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DYNAMIC ANALYSIS BY NUMERICAL SIMULATION OF THE VARIATION OF THE HYDRAULIC PARAMETERS OF THE SOLENOID INJECTOR

BY

VASILE GABRIEL NENERICĂ* and DORU CĂLĂRAŞU

"Gheorghe Asachi" Technical University of Iaşi,
Machine Manufacturing and Industrial Management Faculty,
Department of Mechanical Engineering

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Abstract. The purpose of the paper is the dynamic analysis of the variation of hydraulic parameters, *i.e*. the injected volume and outflow, depending on the electric signal applied to the injector coil. Fig. 1 show the conceptual model diagram made to be simulated using AMESim software. It is considered as input the current drive of the injector coil. The unit-step response, *i.e*. injected outflow and volume variation, is analyzed for three imposed pressure steps, namely 1800 bar, 800 bar, 400 bar. Figs. 3,…, 8 show the unit-step responses of the injected outflows and volumes of the analyzed model, for the imposed pressure stages, *i.e.* 400, 800, 1800 bar.

The analysis of the characteristics shown in Figs. 3,..., 8 corresponding to the three pressure stages, *i.e.* 400, 800, 1800 bar, reveals that the operation mode is stable, the unit-step responses are aperiodical with delay and dead time, the responses may be approximated with a 1st order element with shape delay:

Key words: injector, simulation, injection.

*Corresponding author; *e-mail*: nnrcvasile@yahoo.com

1. Introduction

The term s*imulation* means the validation of the accuracy of a model relying on a real situation in order to understand the impact of the changes in the operation conditions on system behavior and the effect of the implementation of various control strategies. Simulation allows experiencing real or hypothetical situations, which are impossible or difficult to achieve in the real functioning of a system (Călăraşu, 2002; Beucher & Weeks, 2008; Huian *et al*., 2012a; Huian *et al*., 2012b; Huian & Călăraşu, 2013; Watton, 1989; Călinoiu *et al*., 1998).

The simulation of the structure and operation of a preset model allows the creation of all the possible situations (states) of the model and thus enables one to check the existence of the properties set during the analysis stage. The fact that these properties are not confirmed supports the existence of one or several errors either in the structure of the model, or in the determination of its properties. Therefore, only simulation is able to finally validate the achievement of the operation characteristics set by design.

The objective of each simulation program is to predict the behavior of a particular system before building it. Many alternatives of a particular situation may be included in a simulation and the results may be studied comparatively.

Given the high number of fields to which simulation applies as a method of analysis of system and process behavior, many programs and function libraries used in simulation were created and developed. Matlab/Simulink and AMESim are some of the most used programs in engineering system simulation.

The digital simulation of systems including electro-hydraulic components is much simpler with AMESim and allows the fast optimization of the constructive and functional parameters required in practice (Negoiţă, 2011).

Given the numerous possibilities provided by language for the development of submodels by means of interdisciplinary libraries, AMESim was implemented as a basic design tool by reputed system manufacturers (Negoiţă, 2011).

The purpose of the paper is the dynamic analysis of the variation of hydraulic parameters, *i.e.* the injected volume and outflow, depending on the electric signal applied to the injector coil.

2. The Simulation Model of the Solenoid Injectors Used AMESim Medium

In simulation of the operating of the solenoid injector were used following:

− working fluid for simulations ISO 4113
− the viscosity of the working fluid at 40°C 2.5 cSt

− fluid temperature	800 C
− vapour pressure	0.002 bar
− injection hole diameter	0.12 mm
− number of injection holes	6
− supply current injector coil	20A

The unit-step response, *i.e.* injected outflow and volume variation, is analyzed for three imposed pressure steps, namely 1800 bar, 800 bar, 400 bar.

Fig. 1 presents the conceptual model diagram made to be simulated using AMESim software.

