Evolution of Agricultural Tire technologies and their impact on soil compaction

P.Vervaet*1, M. Stettler2, F. Pinet1,

1 Manufacture Française des Pneumatiques Michelin, 63000 Clermont-Ferrand, France
2 Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences HAFL, Länggasse 85, CH-3052 Zollikofen, Switzerland

Modernisation of agriculture has led to a continuous increase of the size of farms in the past decades. To be able to manage those farms, bigger implements were needed requiring higher pulling force from the tractor. As there is an optimal ratio between the pulling force and the weight of the tractor3, this situation implied the usage of always heavier tractors.

Consequently, this increase in vehicle weight has a major impact on the risk of soil compaction. To limit these risks, there have been many evolutions in the agricultural tire technology and design.

The major steps in the last 50 years were

- The transition, since 1970 for agricultural tires from bias (fig 1) to radial (fig 2) structure: in the radial tires, there is a clear separation of the functions of the tread and the sidewall leading to a stability of the contact patch and an homogeneous distribution of stresses in the contact patch

- The evolution of aspect ratios (height of the sidewall as a percentage of the tire width – fig 3) of the tires. For example, for a given tire diameter (1850 mm) and rim diameter (38’’), there has been an evolution in the years 1990 from 520/85 R38 to 580/70R38 then 650/65 R38 leading to an increase of the tread width in contact with the soil and a reduction of the pressure needed to carry a given load. For this range of tire, the needed pressure to carry 3800 kg at 40 km/h being respectively 1,6 - 1,4 and 1,2 bar7
The evolution from standard to ‘IF’ and ‘VF’ tires was introduced on the market in 2004. For a given tire dimension the IF tires can carry an additional 20% load at the same pressure. The gain is 40% with VF tires (fig 4). This gain can also be used to generate a reduction of pressure needed for a given load. For example: a standard 650/65 R42 can carry 4250 kg at 1.6 bars while a VF 650/65 R42 can carry 6000 kg and only need 1 bar for the same 4250 kg.8 This reduction of pressure bringing a gain in the size of the contact patch and in the stress in the agricultural soil.

The usage of Central Tire Inflation Systems (CTIS). A CTIS is a system installed on the vehicle which, through a system of compressor and rotary union can manage in real time the inflation pressure during operations. The first retrofit solutions appeared some 20 years ago but it is only since 2013 that major tractor manufacturers are implementing this system as original vehicle equipment. With this system, it is possible to differentiate the inflation pressure that is use in the various usages of the tractor and, in particular, to use always in the field the lowest possible pressure (higher pressures being needed in road usage due to the higher speed of operation). For example, a 710/70 R42 carrying 5600 kg has to be inflated at 1.6 bar to stand a 65 km/h usage, this pressure can be reduced to 1 bar when operating at less than 10 km/h on the field4.

The latest of these technical evolutions is the ‘adaptive tire’, a tire that is able to change its shape when changing from road to field usage. This technology is illustrated with the new Michelin EvoBib4 first showed in 2017. It consists of a tire that, under the action of a CTIS, dramatically changes its shape to adapt its performances from road to field.

- For field usage, this tire increases its effective tread width by a ‘hinge’ effect in the sidewall (fig. 4). The contact patch surface is increased by more than 20% compared to a similar tire at the same load and pressure. Depending on the soil conditions, it brings a potential increase of 20 to 50% of traction force at a given slip ratio and limit the ballast needed for a given traction force thus reducing the risk of soil compaction.4

- For road usage, the tire presents a narrower tread and its design is completely different from the classical ‘V-lug shape’. In this case, the rolling resistance of the tire is reduced by some 15% compared to classical tire at the same pressure; the comfort and wear performances are also optimized. (fig. 5)
The impact of these evolutions on the soil stresses can be evaluated with the ‘Terranimo’ model. This model evaluates the bulb of soil stress distribution as a function of the load, the tire, the pressure and the soil characteristics. The results of this simulation are presented.

To confirm experimentally those results, we proceeded in 2018 to field testing in collaboration with Agroscope and then Universities of Aarhus and Bern. The results are presented in the ISTRO conference (also in poster session).

The positive impact of these evolutions on the global crop yield has been studied and showed on specific studies conducted at Harper Adams (UK) and University of Illinois (USA) significant improvements in crop yields on corn and wheat with up to 4% gains.10,11

[4] ‘2 in 1 tire’ technology to allow maximal efficiency of the transmission chain in both road and field usage (P.Vervaet, M.Gandillet – EurAgEng November 2017)
[10] Effect of tire inflation pressure on soil properties and yield in a corn-soybean, rotation for three tillage systems in the Midwestern United States (Shaheb*, Grift, Godwin, Dickin, White1 and Misiewicz)