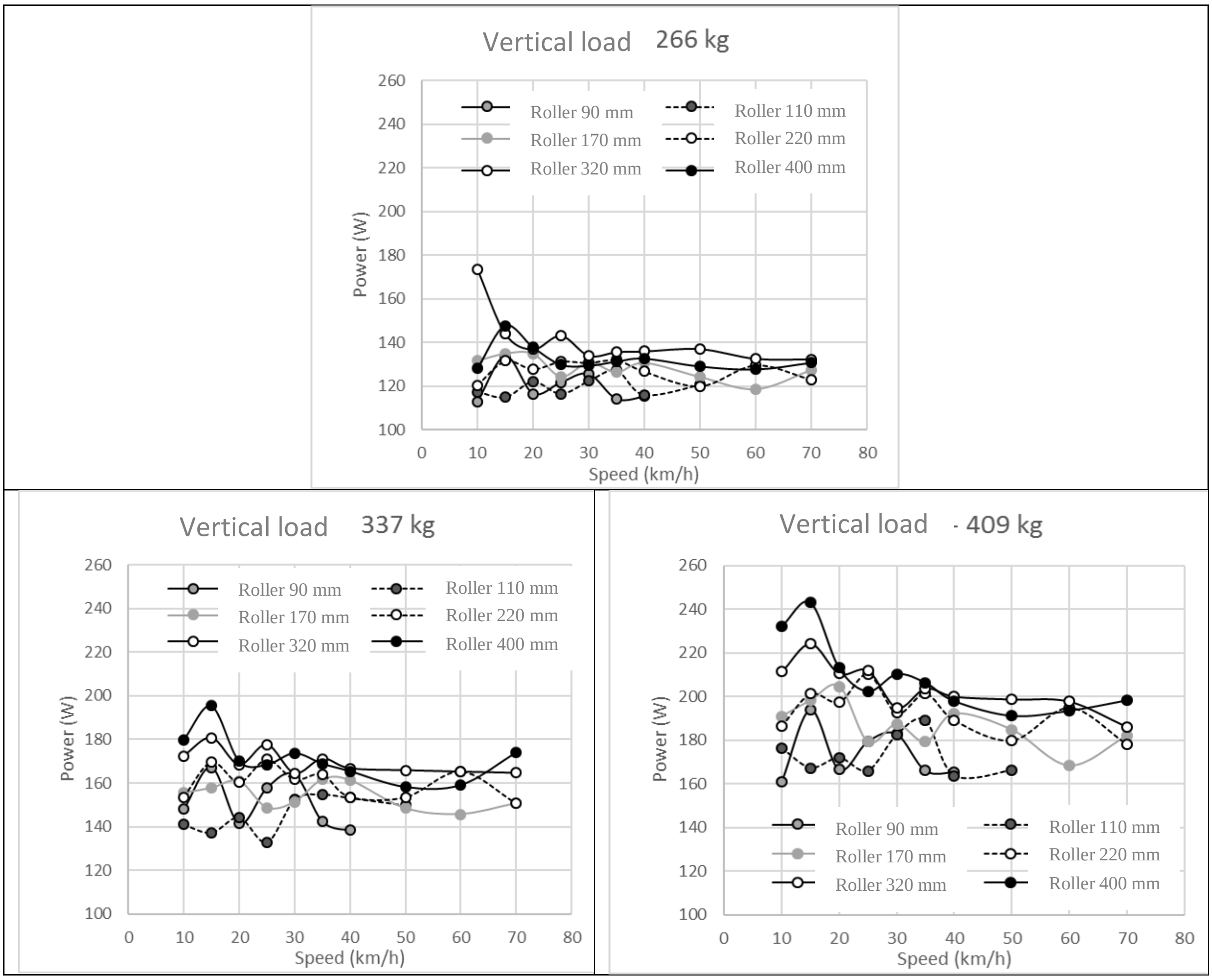

Fig. 4 Percentage comparison of the power needed to overcome the rolling resistance (100 % is the value measured for a vertical load of 205 kg)

For the summarized analysis results see Fig. 5, showing the power values necessary to overcome the rolling resistance with various rollers differing in diameter used, taken relatively to the values obtained on the 400 mm roller. It is obvious from Fig. 5 that the smaller is the roller, the more steeply the required power values grow. This growth is more significant with lesser values of vertical load.

