ANALYSIS OF THE INFLUENCE OF CONSTRUCTIVE AND WORK PARAMETERS OF AGRICULTURAL TRACTOR WHEELS TIRE UPON THE AGRICULTURAL SOIL STRESS

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Abstracts: *In the paper it is analyzed the influence of constructive and work parameters of the tire wheels (types, dimensions, inflation pressure, load,) and of working conditions of the machinery (travel speed, number of passing on the same tracks etc.) over the propagation way of the pressure from the contact surface wheel-soil in the depth of soil and over the penetration resistance and of soils apparent density.*

Key words*: agricultural tractor, tire well, contact surface whell-road, soil stress, soil deformation*

INTRODUCTION

Because of the stresses that act upon the contact surface wheel-road, at the moment of the wheel rolling it is produced a elastic deformation of the tire and the shape of the exterior contour of the tire produces also a soil deformation (fig.1). The elastic recrudescence of the tire surface to the initial shape is determined by the construction of the tire housing and by the internal pressure of the compressed air found in the tire. Unlike the tire, the soil remains with a certain remnant deformation, caused by the plastic deformation of the soil, an irreversible process due to the displacement (flow) of the soil particles. Elastic deformations (reversible) show up only in the moment of the passing of the wheel and can be estimated (quantified) only in that moment.

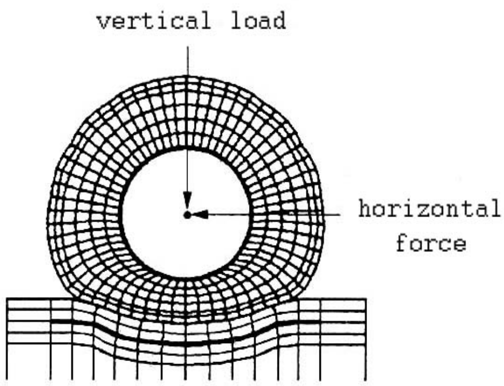

Fig.1.Tire and soil deformations at the contact surface

ESTIMATION OF CONTACT AREAS

In the process of the tires rolling by deformation of the tire shape and of the soil it is formed a contact surface who's shape and size depends on the tires parameters and of the properties of ground surface.

As a result of the flexibility and elasticity of tires, the contact area is smaller on hard surfaces than on the soft ground (fig. 2, b). For estimation of the tire contact area *A* of the tires it is used the relation:

$$A = b \cdot L \qquad (1)$$

where:

b is tire section width;

L –length of the contact area: *L=d/4* on a hard surfaces and *L=d/2* on a soft surfaces (sinkage z>0,05d);

z- tire sinkage in the contact surface;

d - diameter of the tire.

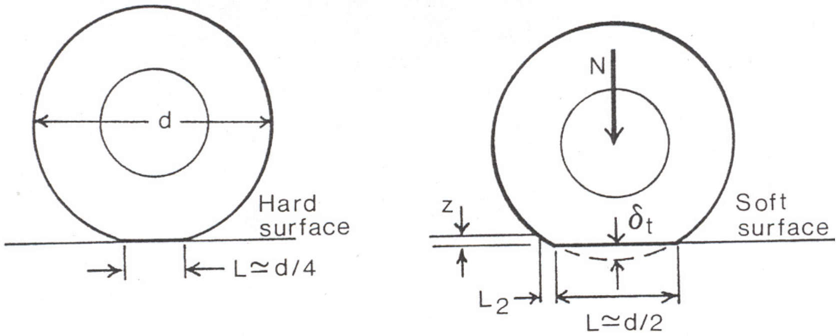

Fig. 2. Estmation of length of the contact of tires on hard and soft surfaces.

The length of the tire contact *L* can be estimated in relation with the load *N* on the tire and the tire inflation pressure *p* of the tire approximately with the relationship [3].:

$$L = \frac{N}{b(p_i + p_c)} - \frac{L_2}{n+1} \quad (2)$$

where: p_i is the tire inflation pressure;

p_c- contact pressure component of tire body flexural stiffness.

An approximate method for estimation for the length *L* from the maximum elastic tire deflection δ_t (s. fig. 5) is given by relationship:

$$L = 2\left(d \cdot \delta_t - \delta^2\right)^{1/2} \quad (3)$$

The use one or another of the mentioned methods for the estimation tire length contact is needed to predict the traction force and slip of well, as well to predict sinkage in soil.

SOIL DEFORMATIONS UNDER THE ACTION OF STRESS

Because the soil is not perfectly rigid material, it deform under the action of stress. In the case when rigid wheels are rolling on the deformable soils (fig. 3, c) it is obtained a displacement of the contact surface wheel-soil in the direction of the motion. On transversal direction the superficial load is thus uniform.

