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Indoor measurement of the lateral characteristics of a cargo bicycle tyre

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Abstract:

The use of bicycles as a cheap and healthy way to travel the "last mile" is spreading widely in the cities. This new way of dealing with short trips, known as "micro-mobility", is also fostered by the new awareness of the global impact of ICE vehicles and rising fuel costs. In recent years, also cargo bikes are knowing a large use, both for families with children and for delivery purposes. They are commonly configured as two-wheeled vehicles with extended wheelbase to carry loads in front the rider (known as "front-loader" bicycles), or behind the rider (models known as "longtail"). This requires fairly skilled riders to deal with driving dynamics, different from the common bicycle we are used to (Miller, M., 2023). They can easily reach a speed of 25 km/h (according to the regulations in most EU countries) being usually pedal-assisted.

Tyre characteristics may strongly affect bicycle dynamics (Bulsink, V., 2015). This applies even more for cargo bikes as they are featured by remarkable load variation (load/unload configuration), relatively high speed and torque applied to the tyres, both during acceleration and braking phases. In this context, it is important to have a good understanding of tyre characteristics. With the aim of designing safer and higher performing bicycles, numerical models are required. Furthermore, existing mechanical models of bicycles mostly ignore tyre dynamics and need to be updated with realistic tyre models (Dell'Orto, G., 2022).

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Figure 1. Test-rig *VeTyT* with the cargo bicycle tyre mounted on. The device was designed to ensure the proper alignment and provide an accurate measurement.

Figure 2. New steel plates for *VeTyT*. To accomplish with the specific dimensions of cargo bicycle wheel, new steel plates were designed and manufactured.

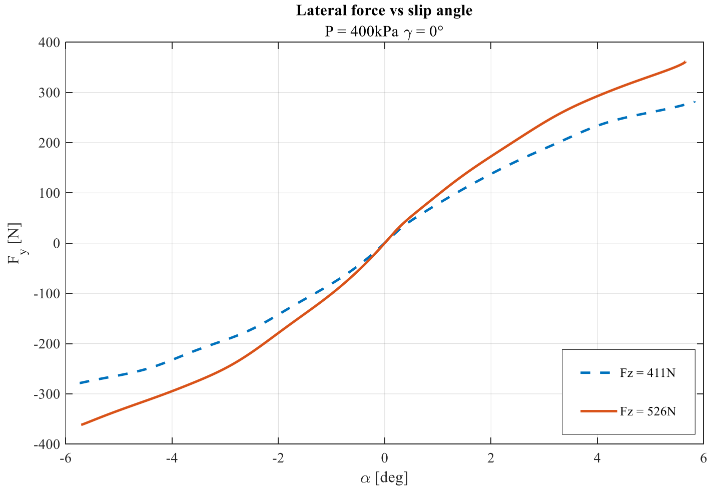

Figure 3. Lateral force $\boldsymbol{F_y}$ [N] as function of slip angle α [deg]. Results were experimentally obtained for inflation pressure of 400 kPa and camber angle equal to 0 deg.

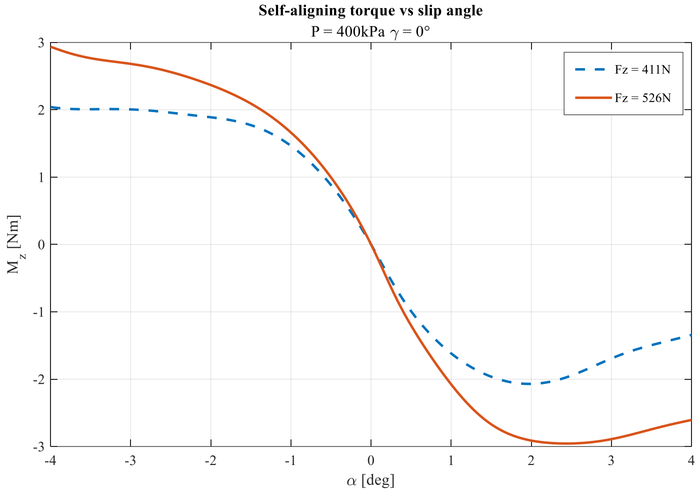

Figure 4. Self-aligning torque $\boldsymbol{M_z}$ [Nm] as function of slip angle α [deg]. Results were experimentally obtained for inflation pressure of 400 kPa and camber angle equal to 0 deg.

Measurements were performed with *VeTyT*, an indoor test-rig specific for bicycle tyres, designed at the Department of Mechanical engineering of Politecnico di Milano (Figure 1) (Dell'Orto, G., 2022). It is the only test-rig for bicycle tyres complying to the standard ISO 9001-2015, ensuring a certified procedure for testing. We can measure lateral force and self-aligning torque, as tyre parameters vary.

The tyre 20"x2,15 was mounted on a standard aluminum rim and tested on flat track. The specific dimensions of the cargo bicycle wheel forced us to update the test-rig, designing a new steel fork to ensure sufficient stiffness and new steel plates to carry the wheel on flat track (Figure 2). Inflation pressure was set to 400 kPa, as recommended by the manufacturer. Tests were performed applying a vertical load of 411 N and 526 N, according to the technical limits of the test-rig. The camber was set to 0 degree, as first stage of the study.

The lateral force and self-aligning torque as function of the slip angle are shown in Figure 3 and Figure 4, respectively. It is clear the difference in outcomes adjusting the vertical load. As the vertical load increases, both the lateral force and the self-aligning torque increase in magnitude. As expected, the tyre can generate higher forces with higher vertical load. It is worth noticing that the peak value of lateral force will be reached for very large slip angles (> |6| degrees, the maximum value tested in this study). Tyres for cargo bicycles are designed to carry large loads, therefore we expect to reach saturation conditions for higher vertical forces or, conversely, large slip angles. The cornering stiffnesses are reported in Table 1: for vertical load 526 N it is 24% higher than that found at 411 N.

Table 1. Cornering stiffness for different vertical loads. In the last column, the variation (in percentage) of cornering stiffness due to increasing vertical load.

Vertical load	Cornering stiffness	Variation %
411 N	*85.1 N/ °*	-
526 N	*105.5 N/ °*	*+24%*

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