An Evolved Version of the British Pendulum Tester for the Experimental Investigation of Contact Between Tire Tread and Rough Surfaces

Vincenzo Ciaravola, Flavio Farroni, Gaetano Fortunato, Michele Russo, Riccardo Russo, Aleksandr Sakhnevych, Francesco Timpone

***Abstract*— This paper deals with the experimental investigation about the sliding contact between tire tread and rough surfaces. To build and to validate reliable tire dynamical behaviour models it is fundamental the knowledge of the local grip in each point of the contact patch since in the contact patch points different conditions arise because of contact pressure, sliding speed, temperature, etc.**

In the paper after a brief description of the different methods usually adopted to experimentally test the tires with this aim, a new test machine, developed starting from a British pendulum at the Technical Centre Europe Bridgestone, as machine for tribological tests on rubber specimens in sliding contact with rough surface is presented. The scheme of the testing machine and the adopted measurement instruments are illustrated, together with the results of a typical test and the possible interpretations of the obtained results.

***Index Terms*— Friction testing, Grip measurement, Surface roughness, Viscoelasticity, Tire interaction.**

I. Introduction

THE knowledge of the local grip in each point of the contact patch is particularly relevant in the study of models aimed to describe tire dynamical behavior, since, in the contact patch points, different conditions arise because of contact pressure, sliding speed, temperature, etc.

As well as the knowledge of the frictional forces arising at the interface between two materials plays a key role in different applications [1], [2], [3], [4], [5].

In recent years, models to study local interaction able to provide an increasingly accurate description of the tire-road tangential interaction taking into account various effects (thermal, frequency, roughness, compounds, etc.) have been developed.

In this ambit is essential the possibility to use models for numerical simulation specifically made for predictive purposes, whose parameters require a prior identification based on experimental data.

An exhaustive analysis of the most widespread theoretical models emerged in recent years is beyond the scope of this work, but just the most common models will be mentioned specifying that they can be subdivided in empirical [6] and theoretical-numerical [7], [8].

Also the authors of the present paper have developed some theoretical models [9], [10], [11], [12] which, like all theoretical models, require the execution of a series of experimental tests for their validation [13].

In recent decades, to validate and/or to tune theoretical models, aimed to compare performances between different tires, built by various researchers together with the manufacturers, several methods for testing the tires have been developed. In particular, phenomena related to the interaction between tire and road are investigated through tests both on tires, and on tread elements, as summarized in Fig. 1.

The tests on tires are carried out both on road (outdoor) and on special test benches (indoor). The purposes of this type of tests are mainly estimation of: friction / adhesion, wear, noise / comfort. With reference to road tests, they can be executed both instrumenting the vehicle [14], both pulling an instrumented specific trailer on which the tire under test is arranged [15].

For bench testing specific machines, in which the tire is coupled to a rotating drum or to a belt running between two rollers, are used [16], [17].

In both types of tests on tires, outdoor and indoor, depending on the purpose, suitable "wheel patterns" are established and performances are evaluated by comparing the results provided by the different types of tested tires. When the tribological detail of interaction between rubber and asphalt has to be deepen, tests will be carried on tread

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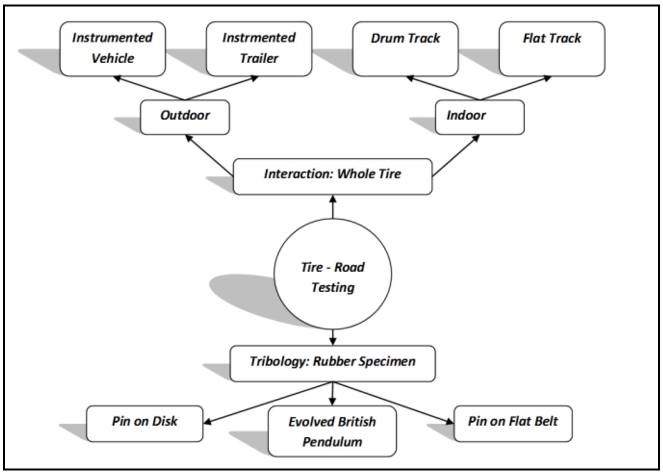

Fig. 1. Several approaches to tire-road testing.

elements sliding on different surfaces. These tribological tests are mainly aimed to the estimation of the friction coefficient, of the wear mechanisms and to the analysis of the thermal behaviour.

