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Journal of Agricultural Machinery
Vol. 5, No. 2, Fall - Winter 2015, p. 345-356

نشریه ماشین‌های کشاورزی
جلد ۵، شماره ۲، نیمسال دوم ۱۳۹۴، ص ۳۵۶-۳۴۵

Investigating the effect of tractive parameters on imposed vertical stresses under driving wheel using a soil bin test rig facility

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Received: 17-11-2013
Accepted: 04-01-2014

Introduction: Tire tractive parameters of the driving wheel are of the most substantial factors for the evaluation of the performance of agricultural tractors. Great tractive efficiency has called the attention of vehicle designers to attain economic efficiency owing to the minimization of fuel consumption. At terrain-tire interface, some soil physical-mechanical changes occur that lead to unwanted soil compaction. Of the influential parameters for the creation of soil compaction is the soil stresses formed owing to the wheeled vehicle trafficking. While the increase of tractive efficiency is desired, minimization of soil stresses should also be considered with the same importance to make a trade-off between the aforementioned parameters. There are numerous studies documented in the literature that deal with the measurement of soil stress/strain data due to the wheeled vehicle trafficking and also those works that address the correlation between the soil stress and soil compaction. It is recognized that in order to reduce soil compaction both at topsoil and subsoil levels, the soil stress at the soil-tire interface should be reduced. There are various parameters that affect the tractive efficiency and the soil stress creation such as wheel load, slip, tire inflation pressure, velocity, etc. On the other hand, the wheel is subjected to the torques and forces exerted to the vehicle and the vehicle dynamics are significantly affected by the soil-wheel interactions. Survey of the literature shows that numerous studies have focused on the evaluation of tractive efficiency both in field test and controlled conditions in laboratories with the intention of increasing tractive efficiency. The studies dedicated to the soil mechanical strength are more engaged with the approaches to minimize the soil stress propagation. The present study considers both factors and considers the most influential tire parameters such as wheel, velocity and slip to assess the relationship between traction and the soil vertical stress in a soil profile using a single-wheel tester and a soil bin facility.

Materials and methods: The soil bin in Department of Mechanical Engineering of Urmia University was used in this study. This soil bin is featured 24 m in length, 2 m in width and 1 m in depth including a single-wheel tester and the carriage. A chain system was used for the power transmission from the electromotor to the carriage. The carriage was able to move alongside the soil bin through four ball bearings which also hold the weight of the carriage. The utilized tire in the study was a 220/65R21 driving wheel. One load cell was situated vertically to measure the wheel load and four S-shaped load cells were horizontally situated between the single-wheel tester and the carriage to measure the traction force. An electric motor was used to empower the carriage while another electric motor was used to empower the wheel tester. The difference between the linear velocities of the carriage and the wheel-tester provided the desired levels of slip. A housing including four load cells situated at the distances of 12.5 cm was used to measure the soil vertical stress transmission in the soil profile. The system was buried at the desired depth in the path of wheel traversal. Under the aforesaid treatments, the experiments were undertaken with the purpose of simultaneous measurement of soil stress propagation and traction force and finally the correlation between these parameters.

Results and discussion: The results were analyzed using the statistical analysis at 1% significance level. The results showed that an increase in traction force leads to an increment of vertical soil stress. It was also recognized that the reduction in the velocity leads to the increase in soil stress which is due to the greater contact duration between the soil and the tire. Also, an increase in wheel load results in an increase of soil stress which has a linear correlation with the traction force. Furthermore, it was deduced that the increase in depth leads to a reduction of soil vertical stresses.

Conclusions: The present study is aimed at investigating the effect of net traction force on the imposed vertical stress under the 220/65R21 driving wheel. Hence, velocity at three levels (i.e. 0.8, 1, 1.2 m s^{-1}), wheel load at three levels (i.e. 2, 3, and 4 kN) and slippage at three levels (i.e. 8, 12, and 15%) were considered to obtain traction force and soil vertical stress at three depths of 0.1, 0.15 and 0.2 m. Experiments were carried out in the complete randomized block design with three replicates on clay loam soil at 12% moisture content. The vertical stress was measured using a manufactured soil stress transducer where the net traction was measured using four horizontally installed load cells

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between the tester rig and the carriage. A correlation was developed between soil stress and traction force. The results revealed that vertical stress increases with respect to increase of wheel load and slippage, whereas vertical stress decreases by increase in depth and velocity. Additionally, it was found that wheel load and slippage bring about increased traction force while velocity has no significant effect on traction force at 1% significance level. Finally, it was deduced that an increase of traction force results in an increase of vertical stress transmission.

Keywords: Driving wheel, Net traction, Slippage, Soil bin, Vertical stress

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