The laboratory station for tyres grip testing on different surfaces

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Abstract. The paper presents the conception of the device for tyre grip testing in the laboratory conditions. The main purpose is to provide a device working in confined spaces, which enables rapid changes of the tested samples of the road surfaces. Among the key assumptions the minimization of the device dimensions and the relative ease of transportation and mobility – the ability to quick assemble and disassemble were also assumed. The main components of the projected workstation includes: the replaceable platform for mounting samples of a road surface, the roller conveyor, the drive of the platform, the wheel mounting assembly and the axial force measuring system. At the design the station a morphological structure method has been used, particular elements have been optimized individually.

1. Introduction
Nowadays in the European Union countries, four types of devices (vehicles) measuring grip factor (traction, friction between tyre and road surface) are used, which differs depending on the method of measurement of traction of tested wheel rolling

• Devices with full wheel lock – e.g. SRT-3 (Skid Resistance Tester). This type of a device carry out the grip measurement of the tested wheel/surface combination in the conditions of the total blockade.

• Devices with constant skid of the wheel – wheel being tested is braked hydraulically and moves relative to the surface with a fixed, known slip, e.g. Griptester used in Norway.

• Devices with variable wheel skid – this group of devices measures friction under conditions of variable skid of the tested wheel. The tested wheel is braked, but not with fixed value of force. The value of the wheel slip is known and may vary, so that these devices can obtain a full characterization of the coefficient of friction. An example of such a device is Norsemeter OSCAR used in Norway.

• Devices with measured wheel positioned angularly corresponding to the direction of movement, allowing measuring not only the longitudinal grip strength, but also cross-grip. The friction coefficient is determined by comparing the lateral force acting on the measured wheel with the static load on the wheel. The measured wheel is not aligned along the direction of movement, it is inclined at a fixed angle, which causes lateral force acting on the wheel, e.g. SCRIM used in Germany.
All of these devices perform measurements on the real road surface, but there is a need for a device capable of measuring these parameters in a laboratory conditions. During the literature review no device suitable for use in the laboratory environment were found. Therefore, it was decided to adapt conception of one of the types of equipment used in road conditions (traction force measuring device via measuring deflected wheel) to the laboratory conditions.

2. Main assumptions
Aim of this study was to develop a device (laboratory station) for measuring the grip of tires on different pavement surfaces. According to the structural assumptions the device should perform measurements in an enclosed room (hall, laboratory). The measurement of the interaction parameters of the pavement surface with the tire is very important because it allows the development of both tires providing better traction, as well as the application of new types of pavement to improve road safety [1].

Working in confined spaces also requires compliance with standards for acceptable noise and emission of substances harmful to health. In the construction of the device the existing standards in the field of tyre grip measuring were taken into account, among others PN-ISO 23671, PN93/C94300/009 and PN-88/C-94300/030.

The laboratory station for tyres grip testing on different surfaces should allow to assess traction of different types of tires on various types of pavement surfaces, so its design should allow easy and quick exchange of tires and pavement samples. Due to the fact that each tire has a different adhesion, weight and other parameters, it cannot be accurately specified what load can occur during the test, the structure of the device should withstand correspondingly higher loads to prevent damage [2].

Another aim was to determine the minimum and maximum of the size of the tire, and thus main dimensions of the device. It was found that the device is capable of carrying out the research of tires for passenger cars in the range from 185/30 X10 X23 to 315/75. The device has been modelled in Autodesk Inventor.

2.1. Design of the laboratory station for measuring the grip of tires on different surfaces
During the construction of such a device, it is advisable to rely on systematic methodology that ensures obtaining the expected results A method of morphological structures have been used to develop the project of the test station, the whole structure have been divided into separate segments which can be individually optimized later Appropriate analysis have been also carried out, using advanced CAD and CAE software (Autodesk Inventor).