The most widespread machines for testing tire specimens are of the pin on disk type [18], [19] in which the specimen of the rubber under investigation is approached to a rotating disc coated with different surfaces. In literature it is possible to find also descriptions of machines for tribological tests constituted by a specimen mounted approached to a tape or to a surface in translational motion [20], [21], [22].

Another tribological test device, developed mainly to characterize the road asphalts rather than the tires, is the so-called "British pendulum”. In this type of testing machine a rubber specimen mounted at the end of a pendulum slides on the testing asphalt when the pendulum is left free to oscillate from a given angular position. The altitude of ascent of the pendulum after sliding characterizes the energy lost during the contact phase and therefore the "goodness" of the asphalt [23].

In this paper is discussed the possibility to use a device developed starting from a British pendulum at the Technical Centre Europe Bridgestone, as machine for tribological tests on rubber specimens.

II. Description Of The Device - Structure And Sensors

The device, specifically developed to measure sliding friction between tire tread and road surfaces is a modified version of the classical BPT (British Pendulum Tester) [24] (Fig. 2). It is equipped, differently from the original one, with two estensimetric load cells, able to measure tangential and normal contact forces arising at the interface between the tread specimen and the ground and with an encoder installed in the revolute joint to measure the angular speed of the arm.

Such innovative device has been designed in order to determine the friction coefficient both in dry and wet conditions, adding further acquired data about the contact between the tested bodies. The commonly considered difference between the starting and the final potential energy, correlated to the position of a mobile index that represents the height difference of the device sliding

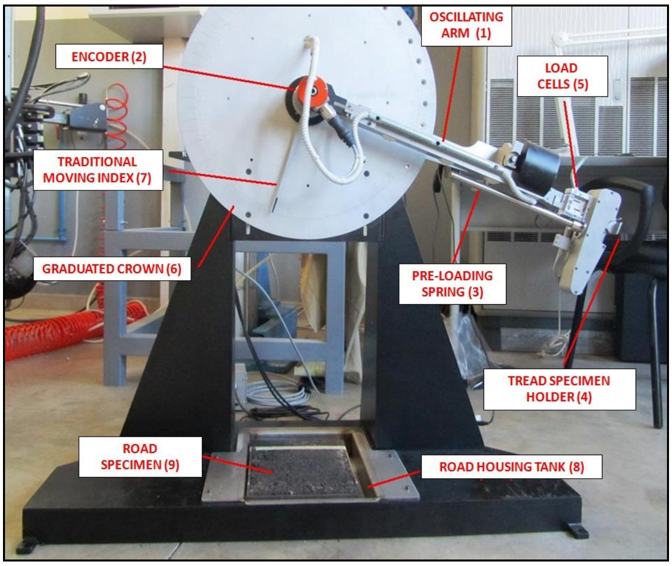

Fig. 2. The British Pendulum - evo friction tester.

extremity does not provide sufficient information about the complex phenomena involved in tire/road interaction.

In detail, the device, called Britush Pendulum - evo (BP-evo), is composed by a 682 mm long oscillating arm (1) linked to a 7.7 kg mass and hinged on a metal framework by a hub equipping an encoder (2). On the opposite side of the arm, close to a sort of "foot" containing a pre-loading spring (3) and a levers system linked to a tread specimen holder (4), the load cells (5) are installed. The framework is covered by a graduated crown (6) on which a moving index

Fig. 3. Detail of the levers system aimed to set tread contact pressure keeping the specimen in contact with the road by means of an elastic force exerted by the traction air spring housed in parallel to the arm (visible in the right figure).

(7) points, after each test, to the final angular position reached by the arm. In the base platform a tank (8) for the

Fig. 4. (left) The equipped load cells.
Fig. 5. (right) The equipped encoder.

road specimen (9) housing has been placed. Particular attention is dedicated to the system composed by levers and pre-loading spring, whose stiffness is responsible of the contact pressure reached at tread/road interface (Fig. 3).

Fig. 4 shows the pair of load cells installed along the arm in order to measure the tangential and the normal contact forces. Both cells have a rated output of 1000 N. Fig. 5 shows the optical encoder that measures the angular velocity of the arm. The measurement signals from the three instruments are acquired by a A/D board and processed in Matlab environment in order to convert them respectively in Newton and in rad/s.

III. Tread And Road Surfaces

A. Tire Tread Specimens

The experimental campaign described in the paper has been carried out on particular tread specimens obtained from three different SB rubber, 5 mm thick, slabs (Fig. 6), provided by Bridgestone Technical Center Europe.

