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Effect of temperature on the mechanical characteristics of bicycle tyres

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1 INTRODUCTION

Bicycles are becoming always more popular as a cheap and healthy tool for urban travels. The concerns for crowded public transport means are changing the habits after the pandemic situation caused by Covid-19, encouraging people towards the use of bicycle [1].
As stated in literature, tyres play a large role in the handling of bicycles [2] [3] [4]. This is why it is necessary to characterize tyres so as to derive useful parameters for modeling. To this purpose, proper experimental methods have been implemented for bicycle tyres [5]. A deepen knowledge of the phenomena occurring at tyre/road contact patch is indeed fundamental to ensure proper adherence and safety conditions [6], especially for vehicles as bicycles or motorcycles working with high camber angles [7].
This paper aims at enabling the future development of bicycle tyres, in order to improve the safety and the performances. Specifically, the focus is devoted to understand how the road temperature can impact on tyre performances, and therefore on bicycle handling.
After a brief section describing the methods and instruments used for this research activity, the results of an experimental campaign carried out on road racing tyre are presented and discussed.

The remarkable variation of temperature of tyre rolling surface can have multiple impacts on the performances. It can affect the noise emissions [8] as well as rolling resistance, as noted in [9], where higher temperature was correlated to lower rolling resistance coefficient. In [10] the temperature influence on car tyre lateral characteristics is investigated on a drum test-rig. A They found a decrease in cornering stiffness as temperature increases, while no particular variations on relaxation length were observed.

Despite the known influence of the temperature on tyre properties, there is a lack of studies regarding bicycle tyres. In [11] a test on test-rig of winter-type tyre revealed remarkable differences with respect to the mechanical characteristics of other tyres tested at room temperature. This may suggest the important role played by temperature on bicycle tyres characteristics, thus affecting the tyre/road interaction.

2 METHODS AND INSTRUMENTS

In this study, tests are performed with a test-rig specifically designed to measure the mechanical characteristics of a wide range of bicycle tyres [12]. Known as *Vetyt*, it consists of a welded frame made of Aluminum 6060 T6 to hold a bicycle tyre on a flat track (Figure 1). Lateral force and self-aligning moment of a road racing bicycle tyre were measured on flat track varying the temperature of the rolling surface.
Tyre was mounted on high-stiffness laboratory rim. In this way, the compliance of the rim does not affect the experimental measurements (the mounting can be seen in Figure 1).

A test with constant temperature was firstly performed (Figure 2), with camber angle set to 0° and slip angles spanning in the range ± 9.5°. The focus was devoted to the lateral force, specifically to the symmetry of the results with respect to the origin of the axes, in order to check the effective operating of *Vetyt*. The tyre should perform similarly if turned at right or left, unless the presence of secondary effects of ply-steer and conicity [13]. The temperature was kept constant at *30 ± 3 °C*. The fact that the plotted curve resulted symmetric with respect to the origin of the axis confirmed the good performances of *Vetyt*. We can assume the temperature as the only variable parameter.

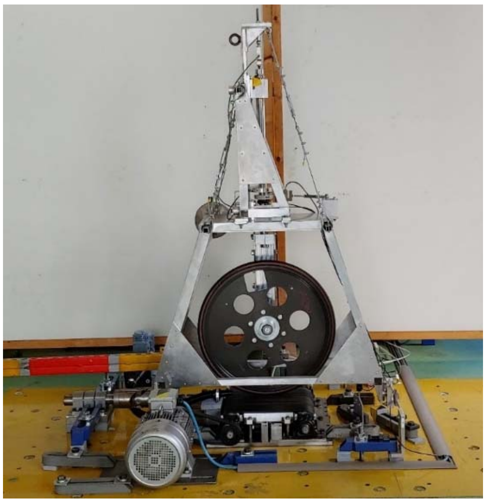

Figure 1 – *Vetyt test-rig at Politecnico di Milano. The frame holds the bicycle tyre on flat track. In this picture, tyre is mounted on high-stiffness laboratory rim.*

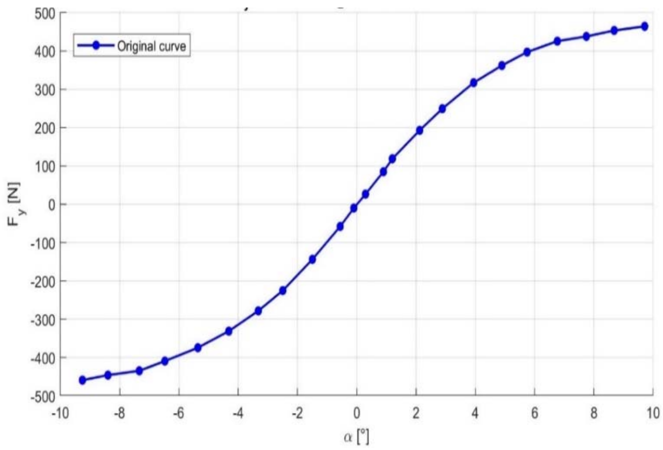

Figure 2 – *Lateral force F_y as function of the slip angle α. The result is obtained keeping the temperature of the flat track belt constant and equal to 30 ± 3 °C.*

