Journal of POLISH CIMAC
Faculty of Ocean Engineering & Ship Technology
GDAŃSK UNIVERSITY OF TECHNOLOGY

THE INFLUENCE OF MUTUAL ANGLE POSITION OF MAIN, PILOT AND PREINJECTION DOSE ON FUEL DOSING IN COMMON RAIL SYSTEM

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Abstract

The common rail fuel supply systems on account of flexibility at injection characteristic shaping, are the most frequently applied fuel supply solution in Diesel engines. The most essential parameters, which have the effect on fuel dosing precision are injection duration, rail pressure and fuel temperature. Also there are other factors, which can cause fuel dosing errors. It might be also other factors caused by specific working of fuel system. The split of fuel dose into a few parts (for example into pilot dose, preinjection dose and main dose) can cause pressure fluctuation in rail and also in the whole system. Next this can cause a chang of set fuel dose. In the article research results connected with influence of mutual angle position of main, pilot and preinjection dose on the total fuel dose. The researches were conducted with test stand equipped with test bench Bosch EPS-815 with electronic measuring of fuel dose. Control of injector was realized by using worked out controller which enables to split of fuel dose into three parts.

***Key words::** Common Rail, fuel injection, injection control, injection pressure, fuel dose*

1. Introduction

The development of compression ignition engines is oriented to ecological requirement, especially in the field of emission limit of nitric oxides and particulate matters. The designers of those engine types have to be up to the challenge resulting from need to limit of fuel consumption at simultaneous to save high dynamic parameters of engine. At realization these tasks the injection system meets the most important part.

Currently, on account of flexibility at injection characteristic shaping, common rail systems are the most frequently applied fuel supply in Diesel engines [2,6]. Because another Euro standards connected with limitation of mentioned pollutions are very strict, therefore such system types have to be very precise at injection characteristic shaping. Next, course injection depends on a lot of phenomena occur in the whole system. Possibility of realization a lot of injections during the same work cycle permits flexibility shaping of injection course, but at the same time it causes arising new problems connected with interaction between injections. Especially it concerns situation, when injections are located near one another. Of course, the most essential parameters effecting on dosing precision are injection duration, rail pressure and fuel temperature. While injection duration can be precise controlled by system controller, fuel pressure and fuel temperature change dynamic effecting on fuel dose and whole injection course.

In the article the effect of mutual angle position of main, pilot and preinjection dose on fuel dosing has been presented. At keeping constant total injection duration and fuel temperature, injected fuel dose and overflow from injector were measured. A high-speed courses (fuel pressure in injection pipe behind rail and before injector) and injector control signals were recorded too. In these scope of researches demonstration test results have been presented. The researches were conducted with test stand equipped with test bench Bosch EPS-815 with electronic measuring of fuel dose.

2. Test stand and measurement methodology

As a basic elements of test stand during researches used are: test bench with measurement system of fuel dose with heat exchanger, high pressure rail and electronic control injector. The fuel was injected into special fuel chamber which enabled observation of injected fuel spray. The scheme of test stand is showed on fig. 1.