During the development of the concept of a device for testing grip of tires on different surfaces main design criteria and assumptions have been formulated:

- minimum dimensions of the device,
- the possibility of assembly and disassembly of the device indoors,
- avoiding excessive noise and releasing of harmful chemicals and fumes during the test,
- the tested wheel is freely turning, it is tilted at an angle relative to the direction of the linear movement performed by the test pavement surface,
- the device must allow changing of the pavement sample surface as easy as possible to be able to run simulations on different surfaces,
- the device should allow mounting of the widest range of the rims used in typical cars.

2.1.1. The concept of the device
The tested wheel is fixed in the holder, mounted on a shaft with appropriate bearing, which is positioned angularly to the moving sample of the pavement. The forces on the bearings of the shaft are dependent on the grip of tested tire. The basic elements of the measuring device are (figure 1): the linear drive unit moving the pavement sample (actuator 1), the pavement sample frame (2) with supporting rollers and its frame, the tested wheel support with force measuring unit (3), and the tested wheel mount (4).
Rectangular pavement sample is mounted in the frame made of angle bars, allowing easy exchange of the sample. The pavement sample surface must be made in the same way for all types of pavements and tires, so that all tests of tyres have been carried out under similar conditions.

![Figure 1. Simplified model of the laboratory station for tyres grip testing.](image)

Pavements samples should be made in such a way as to reflect the specific characteristics of the specific surface, the surface must be flat and positioned evenly, relative to the tested tyre. The minimum dimensions of the pavement sample (and its frame) sufficient for testing are 625 x 1500 mm. The pavement sample is placed in the steel frame and supported by rigid superstructure in order to avoid deformations resulting from the pressure of the tested wheel.

The device support frame have load-bearing rollers mounted, which are necessary to reduce the friction force between the sample surface frame and the main support frame structure, which could distort the results of measurements of friction. Rollers used in the design (RT1-80, manufactured by Europa Systems) come from the belt conveyors used in mining (figure 2), they are characterized by a very simple construction and, above all, very high load carrying capacity, ease of installation and reliability. The rollers will be mounted in a support structure with a length of 3000 mm, sufficient for purpose of testing friction between tyres and pavement surface.

![Figure 2. Half section of the proposed roller.](image)

2.1.2. Linear drive unit moving the pavement sample frame

The double-acting hydraulic actuator has been selected as an element driving frame with pavement sample. Hydraulic drive will allow adjusting the speed by using a flow regulator. Additional advantage of the hydraulic system is the ability to carry very heavy loads and overload, which in determining the
unknown coefficient of friction can be important. In addition, the use of a hydraulic drive advantage is the lack of additional structural elements, like clutches and gears. The power supply of hydraulic system requires the use of noisy pump which should be installed outside of the laboratory. The hydraulic cylinder used in the design should have a pitch ~ 1.5 m, dependent on the length of the carrier path of the sample and the sample pavement frame length.

2.1.3. Tested wheel support unit

This module is a crucial part of the device, because it must ensure the main shaft positioning and bearing with expected accuracy, in the same time allowing measuring of axial and radial forces on bearings, coming from interaction between tested tyre and pavement sample surface. Main shaft is also part, on which tested wheel mount is fixed, carrying load of whole wheel and forces of tyre-pavement contact. The set of sensors measuring force and other parameters must also be installed in the tested wheel support unit, allowing measurements of parameters required in order to calculate friction force. Bearings must withstand variable loads that stems from variable pressure of tested wheel on a moving pavement sample. These loads also depend on the size of the tested wheel. The proposed bearing setting consists of two radial ball bearings and one axial bearing, mounted in the appropriate holders. In the construction of a bearings, angular contact bearing have been abandoned, due to the unbalanced load of bearing which in turn could lead to abnormal pressure on the force sensor measuring the pressure, and erroneous readings.

It is also necessary to ensure the possibility of change the distance from the whole tested wheel support unit to the pavement sample in order to adjust device to the given diameter of the tested wheel. Whole tested wheel support unit will be installed on support frame, allowing adjusting of the position (height).

