SIMULATION AND EXPERIMENTAL RESEARCH OF PROTOTYPE DISTRIBUTOR INJECTION PUMP OF PR4 TYPE

Kazimierz Lejda
Rzeszow University of Technology, Faculty of Mechanical Engineering and Aeronautics
35-959 Rzeszow; Av. Powstancow Warszawy 8, Tel./Fax (48-17) 854-31-12

Summary. The article presents numerical simulation and experimental research results of prototype injection pump of PR4 type. It is distributor pump destined for high speed compression-ignition engines with capacity of cylinder up to 1.3 [dm³]. New injection pump has made in cooperation of Fuel Injection Equipment "PZL-MIELEC" Ltd and Faculty of Automotive Vehicles and Internal Combustion Engines in Rzeszów University of Technology. The worked out construction of distributor pump of PR4 type is Polish counterpart of technically advanced pumps VE of Bosch firm and DP200 of Lucas firm. It is provided that its commercial price will not exceed 50% of quoted foreign pumps price, at simultaneously remained functional values and durability and reliability levels. Besides, in consequence of application of series innovatory solutions assuring injection pressures order of 90 [MPa], one could be influence more effectively on the level of toxic components in exhaust gas.

1. Introduction

Analysts of road transportation development foresee successive growth of interest with car vehicles equipped with compression ignition engines in the nearest years. It refers to passenger cars of course, because other kinds of vehicles used in goods and passenger transport have been based on this source of drive since a long time. In United States and European Union share of passenger cars with diesel engines in sale market persistently grows and nowadays it amount to around 15%. It is prognosed, that in 2005 year this share can reach even 22-24%. The growth of demand is connected with many well-known advantages of compression ignition engines in relation to spark ignition engines. It relates mostly to economical, ecological and durability aspects.

Marketing requirements extort of the producers to continuous researches of new solutions and just in this group of engines the greatest changes are executed. Development of high-speed compression ignition engines clearly drive at direct injection with use of high-pressure fuel systems with injection pressures exceeding 100 MPa. The aim direction is obtainment of energy-saving engines, which will meet criteria of official certificates in range of exhaust cleanness and noisiness level.

Before the new generation of high-speed compression ignition engines will become general standard of equipment in passenger cars and delivery vans, at the present in a large majority the engines with indirect injection to swirl chamber are installed. Combustion system in these engines adequately determines necessity of use different parameters of fuel injection rate, and this can yet assure classical fuel systems. In this group of engines systems with permanently improved and modernized distributor pumps are used. Presentation of simulation results and test stand qualifying investigations of prototype distributor pump is just a content of the article.
2. Description of construction and operation of prototype injection pump

Distributor injection pump PR4 is construction about the piston-distribution system and is equipped in mechanical centrifugal governor [4]. In one-piece frame are following main functional units (Fig. 1):

- propeller shaft of cam disk and speed governor 2,
- cam disk 3,
- piston-distributor 6,
- batcher 15,
- sliding-vane force pump 12,
- gear transmission of speed governor 10,
- roll ring 4,
- centrifugal speed governor 7,
- hydraulic timing unit 11.

Fuel received from the fuel tank by external feeding pump flows through fine filter to sliding-vane force pump 12. Regulating valve 13 assures constant value of pressure fuel $0.3+0.4$ [Pa]. With channels inside of casing pump and distributor cap 5 fuel is brought to force chamber over piston-distributor. Volume of force chamber is appointed with position piston-distributor 6 and batcher 15.

Piston-distributor is started by propeller shaft of pump 2. Across cam disk (stroke) 3 and rollers placed in roll ring 4, piston-distributor obtains, besides rotary motion, also to-and-fro motion. In upper parts the piston-distributor works as high-pressure section in consequence of also to-and-fro motion, instead in lower part determines controller with filling fuels device. Filling begins with moment start so-called jump of power supply (isn’t here initial jump, as in multi-section pumps), instead finishes together with exposure of overflow holes by steering edge of batcher. Position of batcher qualifies therefore quantity of fuel dose. Result of rotary motion of piston-distributor is doses distribution across distributive groove in piston on each outlet and by connector pipes bringing fuel to high-pressure pipes. Piston-distributor executes during one turn so much of jumps (strokes of pressing), how much is connector pipes 16.

Mechanical regulator 7 steers with move of the batcher by lever transferring motion of muff, which is forced with power of governor weights 8. Rotational speed of engine is transfered by toothed gear 10 from propeller shaft of pump on governor weights, which deflect in consequence of centrifugal forces. Greater rotational speed evokes greater deviation of governor weights and in consequence longer move of muff regulator. If engine doesn’t work, starter spring holds starter lever in such position, that with starting moment is automatically given full dose.

Timing unit 11 is controlled in dependence from pressing pressures of sliding-vane force pump. Fuel pressure influences on piston of timing unit, which conquering tension of spring turns roll ring. In this way are changes angle of injection advance. Displacement angle, which assures timing unit of PR4 pump is to $12^\circ$ turn of driving shaft.
Fig.1. Distributor injection pump PR4 type: 1 - pump frame, 2 - driving shaft, 3 - cam disc, 4 - roll ring, 5 - distributor cap, 6 - piston-distributor, 7 - mechanical governor, 8 - governor head, 9 - governor cover, 10 - gear transmission of speed governor, 11 - timing unit, 12 - sliding-vane force pump, 13 - regulating valve, 14 - solenoid valve, 15 - batcher, 16 - connector pipe

Represented description of construction and activity of new distributor pump doesn't scoop certainly all aspects of its working. With moment obtained of construction will presented details of steering with dose of fuel, speed governor work, steering with beginning and finish of injection, activities of dose corrector and smoke limiter, cooperation of pump with EGR system of engine etc.

