ANALYTICAL AND EXPERIMENTAL MODEL OF THE DIESEL ENGINE INJECTOR

A. BĄKOWSKI, L. RADZISZEWSKI, J. JAROSZEWICZ
Kielce University of Technology Poland
Bialystok University of Technology Poland

The test engine used for these measurements was a 3-cylinder compression-ignition Perkins AD3.152 UR. Selected parameters of its performance were tested on the test rig capable of measuring: pressure in the combustion chamber, pressure in the injection pipe, injector needle lift, crank angle. The experimental studies conducted using an engine dynamometer included measurements of the pressure in the injection pipe, in-cylinder pressure and the needle lift. Values from 50 full engine working cycles were recorded as a function of the crank angle with an increment of 1.4^{o} for each parameter, which gave 512 measurement points within one engine working cycle. This study used the results obtained for the engine working at full load at the variable rotational speeds from 1000 to 2000 rpm. The engine ran on diesel or bio fuel.

The first step in the development of an analytical-experimental model of an injector was to carry out a statistical analysis of the tests results for checking stationarity and compatibility of the variables distribution with normally distributed data. The analyses rendered the signals stationary. Autocorrelation function was analysed in this study to confirm the stationarity of the signals. The Lilliefors the Pearson and the Jarque-Bera tests were carried out to determine unequivocally whether the measurement dataset distribution could be said to be compatible with the normal distribution. Analysis of the results confirmed– there was no reason to reject the null hypothesis H0. Analysis of the maximum values of the needle lift recorded for the consecutive engine working cycles indicates that the signal is stationary but for the speeds 1200, 1400, 1600 and 1800 rpm, at least one of the tests provides evidence to reject the H0. In calculations of the fuel dose injected using dependence, parameter $\Delta P$is used relating to the pressure difference between, most often, the injector line and the cylinder. It is thus warranted to attempt building a model that will help track pressure changes in the sac volume and the dose of the fuel injected. For that purpose, analytical dependencies were formulated and experimental data were used. Then selected parameters of the injector model were identified and computer simulations of the injector needle lift and the fuel dose injected were made. The flow continuity equation for the sac volume can be written as

$$\frac{V_S}{E_S}\frac{dp_S}{dt} = \mathrm{sgn}(p_W - p_S)\mu_g A_g \sqrt{\frac{2}{\rho_l}|p_W - p_S|} - \varepsilon_S \mu_r A_r m \sqrt{\frac{2}{\rho_l}|p_S - p_C|} - \frac{dV_S}{dt}$$

where: p_W, p_S, p_C – pressure in the intake tube, sac volume and engine cylinder, respectively, $\frac{dV_S}{dt}$ – a change in the volume of the nozzle cavity in the function of time resulting from the injector needle lift. Dynamic equation of the injector needle motion will have the form:

$$m_W \frac{d^2 h_i}{dt^2} = -\beta_W \frac{dh_i}{dt} - k_{SW}(h_i + h_{W0}) + p_W(A_{ip} - A_i) + p_S A_i - T$$

where: $T = f(p_s)$ – other resistive forces affecting the needle motion (friction forces T).

It was assumed that the sum of these forces is proportional to the pressure in the sac volume $T = f(p_s) = -\text{signum}\left(\frac{dh_i}{dt}\right) \cdot \mu p \cdot p_s$. The quantities used in calculations although connected with the cyclic process, take different values in consecutive engine working cycles. The model proposed here helps determine the values of pressure in the sac volume p_s, the fuel dose injected and the needle lift h_i. The last of these parameters is used to validate the model. The unknown quantities to be identified are the viscous friction coefficientβ_w, spring constant$k_{sw}$and coefficientμp. Identification and determination of the changes p_s and the fuel dose injected should be performed within the crank angle range selected for analysis. Examples of simulation results for the needle lift are shown in fig. 1.

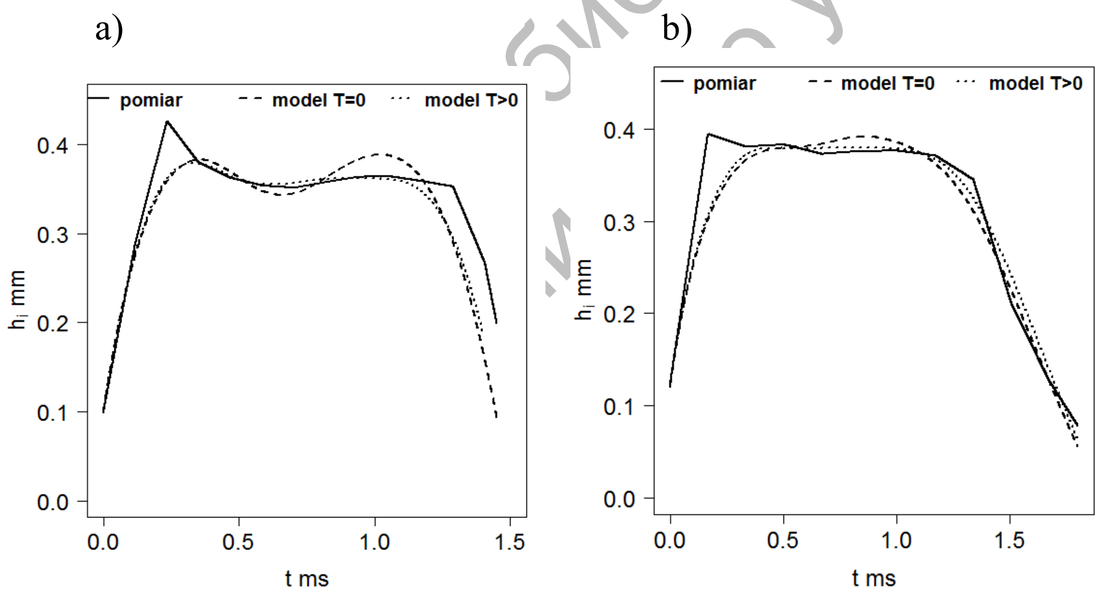

Fig. 1. Model and experimental curves expressing the dependence of the injector needle lift on time for: a – an engine supplied with diesel; rotational velocity of the crankshaft n=2000 rpm; b – an engine supplied with biofuel; rotational velocity of the crankshaft n=1400 rpm

The analytical-experimental injector model proposed here correctly determines the sac volume pressure changes and the needle displacements. The calculated dose of the injected fuel, after identification of the proposed injector model parameters, varies from the theoretical dose by approximately 3 %.