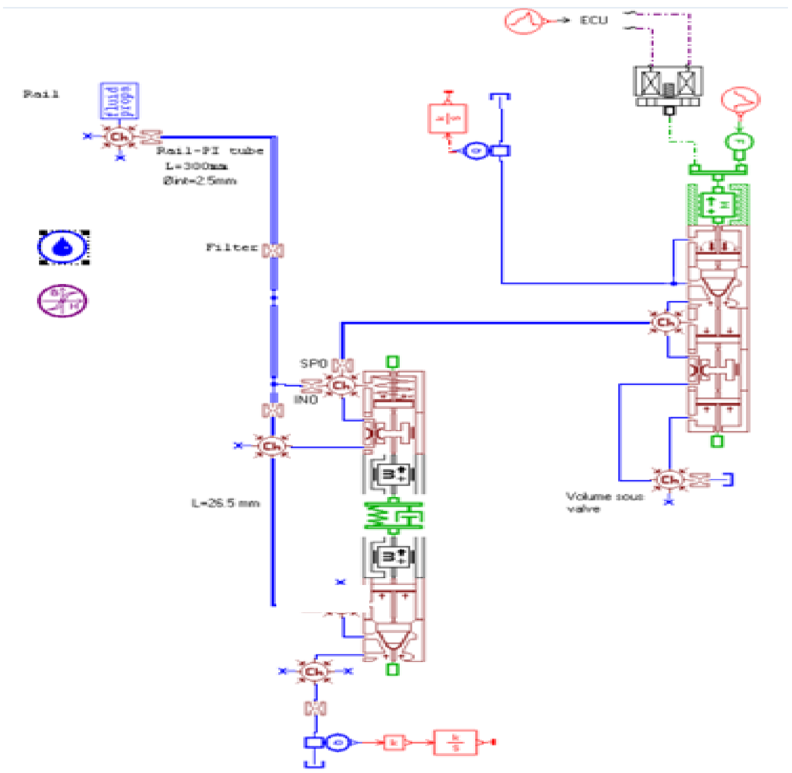

Fig. 1 − Conceptual model of simulation of the injector.

3. Dynamic Analysis of the Solenoid Injector Operation Obtained by Numerical Simulation

It is considered as input the current drive of the injector coil.

Figs. 3,…, 8 show the unit-step responses of the injected outflows and volumes of the analyzed model, for the imposed pressure stages, *i.e.* 400, 800, 1800 bar.

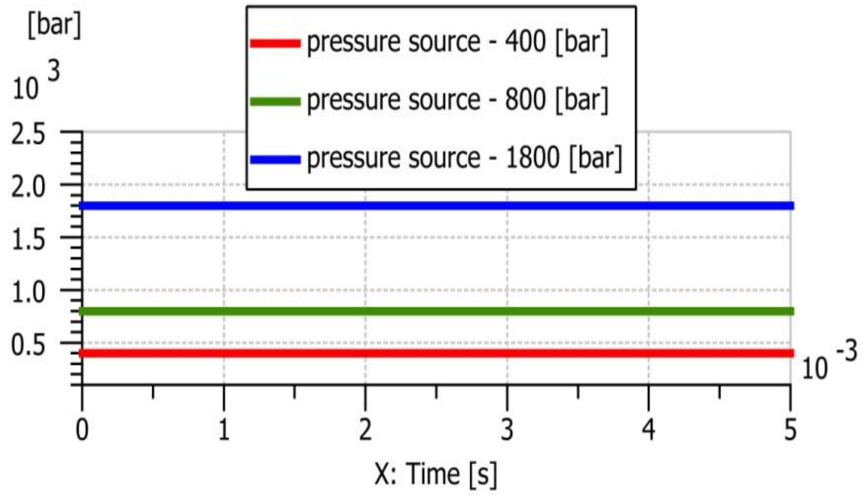

Fig. 2 − The injection pressure required.

