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# Soil vehicle relationship: The peripheral force

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**Abstract**

During the past decades the author has continually worked on and perfected his conception of the interaction between the soil and the wheel. First, this work is summarized in this paper. The author then describes his conception of the mechanical interaction between them and clarifies the connection between the kinematic and dynamic processes that take place when a tractor is exerting pull. He shows by means of his kinematic model how the peripheral force is developed. Finally, he derives the appropriate equations for the computation of the peripheral force and the drawbar pull for both two-wheel-drive and four-wheel-drive tractors. Practical experience has proven that the concept is correct and the method is practical.


*Keywords:* Deformation; Rolling resistance; Soil; Stress; Slip; Traction; Tire; Tractor; Wheel

## 1. Development of the peripheral force

The traction of a wheel is a complex physical process. Most researchers handle traction as a shearing action, but other approaches have also been applied [1–3].

No matter what approach is employed, soil adhesion between the contact surfaces consists of two main components: friction and "stickiness". Friction is the Coulomb friction. Stickiness depends on the material of the surfaces and, possibly, other influential factors. Thus, the stresses in the contact surfaces are similar to shear stresses and can be expressed as

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## Nomenclature

| | |
|---|---|
| $\tau^*$ | adhesive stress |
| $c^*$ | coefficient of stickiness |
| $c^0$ | initial static value of the coefficient of stickiness |
| $\mu^0$ | initial static value of the coefficient of friction |
| $\mu$ | coefficient of friction |
| $\sigma$ | normal stress |
| $V$ | travel velocity |
| $S$ | slip as defined by the ISTVS [6] |
| sV | slip velocity |
| $F_{\mathrm{K}}^{\mathrm{m}}$ | maximal peripheral force (or gross tractive effort) |
| $F_{\mathrm{K}}$ | peripheral force |
| $A$ | contact area of the tire |
| $Q$ | wheel load |
| $R$ | external or maximal radius of the tire |
| $\Delta R$ | deflection of the tire |
| $R_{\mathrm{st}}$ | static wheel radius measured at rest |
| $R_{\mathrm{g}}$ | rolling radius or dynamic radius |
| $s_{\mathrm{D}}$ | slip caused by the deformation of the tire |
| $s_{\mathrm{D}}$ | initial value of $s_{\mathrm{D}}$ |
| $s_{\mathrm{R}}$ | $s + s_{\mathrm{D}}$, or the relative slip |
| $\eta_{\mathrm{adh}}$ | coefficient of utilization of the adhesion |
| $Q_{\mathrm{d}}$ | adhesive load on the rear axle |
| $Q_{\mathrm{st}}$ | static load on the rear axle |
| $F_{\mathrm{v}}$ | drawbar pull |
| $F_{\mathrm{g}}$ | rolling resistance acting against the motion of the tractor |
| $m$ | height of the drawbar over the soil surface |
| $L$ | wheel base of the tractor |
| $Q_{\mathrm{d}}$ | adhesive load on a single driving wheel |
| $Q_{\mathrm{st}}^{\mathrm{k}}$ | static load on one wheel |
| $F_{\mathrm{v}}^{\mathrm{k}}$ | drawbar pull exerted by one wheel |
| $F_{\mathrm{K}}^{\mathrm{k}}$ | peripheral force exerted by one wheel |
| $F_{\mathrm{K}}^{\mathrm{h}}$ | peripheral force exerted by a rear wheel |
| $F_{\mathrm{K}}^{\mathrm{e}}$ | peripheral force exerted by a front wheel |
| $Q_{\mathrm{st}}^{\mathrm{e}}$ | static load on the front wheel |
| $Q_{\mathrm{st}}^{\mathrm{h}}$ | static load on the rear wheel |
| $F_{\mathrm{K}}^{\mathrm{tr}}$ | peripheral force the vehicle is capable to exert |
| $F_{\mathrm{K}}^{\mathrm{h4k}}$ | peripheral force exerted by the rear wheel of a four-wheel-drive tractor |
| $F_{\mathrm{K}}^{\mathrm{e4k}}$ | peripheral force exerted by the front wheel of a four-wheel-drive tractor |
| $Q_{\mathrm{d}}^{\mathrm{h4k}}$ | adhesive load on the rear wheel of a four-wheel-drive tractor |
| $Q_{\mathrm{d}}^{\mathrm{e4k}}$ | adhesive load on the front wheel of a four-wheel-drive tractor |
| $\Delta Q$ | increase in the adhesive load |