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ANALYSIS OF THE INFLUENCE OF LOADING FORCE VARIATION ON THE HYDRAULIC WIM SYSTEM BEHAVIOR

BY

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Abstract: The importance of Weigh-In-Motion (WIM) systems is recognized worldwide, both for the information about the weight of vehicles in motion, with direct influence on road infrastructure, and for other informations that these systems can provide: speed, number of bridges etc. Traffic monitoring systems can provide this kind of information which simple WIM can not. In this paper are presented some results obtained using an experimental model of a hydraulic WIM system which reveal the influence of frequency variation of loading force on the pressure in WIM system.

Key words: WIM hydraulic system, loading force variation.

1. Introduction

Weigh in motion (WIM) is the process of measuring dynamic forces acting on the tyre of a vehicle in motion and the estimation of the static load on the tyre (ASTM Standard). Weighing in motion systems can provide weight on wheels, deck, bridge group and the weight of the whole vehicle.

The main types of WIM systems used nowadays are those with strain gage - rigid Board with strength sensor (de Beer & Fisher, 1997), flexible plate

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subjected to deflection (Bârsănescu *et al.*, 2007) - as well as piezometric (piezo-quart, piezoceramic and piezopolymeric), (Liu *et al.*, 2005). Comparative studies carried out over time, and having considered various criteria of comparison (costs and maintenance, accuracy, sensitivity, applicability, etc.), reveal that piezoelectric sensors are cheaper than sensors with strain gage, but measurement accuracy and life length are lower (Zhang, 2007).

Due to the importance of the information provided by these systems, various teams of researchers have tried implementing also other technologies for measuring the weight of vehicles. They tested the optic fibers WIM systems (Caussignac *et al.*, 1996), Bragg fibres systems (Li *et al.*, 2008) and microwave systems (Liu *et al.*, 2005). These technologies are still in the testing phase.

In this paper are presented the results obtained by testing in laboratory conditions of a new kind of weigh in motion, namely a hydraulic WIM system.

The proposed structure for the system includes an oil filled enclosure subjected to vehicle weight, pressure sensors, hydraulic adjustable resistance and pneumohydraulic accumulator. Experimental model based on proposed structure allowed to develop laboratory research. On the basis of this researches results the analysis of influence of some parameters on behavior of hydraulic WIM system.

2. Experimental Equipment

The element on which acts the weight in motion is the mineral oil filled enclosure. The wall of the enclosure deforms under the weight, the volume occupied by the oil in the chamber changes and conseuently changes also the pressure inside. The other five walls of the enclosure are rigid.

In order to study in laboratory conditions the behaviour of the system, was conceived an experimental model, in which deformable wall of the enclosure was assimilated with the piston of a single acting cylinder (Fig. 1).

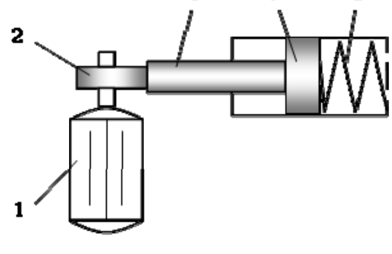

Fig. 1 − Enclosure with hydraulic oil and deformable wall:
1. electric motor, *2.* cam, *3.* rod, *4.* piston, *5.* spring.

The movement of the piston is produced by an electric motor via a mechanism cam-follower. Cam is circular, eccentric on engine shaft, and the follower is the hydraulic cylinder rod. The sensor is the elastic wall of the enclosure loaded by vehicle tyres. Changes of the signal frequency are obtained as a consequence of the variation of the speed of rotation of the electric motor. In Figure 2 is shown the hydraulic circuit for the experimental model.

