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# STUDIES ON INFLUENCES OF FUEL INJECTION PARAMETERS ON POLLUTANT EMISSION OF DIESEL ENGINE, USING VIRTUAL ENVIRONMENT TOOL

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***Abstract :*** *Virtual environment studies, represents reasonable tools for nowadays engineers, which are working in the mechanical engineering fields and not only . The advantages like: low acquisition price (comparison with experimental tools), post processing options which leads to less working time, gives engineers confidence to use this kind of tool.*
*The paper presents studies on injection system performances (different injection pressures), and how they are influence the pollutant emission formation. Also, it was studied, which is the most opportune injection strategy, in order to achieve less pollutant emission.*
*Virtual simulation work was done, using the AVL-Fire software, which is a CFD specialized software for calculating internal combustion engines processes. The first step was to build the combustion engine layout, after these, the input parameters were set-up, and finally simulation was run.*
*Post-processing data, regarding pollutant emission of Diesel engine, will be presented at the end of the paper.*
***Keywords:*** *Diesel engine, Injection, Fuel Spray, Simulation, Pollutant emission.*

## 1. INTRODUCTION

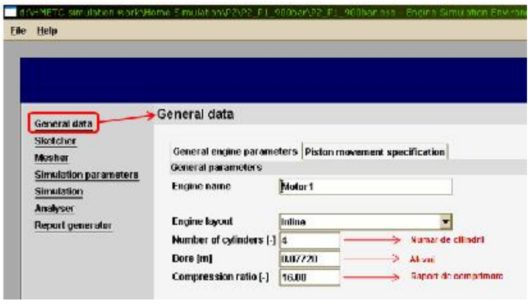
Nowadays, diesel engine specialists are making hard effort for reducing the pollutant emission of those engines. Following this purpose, the engineers are working with virtual simulation software, which is the first step for developing new engine products or new processes, (air and fluid control, thermodynamic process). This paper will emphasize the effect of different injection strategy and injection pressures, on pollutant emission.

## 2. SIMULATION SET-UP

In order to determine the impact of different injection process features on pollutant emission of diesel engines, it was used specialized CFD software, developed by AVL-Graz, named AVL-Fire. This one offers a number of options which help the user to save precious time for researching and developing. The CFD software is characterized by a various number of piston bowls, and injector nozzles, which can be modeled and also different features of Diesel engine: bore, stroke, con rod, e.g.

### 2.1. Input of engine geometrical features

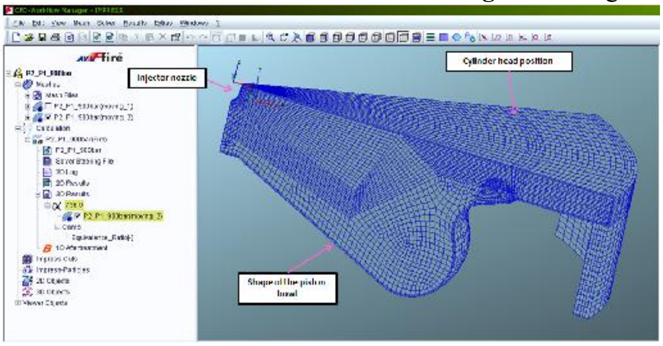
The first step in engine modeling is to input the engine geometrical features.




The simulated engine has the following general data: Bore=77.2mm, Stroke=84.5mm, Connecting rod=140mm, Compression ratio=16

After this step, it is necessary to design the piston bowl, or to input this in the software. The CFD program offers the user the possibility to model the bowl, from serial templates. Next step, leads to input data which refers to the injector nozzle, like: number of nozzle holes, hole diameter, nozzle protrusions, hole elevation angle. The final step is meshing the internal surface of the combustion chamber. (Fig. 2)

**Figure 1:** Engine features




After finalizing the meshing process, the software acquires date which refers to the input working fluid condition: air temperature, air pressure, injected fuel quantity, injection flow rate, injected fluid temperature e.g.

The mathematical equation, which calculate the pollutant emission of O2, N2, CO2, CO, H2, H2O, O, H, N, OH is based on mass fraction transport which is describe in the ECFM-3Z serial equations. [1]. Calculation of NO emission, is strongly related to the in cylinder fluid temperature (>1800 K).

