Agricultural tires' behaviour during laboratory reproduction of lateral forces

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Abstract
The development of the EU legislation is carrying on to a growing interest in the behavior of agricultural tractors at high speed and in their comfort properties.
The lateral forces acting on a tractor characterize the tractor behavior in line-change tests, road transport with trailers or implements and the distribution of vibration for operator's comfort. To evaluate and to define the elastic lateral properties, in operational conditions, of agricultural tires the CRA-ING of Treviglio has carried out a first approach to simulate in laboratory the effect of lateral forces on an agricultural tractor.
This work aims to define a methodology, test conditions and apparatus for evaluating the lateral elastic constant of an agricultural tire during turnings.
A 4WD tractor fitted with different couple of rear tires has been used. The front axle of the tractor was picked up for having a null vertical reaction on the ground for not influencing test on the rear axle. A hydraulic cylinder was used for pulling laterally the tractor.
The tested tires have shown a curve constituted by two linear parts both characterised by a combination of the vertical stiffness, of the reaction to the torque of the roll and of the lateral stiffness. Tires were tested at 1.2 and 1.6 bar, this last setting has shown always, as expected, a greater elastic constant.
Future development of the project will take in account correlation with the response of the vehicle on test track.

Keywords: Agricultural tractor, handling, tire, lateral forces.

Foreword

The development of the EU legislation (1) is carrying on to a growing interest in the behaviour of agricultural tractors at high speed.

One of the most actual topic includes safety and comfort; these requirements ask to define the tractor behaviour both during testing (2) and in modelling (3).

The lateral forces acting on a tractor have a great influence on handling, comfort and safety. They characterise the tractor behaviour in line-change tests, road transport with trailers or implements and the distribution of vibration for operator's comfort. To evaluate and to define the elastic lateral properties, in operational conditions, of agricultural tires the CRA-ING of Treviglio has carried out a first approach to simulate in laboratory the effect of lateral forces on an agricultural tractor. In fact the agricultural tires must guarantee stability to the tractor also with heavy implements or trailers. The response to lateral force with high vertical loads is characterized from the mechanical properties of the tire. These last depend, above all, from carcass and belts features (fig.1).

The project, solicited by a tyres' manufacturer, is a first approach to correlate the elastic characteristics of the tires with the tractor behaviour. This work aims to define a methodology, test conditions and apparatus for evaluating the behavior of an agricultural tire.

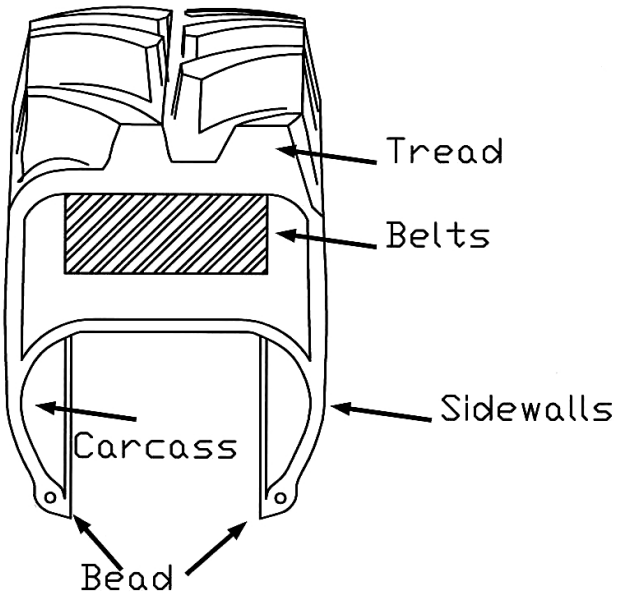

Figure 1. Main tire's components

Materials and methods

The methodology followed for this work was defined according with the manufacturer.

A 4WD tractor fitted with three different couple of rear tires different for design and construction but identical in overall dimensions has been used (fig.2). Two plates of iron were disposed under the tires for having a standard friction surface.