The three slabs have been chosen with the aim to represent three very different compounds as regards their optimal thermal working ranges. In particular, at ambient

Fig. 6. The tire tread slabs.

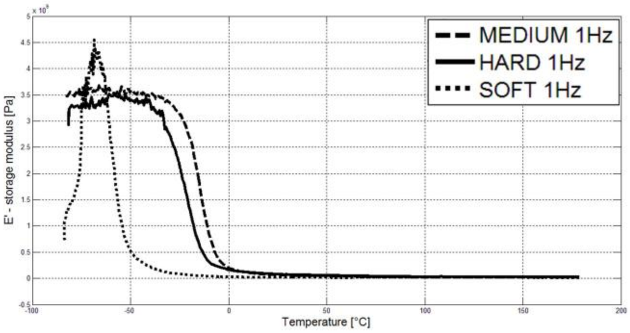

Fig. 7a. Storage Moduli of the tire tread slabs.

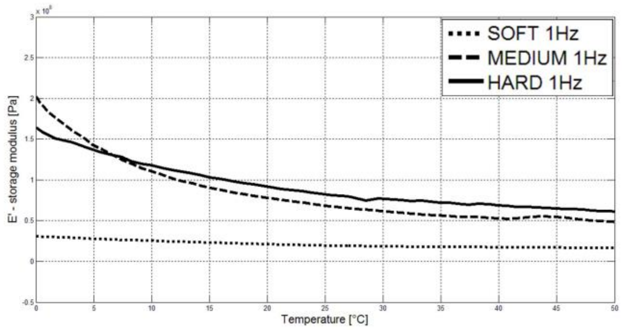

Fig. 7b. Enlargement of the previous figure 7a in the temperature range [0, 50] °C.

temperature they show a qualitative behaviour, as concerns the tactile perception of their hardness, able to assign them the indicative names of "hard", "medium" and "soft" compound. More precisely, in a rigorous definition, the compounds are characterized by marked differences in their glassy transition temperature Tg [25], evident in the diagrams showing their storage moduli and tan(δ) (Fig. 7 and 8), obtained by means of dynamic mechanic analysis (DMA) test [26] performed at 1 Hz and from -80 to 180 °C.

The SB specimens have been obtained cutting away 21 x 24 mm rectangles from the three different slabs, keeping their same thickness (Fig. 9a). The rectangles are glued to the tread specimens holder by means of an ethyl-cyanoacrylate glue being careful that the specimen leading edge is aligned to the specimen holder one (Fig. 9b), in order to guarantee the identical geometrical conditions for each test.

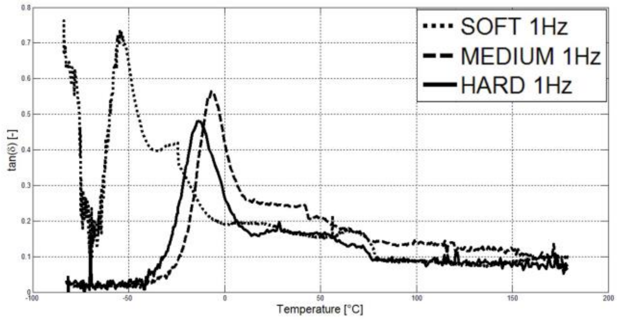

Fig. 8. Tan(δ) of the tire tread slabs.

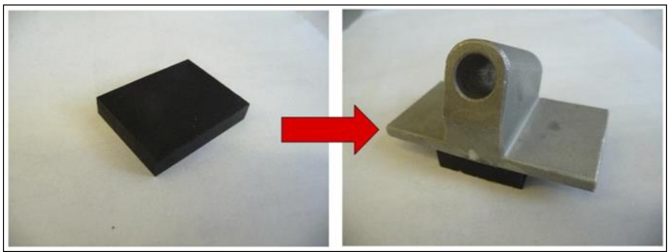

Fig. 9a. (left) A generic SB tread specimen after the cutting from its slab.
Fig. 9b. (right) Final setting of the couple specimen + specimen holder