**Figure 2:** Part of piston bowl

In conclusion, the thermodynamic mechanism is the one which generates a high quantity of nitro oxides, in the flame surface, but also in the exhaust gases [2], [3]. The chemical mechanism of NO formation, is a very complex one, but can be describing by Zeldovich [4], based on the following formulas:

$$N_2 + O \underset{k_{1b}}{\overset{k_{1f}}{\leftrightarrow}} NO + N \tag{1.1}$$

$$N + O_2 \underset{k_{2b}}{\overset{k_{2f}}{\leftrightarrow}} NO + O \tag{1.2}$$

$$N + OH \underset{k_{3b}}{\overset{k_{3f}}{\leftrightarrow}} NO + H \tag{1.3}$$

### 2.2. The test matrix of simulation process

Following the purpose of the study, it was build a test matrix which presents the simulation conditions. In the test matrix it is presented the engine speed: 2000 rpm, break mean effective pressure of 8.3 bar, and total injected quantity/cycle of 20.5 mg.

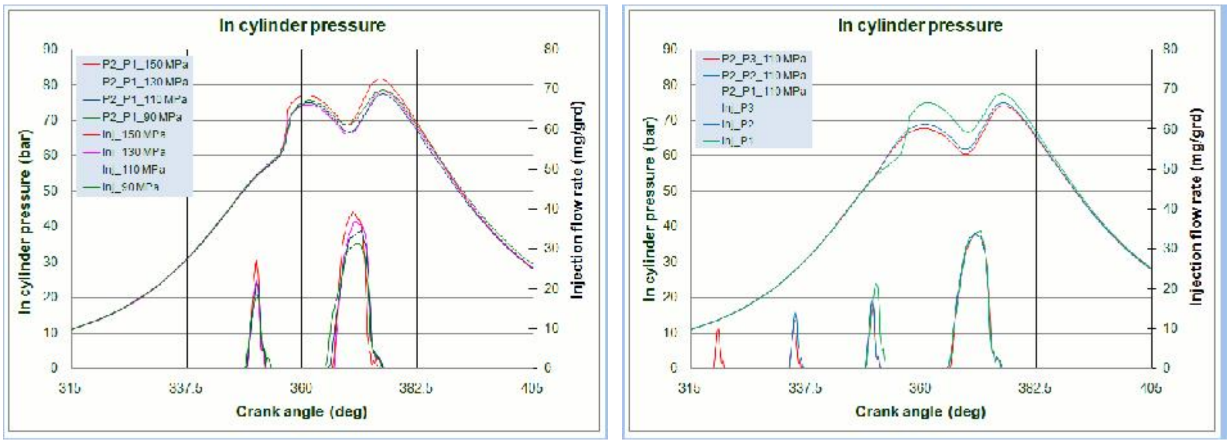
**Table 1:** Test matrix

| | | 2000rpm/b.m.e.p.=8.3/Q_inj=20.5mg | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rail pressure (MPa) | => | 90 | | | 110 | | | 130 | | | 150 | | |
| Q_Pilot_3 (mg) | => | 0.5 | X | X | 0.5 | X | X | 0.5 | X | X | 0.5 | X | X |
| Q_Pilot_2 (mg) | => | 1.0 | 1.5 | X | 1.0 | 1.5 | X | 1.0 | 1.5 | X | 1.0 | 1.5 | X |
| Q_Pilot_1 (mg) | => | 2.0 | 2.0 | 3.5 | 2.0 | 2.0 | 3.5 | 2.0 | 2.0 | 3.5 | 2.0 | 2.0 | 3.5 |
| Q_Main | => | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 |

Simulation point

The injection process features, which were varied are: Injection pressure: 90, 110, 130, 150 MPa, and Injection strategy: “Q_Pilot_1 + Q_Main”, “Q_Pilot_2 + Q_Pilot_1+ Q_Main” and “Q_Pilot_3 + Q_Pilot_2+ Q_Pilot_1+ Q_Main”.

