SOME ASPECTS REGARDING THE INFLUENCE OF TEMPERATURE IN A WIM HYDRAULIC SYSTEM

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ABSTRACT: Weighing in motion systems (WIM), regardless the type of sensor that the system utilizes, works in difficult conditions: dust, slag, layer of ice or snow, high humidity, varying temperatures during a day, or a year. All these conditions have impact on the accuracy of measurement and require considering the correction factors. In this paper it is presented the analysis of the temperature influence on a weighing in motion sensor. It is examined a type of WIM sensor actually rarely used, namely a hydraulic sensor, in order to see performances of such a solution. On the basis of a proposed structure for experimental model, it is presented the corresponding SimHydraulics block diagram, considering some aspects regarding the decision for choosing one or another solution. Using this block diagram and considering different values for the temperature, some results and consequently some conclusions were obtained.

KEY WORDS: weigh-in-motion hydraulic system, temperature influence, SimHydraulics block diagram, simulation.

1 INTRODUCTION

The actually used weighing in motion systems uses strength gauges sensors (flexible plate deflection subjected and rigid plate with strength sensor), and piezometric sensors (ASTM E1318-02, 2009; Mardare, 2013). However, there are other technologies that are now online, namely sensors with fiber optics and the microwave (COST 323). The system presented in this paper utilizes hydraulic environment for the signals transmission related to weight. This system has a simple structure, the entire equipment signal acquisition and processing thereof, being outside of the road. This means that the operation and maintenance of this system is done with minor interventions on vehicle traffic.

To test the possibility of creating such a system, it has been designed, based on the principle of it, an experimental model for testing in laboratory conditions behavior system. For a number of parameters, which could not be tested in the lab, it was conceived a SimHydraulics block diagram, in order to get signals, which allows the analysis of the influence of some functional parameters.

This paper presents the block diagram designed to simulate experimental model used in the laboratory.

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There are also presented the results obtained through simulation, on the influence of temperature on the experimental model tested, known as its importance on the hydraulic oil behavior used by this system of weighing.

2 STRUCTURE OF THE PROPSED EXPERIMENTAL MODEL

The structure of hydraulic weighing in motion system (Figure 1) includes a metallic enclosure (6), whose upper wall is deformable, the others being considered as rigid walls. In connection with it, a pipe (7) which has two pressure sensors (8) and (9) is mounted. Between these sensors there is a hydraulic resistance (10).

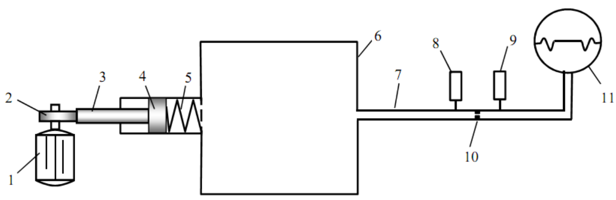

Figure 1. Schematics for experimental model

It is also included a gas-charged accumulator (11), which will counterbalance the pressure variations due to day-night temperature variation (Bucuresteanu, 2001; Topliceanu et al., 2012).

To test in the laboratory condition the behavior of hydraulic weighing in motion system, it arrived at a solution to generate pressure pulses, through the load action of the deformable wall of enclosure with hydraulic oil.