Fig. 5 shows the influence of speed as the value of standard deviation. The greater is the deviation, the more significant is the speed. In this light, the rollers smaller in diameter seem to be less suitable for use on the roller tests stands and this makes correct setting of loading forces more demanding. The power necessary to overcome the rolling resistance with a 200 mm roller will rise by about 20–25 % with a 400mm roller and by about 90–100 % with a 100 mm roller.

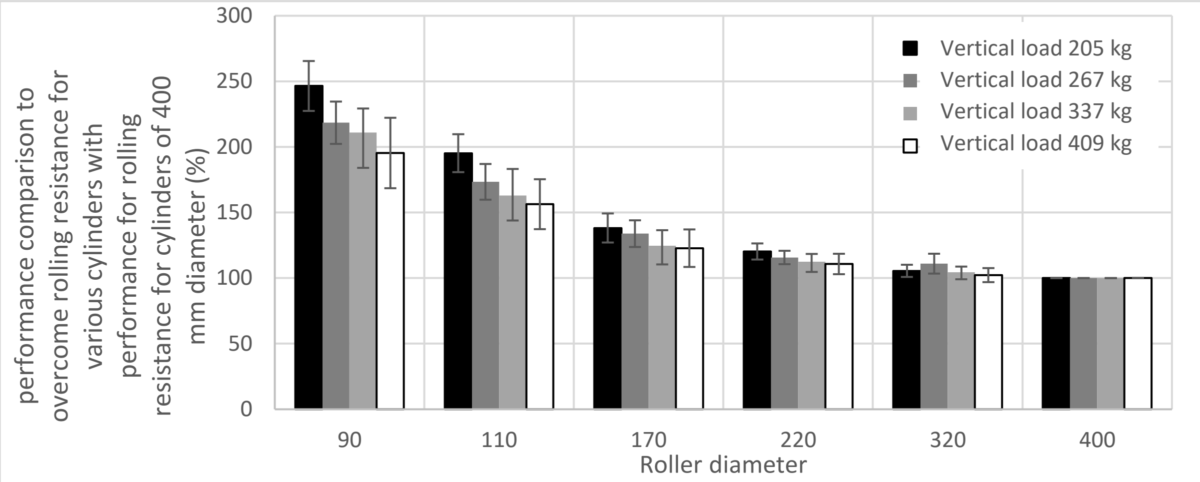

Fig. 5 Overall evaluation of the change in power needed to overcome the rolling resistance at variable speed, vertical load and various roller sizes (%) – 100 % are values for a 400 mm roller diameter.

CONCLUSIONS

Construction of roller test stands is considerably more demanding for investment mainly then in the event of the underground ones. In respect of the maintenance and inspection stations, it would be more interesting to conceive them as of the overground type. This, however, mostly results in use of the rollers having less than obvious diameter cca 200 mm. This change in the roller diameter manifests itself as follows:

- As for the vertical load it can be said that the greater vertical load is used, the greater is the power required to overcome the rolling resistance, growing more rapidly with lesser roller diameters than with the greater ones. Increase in vertical load from 205 to 266 kg will cause 1.3-times growth in power to overcome the rolling resistance. Due to the 205 to 337 kg growth in vertical load the power necessary to overcome the rolling resistance will increase ca 1.6-times, and due to the vertical load increase from 205 to 409 kg the power to overcome the rolling resistance will rise ca 1.9-times.
- Concerning the circumferential speed, it can be stated that the power necessary to overcome the rolling resistance will record an increase. The increase is more significant with the lesser-diameter rollers where broader dispersal of values is moreover achieved.
- As to the roller diameters, it can be stated that the power required to overcome the rolling resistance with a 200 mm roller will rise by about 20–25 % with the 400 mm diameter while with a 100 mm roller the necessary power will increase by 90–100 %, i.e. to a double of its original value.

From the viewpoint of the roller testers the test results yet remain to be transformed as most roller testers work with pair of rollers, not with a single one. This transformation cannot however be generalized otherwise than mathematically when the transformation results strongly depend on diameter of the rollers and their axis-to-axis spacing.

The measurement results show that the use of rollers of small diameter (below 150 mm) for roller testers is possible. A number of publications deal with the problem of rolling tires on the road. However, the publications are focused on large road simulating rollers *(Ejsmont 2019)*, tire wear *(Taryma 2018)* or vehicle emissions issues *(Lee 2018)*. Many authors are engaged in modeling rolling resistance *(Cho 2013, Andersen 2015, Volskaya 2018)*. There is currently no author in the literature available to experimentally determine the tire rolling resistance on rollers.

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