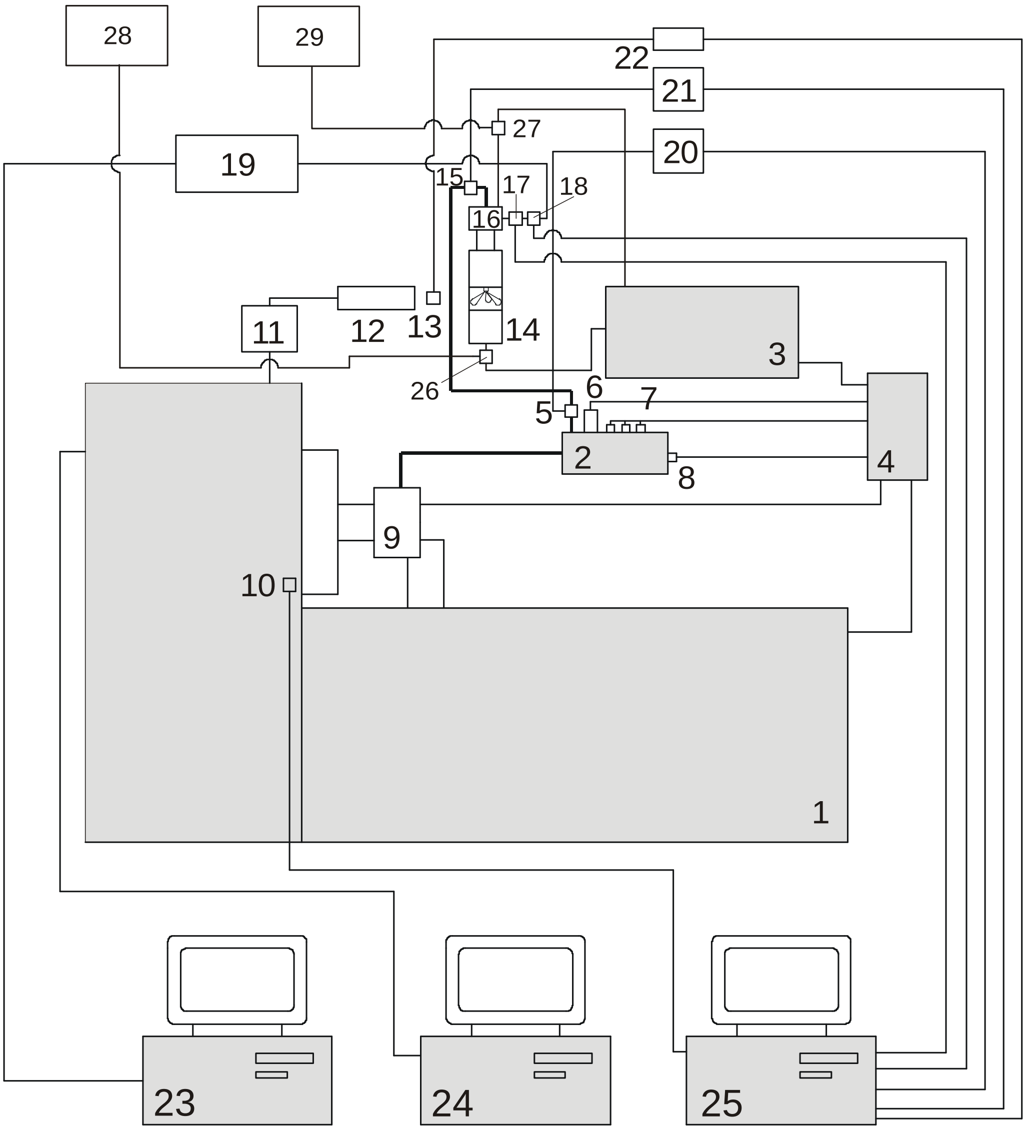

Fig. 1. Scheme of test stand: 1-test bench Bosch EPS 815, 2-rail of high pressure, 3-set of fuel dose measurement Bosch KMA 822 with heat exchanger, 4-control module of high-pressure pump, 5,15- piezoquartz pressure sensors, AVL QL21D, 6- rail pressure sensor, 7- rail pressure regulators, 8-fuel temperature sensor, 9-high pressure pump Bosch CR/CP1S3/L70/10-1V 445 010 343-02, 10-optical position and rotational speed sensor of pump shaft AVL 365C, 11-controler of stroboscopic tube Tech-Time 3300-S, 12-stroboscopic tube, 13-photoelement, 14-visualization chamber, 16-tested injector, 17-measurement connector of injector control voltage, 18-injector current sensor PA-55, 19- microprocessor controller of injector, 20, 21-charge amplifiers AVL 3057-A01, 22-voltage amplifier, 23-computer with control software of injector, 24-computer with software for test bench controlling and for measuring of fuel dose, 25-computer with data acquisition devices for high-speed courses recording, 26,27-temperature sensors, 28,29-termometers EMT 101

The description of fuel dose in dependence on its split strategy was the fundamental aim of researches. The distances between starts of injector control signals as well as a fuel doses were changed. Tests have been conducted for dose splitting into two parts (pilot dose and main dose) and for three parts (pilot dose, preinjection dose and main dose). Adjusted total injection duration $\mathbf{t_{inj}}$ was 1,0 lub 3,0 ms depending on test program. As a injection duration one should understand a duration of control signal using to injector opening. The distances between starts of control signals are as adjusted parameters and one shouldn't identify them with real injection starts. These problems were discussed accurately in the works [3,4,5,7,8].