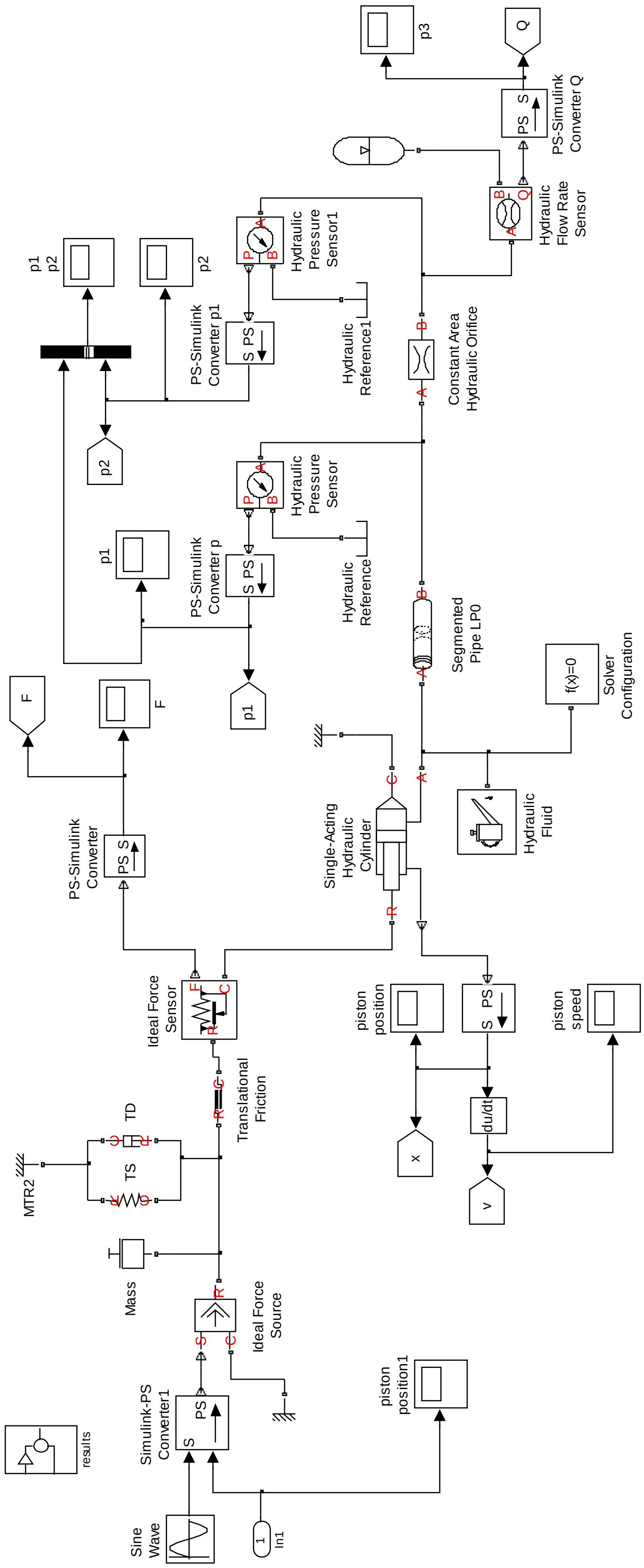

Figure 2. SimHydraulics block diagram of the experimental model

It was used a cylinder with simple action and return spring (Tita, 2009), whose translation movement follows a cam (Ibanescu & Ungureanu, 2012) mounted on the axle of an electric motor drive.

The particularity of the single acting cylinder mounted in hydraulic circuit is that if in the usual way, a hydraulic cylinder converts hydraulic energy to mechanical energy, in this case, hydraulic cylinder converts mechanical energy in the hydraulic energy. In this case, the spring of the cylinder does not ensure the return of piston, but keeps contact with the cam mounted on the axle of the electric motor. The hydraulic cylinder simulates the load on the weigh-in-motion sensor. If one wants to consider different loads on the sensor, it must be changed the stroke of the piston. If one wants to consider different speeds of the weight vehicle, it must be changed the speed of the electric motor.

3 BLOCK DIAGRAM OF THE EXPERIMENTAL MODEL

Design simulation of reaction scheme for hydraulic weighing in motion system, takes into account all the existing elements in the experimental model, namely: simple action cylinder, enclosure with hydraulic oil, inside pipes, hydraulic resistance (with variable section), gas-charged accumulator, pressure transducers and the existence of the return circuit.

In the two libraries of functional elements Simscape (Library Foundation and Hydraulic Utilities Library), there have been chose the elements corresponding to those on the experimental facility (Zahariea, 2010; Jedrzykiewircz et al., 1998).

When simulation blocks work based on simplifying assumptions, which are not covered in mathematical modeling of simulated elements, subsystems may be created by introducing additional blocks.

The block diagram in Figure 2 contains the system for generating the signal input at the piston of single acting hydraulic cylinder having all forces considered, meaning inertia, translational friction, damping force which simulates the forces that act on it, as well as blocks to simulate the measuring instruments used in the experimental installation, in order to determine some parameters (pressure, flow, force, displacement and velocity of the piston).

The presence of cam mounted on the motor spindle in contact with the piston of the cylinder was simulated by introducing an input signal of sinusoidal shape, to which the signal amplitude depends on the value of the cam design eccentricity. Also there have been used elements from the Simulink libraries and Simscape/SimHydraulics, elements able to simulate the force acting on the piston of the single acting cylinder.