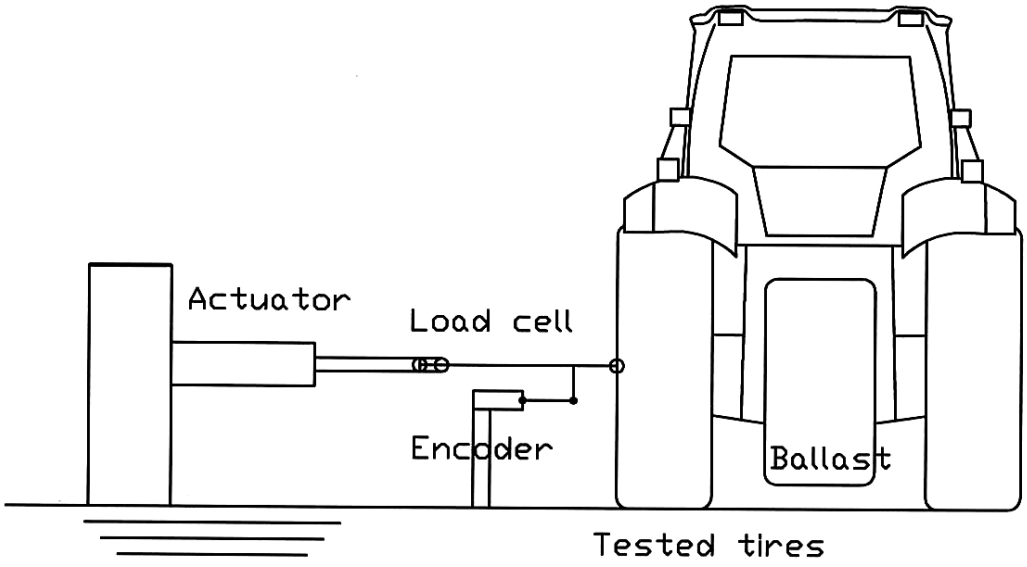

Figure 2. The testing plant

The front axle of the tractor was picked up by a crane for having a null vertical reaction on the ground for not influencing test on the rear axle that was adopting the tested tires.

The measure of the tested tires was 710/70R38. A hydraulic cylinder was used for pulling laterally the tractor. The point of hook for pulling was at the height of the rear axle. Test condition are listed in table 1.

Table 1. Test conditions

	Weight (kg)	
Agricultural tractor (ballasted for test)	Front	2140
	Rear	7900

Tests were replicated with tires inflated at 1.2 and at 1.6 bar. An instrumental chain based on a load cell and on a linear encoder, completed with a PC as data recorder, was used.

Results

The tested tires have shown a curve constituted by two linear part (fig. 3), both characterised by a combination of the vertical stiffness, of the reaction to the torque of the roll and of the lateral stiffness. The pulling force was initially divided among the two rear wheels, than almost all the reaction was of the external tire. For this reason, the tire initially react to compression and to lateral forces, than only to lateral. The consequence is that there's a first linear part characterising a greater elastic costant and a second part of lower value where the displacement increases faster.

The tires at 1.6 bar have showed a greater stiffness both to pure lateral and compression forces, so the first part of the resulted curve has always, in this case, greater costant values than the curve obtained at 1.2 bar. But the results are almost the same for great values of load, cause in this case the tire construction was more important than inflate pressure.

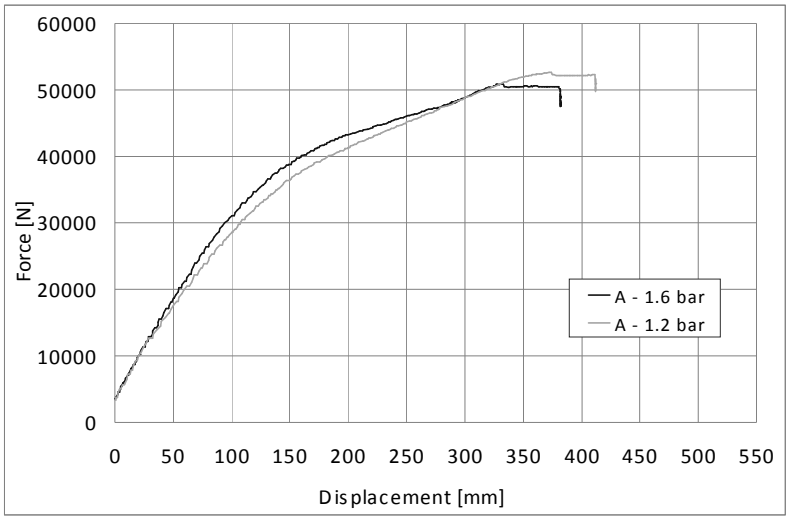

Figure 3. The elastic constant of the lateral stiffness of tire "A"

The tests carried on a tire of the same size but with different mechanical properties show that the lateral stiffness is very important in the first part of the curve characterising the response at medium and low loads (fig. 4).