For shorter total injection duration the researches only for pilot and main injection were conducted, while for longer duration also preinjection was used.

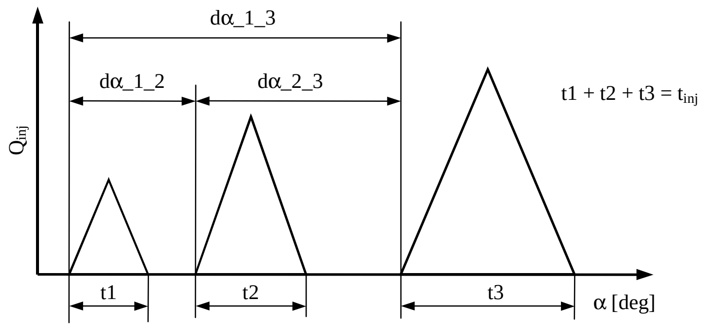

Fig. 2. Scheme of symbols described the injection strategy

Each series of test at constant injected fuel temperature $\mathbf{T_{inj}}$, fuel pressure $\mathbf{p_{rail}}$ and frequency running of injector was conducted. A frequency running of injector resulted from rotational speed **n** of the shaft of high pressure pump.

The parameter values connected with fuel injection on the figures presenting test results have been presented. The symbols described the injection strategy are showed on fig. 2.

During researches the series injector Bosch signed CR/CP1S3/L70/10-1V 445 010 343-02 was used. It was controlled by worked out controller enabling to split of fuel dose and their angle location in wide range. Detailed description of controller and set of injection system are presented in the work [1].

3. Test results

On fig. 3 the effect of distance between start of pilot injection and start of main injection **dα_1_3** on fuel dose $\mathbf{Q_{inj}}$ at various rail pressure $\mathbf{p_{rail}}$ and at rotational speed of pump **n = 600 rpm** has been presented. In this case at split of fuel dose into two parts, total injection duration amounted 1,0 ms (pilot dose 0,5 ms and main dose 0,5 ms). As showed on fig. 4, the largest dose fluctuations appear for shorter distances between doses and for lower pressures. On fig. 4 recorded course of fuel pressure $\mathbf{p_{inj}}$ before injector and control signal $\mathbf{U_s}$ for two various angle distances between pilot dose and main dose (15° and 20°) at rail pressure 75 MPa are presented. For these points, difference between obtained dose values amounted above 10 mm^3/injection (fig. 3). As showed on fig. 4, the pressure courses are shifted in phase and for 15 deg between injections the main injection is realized on descending pressure wave (solid line), while in the second case (dashed line) on rising pressure wave. Taking into consideration fact that for these conditions the changes of pressure before injector amount 30-40 MPa, it results in considerable deviation of fuel dose. The largest stabilization of fuel dose was observed for larger distances between doses and for the largest value of rail pressure $\mathbf{p_{rail}}$. Ambiguous character of fuel dose change results from random wave phenomena in injection system, which intensify at shorter distances between fuel doses. In these cases, opening of injector can occur both lower and larger values of pressure $\mathbf{p_{rail}}$ in relation to adjusted value (compare fig. 4).