2.1 Experimental tests varying temperature

The effect of the rolling surface temperature on the mechanical characteristics of road racing bicycle tyre was investigated. In Figure 3, lateral force and self-aligning moment are depicted as function of the recorded temperature. The slip angle was set to 3.3°. It is possible to note the remarkable correlation between the decrease of the measured values and the increase of temperature. While the temperature increases of 51%, lateral force decreases of 11% and self-aligning moment of 37%, showing an almost quadratic decreasing trend. The decreasing trend at increasing temperature is confirmed for other slip angles $|\alpha| > 3°$. Repeating the test for slip angle equal to 1°, the results are completely different, as shown in Figure 4. The variability is much smaller and limited to less than 1% for lateral force and around 8% for self-aligning moment.

Observing Figure 4, it is possible to note that values seem to achieve a maximum for temperature of 40 °C, then to decrease. This is more evident for self-aligning moment. Repeating tests for other slip angles $|\alpha| < 3°$ a clear trend cannot be distinguished, but variability remains however lower than 8% for self-aligning moment and 1-2% for lateral force.

3 CONCLUSIONS

In this article, the effect of temperature variation on mechanical characteristics of bicycle tyres is studied.
The test-rig *Vetyt*, developed in the Department of Mechanical Engineering of Politecnico di Milano, has been employed to characterize a road racing bicycle tyre. The focus was on the measurement of the lateral force F_y and self-aligning moment M_z when the temperature of rolling surface remarkably varies. The variation in temperature of rolling surface resulted as a relevant source of variability for tyre parameters. In particular, the extreme responsiveness of self-aligning moment to the temperature was noticed. While the temperature increases of 51%, passing from 31 °C to 50 °C, the measured lateral force decreases of 11% and self-aligning

moment of 37%, showing an almost quadratic decreasing trend. This result was verified for slip angle equal to 3,3°, and confirmed for slip angles larger than |3°|.

Different trend was however recorded for slip angle slip angles $|\alpha| < 3°$. Any increasing or decreasing trend cannot be distinguished, and the variability remains lower than 8% for self-aligning moment and 1-2% for lateral force.
These effects could be relevant considering paved roads during summer, when the presence of shaded corners may cause a sudden increase/decrease in road temperature, thus changing the bicycle handling. This is strictly connected to bicycle dynamics, and it could be relevant for the occurrence of sudden and dangerous dynamic instabilities [14].

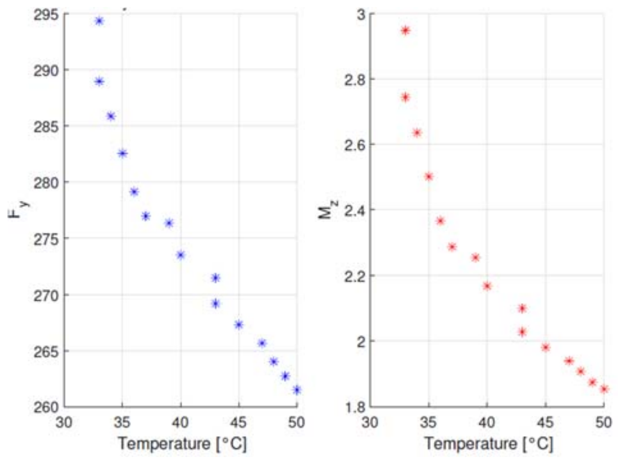

Figure 3 – *Lateral force (at left) and self-aligning moment (at right) as function of recorded temperature of belt, for slip angle equal to 3.3°.*

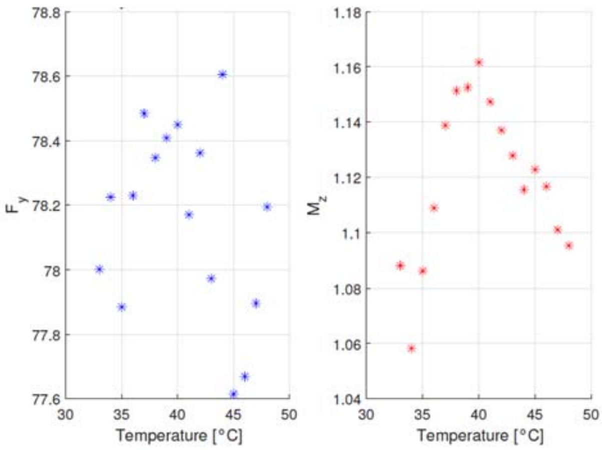

Figure 4 - *Lateral force (at left) and self-aligning moment (at right) as function of recorded temperature of flat track belt, for slip angle of 1°.*