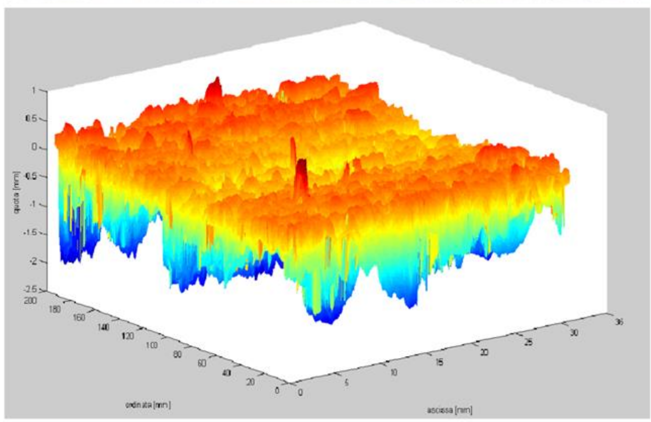

Fig. 10a. (top) The "closed" german asphalt road specimen (NEW GA).
Fig. 10b. (bottom) A 3D laser scan of the NEW GA road

B. Road Specimens

The experimental campaign has been carried out over three different countersurfaces:

- A brand new German Asphalt [27] (Fig. 10), identified by "NEW GA" code, whose surface is substantially "closed", i.e. lacking of the empty spaces due to the removal of bitumen consequent to wear. This asphalt is expected to exhibit higher values of the friction coefficient, both for better chemical attitude with SB polymers (friction adhesive component [8], [28]) and for a good indentation level due to asperities penetration into rubber tread (friction hysteretic component [8], [28]).

- A worn German Asphalt (Fig. 11), identified by "OLD GA" code, whose surface is "open", in which the bitumen has been removed. This asphalt is expected to exhibit lower values of the friction coefficient.

- A graphite surface (Fig. 12) employed with the aim to adopt a surface with a very low macro-roughness, in order to observe the effect of the only micro-roughness scale in the contact phenomena, highlighting the adhesive component of the friction coefficient [18].

A 3D laser scan device has allowed to acquire the profile of the german asphalt surfaces, analyzing it in order to estimate the Ra and λ roughness indices [29] for the road specimens. As regards graphite surface, having the 3D scan an unsatisfactory resolution, a contact rugosimeter has been employed, providing the only Ra measurement. The results of the profile data analyses are summarized as follows:

	NEW GA	OLD GA	GRAPHITE
R_a (mm)	0.2	0.8	0.0019
λ (mm)	5.1	9.9	-

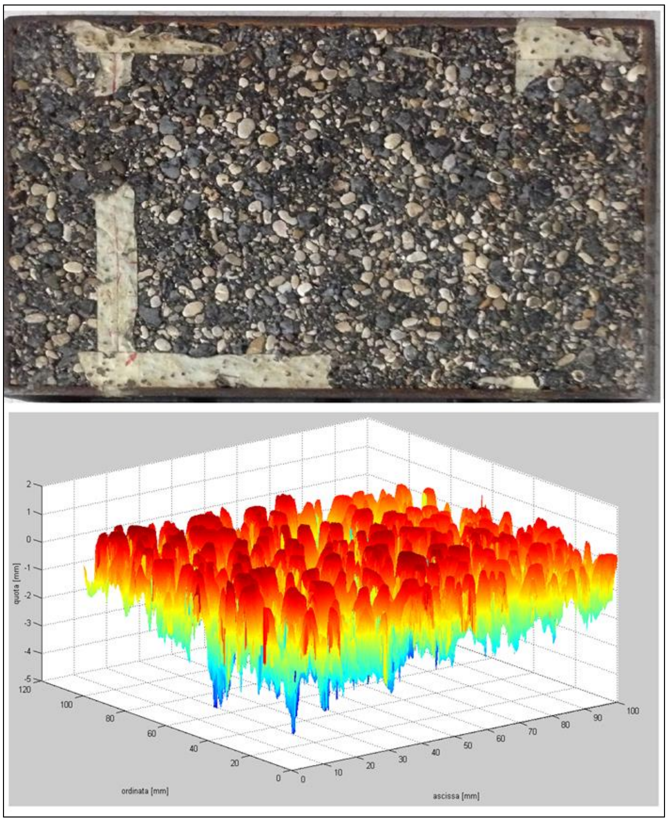

Fig. 11a. (top) The "open" german asphalt road specimen (OLD GA).
Fig. 11b. (bottom) A 3D laser scan of the OLD GA road.

Fig. 12. The graphite surface, characterized by the sole micro-roughness scale.

