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CONTACT AREA DETERMINATION OF AGRICULTURAL TRACTOR WHEEL WITH SOIL

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ABSTRACT. The study is established based on contact area determination of tractor wheel. The significance of contact area in domain of wheel-soil interactions is considerable. Requirement for contact area estimations has prompted the researchers to determine numerous theoretical models. In this study, an experimental test was conducted inside a soil bin facility providing entirely reliable and controlled condition for the test. The soil bin included a carriage, a single wheel-tester and a frame. The utilized tire was a towed Good year 9.5L-14, 6 radial ply agricultural tractor tire which is used in John Deere tractors This test has the advantage of utilizing images taken of the contact areas and subsequently, using a plantimeter to obtain the values of contact area precisely. Test variables were the two most prominent and influential parameters i.e. tire inflation pressure in three levels (i.e. 100, 150, and 290 kPa) and vertical load applied on wheel in three levels (i.e. 1962, 2943, and 3924 N). The acquired results revealed that there is an increase in contact area induced by increase of vertical load and decrease of contact pressure. Contact area is shown to be highly influenced by vertical load in reduced tire inflation pressures.

Key words: Contact area; Wheel; Soil bin; Tire.

INTRODUCTION

The globally increasing demand for food production magnifies the importance of crop yield of farmlands. Consequently, soil-tool interactions should be evaluated comprehensively to achieve this aim since crop yield is a function of farm condition. In the countries with mechanized agriculture, the intensive application of heavier tractors due to increasing farm operations endangers the soil condition of farm through all the forces applied to the ground. Determination of contact area between tire and soil plays an important role on both the intensity of soil compaction and also in other soil-wheel interactions. Estimation of tire contact area contributes to

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determination of contact pressures, stress-strain propagation, and potential risk of compaction which in turn, affects crop yield. Moreover, wheel is of significant parameters generating traction of agricultural tractors. Accessing the desired traction, contact area is greatly influential in concern with this purpose. Traction can be increased by increase of contact area. Additionally, fuel consumption of tractors is dependent on rolling resistance which rolling resistance in turn, is function of contact area between soil and wheel.

Wide tires and dual tires increase the contact area resulting in increase of traction and reduced soil compaction. Hence tires should be managed to have high contact area with soil surface. In addition, increasing of contact area of tires reduces the pressure exerted by the tire on the ground. This pressure relies on tire inflation pressure and vertical load on the wheel. Therefore, contact area requires to be estimated precisely.

In order to facilitate the contact area determinations, models were determined. Contact area models can be empirical, semi-empirical or theoretical. Theoretical models were developed with the intention of contact area determination by many researchers (Krik, 1969; Söhne, 1969; Pillai and Fielding, 1986; Febo, 1987; Silversides and Sundberg, 1989; Komandi, 1990; Godbole, 1993; Grecenko, 1995). The simplest algorithms were developed assuming contact area as circular, rectangular or ellipsoidal. Latter investigations proved that contact area neither being circular nor rectangular. This matter persuaded researchers to introduce modified ellipsoidal models. Theoretical models are mostly complicated while being simplified, inevitable errors would be produced. This deficiency in concern with theoretical modeling prompted the attribute toward experimental studies. Experimental investigations have the advantage of accurate results being obtained but the number of experimental tests in regards to this subject does not suffice particularly there is the minority experiment being conducted in soil bin facility while it provides absolutely controlled and reliable condition. Of the equations used to calculate contact area of wheel with soil as well as experimental ones, mostly inflation pressure and vertical load acting on wheel have been considered to be major variables and necessitates the experimental studies to include these variables.

Considering the immense requirement for contact area measurement in agriculture and in regard to major variables affecting contact area (i.e. tire inflation pressure and vertical load), this study intends to determine contact area of agricultural tractor wheels with soil in a soil bin facility considering the contact area to be highly dependent on vertical load and tire inflation pressure. The experiment was conducted with three levels of inflation pressure as well as three levels of vertical load.