The input signal of sinusoidal form is obtained by the action of the force on the piston hydraulic cylinder. At the R port, there is connected blocks which simulates the forces acting on the cylinder piston and road: friction force (Translational Friction, the force of inertia (Mass) elastic force (Translational Spring) and damping force (Translational Damper).

To simulate the pressure chamber in the hydraulic circuit, there has been used Segmented Pipe LP block, connected to the port of the cylinder with simple action. Sudden change of section of passage into and out of the chamber pressure was simulated by introducing in the window of the control parameters of a value corresponding to an equivalent length of straight pipe. In the simulation diagram, there are connected also the blocks that simulate hydraulic resistance (Constant Hydraulic Orifice Area), as well as the hydro-pneumatic accumulator (Gas-Charged Accumulator).

Power losses due to pipe fittings used for mounting circuit were considered as the equivalent length of straight pipe. The resulting value has been entered in the corresponding window of the control parameters of the functional element Segmented Pipe LP, connected to A, respectively B ports of the Constant Functional Area Hydraulic Orifice.

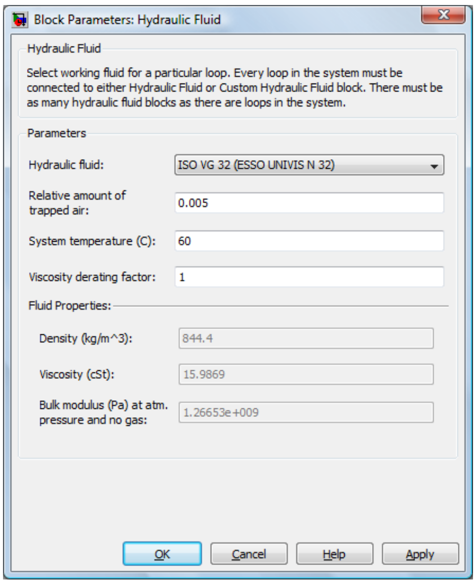

Figure 3. Parameters for Hydraulic Fluid

The characteristics of hydraulic fluid are specified in the Hydraulic Fluid block (Figure 3).

In the control parameters block of the functional element, one can select the type of hydraulic fluid, relative amount of trapped air and working temperature, information depending on are visualized particular fluid properties, namely: density, kinematic viscosity, and bulk modulus.

By changing the temperature in this block, there were obtained the results of the simulation, which allowed the analysis of the temperature influence on system. On the basis of this analysis, some conclusions to be used in future researches and prototype design could be developed.

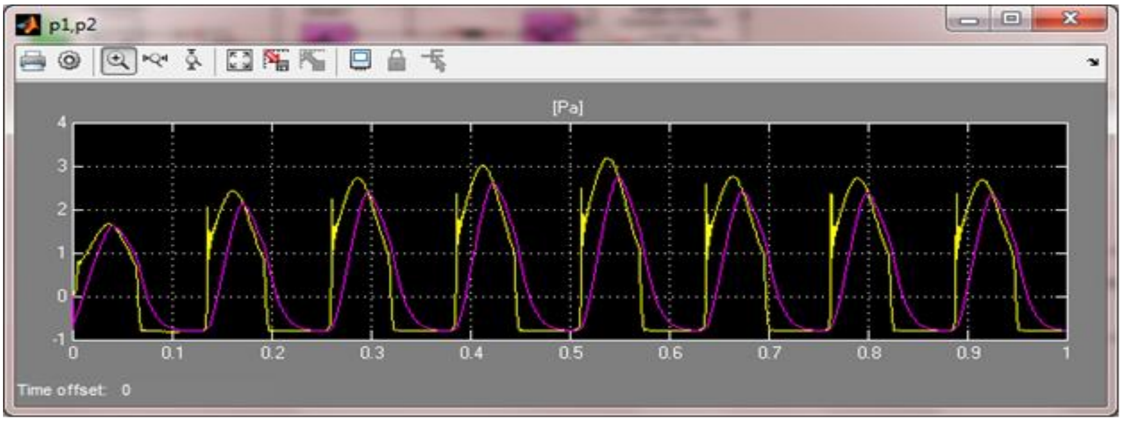

Figure 4. Pressure signals upstream respective downstream hydraulic resistance at t =30°C