IV. Testing Procedure And Data Processing

After the attachment of the tread specimen on the specimen holder, the road surface is placed in the specific housing tank and the bench is calibrated, with the aim to remove the eventual load cells offsets and to set the length of the contact zone during the sliding of the tread over the countersurface. In order to set such length equal to the nominal value of 50 mm, the height of the joint of the oscillating arm can be varied by means of an adjustment mechanism linking the circular framework to a threaded rod (Fig. 13), which has been designed and placed on back.

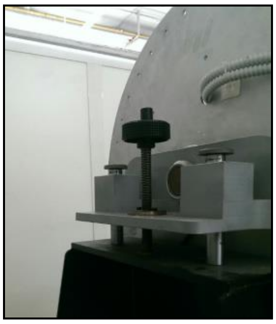

Fig. 13. The mechanism for the regulation of the oscillating arm height.

Two important phenomena have to be taken into account during the experimental sessions, in order to keep the working parameters and the boundary operative conditions as most constant as possible: the tread specimens wear and the "rubberization" of the road, both consequential to the progressive deposition of SB particles due to sliding contact with friction. In order to limit the influence of such phenomena, for each set of testing conditions a sequence of 20 oscillations is acquired and between each sequence the road surface is cleaned by means of a metal brush. The useful life of the tire specimen is defined observing the repeatability of the results of each sequence, which, to be considered acceptable, must be characterized by a standard deviation lower than 5 %.

The preliminary test plan is structured as follows:

- 6 different sliding speeds Vs, depending on 6 different starting angles θ of the oscillating arm (an angle of 0° corresponds to an horizontal starting position):

Vs ≈ [0.50 - 0.85 - 1.15 - 1.50 - 2.00 - 2.20] m/s, measured as the average speeds during the sliding phase and respectively obtained from [85 - 80 - 75 - 70 - 60 - 50] ° starting angles θ.

- 3 different starting tread temperatures T, reached by means of an industrial phon and measured by an infrared pyrometer:

T ≈ [25 - 65 - 100] °C.

• 3 different contact pressures p, obtained employing different air springs and measured as the average load during the sliding phase applied on the nominal specimen area:

p ≈ [50 - 150 - 250] kPa.

Each tread specimen is tested following the described plan on each road surface, acquiring the time histories of the arm angular speed, converted in tangential sliding speed, and of the tangential and normal forces, measured by the load cells (Fig. 14).

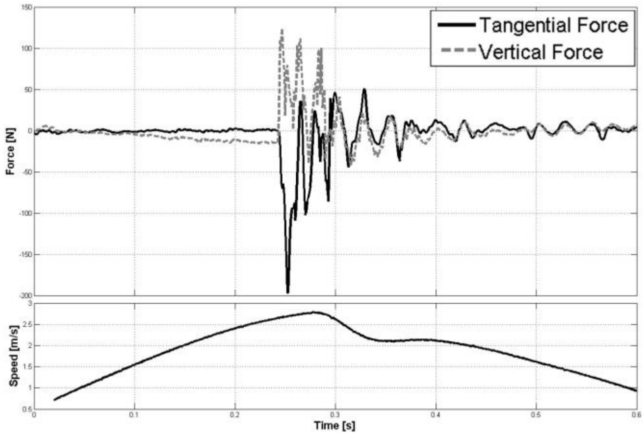

Fig. 14. An example of the acquired data, as plotted in the test panel: on the top, the tangential load and the vertical load, on the bottom, the specimen tangential speed for a medium compound on a NEW GA road under a 150 kPa spring preload.

A specifically developed processing algorithm provides an estimation of the friction coefficient considering the acquired points in the neighborhood of the normal force maximum value, representative of the leading edge contact and of the subsequent initial sliding phase of the specimen. Only the initial phase is analysed because, as showed in Fig. 14, the contact between the bodies generates an unavoidable damped oscillation that causes friction misestimations, kept consequently out of the analyses.

The friction coefficient for each set of testing conditions is the average of the 20 repeated oscillations. Plotting the results as a function of the sliding speed, as showed in Fig. 15, allows to observe the typical friction characteristic curves, highlighting (choosing proper diagrams) the dependences from working variables as temperature, contact pressure and speed and from compounds and road characteristics.