In the case of rolling of the pneumatic elastic wheel on deformable soils (fig. 3,d), which represents the real case of the tires of the tractors and agricultural machineries, the distribution of the loads is uneven on the longitudinal direction an as well on the transversal direction. The center of the contact surface is displaced, also, on the motion direction because of the rolling resistance effect.

If it is considered that on the rigid rolling path the width *b* of the tire contact is constant and the elastic deformation δ_R of the tire is small in relation to the diameter *d* of the tire, it is obtained proportionality between the support surface (contact) and the value of the deformation, expressed through relation [4]:

$$A = B \cdot L = B \cdot 2\sqrt{(D_R/2)^2 - (D_R/2 - \delta_R)^2} \approx 2 \cdot B\sqrt{D_R \cdot \delta_R} \approx \sqrt{\delta_R} \quad (4)$$

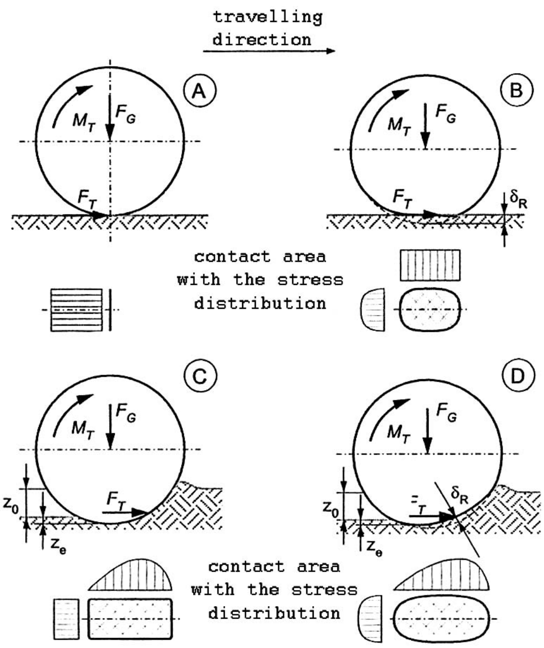

Fig. 3. The qualitative representation of the wheel and soil deformation, of the contact surface as well as the stress distribution for various situations:
a – rigid wheel on rigid surface (undistorted); b-wheel with elastic tire on a rigid surface; c-rigid wheel on deformable soil; d-wheel with elastic tire on deformable soil; δ_R *- elastic deformation of the tire;* z_0 *- the deepness of the soil mark (deformation*)

It results that the area of the contact surface A is proportional with the square root of the elastic deformation δ_R of the tire. It results that the area of the contact surface A is proportional with the square root of the elastic deformation δ_R of the tire.

As different authors showed it, can be considered that the stiffness of the tire c_R is independent by the load F_G on the wheel, then $F_G = c_R \cdot \delta_r$, from which results the relation $c_R \approx \frac{1}{\delta_r}$. Based on [4] it can be considered that there is a proportionality between the stiffness of the tire c_R and the internal pressure of the air inside the tire p_i, meaning $c_R \approx p_i$, such that the contact surface $A \approx {}^{1}\!/\!\sqrt{p_i}$ (that is inverse proportional with the square root of the internal pressure from tire). Experimental determinations confirm this aspect, as follows from the graph presented in figure 4.

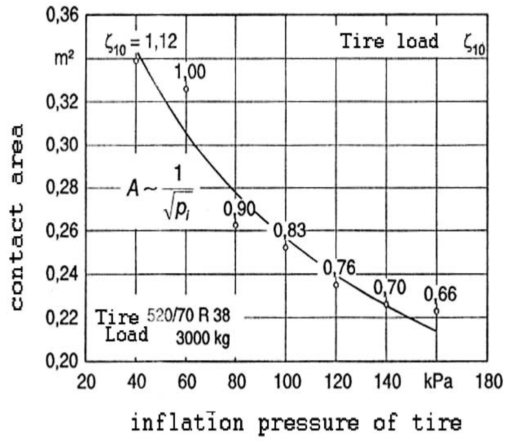

Fig. 4. Variation of contact area acording to inflation presure of the tire

INFLUENCE OF CONSTRUCTIVE AND FUNCTIONAL PARAMETERS OF VEHICLES TIRES UPON SOIL COMPACTION

The process of compaction is favored by the use of heavy-weighted equipment, increase of number of wheel's rolling on the same trace and by the running velocity of agricultural vehicles. The increase of the compaction degree has as consequence the worsening of soil's mechanical-physical properties: increase of soil resistance to penetration, increase of apparent density, decrease of porosity etc.