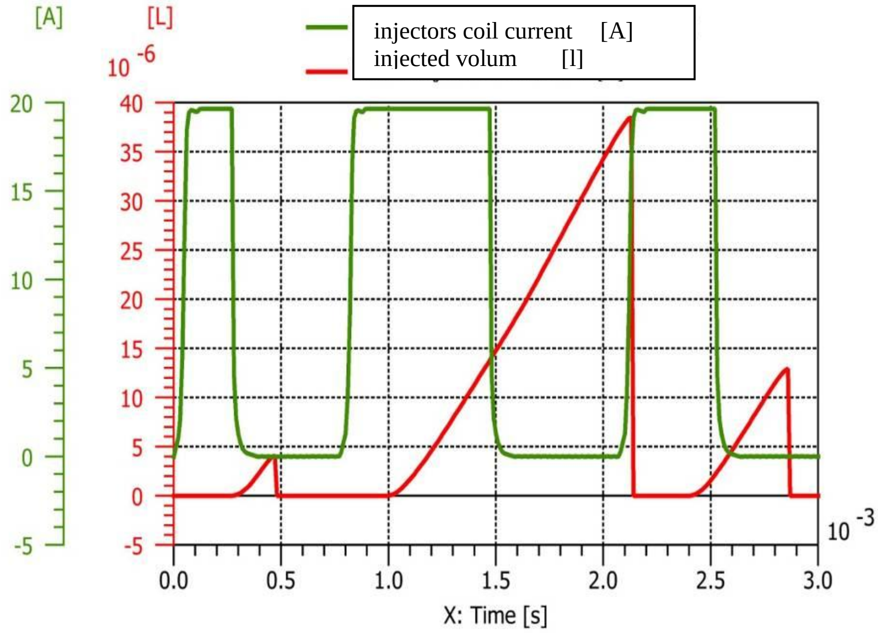

Fig. 3 − The step response of the injected volume
at the pressure of 1800 bar.

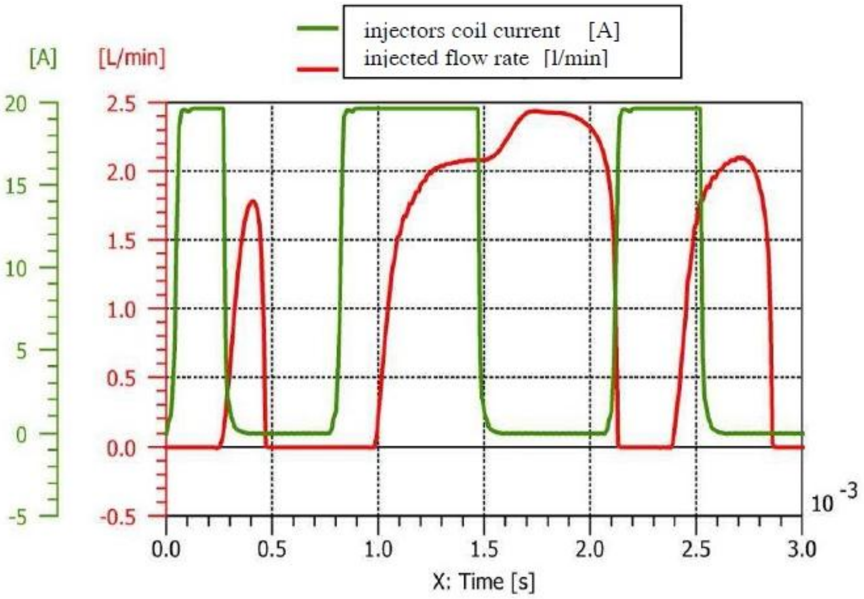

Fig. 4 − The step response of the injected flow rate at the pressure of 1800 bar.