How observable in Fig. 15, the results are physically in good agreement with the theoretical expectations. In particular, the middle plots highlight the compounds dependence on temperature and, as expected thanks to the analysis of the specimens characteristics (Fig. 8), soft compound exhibits lower friction at increasing temperature, due to its low tan(δ) in such conditions and to its lower glassy transition temperature if compared to the other two specimens. Moreover, at increasing temperature, medium compound exhibits higher friction than hard one, mainly due to its higher tan(δ).

As concerns the bottom plots of Fig. 15, it is interesting to notice the high performance of soft compound on graphite; such surface, because of its low roughness, is able to highlight the adhesive part of friction, strongly correlated to the inverse of E' rubber modulus. Being soft compound characterized by low E' (Fig. 7) and consequently high adhesion, its performance over graphite is fully physically agreeable. On the opposite, the higher friction at low speed and temperature of hard compound, compared with medium one, should be due to their E' inversion at about 7°C (Fig. 7), that, shifted by means of the WLF law [25], allows to explain the reciprocal relationship in terms of performance on the different surfaces.

This is a preliminary, but complete, experimental campaign and the discussed physical results show the potentiality of the presented device to conduct more extended campaigns on more compounds and more surfaces, this will be done in the following stages of the activity with the support of the Bridgestone Technical Centre Europe.

V. Conclusions and Further Developments

A new test machine devoted to lead tribological analysis on samples of rubber in sliding contact with the asphalt road has been presented.

The test machine is inspired by the "British Pendulum", but, in addition to the possibility to analyse and discriminate different types of asphalt in both dry and wet conditions, also allows to evaluate the frictional performance for different rubbers, varying the contact conditions: pressures, sliding speeds, temperatures, etc.

To show the potential of the presented test machine the results of a series of measurements have been shown. The tests have been carried out with three different types of SB rubber compounds, interfaced with three different types of contersurface, at three different temperatures, with three different contact pressures and six different sliding speeds.

The preliminary presented results are in good agreement with theoretical expectations and with the results provided by other standard testing machines. Also the repeatability of the results appears to be high.

So it is possible to conclude that the test machine can be used to conduct a wide test campaign by extending the number of testing compounds, of contersurfaces, the range of variability of the control parameters, such as contact pressure and sliding velocity, allowing to acquire fundamental information concerning the comprehension of the phenomena involved in the field of sliding contact between deformable bodies and rigid random surfaces.

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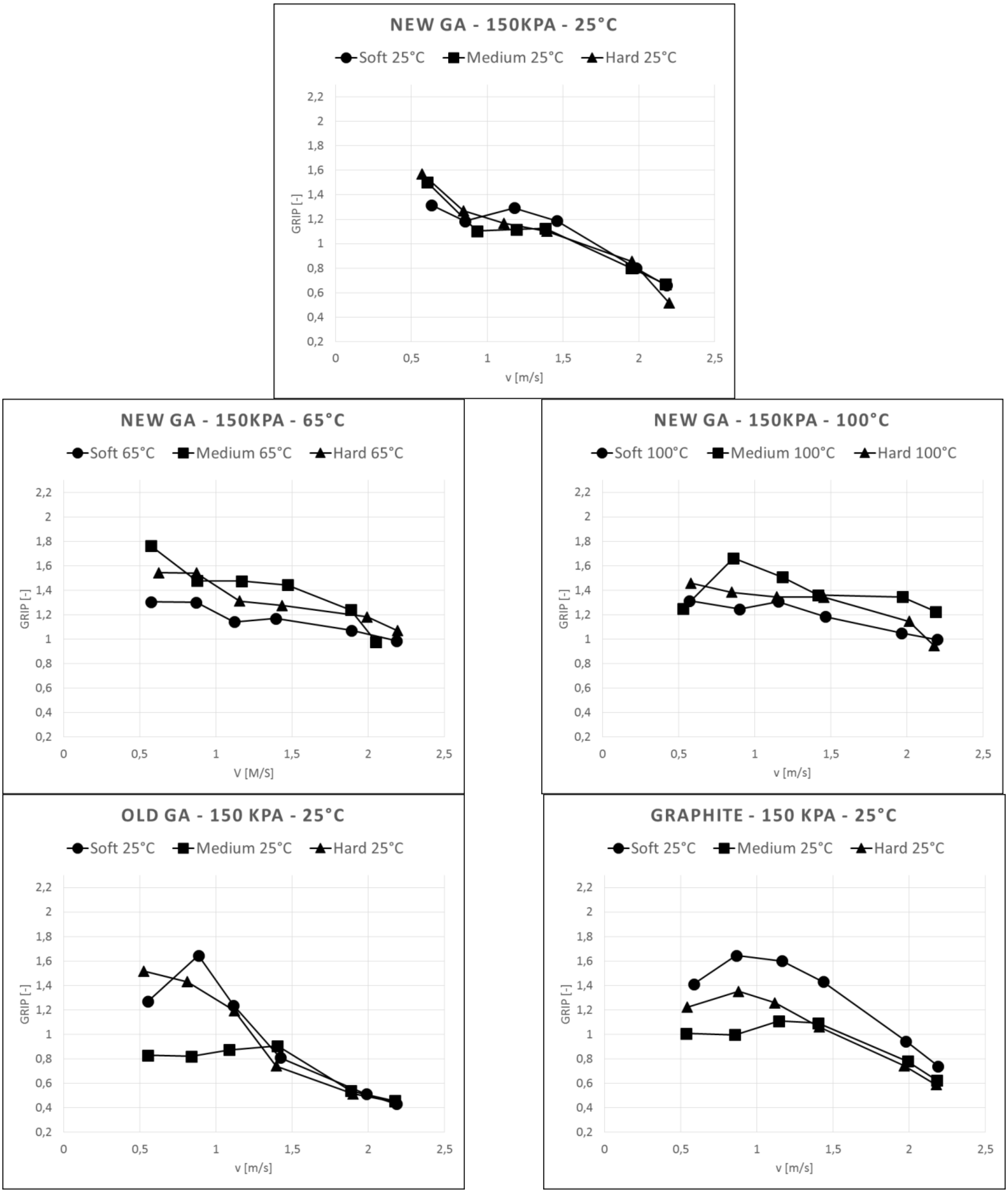