MATERIALS AND METHODS

A long soil bin facility was utilized in the Faculty of Agriculture, Urmia University, Iran (Mardani *et al.,* 2010). The soil bin was consisted of a wheel carriage, a single-wheel tester and bin frame. The single wheel-tester was equipped with a vertical load cell as shown in *Fig.1.* The load cell was interfaced to data acquisition system included a data logger, enabled monitoring the data on a screen and simultaneously, the data were sent to a computer. The load cell was used to measure the load applied to the wheel vertically.

Figure 1 - Soil bin set up and its equipments

For each of the treatments, tire inflation pressure was adjusted before each run. The soil bin was filled with clay-loam soil. Particular equipments were used to organize soil bed including leveler and harrow since it's very important to have well-prepared soil inside soil bin for acquiring reliable and precise results from this experiment. Chalk powder was used to determine the footprint and contact area of wheel on the soil surface in various treatments of vertical load and tire inflation pressure. *Fig.2* demonstrates the contact areas of tire in the length of soil bin. In order to increase the accuracy of the experiment results, repetition for each test was conducted three times and the mean of obtained results were measured. A digital camera was utilized to capture the images of contact area in each treatment. These images were captured from a fixed distance. An index of 11*11 (cm ^{2}) was used beside each image in order to calibrate the calculations.

The obtained images were processed in AutoCad 2007 software as shown in *Fig.3.* A planimeter was used in order to acquire the contact area from the processed images. The summary of treatments tested is shown in *Table 1*.

Figure 2 - A sample of contact area being measured

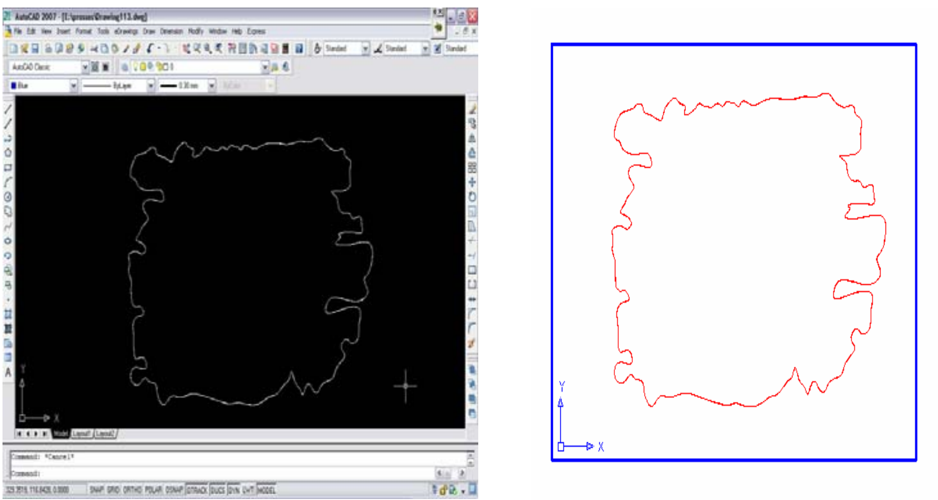

Figure 3 - An example of processed image in AutoCad 2007 software

Table 1- Summary of experiment conducted

Independent Parameters		Dependent Parameter
Vertical Load (N)	Inflation Pressure (kP)	
1962	100	Contact Area
2943	150	
3924	290	

The utilized tire was a towed Good year 9.5L-14, 6 radial ply agricultural tractor tire which is used in John Deere tractors. Microsoft Office Excel was used to process, evaluate and determine the relation between objective parameters and variables.

RESULTS AND DISCUSSION

The results of each treatment with three repetitions were developed. The mean value for each contact area was calculated. *Fig. 4* illustrates the relation being obtained from the experiments.

