New experimental method for measuring the energy efficiency of tyres in real condition on tractors

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New experimental method for measuring the energy efficiency of tyres in real condition on tractors

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Abstract

The ENTAM as the European Network of Testing stations of Agricultural Machines and equipment has settled up a new ENTAM Technical Working Group in order to draft a common methodology to test the agricultural tyre energy efficiency, in close cooperation with one of the biggest tyre manufacturer. The aim was to find a compromise between easiness and representativeness of the measurements, with reproducible records carried out on real agricultural fields, in standardized soil conditions. It is described a proposal for a dimensionless tyre performance index and a way to standardize the test methodology and the test devices.

Aim and scope

The European agriculture is more and more concerned by energy efficiency considerations, for various reasons: the pressure put by the society and the public authorities (eco-labelling…), the economical impact of energy waste, or the farmers' personal commitment toward a "greener" agriculture. Mobile machinery and the pneumatic tyres in particular, play a very significant role in this context. So far, no standard test is existing yet, so as to evaluate the performance of the tyres in this respect. In 2011 according to this new requirement a newest 9th ENTAM Technical Working Group has been established in order to draft a common methodology to test the “Agricultural Tyre Energy Efficiency”. [1]

This paper proposes a draft for defining such a standard method, encompassing two main field usage conditions, which are the followings: the pulling on field, the carrying on field. We will concentrate first on the case of agricultural tractors. For the field usage conditions, a specification of the reasonable soft soil to be used in the test is proposed, based on soil parameters and the way to control them. The physical signals to be recorded are described, as well as some features of the testing devices.

Proposed material and method of experiments for the future standard test

The worked out “Test Protocol” strictly describes the test conditions. Concerning the soil, it was decided to conduct the study in real, as homogeneous as possible agricultural soil, in open field. The reason for this technically challenging decision is to operate the tyre in convincing usage conditions, as viewed by the farmers. Evidently, the soft soil must not be selected anyhow. So far, 3 criteria must be respected in the Test Protocol: The texture: clay between 5 and 15%, silt between 10 and 30%, sand between 55 and 75% (texture determined according to ISO 25177:2008) [2], the moisture content (water mass / dry mass) between 10 and 14% (according to NF ISO 11465) [3], the cone index value (according to ASABE EP542 and ASABE S 313) [4, 5] between 0.5 and 0.9 MPa, with optimal value 0.7 MPa. On each test plot 10 individual cone penetration measurements are carried out on each of four 50 metres long zones.

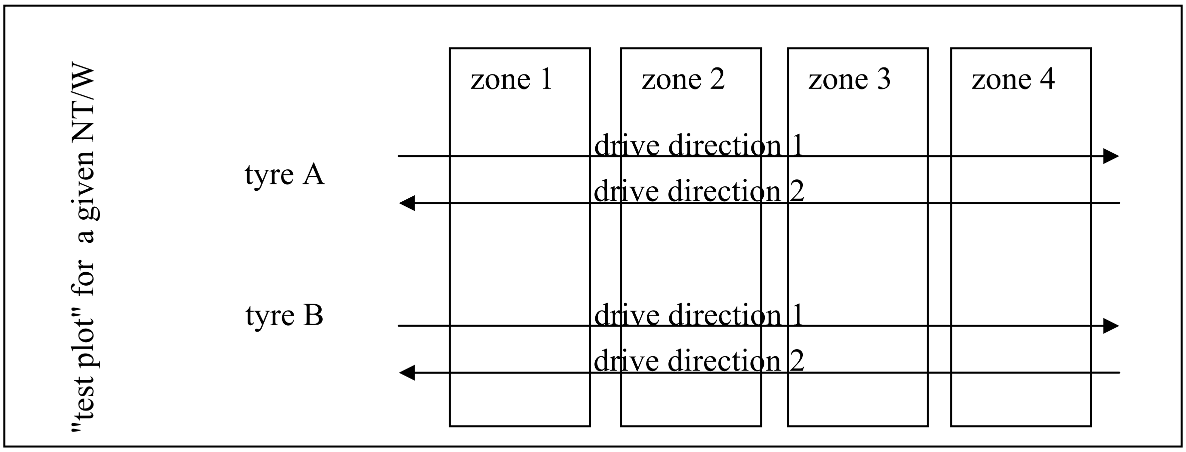

Fig. 1. Spatial repartition of the tests in a field plot.