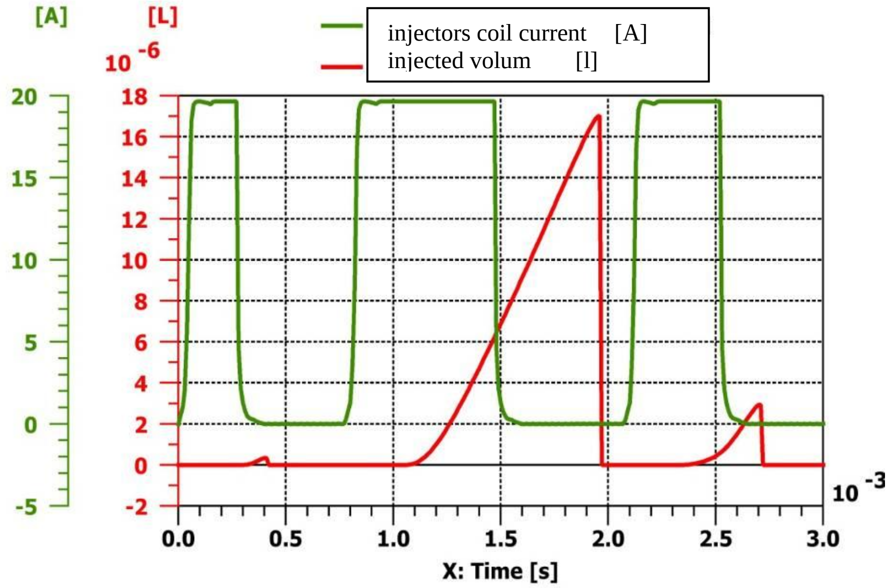

Fig. 5 − The step response of the injected volume at the pressure of 800 bar.

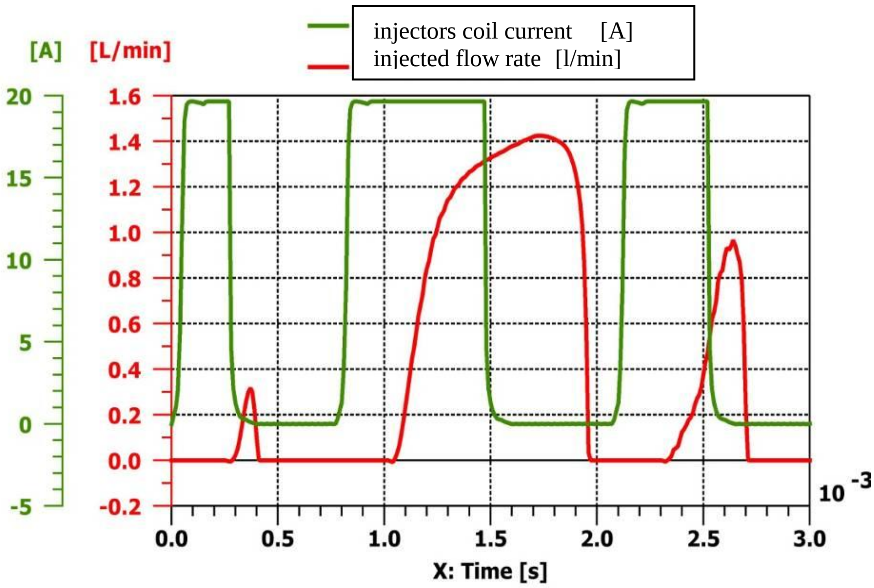

Fig. 6 − The step response of the injected flow rate at the pressure of 800 bar.

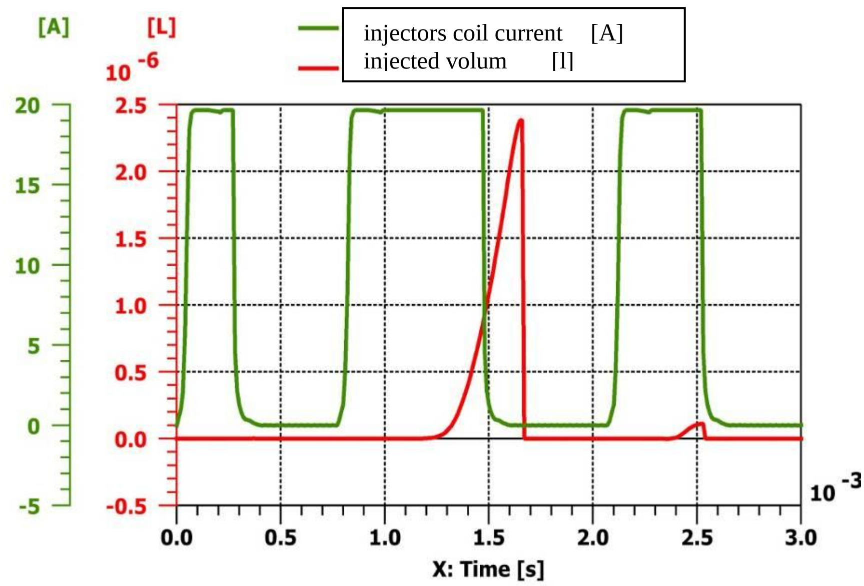

Fig. 7 − The step response of the injected volume at the pressure of 400 bar.