REFERENCES

[1] BEUC, "Mobility habits following COVID-19," *Eur. Consum. Organ.*, no. October, 2020, [Online]. Available: https://www.beuc.eu/publications/mobility-habits-following-covid-19-snapshot-study-and-beuc-policy-recommendations.

[2] V. E. Bulsink, A. Doria, D. Van De Belt, and B. Koopman, "The effect of tyre and rider properties on the stability of a bicycle," *Adv. Mech. Eng.*, vol. 7, no. 12, Dec. 2015, doi: 10.1177/1687814015622596.

[3] F. Klinger, J. Nusime, J. Edelmann, and M. Plöchl, "Wobble of a racing bicycle with a rider hands on and hands off the handlebar," in *Vehicle System Dynamics*, May 2014, vol. 52, no. SUPPL. 1, pp. 51–68, doi: 10.1080/00423114.2013.877592.

[4] M. Plöchl, J. Edelmann, B. Angrosch, and C. Ott, "On the wobble mode of a bicycle," *Veh. Syst. Dyn.*, vol. 50, no. 3, pp. 415–429, Mar. 2012, doi: 10.1080/00423114.2011.594164.

[5] G. Dell'Orto, F. Ballo, and G. Mastinu, "Experimental methods to measure the lateral characteristics of bicycle tyres – a review," pp. 1–18.

[6] D. Gordon Wilson, T. Schmidt, and J. M. Papadopoulos, *Bicycle Science*, 4th ed. MIT Press, 2020.

[7] T. Fujioca and K. Goda, "Discrete Brush Tire Model for Calculating Tire Forces with Large Camber Angle," *Veh. Syst. Dyn.*, vol. 25, no. sup1, pp. 200–216, Jan. 1996, doi: 10.1080/00423119608969196.

[8] M. Sánchez-Fernández, J. M. Barrigón Morillas, D. Montes González, and G. Rey Gozalo, "Relationship between temperature and road traffic noise under actual conditions of continuous vehicle flow," *Transp. Res. Part D Transp. Environ.*, vol. 100, no. September, 2021, doi: 10.1016/j.trd.2021.103056.

[9] J. Ejsmont, S. Taryma, G. Ronowski, and B. Swieczko-Zurek, "Influence of temperature on the tyre rolling resistance," *Int. J. ...*, vol. 19, no. 1, pp. 45–54, 2018, doi: 10.1007/s12239−018−0005−4.

[10] C. Angrick, S. van Putten, and G. Prokop, "Influence of Tire Core and Surface Temperature on Lateral Tire Characteristics," *SAE Int. J. Passeng. Cars - Mech. Syst.*, vol. 7, no. 2, pp. 468–481, 2014, doi: 10.4271/2014-01-0074.

[11] A. Doria, M. Tognazzo, G. Cusimano, V. Bulsink, A. Cooke, and B. Koopman, "Identification of the mechanical properties of bicycle tyres for modelling of bicycle dynamics," *Veh. Syst. Dyn.*, vol. 51, no. 3, pp. 405–420, Mar. 2013, doi: 10.1080/00423114.2012.754048.

[12] F. B. G. Mastinu, M. Gobbi, G. Previati, "Measurement of forces and moments of bicycle tyres," *Bicycl. Mot. Dyn. 2019 Symp. Dyn. Control Single Track Veh. 9 – 11 Sept. 2019, Univ. Padova, Italy*, vol. 51, no. 3, pp. 405–420, 2019, doi: 10.1080/00423114.2012.754048.

[13] A. Lattuada, G. Mastinu, and G. Matrascia, "Tire Ply-Steer, conicity and rolling resistance - Analytical formulae for accurate assessment of vehicle performance during straight running," *SAE Tech. Pap.*, vol. 2019-April, no. April, pp. 1624–1630, 2019, doi: 10.4271/2019-01-1237.

[14] N. Tomiati, A. Colombo, and G. Magnani, "A nonlinear model of bicycle shimmy," *Veh. Syst. Dyn.*, vol. 57, no. 3, pp. 315–335, Mar. 2019, doi: 10.1080/00423114.2018.1465574.