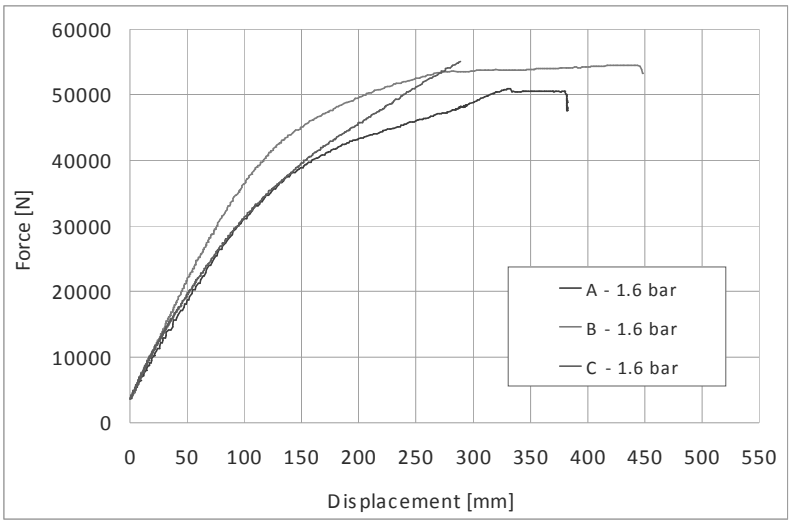

Figure 4. The elastic constant of tire "A" compared with tire "B" and "C"

Considering that on track, generally, lateral acceleration maximum values of 0,7 g, it can be assumed that all the curve trend could be of interest during turning, but the driver feedback response during handling test in a double lane change indicated that a greater stiffness of the first part of the curve and a low gradient in the second are the most important parameters.

In figure 5 are displayed the possible curve groups that could result from this type of test. The curve A indicates low lateral stiffness, probably due to the carcass influence that gradually becomes more rigid for tire B and C. The response at high loads has to be investigated (i. e. curve A) for defining the influence of the components, or their combination, of the tire.

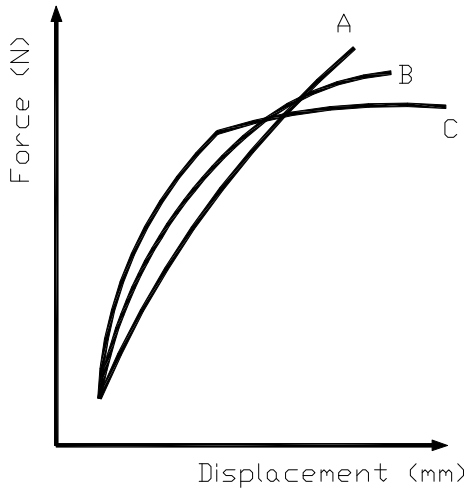

Figure 5. Theoretic trend of the possible curves

The optimum choice is obviously depending from the possible and main destination of use of the tractor.

Future development have to take in account and to quantify the influence of the single parts of the tire (above all carcass, belts and tread) on the tractor behaviour and to evaluate the correlation with the response of the vehicle on test track.

Conclusions

The behaviour of the rear tires of a tractor during turning has been reproduced in static conditions.

The experimental test has allowed obtaining immediately the response of the rear axle and then, of the vehicle, to lateral forces.

Three main groups of possible response have been identified, depending from the construction characteristic of the tires.

Next step of the project will be carrying on tests on test track that will allow to correlate tires properties with vehicle behaviour during tests as line change or double line change in order to a previsional evaluation of comfort and safety behaviour of the tractor trailer train.

References

Braghin F., F. Cheli, E. Sabbioni, M. Cutini, C. Bisaglia, 2007. Validation of a MB agricultural vehicle model through indoor and outdoor experimental tests. XXXII CIOSTA-CIGR Section V, 17-19 September, Nitra (Slovack Republic), Part I, p. 130-138 (ISBN 978-80-8069-923-9).

Directive 2003/37/EC of the European Parliament and of the Council of 26 May 2003 on type-approval of agricultural or forestry tractors, their trailers and interchangeable towed machinery, together with their systems, components and separate technical units and repealing Directive 74/150/EEC.

ISO 3888-1:1999, Passenger cars – Test track for a severe lane-change manoeuvre. Part 1: Double lane change.