During each test conditions, 4 quantities are recorded: The drive torque at wheel centre (T), the Net Traction force (NT), the rotation speed of the wheel (Ω) and the travel speed relative to soil surface (V).

Two dimensionless performance indices can then be computed: The Pull Loss Index (PLI) and the Carry Loss Index (CLI).

Case of pulling (so NT>0) :
$$Pull\_Loss\_Index \equiv PLI = \frac{T \times \Omega}{NT \times V} - 1$$

Case of self-propelling (so NT=0):
$$Carry\_Loss\_Index \equiv CLI = \frac{T \times \Omega}{W \times V}$$

The smaller the indices' values, the better the energy efficiency of the tested tyre. In case of PLI, for instance a value of 55% means that if the implement behind the tractor requires a drawbar power of 100 kW, the tractor (=engine + transmission…) will have to deliver 155 kW to tractor wheel axle. The advantage of this index is that the tyres can be compared on a given delivered basis (the 100 kW in above example, transmitted by drawbar to implement), like if they had to "work the same field". However, other indices can also be calculated (like the "tractive efficiency") using the same input quantities (T, NT, Ω and V). In case of CLI, the values are close to the motion resistance ratio, in case the "free rolling" and the "self propelling" modes are very comparable to each other, on the given soil.

Achievement of feasibility tests

According to the preliminary developed method for Agricultural tyres test feasibility tests were performed in 2012, at two testing stations: MGI in Hungary, and IRSTEA in France. One tyre conception was used, of dimension 650/65R38. Tyre settings like tyre vertical load and tyre inflation pressure were varied, so as to produce varied levels of tyre energy efficiency. Tyre dynamic vertical loads were varied from 2500 to 4000 kg. Here, the "dynamic" vertical load is considered, that is to say the load when the tyre is in operation. Tyre inflation pressures were varied from 60 kPa to 160 kPa. Several levels of tyre traction (NT) were tested, namely 20%, 30%, 40%, 50% and 0% of dynamic vertical load (W). As these preliminary tests were feasibility tests, two different soil preparations were tested. [1]

Tests by the MGI

The MGI in Hungary carried out the tests by a modified tractor to measure the energy efficiency of tyre with ENTAM and to measure the fuel consumption of the tractor mounted with the above mentioned tyre.

Fig. 2: Modified tractor and the dynamometer vehicle during the tests

Both the energy efficiency of tyre and the specific fuel consumption measurements were carried out with all traction levels, tyre loads and inflation pressure (2 loads x 2 pressures x 2 soil conditions x 5 traction levels x 4 zones x 2 directions in the field). During the measurement same throttle position and gear was used. Simultaneously, the necessary traction force was set with the dynamometer vehicle attached behind. Measurements were carried out on four each 50 meters long measuring zones with constant condition (travel speed, drawbar force) without stopping. [6]

Tests by Irstea

Irstea used a specific device named "single-wheel-tester" to measure the tyre efficiency. Coupled with a 140 horse-power tractor, and composed by a specific metallic frame avoiding vertical load transfer, it allows to apply a given driving torque on a unique tyre and to measure, using different sensors, all the other parameter (horizontal force, real speed, angular tyre velocity, …). The speed was fixed to 1m.s^{-1} during all the successive measurement repetitions, each carried out along a series of 50m long zones. The vertical loads applied on the wheel were obtained using different mass.

Fig. 3: Single-wheel-tester

Several net traction coefficient values (NT/W) have been tested, from null to 0.4. The tyre performance level is well determined, as one unique tyre is tested at a time, with well defined dynamic load and directly measured net traction (NT). [7]

Evaluation of results from test stations

Fig. 4 shows the Pull Loss Index values, as measured by MGI. The most important point is that depending on the usage condition (NT/W and soil), the PLI may be very big, and even exceed 50%: The tyre has a very significant impact on energy efficiency of the whole tractor, and the present project of standardized test is addressing an important issue.