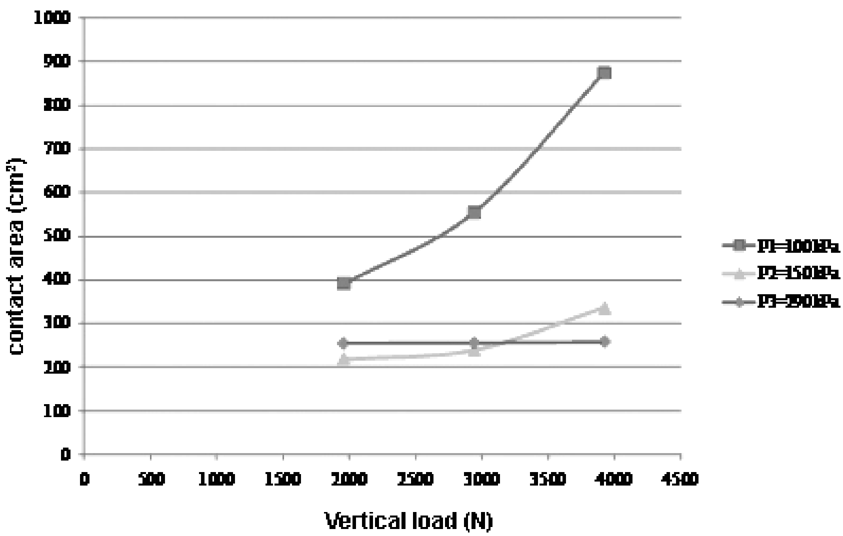

Figure 4 -The relation between vertical load and contact area in pre-described treatments

It is inferred that in the tire inflation pressure of 100 kPa, the highest amount of contact area is obtained in comparison with the other tire inflation pressures. The explanation of this matter is laid on the phenomenon of higher wheel deflection for increased vertical load in decreased inflation pressure. Besides, wheel deflection is shown to be increased almost linearly by increase of vertical load. Contact area is much impressed by vertical load for lower contact pressure since tire is deflects simply.

Obviously for inflation pressure of 150 kPa, the contact area is still dependent on vertical load but if compared with inflation pressure of 100 kPa, it is less affected by vertical load and provides lower contact area values in the same range.

Inflation pressure on 290 kPa offers almost independent relation with vertical load while negligibly varies in the pre-described range.

High inflation pressure changes the flexible tire's behavior into a rigid tire which clearly deflects slightly even under different values of vertical load.

In general, contact area variations in high tire inflation pressures are not significant although this relation is reversely correct.

CONCLUSION

The effect of three various vertical loads acting on wheel were evaluated on contact area and as well, three levels of tire inflation pressure varied to acquire the related results. The increase of contact area by increase of vertical load was confirmed in this study. Moreover, increase of contact area in lower inflated tires had greater rates in comparison with inflated tires. Variation of contact area for tire inflation pressures more than 150 kPa was not significantly meaningful. However, the prominent obtained results revealed the shape of contact area to be ellipsoidal for higher inflation pressures and circular shape for lower inflation pressures of tire.

REFERENCES

Febo P.,1987 - Contact area tests of a new wide section agricultural tyre. Proceeding of the 9th International ISTVS conference, Barcelona, Spain, 31 August-4 December 1987.1:236-243.

Godbole R., R. Alcock, D. Hettiaratchi, 1993 - The prediction of tractive performance on soil surfaces. Journal of Terramechanics 30(6):443-459.

Grecenko A., 1995 - Tyre footprint area on hard ground computed from catalogue value. Journal of Terramechanics 32(6):325-33.

Komandi G., 1990 - Establishment of soil-mechanical parameters which determine traction on deforming soil. Journal of Terramechanics 27(2):115-124.

Krick G., 1969 - Radial and shear stress distribution under rigid wheels and pneumatic tyres operating on yielding soils with consideration of tyre deformation. Journal of Terramechanics 6(3):73-98.

Mardani A., K. Shahidi, A. Rahmani, B. Mashoofi, H. Karimmaslak, 2010 – Studies on a long soil bin for soil-tool interaction. Cercetări Agronomice în Moldova, Iaşi, XLIII (No. 2 (142)): p. 5-10.

Pillai P.S., G.S. Fielding-Russel, 1986 - Empirical equation for tire footprint area. Rubber Chem. Tech. 59(1):155-159.

Silversides C.R., U. Sundberg, 1989 - Operational efficiency in forestry. Vol. 2. Practice. Kluver Academic Publishers, Dortrecht /Boston/ London. 169 p., ISBN 0-7923-0063.

Söhne W., 1969 - Agricultural engineering and Terramechanics. Journal of Terramechanics (4):9-18.