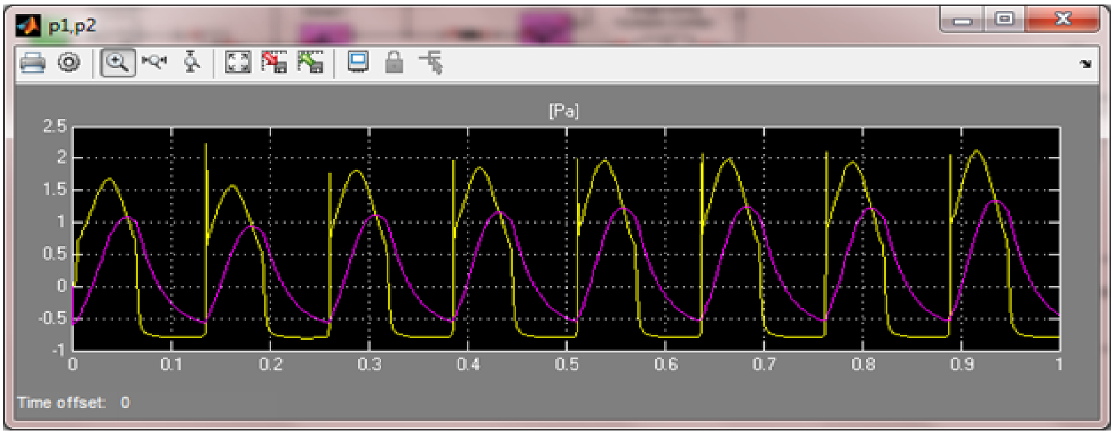

Figure 5. Pressure signals upstream respective downstream hydraulic resistance at t = -10°C

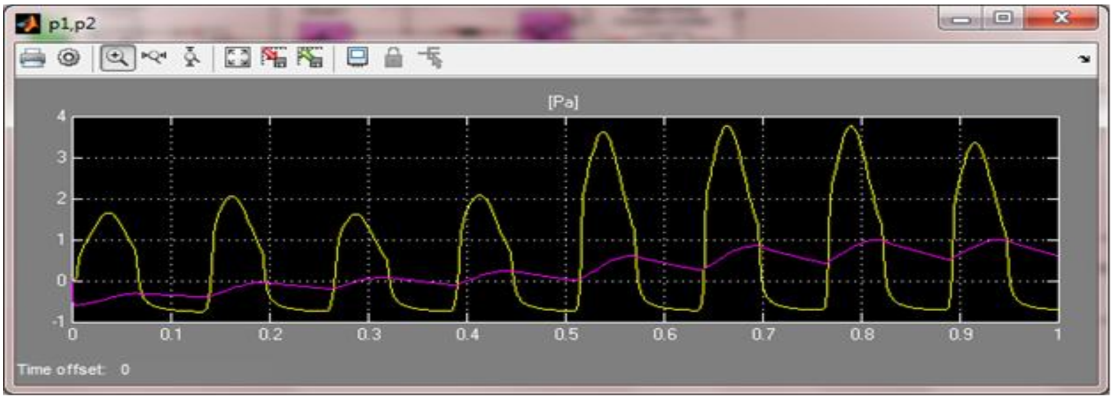

Figure 6. Pressure signals upstream respective downstream hydraulic resistance at t = -30°C

4 RESULTS OBTAINED BY SIMULATION

After choosing the hydraulic fluid in the block parameters (ISO VG 32, similar to that of the experimental installation), there were selected the other parameters and for a lot of simulations both positive and negative temperatures.

Table 1. Main parameters

Single acting cylinder		
Piston area	0.001962	m^2
Dead volume	0.00001962	m^3
Cylinder orientation	Acts in negative direction	-
Spring rate	1400	N/m
Damping	25	N/(m/s)
Friction force	F_{brk}=30, F_C=30	N
Constant area hydraulic orifice		
Orifice area	$0.314\cdot10^{-7}$	m^2
Flow coefficient	0.65	
Gas-charged Accumulator		
Capacity	0.0006	m^3
Preload pressure	$15\cdot10^5$	Pa
Specific heat ratio	1.4	
Hydraulic fluid		
Type	ISO VG 32	
Density	889,2	Kg/m^3
Kinematic viscosity	$105,41\cdot10^{-6}$	m^2/s
Bulk modulus	$1.71\cdot10^9$	Pa
Temperature	15	^oC
Input signal		
Amplitude	105000	-
Frequency	50	Hz

