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Research Paper

Influence of the speed on soil-pressure over a plough

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During ploughing work wear is generated by the interaction between tillage tool and soil. Wear rate on tillage tools is mostly affected by soil-tool pressure distribution and it compromises plough functionality during its life cycle. In this paper, a methodology to measure and analyse pressure signals on a plough has been developed and the influence of the speed was investigated. Field tests were carried out with a four-furrow plough and the pressure on 10 different points was measured with tactile sensors. The plough was tested on a silty-clay-loam soil at three different speeds. The analysis of the results shows that pressure signals are close to zero for a range from 14 up to 92% of the travelled distance and short spikes frequently occur. This behaviour can be explained by the granular structure of soil that determines a non-constant contact between the soil and tool in some points. Spike patterns are markedly affected by the speed especially in terms of the number of spikes and their distribution. Moreover, the mean pressure quadratically varies with the speed in mouldboard (MBL) and ploughshare (PS) while on wear plate (WP) no influence was found because this part is parallel to the ploughing direction. The methodology and the results introduced in this paper will be useful for the validation of mathematical models to simulate the ploughing process but also, to improve the comprehension of the soil cutting process.

1. Introduction

Many methods to analyse load data from agricultural machines have been provided for durability evaluation during the last years (Mattetti, Molari, & Vertua, 2015; Perozzi, Mattetti, Molari, & Sereni, 2016). Durability is the capability of a machine to maintain its functionality during the intended service life. Among all the agricultural machines, plough is the most popular and its function is to cut, crumble and turn the soil in order to create the right conditions for crop growth. Ploughing is a very energy consuming operation because of the developed draught, which varies quadratically with the travel speed and linearly with the tillage depth (Molari,

Abbreviations: DSMV, distance-segmented mean value; DBP, distance base pressure; MBL, mouldboard; PS, ploughshare; TSMV, time-segmented mean value; WP, wear plate.

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Table 1 – Specifications of the tractor used for the test.

Tractor	New Holland T7.260
Max engine power [kW]	194
Max torque [Nm]	1349
Transmission	Full powershift (gears: 18 forward, 6 reverse)
Front tyres	Michelin MACHXBIB 600/65 R28 (12 kPa)
Rear tyres	Michelin MACHXBIB 710/70 R38 (12 kPa)
Mass [kg]	8950

Table 2 – Specifications and settings of the plough adopted in the test.

Type of plough	Double or reversible mouldboard
Number of furrows	4
Connection to the tractor	Mounted
Maximum power required by the tractor [kW]	176
Weight [kg]	1720
Width of cut [m]	2.00
Distance between bodies [m]	1.05

Mattetti, & Walker, 2015; Owende & Ward, 1996). Many studies have been carried out in order to reduce the developed resistance and to increase ploughing efficiency by optimising the shape of plough bodies. This was carried out by means of numerical models (Godwin, O'Dogherty, Saunders, & Balafoutis, 2007; Shrestha, Singh, & Gebresenbet, 2001) and experimental tests (Godwin, 2007). Plough bodies, even though optimised, cannot be easily maintained on service because they are heavily subjected to wear. The most prevalent wear mode on tillage tools is the abrasion but loss of material occurs also by means of impact, fretting, and chemical action (Bayhan, 2006). Wear has to be minimised because it affects tractor fuel consumption, tillage quality, and maintenance costs due to higher replacement rate of tool parts (Horvat, Filipovic, Kosutic, & Emert, 2008). Wear rate is mostly affected by soil texture, water content, particle angularity, hardness of the tool material, and soil-tool pressure distribution (Karmakar & Kushwaha, 2006; Natsis, Papadakis, & Pitsilis, 1999; Swanson, 1993).

Few studies were carried out on pressure distribution between soil and tillage tools, especially by means of analytical models based on the earth pressure theory (Godwin & O'Dogherty, 2007; Godwin & Spoor, 1977; Hettiaratchi & Reece, 1967; McKyes, 1985) and numerical models such as Finite Element Modelling (FEM) (Abo-Elnor, Hamilton, & Boyle, 2004; Bentaher et al., 2013; Mouazen & Neményi, 1999), Discrete Element Modelling (DEM) (Shmulevich, 2010; Shmulevich, Asaf, & Rubinstein, 2007; Ucgul, Fielke, & Saunders, 2014), and Computational Fluid Dynamics (CFD) (Karmakar & Kushwaha, 2006). From these studies, pressure signal on a tillage tool is irregular and the pressure is correlated with soil shear strength (Elijah & Weber, 1971), working depth, and tool travelling speed (Mayauskas, 1958). Moreover, by using FEM, the higher pressure areas were found at the tool edge (Chi & Kushwaha, 1989). Accurate mathematical models are necessary to design optimised tools because they allow the prediction of the pressure distribution over the entire tool surface in many different operating conditions. Mathematical models have to be validated and therefore more extensive experimental studies have to be carried out. In

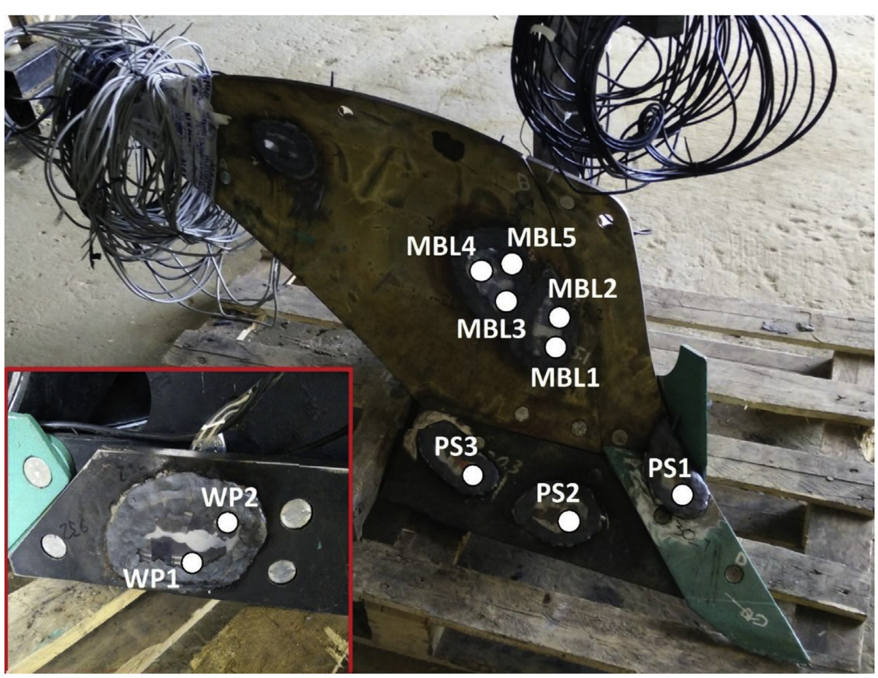

Fig. 1 – Positions of the pressure sensors and denomination of pressure signals.