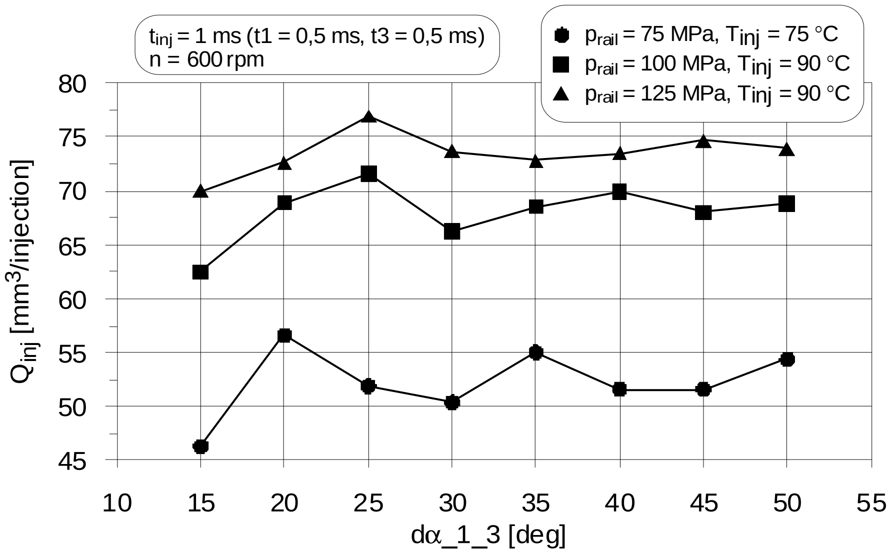

Fig. 3. Effect of distance between starts of pilot and main injection dα_1_3 and various rail pressures p_{rail} on fuel dose Q_{inj} (adjusted total injection duration t_{inj} = 1,0 ms)

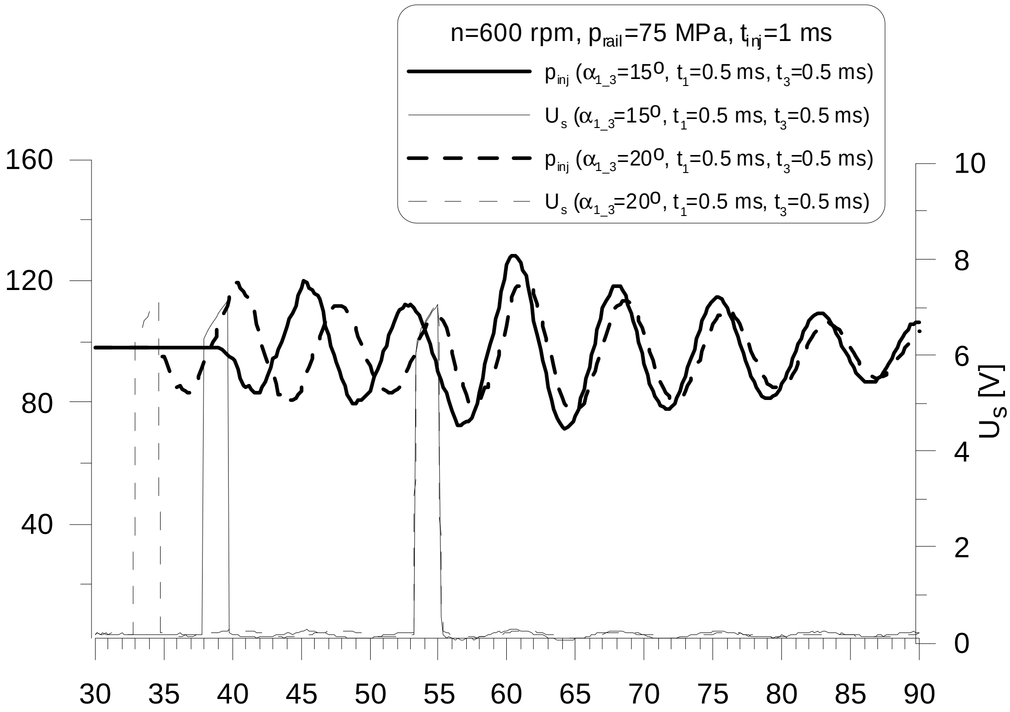

Fig. 4. Pressure courses in injection pipe before injector p_{inj} for two different ways of injector control by signal U_s, at the same total injection duration (rotational speed of pump n=600 rpm, p_{rail}=75 MPa, injection duration t_{inj}=1,0 ms)