For 30°C temperature, hydraulic fluid characteristics are: density ρ = 863.6 kg/m^3, kinematic viscosity $\upsilon = 486.923\cdot10^{-6}$ m^2/s, bulk modulus $\beta = 1.54\cdot10^9$ Pa. The results obtained by using the block diagram in Figure 2 are those shown in Figure 4. One can see a small decrease in magnitude, when temperature increases.

At a negative value for temperature (t = - 10 ^oC), for this value of temperature characteristics of hydraulic fluid are: density ρ = 889.2 kg/m^3, kinematic viscosity $\upsilon = 626.57\cdot10^{-6}$ m^2/s, bulk modulus $\beta = 2.03\cdot10^9$ Pa.

Results obtained from the simulation in this case are presented in Figure 5. It is found that at negative temperatures, pressure signals amplitude decreases because of the kinematic viscosity and density of oil increase, this being more accentuated for registered signals downstream hydraulic resistance.

For a simulation at a lower value for temperature t_u = - 30 ^0C, hydraulic fluid characteristics are: density ρ = 902 kg/m^3, kinematic viscosity $\upsilon = 5112.53\cdot10^{-6}$ m^2/s, bulk modulus $\beta = 2.34\cdot10^9$ Pa. The results obtained from the simulation are presented in Figure 6.

One can see in this case ununiform signals upstream respective downstream hydraulic resistance and a decrease of signal amplitude registered downstream orifice.

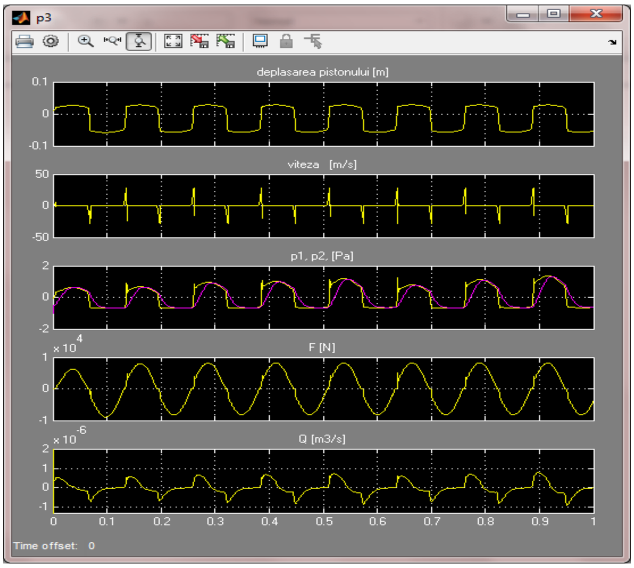

Figure 7. Visualization in Results block

The block diagram allows analyze by correlation, showing variation of main parameters. In Figure 7, there is presented the Scope in the Results block. One can see simultaneously piston position, piston speed, pressure upstream and downstream the orifice, load at the cylinder and flow at the accumulator.

5 CONCLUDING REMARKS

In this paper, there is presented the SimHydraulics bloc diagram for a hydraulic WIM system. The diagram is conceived for the case of experimental model, design to be tested in order to realize a future prototype for a hydraulic WIM system.

One can see the values for parameters, the methodology and the results obtained using the block diagram.

From the analysis of signals obtained by using simulation scheme (Figure 2), there is the certainty that there is a direct influence of temperature on pressure signals.

It is necessary to test and use appropriate additivated hydraulic fluids, so that they can give expected results at extreme temperatures (temperature variations between seasons and during a day).

Another option for solving this problem is the adoption of constructive solutions of weighing in motion system that allows changing of the hydraulic fluid spring and autumn. Any constructive version will be chosen, given the fact that the entire equipment for acquisition and processing of the signals is out of the road, hydraulic fluid changing will be achieved without stopping traffic. This represents a great advantage of this type of a system, with positive economic significance for both major carriers and road system administrators.

It is also necessary to determine the correction factors for pressure signals (Gajda et al., 2007), which must take into account the temperature variation along a day.

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