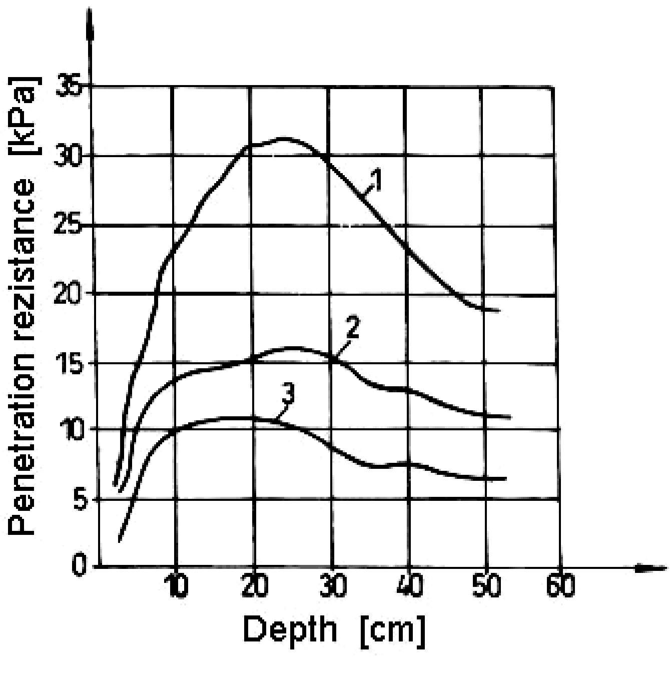

Fig.5. Variation of soil resistance to penetration according to the penetration depth and to the types of tires that equips the tractors' running system:

1 – tires with narrow width and great inflation pressure; 2 – tires with wide width and small inflation pressure; 3 – tires with reduce inflation pressure and small wheel load.

In case of equipping tractors with small dimensioned-tires and with great inner pressures and at great wheel loads there is produced a strong soil compaction, so that the resistance to penetration increases (fig.5). The value of the resistance to penetration reaches a maximum at the depth of 20…30 cm, after which it begins to decrease (curve 1). By using some tires with large dimensions and small inner pressures (curve 2), the resistance to penetration is reduced with about 50% as compared to the case when there are used tires with narrow width and great inner pressures (curve 1). If concomitantly with the reduction of the inner pressure it is also diminished the wheel load (curve 3), the reduction of the resistance to penetration is even more accentuated. However the researches showed that the reduction of soil compaction through the decrease of the wheel load is less obvious than the one obtained by decreasing the pressure in tires.

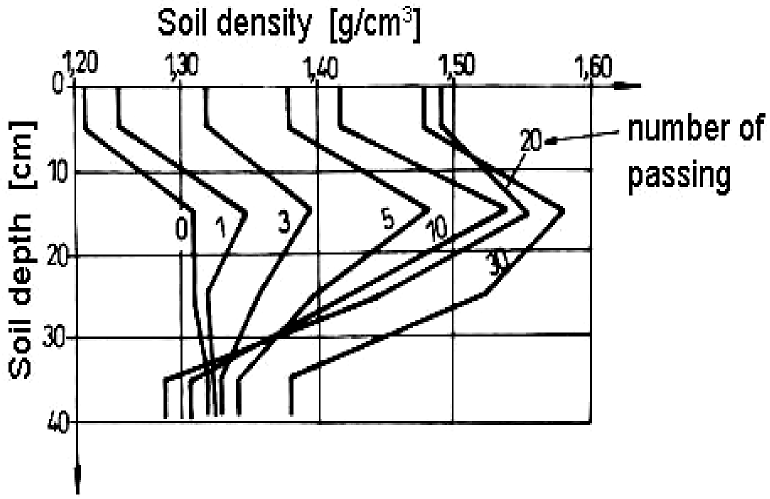

Fig.6. Change in depth of the apparent soil density under the influence of the number of wheels rolling on the same trace

The soil compaction, achieved through deformation and compression is obviously influenced by the number of agricultural aggregates' wheels rolling on the same trace (the repeated rolling on the same trace is necessary in order to address the culture-related technologies. The change of soil compaction at different depths at wheels rolling on the same trace, assessed through the change of apparent soil density, is emphasized in figure 6. The analyses of experimental researches have led to the conclusion that there is a rapid increase of the apparent soil density up to 10 passing on the same trace, after which, the influence of the rolling number is more reduced.

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