The main shaft of the device should allow the carrying of loads occurring in the system and has been designed using advanced CAD and CAE (Finite Elements Method - FEM) software (figure 4 and figure 5). The same software was used for parameter selection and verification of bearings and their fittings, and other components.

At the end of the main shaft, tested wheel mount is installed, so the shaft must be appropriately shaped, allowing interfacing with the family of other components. The total length of the shaft equals 830 mm.

The sensor set installed in the tested wheel support unit is intended to provide the ability to measure key test station parameters, such as the axial and diagonal forces in bearings, wheel rotational speed and linear speed of the pavement sample frame.

![Figure 4. The main shaft FEM analysis – the load and FEM mesh.](image)

The pressure (force) values (axial and radial forces) will be measured by the sensors, e.g. Tecsis power converter F12131310436 (measuring range 0…1 kN, measurement accuracy 0.1%, measurement time 2 ms, signal output: voltage 0…10V) [7].

Another value measured to calculate the kinetic friction of the tire on pavement sample is the speed of movement of pavement samples, so it is necessary to use the linear position sensor, allowing calculation of the speed of the pavement sample. Among the available sensors, it was decided to use magnetic linear sensor, e.g. ETMA 1 (Resolution: 0,1 mm (0,025 mm if by reading each front, zero
pulse every 5 mm, repeatability +/- 0.025 mm, output type – line driver/push pull, max speed 4 m/s, magnetic tape EBM L = 0.5 m – 32 m) [8]. This sensor have been chosen because of its high accuracy and, above all, resistance to vibration, much higher than rotary-pulse sensors.

The magnetic linear encoder is composed of diamagnetic sensor and a three-layer magnetic tape which can be fixed on pavement sample frame, allowing direct measurement of pavement sample speed.

![Figure 5](image)

**Figure 5.** Examples of main shaft FEM analysis: the total displacement in all axes, equivalent stress (Von Mises), the tension relative to the XX axis.

### 2.1.4. Tested wheel mount

A wheel (tyre with rim) is mounted on the main shaft, set angularly relative to the direction of movement of the pavement sample. It is important that tested wheel mount should assure the lack of slipping between the tested wheel and shaft, and its operation at a constant angle. In addition, mounting and shaft, which is mounted on the wheel must be strong enough to move the load acting on them. In addition, tested wheel mount and shaft, on which this mount is fixed, must be strong enough to endure the load acting on them.

Tested wheel mount will be installed on the main shaft extension.

Interface allowing fixing the tested wheel to the shaft must be made in such a way as to allow mounting of wheel rims of different diameters of the bore, so that there will be no need to provide different adapters for each tyre/rim size. The solution to this problem would be fixing the rim using the central clamp on the cone.

Examples of such mountings used in wheel balancing machines, are depicted in the figure 6.

![Figure 6](image)

**Figure 6.** Two versions of the wheel mount: with truncated centering cone, and with centering disc.
3. Conclusions
Within the work carried out, device measuring the friction and adhesion of the tire in different conditions in the enclosed laboratory room have been designed, based on the concept of the design of one of the devices intended to conduct such tests in the real road conditions (group of devices with measure parameters of wheel positioned angularly corresponding to the direction of movement). The morphological structure method has been used to design the test station, the whole structure is divided into separate segments, which have been individually optimized. The dimensions of the device were chosen in such a way as to allow testing of all the typical sizes of tyres used for passenger cars. In order to test tyres with different pavements, it was decided to design the frame that allows installation of samples of different pavement surfaces. Pavement sample frame moves along main support frame with rollers. To move the sample it was decided to use a double acting hydraulic actuator that provides force sufficient to move the sample and to overcome the friction of the tyre. The last important part of the laboratory station is a tested wheel support unit with sensors, allowing measurement of forces and speed, necessary to calculate friction between tyre and pavement surface.

Strength calculations, support reactions and stress analysis had been carried out in Autodesk Inventor, and indicated the proper selection of the construction parameters.

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