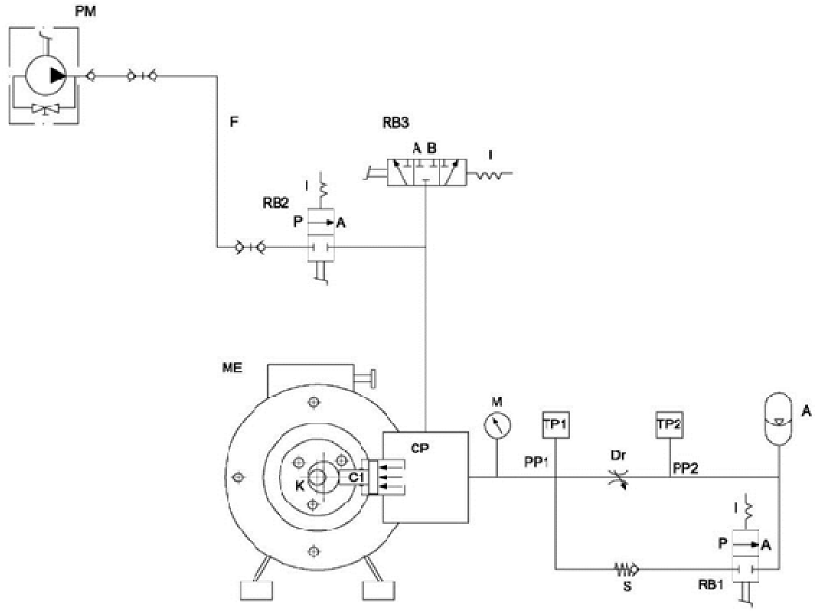

Fig. 2 − Hydraulic circuit for experimental model
PM- manual pump, ME-electric motor, K-cam, C1- single acting cylinder, CP- oil filled enclosure, RB1-valve that connect bypass circuit, RB2- valve that connect power supply circuit, RB3-valve for ventilation circuit, TP1, TP2-pressure transducers, Dr- throttle valve, A- pneumohidraulic accumulator, S- check valve, F- hose with quick action couplings, PP1 şi PP2- pressure intakes, M- pressure gauge

As working hypothesis is considered isothermal system behavior during a measurement.

The variation of rotational speed was achieved by using a frequency converter Mitsubishi FR-520S CE, 2,2 kW integrated in one electrical unit. To carry out automatic and/or semi-automatic speed variation of the electric motor, as well as for data acquisition, the stand was equipped with a programmable automation system in the NI CompactRIO product by National Instruments (Fig. 3). In its composition was implemented two modules with analogic input and output and two output digital modules. Through their component analog modules (analog-to-digital converter, digital-to-analog) allow the purchase of electrical signals from an experimental facility, as well as establish reference values for controlling the speed of rotation of the electric motor through the frequency converter.

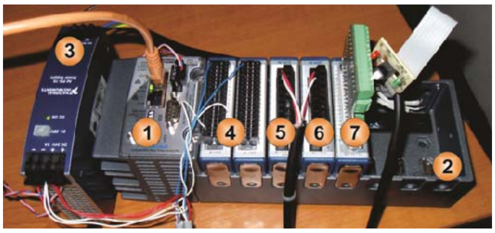

Fig. 3 − NI CompactRIO System
1. Programmable controller, 2. Motherboard, 3. Power supply,
4. Analog input module for pressure signals, 5. Analog input module for speed ,
6. Analog input module for controlling frequency converter, 7. Analog output module for the rotation sense of ME.

Switch on or off for the electric motor, as well as the direction of rotation, is carried out by means of a bi-directional digital module. Output module acts directly upon the replacement frequency. On this hardware platform was developed a dedicated software for the operation of the stand and the realization of data relating to the tests carried out, using the LabVIEW graphical programming environment.

3. Experimental Results

Using the experimental equipment in figure 2 one can register pressure signals obtained when we are changing rotation speed of the electric motor, crossection of hydraulic resistance or preloading pressure for pneumohidraulic accumulator. In this chapter will be presented the results obtained changing the speed rotation of the electric motor.

Ongoing program of experiments aimed different crossections of hydraulic resistance, different rotational speeds for the electric motor Registration of pressure upstream the resistance have been carried out for five different values of the rotational speed of the motor shaft. Other registrations were done for other values of the stroke of the mobile component of hydraulic resistance at different preloading pressures for the pneumohydraulic accumulator.

In Figure 4 one can see a superposition of signals registered pressure upstream of hydraulic resistance, corresponding rod stroke $C= 2\cdot10^{-3}$ m, a preloading pressure $p_0= 20\cdot10^5$ Pa and five different rotation frequencies of the electric motor shaft, $f_1 = 2$ Hz, $f_2 = 3$ Hz, $f_3 = 4$ Hz, $f_4 = 5$ Hz şi $f_5 = 6$Hz.