Fig. 15. Estimated friction coefficients as a function of sliding speed: on the top, a reference curve for three different compounds on NEW GA road at 25 °C with a 150 kPa spring preload, in the middle, the effect of temperature is observable at 65 °C and 100 °C, on the bottom, the effect of road roughness can be observed on OLD GA and graphite surfaces.

REFERENCES

[1] Feng, Q., *"Approximating Discrete Models for a Two-degree-of-freedom Friction System"*, IAENG International Journal of Applied Mathematics, vol. 38, no. 1, pp 1-8, 2008.

[2] Della Pietra, L., Timpone, F., *"Tension in a flat belt transmission: Experimental investigation"*, Mechanism and Machine Theory, Volume 70, 2013, Pages 129–156, doi:10.1016/j.mechmachtheory.2013.07.003

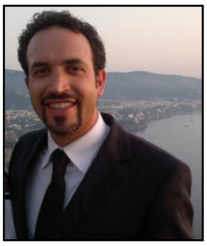
[3] Yoshihiro Takita, Hisashi Date, Shinya Ohkawa, *"High-speed driving of Lateral Guided Robotic Vehicle with a Rear Wheel Steer Mechanism Controlled by SSM"*, Engineering Letters, vol. 20, no. 1, pp 20-27, 2012.

[4] Andaluzia Cristina Mate, "*Weak Solutions via Lagrange Multipliers for a Slip-dependent Frictional Contact Model*", IAENG International Journal of Applied Mathematics, vol. 44, no. 3, pp 151-156, 2014

[5] Cazzulani, G., Resta, F., Ripamonti, F., "*Active Modal Tuned Mass Damper for Smart Structures*", Engineering Letters, vol. 19, no. 4, pp 297-303, 2011

[6] Pacejka H. B., *"Tyre and Vehicle Dynamics"*, Butterworth-Heinemann, 2006.

