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ANALYSIS SOLICITATIONS INJECTION SYSTEMS OF HIGH AND VERY HIGH PRESSURE USING MULTI DOMAIN SIMULATION

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Abstract: An important role for the implementation, in the cylinders of compression ignition engines, of an efficient combustion process, is represented by the mixing process of intake air and fuel. The efficiency of this process in turn depends to a great extent on the quality of fuel injection. A high quality fuel spray requires high finesse of the fuel jet, which requires the highest possible injection pressure. Because pressure increase modifies the stress values, in this article is presented the dependency of some forces by injection pressure. The analyzed forces stress some components of the Common Rail injection system high pressure pump, allowing a fuel pressure increase without design complexity. Analysis of these forces was possible by modeling the radial piston pump, using 1D multi-domain software LMS AMESim (Advanced Modeling Environment for Performing Simulation of Engineering Systems).

Keywords: injection pressure, radial piston pump, stress

1. INTRODUCTION

The quality of the combustion process in compression ignition engine cylinders depends directly on the quality of the fuel spray, or more precisely its degree of smoothness. The greater the smoothness the more homogenous is the mixing, resulting in a more efficient combustion process. [1]

Improving fuel spraying can be achieved both by increasing injection pressure and by a suitable choice of the spray holes geometry. Given the short time in which the injection must take place to ensure the entire quantity of fuel required for the combustion process, diminishing the spraying hole sections should be done at the same time with a significant increase in the injection pressure. [3]

In addition, a high injection pressure will ensure a high energy of the jet fuel. This situation is imposed partially by the increasingly higher density of the air in the compression ignition engines' cylinders, equipped with high pressure superchargers.

However, when the injection pressure increases so do the forces stressing the system, so optimizing intensity levels of the stress on the injection system components with the injection pressure value becomes a necessity.

Given the above and the foremost role of the high pressure pump in the injection system, in this paper is outlined, through a simulation model, the influence of the injection system pressure on certain components of the Common Rail injection system high pressure pump.

2. GENERALITIES

Common Rail injection system offers the advantage of high pressure injection, obtained

independently from the injection itself and from engine load.

In this system a low pressure pump transports the fuel from the tank to the high pressure injection pump, which has a fuel flow control system. This control system allows only the necessary fuel quantity for the injection process to be compressed.

The high pressure pump from the Common Rail injection system is a radial piston pump, like the one shown in Figure 1. Through an eccentric shaft, driven by the crankshaft, the pistons perform a translational motion, ensuring the injection pressure. Permanent contact between the piston and eccentric shaft is ensured by a spring. Inlet and outlet of the fuel in the pump cylinders is made through check valves.
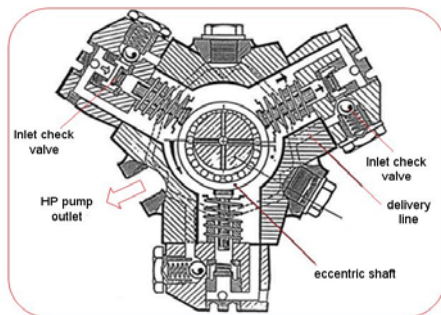

Fig. 1. The scheme for radial piston pump [4]

Thus, the high pressure pump only serves to transmit the fuel to the pressure accumulator and finally to the injectors with enough pressure to ensure a satisfactory injection process.

Compared to classic injection systems, where design complications would occur, the Common Rail injection system can be improved by increasing the injection pressure, due to its working principle. [2]

3. AMESim SIMULATION PROGRAM

The simulation model of the radial piston pump used in the Common Rail injection system, was conducted using 1D multi-domain software from LMS, AMESim (Advanced Modeling Environment for performing Simulation of engineering systems). With this program one can model most of the technical systems that work on different physical principles.

Representation of the components in these systems is done using standardized ISO symbols used in engineering. Graphical User Interface of the software is shown in Figure 2.
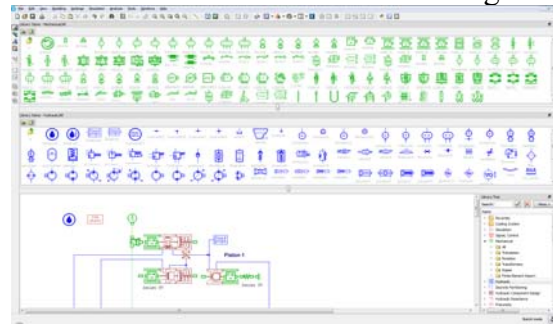

Fig. 2. Graphical User Interface of the AMESim simulation program

The software allows multi-domain simulation models of different physical systems to be created by assembling and validating models from the database (libraries). The database contains mathematical models that can be customized according to user requirements.