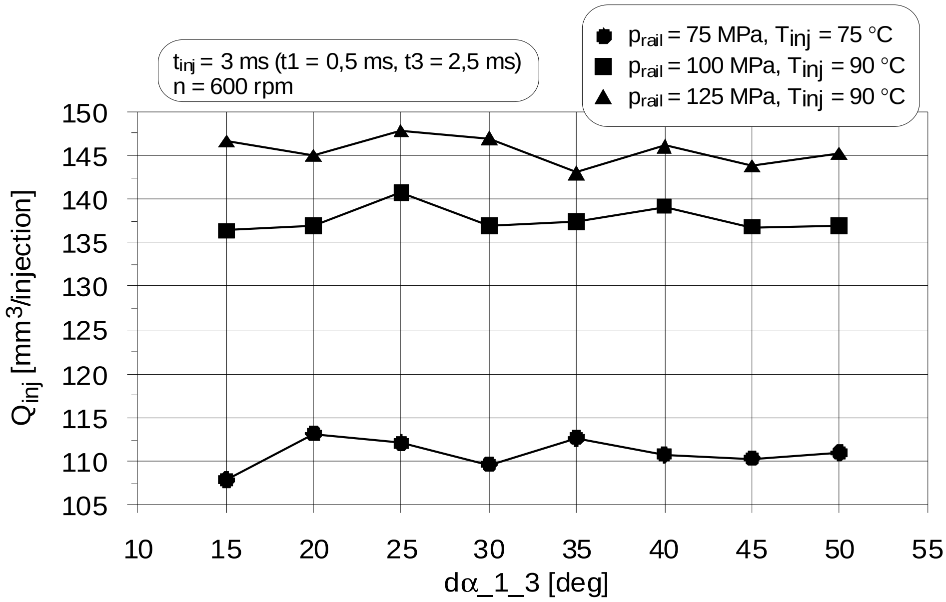

Fig. 5. Effect of distance between starts of pilot and main injection dα_1_3 and various rail pressures p_{rail} on fuel dose Q_{inj} (adjusted total injection duration t_{inj} = 3,0 ms)

On fig. 5 in similar order, as on fig. 3 test results are presented – in this case the different depends on using larger fuel dose. In this case a total injection duration amounted **t_{inj} = 3,0 ms** (for pilot dose was **t_1 = 0,5 ms** and for main dose was **t_3 = 2,5 ms**). Like in earlier analyzed case a certain stabilization of fuel dose for larger angle distances between pilot dose and main dose can be observed. Also is showed that for the lowest pressure value (**p_{rail} = 75 MPa**) a dose fluctuation are considerably lower than for lower total dose (**t_{inj} = 1,0 ms**, compare fig. 3).

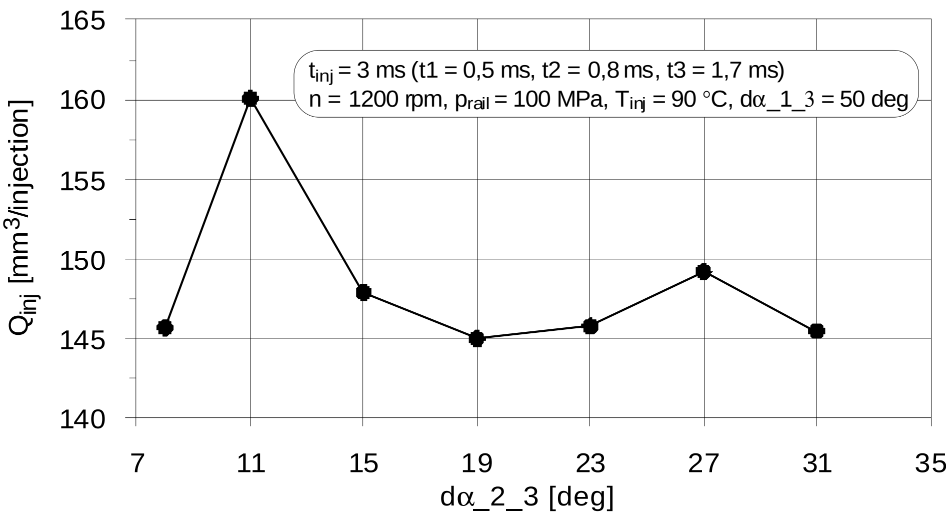

Fig. 6. Effect of distance between starts of preinjection and main injection dα_2_3 on fuel dose Q_{inj} (adjusted total injection duration t_{inj} = 3,0 ms)