## 3. RESULTS




a) b)

**Figure 3:** In cylinder pressure, for different injection pressure and injection strategy

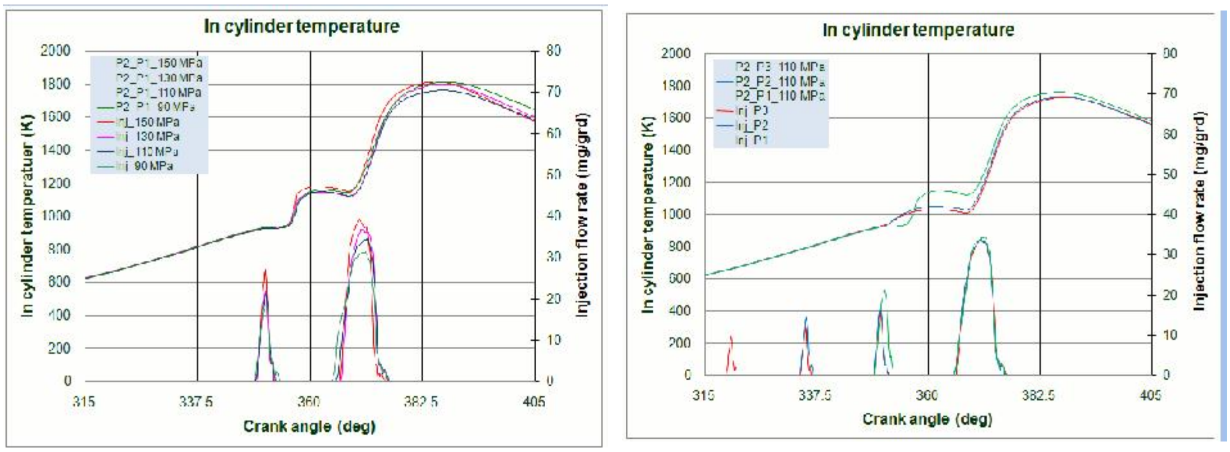



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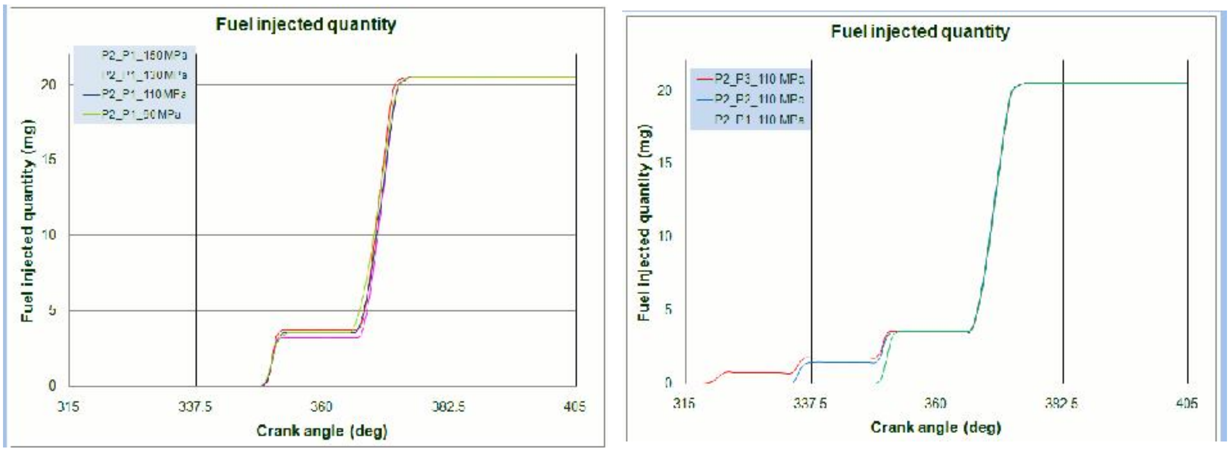
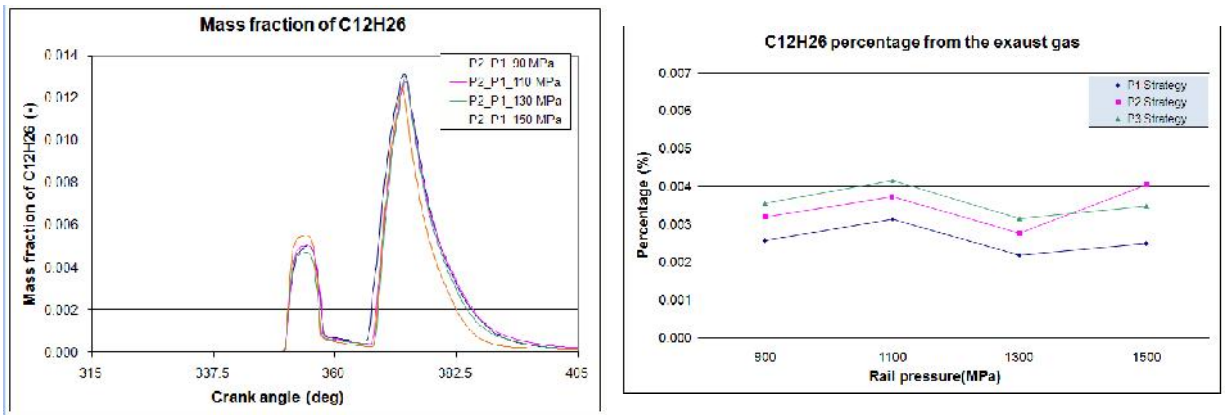
**Figure 4:** In cylinder temperature, for different injection pressure and injection strategy