Beside the impact of net traction coefficient value (NT/W) and soil preparation (variable in this feasibility test), it is interesting to observe that for a given usage condition, the energy loss can be even 1.6 times, depending on the tyre settings (dynamic weight and inflation pressure). So the right choice of tyre setting or the right choice of tyre is key to tractor performance. [6]

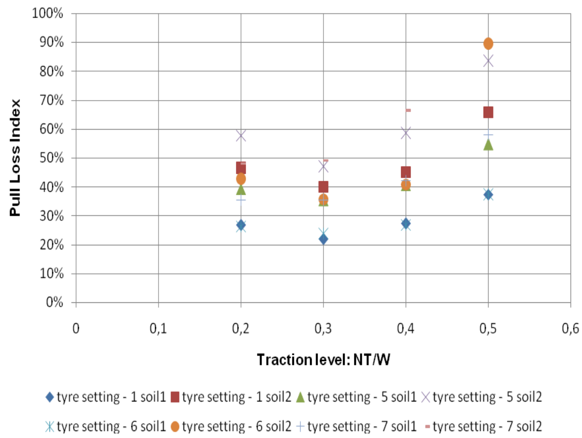

Fig 4. Pull loss indices at MGI

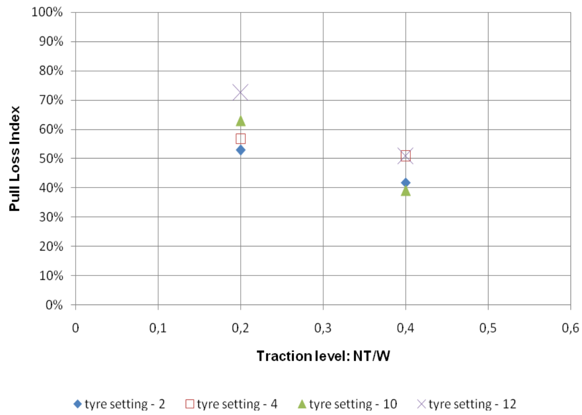

Fig 5. Pull loss indices at IRSTEA

Alignment between the two test centres:

Figs 6 and 7 below show that the range of magnitudes of the results obtained in both test centres are very comparable, which is encouraging. However, it can be seen in the graphs (and in other data) that some improvement in test methodology still has to be made, in order to improve tyre comparisons, when the differences between them are small.

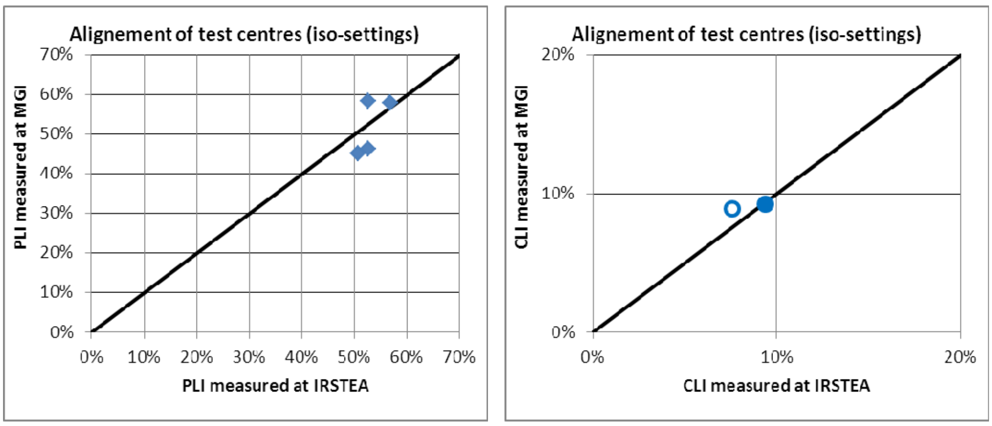

Fig 6 & 7: Status of the alignment between the two test centres

Conclusion

The ENTAM network was born in order to define a common methodology for testing of agricultural machines and equipment on the basis of international standard. The ENTAM besides the 8 TWGs established the 9th one, the Eco-technologies TWG inter alia to develop and to test the “Agricultural Tyre Energy Efficiency". According to the developed method two feasibility tests were performed in 2012: One at the MGI in Hungary and one at the French IRSTEA. The results show that there is strong correlation between measured indices. By analysing common tyre settings, we observed that alignment of the two test centres' results has appeared to be acceptable. The next step will be to homogenize the test methodology and test devices, so that the tyre rankings are same too, whatever the test centre is. Some improvements have been suggested and implemented in following tests, especially on soil preparation in order to reduce the natural variability of “soil cone index” measures.

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