The mathematical model of the system is resulted by analyzing the steady state and the dynamic behavior of the system. The mathematical model can be resulted in the form of differential equations, partial differential and algebraic.

4. SIMULATION MODEL

The making of the radial piston pump's simulation model (Figure 3) involved the use of components from hydraulic and mechanical libraries of the software.
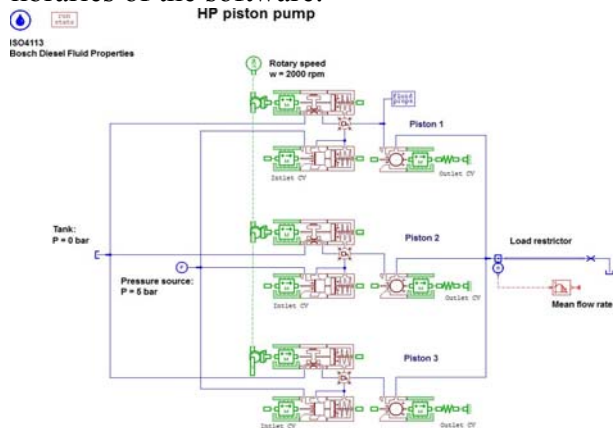

Fig. 3. The simulation model of radial piston pump

The meaning of the symbols used in the simulation model of the high-pressure pump with radial piston, are described in Table 1.
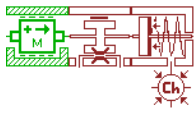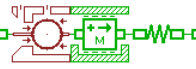
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**The signification of the main symbols used for building the simulation model**

Table 1

Symbol	Signification
	Piston and cylinder assembly
	Inlet check valve
	Outlet check valve

The studied pump's modeling and the simulations in AMESim were realized according to the following steps: the building up of the model using the symbols from the mentioned libraries of the software, the selection of the sub models with the proper mathematical model, the insertion of the parameters, and the simulation itself.

Following these steps made possible, using the results, to describe the behavior of the radial piston pump which operating at different values of injection pressures.

5. THE SIMULATION RESULTS

As mentioned above, simulations purpose was to identify the influence of the fuel pressure in the injection system on the stresses that occur in the high pressure pump's components. In Figure 4 is shown for one piston of the high pressure pump: *the torque of the eccentric shaft* (M_{es}), the *contact force between the eccentric and the piston* (F_c) and *the force in the outlet check valve* (F_{ov}).
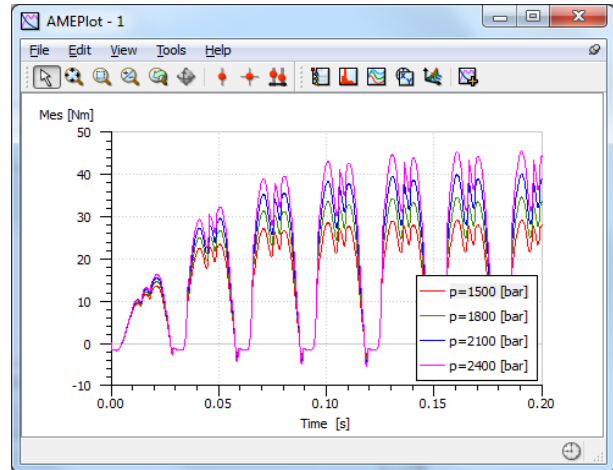
a.
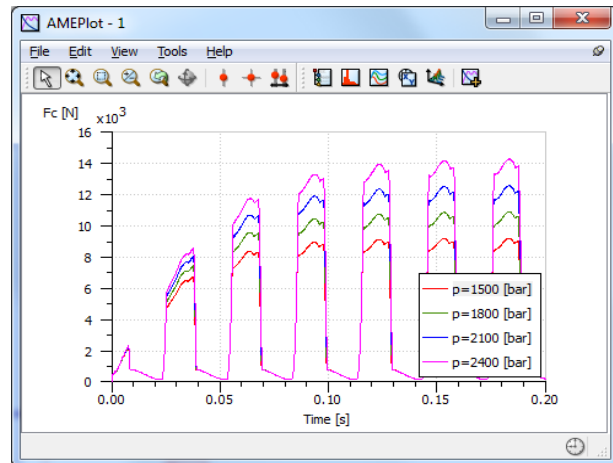
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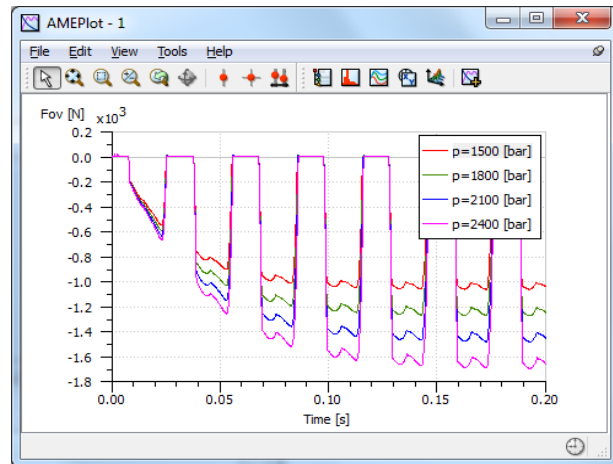
c.