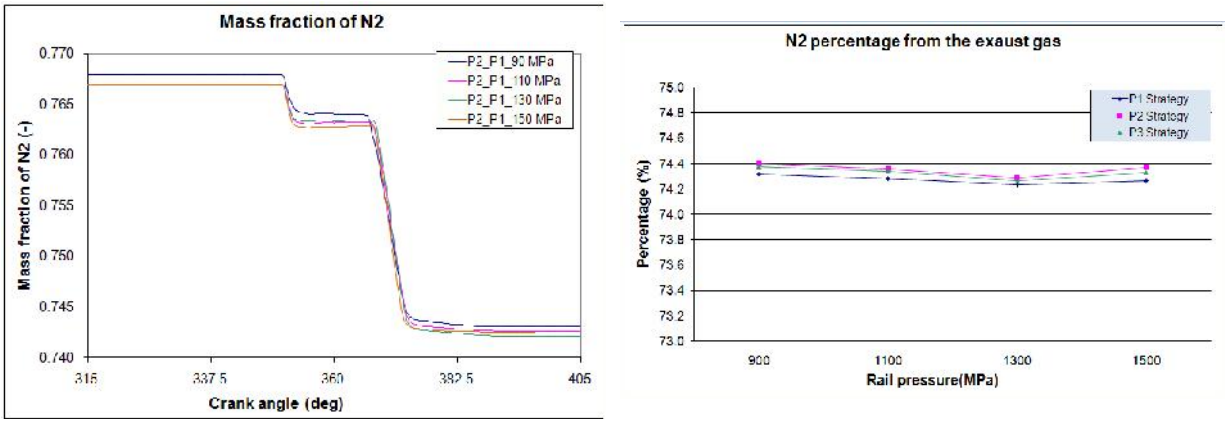

a) b)