On fig. 6 test results concerning the split of fuel dose into three parts are presented. The injection durations for pilot, preinjection and main dose were **t_1 = 0,5 ms, t_2 = 0,8 ms i t_3 = 1,7 ms** respectively. The distance between starts of pilot dose and main dose **dα_1_3** was constant and amounted 50 deg. However, a distance between start of preinjection dose and main dose **dα_2_3** was changed. As showed, for lower distances between preinjection dose and main dose there are considerable fluctuations of fuel dose. It results from too short time to closing of spray nozzle. In such cases algorithm of fuel injection control has to work right correction of fuel injection duration, in order not to change adjusted total opening duration of injector.

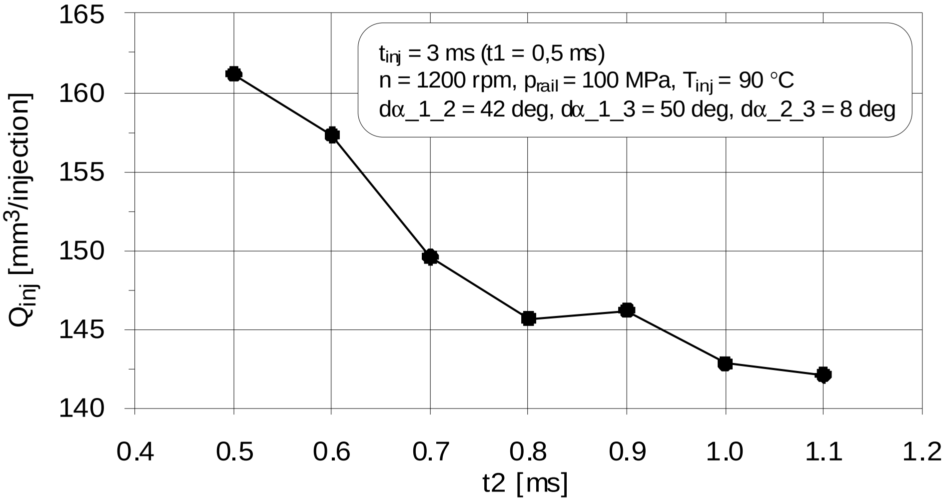

Fig. 7. Effect of preinjection duration t_2 on fuel dose Q_{inj} (adjusted total injection duration t_{inj} = 3,0 ms and pilot injecton duration t_1 = 0,5 ms)

At set of distances between fuel doses but for changing of preinjection duration, considerable decreasing of fuel dose was observed – fig. 7. Analyzing fig. 6 and 7 it can find that there are certain minimum distances between doses, after exceeding one occurs considerable decreasing of fuel dose.

4. Conclusions

Obtained test results show that change of mutual angle position of individual parts of dose at multi injection causes deviations during fuel dosing and decreases precision of control. It results from large fluctuation of pressure in injection pipe, which appear even after injection of not large doses. Because between doses (pilot dose, preinjection dose and main dose) occur not large angle distances, pressure wave isn’t damping and occurring pressure fluctuations causes change of dose even though the total duration is equal. Dosing changes result from points on pressure wave where occurs injector opening. Taking into consideration that length of wave depends on a lot of factors (for example fuel property) these deviations can be difficult to compensate in controller. The changes of fuel temperature in injector, resulting from various work conditions have negative influence on dosing precision too.

To decrease a dosing deviation can be obtained by using larger pressures in the injection system and by shorting a way of flow from rail to spray nozzle. Length of injection pipes and length of fuel channels inside injector are very important also.

To sum up, it should be stated that during working of common rail system can occur considerable deviations of measure fuel dose, what can negative influence on pollution emission and functional parameters of compression ignition engine.

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