Fig. 4. The evolution of stresses in a piston of a high pressure pump

In Figure 4 one can observe the dependency between the fuel pressure and the stress increase. The highest stresses occur in the contact area between the eccentric shaft and piston.

The evolutions of these stresses are represented in case of four maximum injection pressures: **1500**, **1800**, **2100** and **2400** [bar]. Figure 5 illustrates, for each of the three pistons, evolution injection pressure of 1500 [bar]. By adding the pressures in each piston, as shown in Figure 6, we obtain the evolution of the injection pressure at the high pressure pump's output.
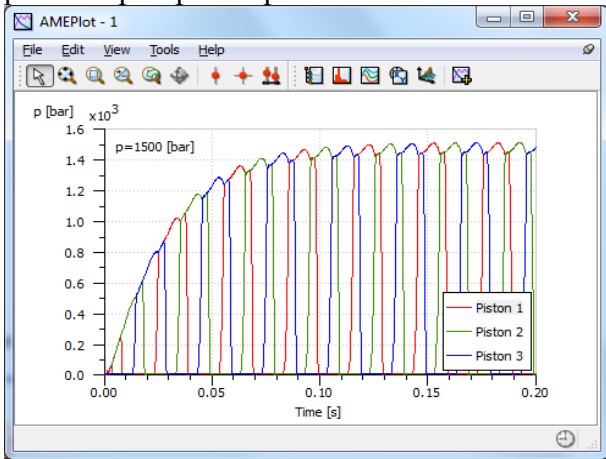

Fig. 5. The evolution of pressure in all the pistons of the high pressure pump
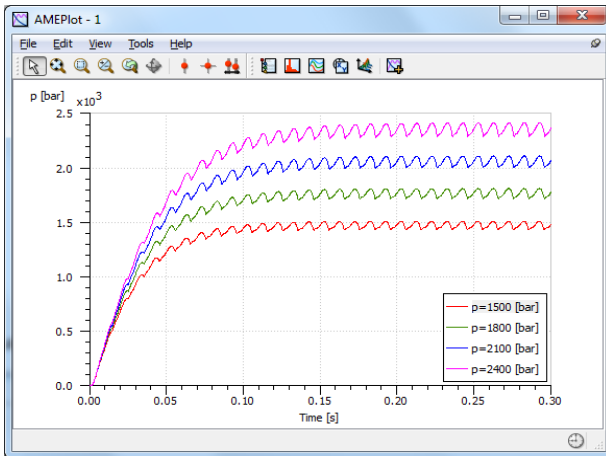

Fig. 6. The pressure evolution at the output of the high pressure pump

To highlight the magnitude by which the high pressure pump's components stress changes in relation to maximum injection pressure change, in Table 2 were represented the percentages by which the stress varied, in three cases of the maximum pressure increase. These cases have assumed sequential increase of the 1500 bar pressure by 20 %.

Stress increase on the pump components in relation to maximum pressure increase

Table 2

Absolute values of the maximum pressure increase range	The percentage of amending the:			
	P	M_{es}	F_c	F_{ov}
	%	%	%	%
Case I: 1500 [bar]→1800 [bar]	20	19	19	20
Case II: 1500 [bar]→2100 [bar]	40	38	37	40
Case III: 1500 [bar]→2400 [bar]	60	57	56	60

As shown in the table above, the increase in pressure determines a proportional increase in stress on the high pressure injection system's components.

6. CONCLUSIONS

Increased injection pressure as a solution to increase the efficiency of the injection process and implicitly the combustion process, modifies the working conditions of the injection system components'.

In the simulations, realized with the AMESim software, which describes the behavior of the radial piston pump operating at different values of the maximum injection pressure, resulted that the stress on the high pressure injection system increase with the same percentage as the fuel pressure increases in the system.

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4. AMESim Assistance help.