3. Results of injection process simulation

Computational experiment of the distributor pump PR4 was passed basing oneself on the computer programs with enable analysis of injection process. Automobiles and Internal Combustion Engines Department PRz possesses elaborated and verified programs to numerical simulation of hydrodynamic occurrences in different injections installation systems. On stage of new construction creation of pump or its modification, as also designs of other fuel apparatus part, computational models permit on generating data about
reaction of the system in definite structure of experiment. This manner we get information to prognosis maintenance of injection pump for different work conditions.

Computer simulation has been executed by used computational program worked basing oneself on modified model introduced e.g. in works [1,2,5]. Range of calculations included identification all of possible parameters of injection process for different configuration of geometrical values of basic composition elements, as also of variable conditions of load and rotational speed [3,6]. In this article are presented preliminary results of simulation for select pump parameters in function of rotational speed $n$ and jump working plunger $h_r$.

Represented following parameters of injection process:
- distribution of maximum pressure at the beginning of injection pipe $p_{1\text{max}}$ (Fig. 2),
- distribution of maximum pressure in pipe before injector $p_{2\text{max}}$ (Fig. 3),
- distribution of opening period of sprayer needle $t_{hi}$ (Fig. 4),
- distribution of flowing out dose from sprayer $Q_n$ (Fig. 5).

---

Fig. 2. Distribution of maximum pressure at the beginning of injection pipe $p_{1\text{max}}$
Fig. 3. Distribution of maximum pressure in pipe before injector $p_{2\text{max}}$

Fig. 4. Distribution of opening period of sprayer needle $t_{hi}$
Selection of above parameters of the injection process assures sufficiently analysis of hydrodynamic occurrences occurring on pressing side of pump. We can to investigate distribution of fuel pressures in most important sections of injection system, activity of sprayer needle and course of injection to combustion chamber. On stage of create of the new construction injection pump simulation of occurring physical occurrences accelerates process for obtainment of optimum solution.

4. Results of experimental research

Investigations have been done on the engine test stand in Research Laboratory of ZPSiSS. It is equipped among other things in dynamic dynamometer type DYNAS2 of Schenck firm and complex system to exhaust analysis of Pierburg AG firm. Qualifying identification of prototype pump was done on engine of type 4C90 "Andoria". Range of investigations included realization of external characteristic and speed characteristics of engine with estimation of exhaust toxicity. Emission of toxic components was fixed according to 13-stage stationary test ECE R-49. Results of investigations for select parameters allowing on estimate of pump values are presented graphically on Figs 6, 7, 8 and tabular in table 1. Additionally on the figures engine parameters obtained with Motorpal factory pump are showed.
Fig. 6. External characteristic of 4C90 engine with PR4-01 and Motorpal pumps
Fig. 7. Speed characteristic of selected parameters of 4C90 engine with PR4-01 and Motorpal pumps
Fig. 8. General characteristic of 4C90 engine with PR4-01 and Motorpal pumps
5. Recapitulation and conclusions

Results of investigations delivered interesting material to analysis. One should unequivocally
found that obtained results are fully satisfactory on this stage of works. The basic parameters
of engine are comparable with hitherto existing multisection pump PP4M (MOTORPAL
firm), which enters in standard equipment of engine 4C90.

Distributor injection pump type PR4 is new generation pump. This kind of pump assures
obtainment increase of injection pressures. It characterizes with modern technical and
and technological execution, which are unique in relation to produced at present pumps of firms
Bosch (models VE, RP44) and Lucas (model DP200). In comparison with these executions to
most important differences we can include:

- separation of steering pressure from pressure which there is in pump (in hitherto existing
pumps with parallel piston to driving shaft axis, steering pressure fills all volume of frame
and regulator cover, what considerably enlarges danger of fuel leakages both in motion
and not-motion connections),
- driving shaft is built on roller and ball bearings (in hitherto existing pumps are slide
bearings), what eliminates propensity to seizing and reduce quantity of emanated warm
inside pump in consequence of friction forces,
- geometrical dimensions of forcing, driving and regulating pump elements are chosen on
enlarged static and dynamic loads; it assures permanent and reliable work-at injection
pressures of 100 MPa and doses of fuel to 150 mm$^3$/injection, with pressing speed to 25
mm$^3$/1$^{\circ}$OWK (in relation to above pumps of foreign firms diameter dimensions and length
are slightly greater than pump type VE, but clearly smaller than pumps type DP200 and
RP44).

Executed comparisons by realizers of project in relation to application distributor pump type
PR4 shows, that with success it will be able to replace not only above mention distributor
pumps firms Bosch and Lucas, but also following models of line pumps:

- P2, P7, PWM in versions 2-, 3-, 4-, 6-sections (produced by WAW "PZL-MIELEC")
- A, MW in versions 2-, 3-, 4-, 6-sections (produced by firm Bosch)
- My, Mf, M3 in versions 2-, 3-, 4-, 5-, 6-sections (produced by firm MOTORPAL)

Originally of project realizers pump PR4 should meet indispensable useful values for
compression ignition engines about capacities of cylinder to 1,3 [dm$^3$]. Innovatory solutions
used in construction of pump were confirmed with results in simulation and experimental
investigations. There are work parameters answering to the best solutions of distributor
pumps produced by acknowledged world firms.
Bibliography


