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Effects of reduced inflation pressure and vehicle loading on off-road traction and soil stress and deformation state

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Abstract

Field experiments on off-road vehicle traction and wheel–soil interactions were carried out on sandy and loess soil surfaces. A 14 T, 6×6 military truck was used as a test vehicle, equipped with 14.00-20 10 PR tyres, nominally inflated to 390 kPa. Tests were performed at nominal and reduced (down to 200 kPa) inflation pressures and at three vehicle loading levels: empty weight, loaded with 3.6 and 6.0 T mass (8000, 11,600 and 14,000 kg, respectively). Traction was measured with a load cell, attached to the rear of the test vehicle as well as to another, braking vehicle. Soil stress state was determined with the use of an SST (stress state transducer), which consists of six pressure sensors. Soil surface deformation was measured in vertical and horizontal directions, with a videogrammetric system. Effects of reduced inflation pressure as well as wheel loading on traction and wheel–soil interactions were analyzed. It was noticed that reduced inflation pressure had positive effects on traction and increased stress under wheels. Increasing wheel load resulted in increasing drawbar pull. These effects and trends are different for the two soil surfaces investigated. The soil surface deformed in two directions: vertical and longitudinal.

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Vertical deformations were affected by loading, while longitudinal were affected by inflation pressure.

Keywords: Off-road traction; Drawbar pull; Net traction; Rolling resistance; Soil stress; Soil deformation; Rut depth; Soil displacement; Reduced inflation pressure; Wheel loading

1. Introduction

Vehicle performance on soft surfaces depends strongly on the following two major factors. First, the design of a vehicle – power unit, transmission, suspension and tyres, etc. and second, the type and kind of soil surface that must be traversed, as well as its actual state – water content, compaction, and structure. In some cases, vehicle related parameters can be improved across a wide range and traction depends upon soil surface strength. Heavy vehicles running on soft, moist soils cause huge deflections of soil surface, which are irreversible and immediate after the first pass of a vehicle. A soil deforms under vehicle loading because of its strength or weakness and, furthermore, bearing capacity, or lack thereof. The total amount of soil deformation can be related to soil compaction, which should be minimized in the case of agricultural tractors and machinery. This can be achieved by use of wide, low-pressure tyres, parallel wheels, or by reducing of vehicles' mass. The more the soil deforms, the greater the rolling resistance will be, as more traction energy is consumed on soil deformation. Then, fuel consumption increases. Unfortunately, it is not practical to use wide, low-pressure tyres on paved roads, as their performance is poor. So, another solution must be found for vehicles that must travel both on paved roads and off-road.

One efficient method for improving off-road traction is to reduce inflation pressure, which enlarges the wheel–soil contact area, improving positive friction between the tyre and the soil. This method is limited, however, by the increased rolling resistance of low inflated tyres.

On the other hand, an increase in wheel load may have positive influence on traction. Higher loads compact the soil surface and increase soil strength. Also, high contact pressure creates more intensive friction between the tyre and the soil surface, which leads to higher shear stresses. Shear stress or shear resistance of soil surface is a generic measure for drawbar pull force. It is obvious that increasing of wheel (or vehicle) load requires more power and affects fuel consumption. But in case of required mobility, for instance in military operations, this is not a concern.

For the present study, it was assumed that reducing inflation pressure and increasing wheel load may significantly increase drawbar pull and decrease soil deformation. Small or moderate reductions in inflation pressure for the off-road operations may be easily achieved and should not affect tread wear and hard pan traction. It is also interesting to see how increasing the wheel load affects traction, especially on different soil surfaces. To obtain a deeper understanding of the phenomena of interest here, wheel–soil interactions were investigated: soil stress at