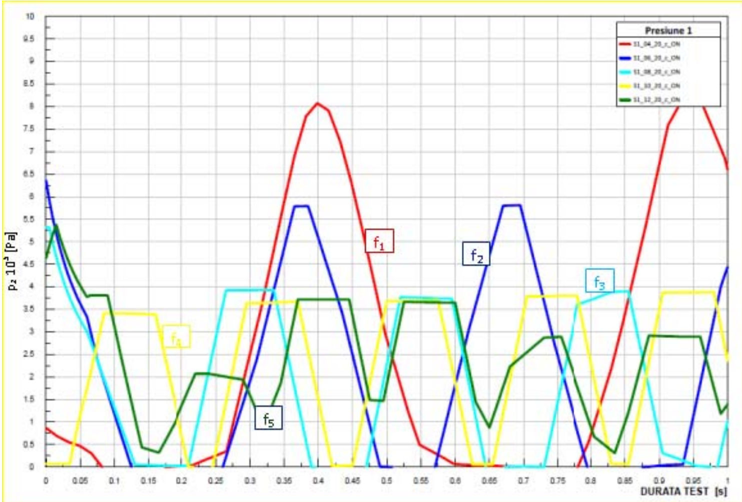

Fig. 4 − Pressure signals for five different rotation frequencies of electric motor shaft (f_1=2 Hz, f_2=3Hz, f_3=4Hz, f_4=5Hz, f_5=6Hz; C=$2\cdot10^{-3}$ m).

Figure 5 shows the same analysis for another range of mobile hydraulic resistance (C=$4\cdot10^{-3}$ m) and a preloading pressure p_0= $15\cdot10^5$ Pa.

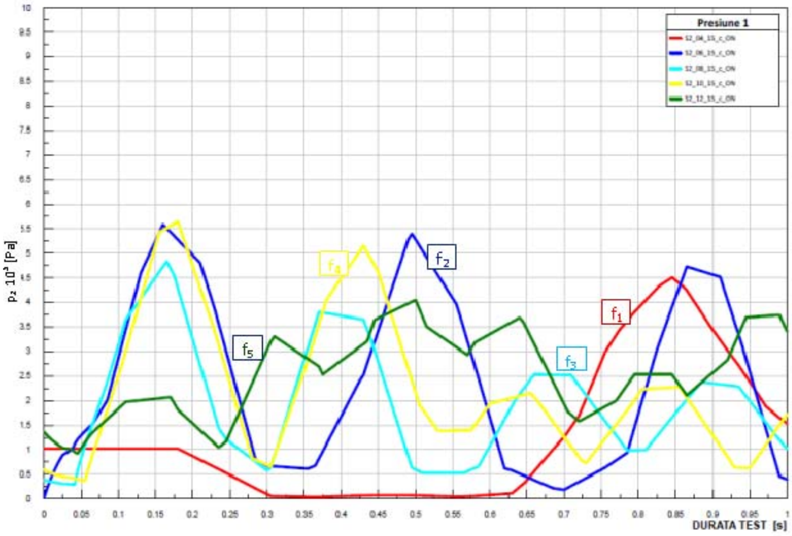

Fig. 5 − Pressure signals for five different rotation frequency of electric motor shaft (f_1=2 Hz, f_2=3Hz, f_3=4Hz, f_4=5Hz, f_5=6Hz; C=$4\cdot10^{-3}$ m).

One can see that with the increase of hydraulic resistance and decrease of preloading pressure, signal amplitude of pressure decrease in a smaller measure.

4. Conclusions

The amplitude of measured signals decreases with increased frequency of rotation of the electric motor shaft, but the decrease was smaller, if the crossection of the hydraulic resistance increases and the preloading pressure of the accumulator decreases. For the proposed variant of the experimental model, if one will do the testing at high frequencies, it is recommended to use bigger crossections for hydraulic resistance, in order to increase amplitude of the registered signals.

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ANALIZA INFLUENŢEI FRECVENŢEI DE VARIAŢIE A ÎNCĂRCĂRII ASUPRA COMPORTĂRII UNUI SISTEM WIM HIDRAULIC

(Rezumat)

În acest articol sunt prezentate rezultatele obţinte prin testarea în condiţii de laborator a unui sistem de cântarire în mişcare (WIM) hidraulic şi influenţa frecvenţei de variaţie a încărcării asupra semnalelor de presiune generate în sistem. Este explicat modul în care s-a simulat în laborator generarea semnalelor de presiune de către sistemului WIM hidraulic şi circuitul hidraulic care a constitui modelul experimental, cu ajutorul căruia s-au obtinut rezultatele grafice. Sunt prezentate rezultatele analizei variaţiei frecvenţei de rotaţie asupra semnalelor de presiune şi concluziile desprinse în urma acestei analize.