**Figure 5:** Fuel injected quantity



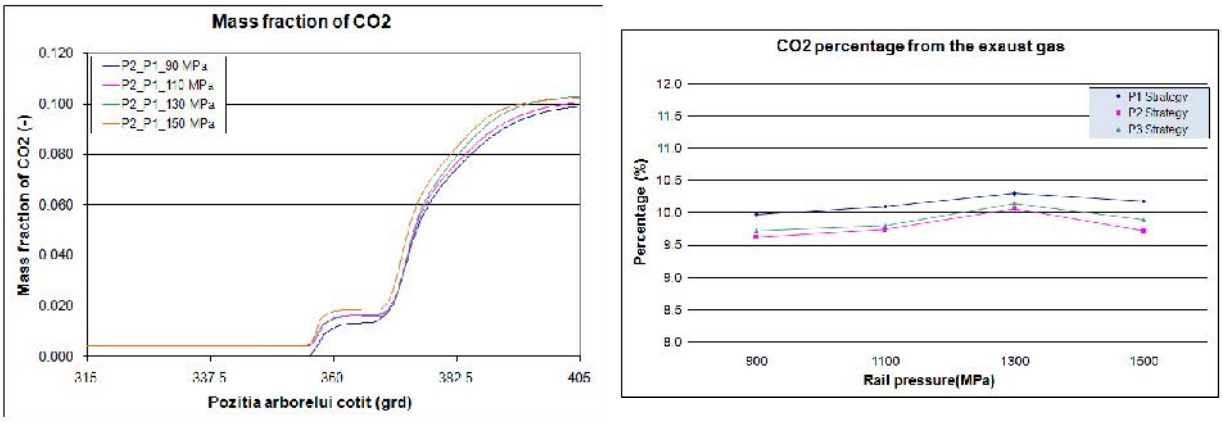

a) b)

**Figure 6:** Mass fraction of C12H26



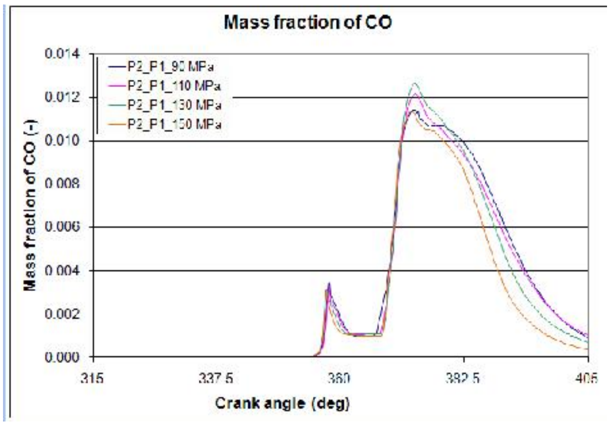

a) b)

**Figure 7:** Mass fraction of N2

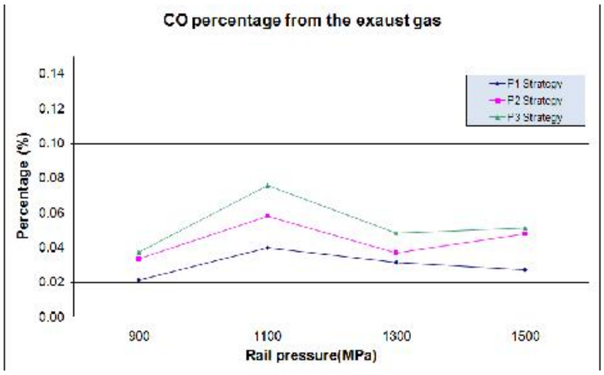



a) b)

**Figure 8:** Mass fraction of CO2




a)




b)

**Figure 9:** Mass fraction of CO

## 4. CONCLUSION

The results presented in the previous chapter leads to following conclusions:

- Figure 3 a) and b) shows that for high pilot quantity injected, (3.5 mg), the pressure gradient is higher, this means, that the engine is running more noisy.

Another disadvantage is higher in cylinder temperatures, which encourage the formation of NOx. (Fig. 4 b)

- Analyzing the Fig.6 a), we can conclude that increasing rail pressure, the percentage of $C_{12}H_{26}$ shows no high deviation, but if we are going for more injection pilot strategy, the percentage of $C_{12}H_{26}$, will increase.
- Fig. 7 shows no major impact of injection strategy, on $N_2$ pollutant emission. When we are applying for higher rail pressure the figure shows low tendency for decreasing $N_2$. This is due to lower Sauter Mean Diameter of the fuel droplets.
- In Fig 8, it is obvious, that if we are going for higher injection pressure, the $CO_2$ emission will increase. Higher $CO_2$, means better combustion.
- Fig 9 shows how CO emissions are influence by rail pressure and injection strategy. More pilot injection (P3), leads to higher CO. This higher quantity of CO, means worst combustion.

But if we want to run the injection process at high pressures, we see that the CO emission will decrease.

- The injection pressure and strategy variation, shows no deviation on the power and engine torque
- CFD simulation tool, like AVL-Fire, provide helpful information on internal combustion engine processes, and leads the engineers to better understanding of those phenomena.


## ACKNOWLEDGMENTS

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