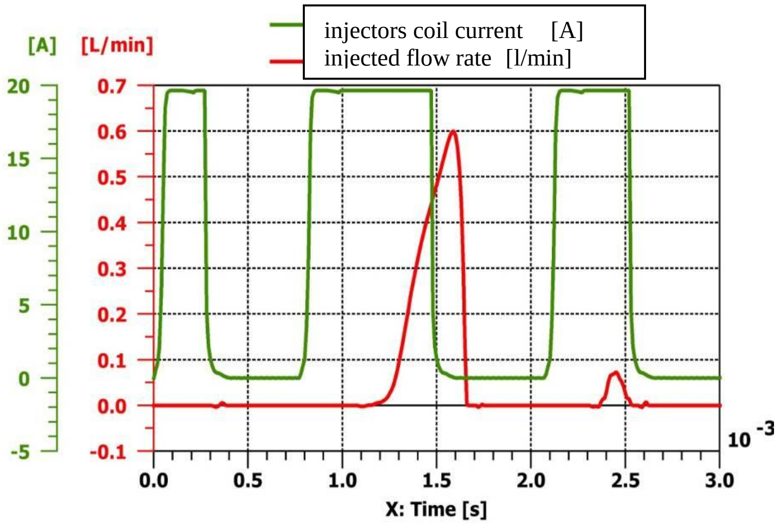

Fig. 8 − The step response of the injected flow rate at the pressure of 400 bar.

The analysis of the characteristics shown in Figs. 3,..., 8 corresponding to the three pressure stages, *i.e*. 400, 800, 1800 bar, reveals the following:

− the operation mode is stable;

− the unit-step responses are aperiodical with delay and dead time;

− the responses may be approximated with a 1st order element with shape delay:

$$T_1 \frac{dx_e(t)}{d(t)} + x_e(t) = kx_i(t - T_m)$$

where: T_1 – the delay time constant; T_m – dead time.

The step-like electrical signal applied corresponds to the injection, pre-injection, main injection and post-injection stages.

The pressure increase reduces the down time, increases the stationary value, which the injected outflow tends to, and increases the injection time.

4. Conclusions

1. The unit-step responses (volume, outflow) obtained in the study of an auto injector for various pressure steps allow the analysis of the functioning of the injector and its components (valve and injection nozzle), during the stages corresponding to injection: pre-injection, main injection and post-injection.

2. The analysis of the characteristics obtained for three pressure stages, *i.e*. 400, 800, 1800 bar, enabled us to conclude that: the operation mode is stable, the unit-step responses are aperiodical with delay and down time.

3. The pressure increase reduces the down time, increases the stationary value, which the injected outflow tends to, and increases the injection time.

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ANALIZA DINAMICĂ PRIN SIMULARE NUMERICĂ A VARIAŢIEI PARAMETRILOR HIDRAULICI A INJECTORULUI CU SOLENOID

(Rezumat)

Lucrarea urmăreşte analiza dinamică a variaţiei parametrilor hidraulici, respectiv volumul şi debitul injectat funcţie de semnalul electric aplicat bobinei injectorului.

În Fig. 1 se prezintă schema modelului conceptual realizată pentru a putea fi simulată cu ajutorul programului AMESim. Se consideră ca mărime de intrare curentul de acţionare a bobinei de comandă a injectorului.

Se analizează răspunsul indicial, respectiv variaţia debitului şi a volumului injectat, pentru trei trepte de presiune impuse, respectiv 1800 bar, 800 bar, 400 bar.

În figurile 3,…, 8, se prezintă răspunsurile indiciale ale debitelor şi volumelor injectate ale modelului analizat, la treptele de presiune impuse, 400, 800, 1800 bar.

Din analiza caracteristicilor din figurile 3,…, 8, corespunzătoare celor trei trepte de presiune, respectiv 400, 800, 1800 bar, se constată că: regimul de funcţionare este stabil, răspunsurile indiciale sunt de tip aperiodic cu întârziere şi timp mort, răspunsurile pot fi aproximate cu un element de ordin I cu întârziere.