[7] Tsotras A., Mavros G., *“The simulation of in-plane tyre modal behaviour: a broad modal range comparison between analytical and discretised modelling approaches”*, Vehicle System Dynamics, 47 (11), pp. 1377-1400, 2009.
[8] Farroni F., Russo M., Russo R., Timpone F., *“A physical–analytical model for a real-time local grip estimation of tyre rubber in sliding contact with road asperities”*, Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 228 (8), pp. 955-969, 2014.
[9] Calabrese F.; Farroni F.; Timpone F., *“A flexible ring tyre model for normal interaction”*, International Review on Modelling and Simulations, 6 (4), pp. 1301-1306, 2013.
[10] Capone G.; Giordano D.; Russo M.; Terzo M.; Timpone F., *“PH.AN.TY.M.H.A.: a physical analytical tyre model for handling analysis - the normal interaction”*, Vehicle System Dynamics, 47 (1), pp. 15-27, 2009.
[11] Farroni F.; Giordano D.; Russo M.; Timpone F., *“TRT: Thermo Racing Tyre a physical model to predict the tyre temperature distribution”*, Meccanica, 49 (3), pp. 707-723, 2014.
[12] Farroni F.; Sakhnevych A.; Timpone F., *“An Evolved Version of Thermo Racing Tyre for Real Time Applications”*, Lecture Notes in Engineering and Computer Science, II, pp. 1159-1164, 2015.
[13] Farroni F., Timpone F.; *“A Test Rig for Tyre Envelope Model Characterization”*, Engineering Letters, vol. 24, no. 3, pp 290-294, 2016.
[14] Farroni F., “*T.R.I.C.K. - Tyre/Road Interaction Characterization & Knowledge - A tool for the evaluation of tyre and vehicle performances in outdoor test sessions”*, Mechanical Systems and Signal Processing - currently under review.
[15] Flintsch G., de León Izeppi E., McGhee K., Roa J., *“Evaluation of International Friction Index Coefficients for Various Devices”*, Transportation Research Record: Journal of the Transportation Research Board, DOI: http://dx.doi.org/10.3141/2094-15, 2015.
[16] Cabrera A., Ortíz A., Simón A., García F., Pérez La Blanca A., *“A Versatile Flat Track Tire Testing Machine”*, Vehicle System Dynamics, 40 (4), pp. 271-284, 2003.
[17] De Falco D., Di Massa G., Pagano S., *“A Full Scale Motorcycle Dynamic Rig”*, International Review of Mechanical Engineering, 7, pp. 519-526, 2013.
[18] Farroni F., Russo M., Russo R., Timpone F., *“Tyre - Road interaction: Experimental investigations about the friction coefficient dependence on contact pressure, road roughness, slide velocity and temperature”*, ASME 2012 11th Biennial Conference on Engineering Systems Design and Analysis, ESDA 2012 Volume 4, pp. 521-529, 2012.
[19] Guo K. H., Zhuang Y., Chen S. K., Willlam L., *“Experimental Research on Friction of Vehicle Tire Rubber”*, Front. Mech. Eng. China, 1 (1), pp. 1-14, 2006.
[20] Wallaschek J., Wies B., *“Tyre tread-block friction: modelling, simulation and experimental validation”*, Vehicle System Dynamics, 51 (7), 2013.
[21] Tuononen A. J., *“Digital Image Correlation to analyses tick–slip behaviour of tyre tread block”*, Tribology International, 69, pp. 70-76, 2014.
[22] Lorenz B., Persson B.N.J., Dieluweit S., Tada T., *“Rubber friction: Comparison of theory with experiment”*, Eur. Phys. J. E, 34 (129), 2011.
[23] Horigan Smith R., *“Analyzing Friction in the Design of Rubber Products and Their Paired Surfaces”*, CRC Press, 2008.
[24] Liu Y., Fwa T. F., Choo Y. S., *“Effect of Surface Macrotexture on Skid Resistance Measurements by the British Pendulum Test”*, Journal of Testing and Evaluation, 32 (4), 2004.
[25] Ferry J. D., *“Viscoelastic Properties of Polymers”*, Wiley, 1980.
[26] Lorenz B., Pyckhout-Hintzen W., Persson B. N. J., *“Master Curve of Viscoelastic Solid: Using Causality to Determine the Optimal Shifting Procedure, and to Test the Accuracy of Measured Data”*, Polymer, 55 (2), pp. 565–571, 2014.
[27] Rubio M. C., Martínez G., Baena L., Moreno F., *“Warm mix asphalt: an overview, Journal of Cleaner Production”*, 24, pp. 76–84, 2012.
[28] Carbone G., Lorenz B., Persson B.N.J., Wohlers A., *“Contact mechanics and rubber friction for randomly rough surfaces with anisotropic statistical properties”*, Eur. Phys. J. E, 29, pp. 275-284, 2009.
[29] Gadelmawla E. S., Koura M. M., *“Roughness Parameters”*, Journal of Material Processing Technology, 123, 2002.



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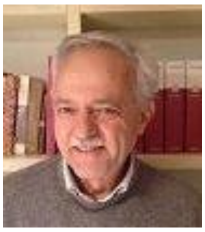

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