LIQUID FUEL JET SHAPE ANALYSIS USING A HIGH WEAR INJECTOR TESTED AT LOW PRESSURE

BENIUGA Marius Constantin[1], MIHAI Ioan[1]

[1]Department of Mechanical Engineering, Stefan cel Mare University of Suceava, Romania 13 University Street, 720229, email: beniugamarius@gmail.com

Abstract: *The article presents an experimental study on the atomized fuel jet envelope through an injector that equips SI (spark ignition) type internal combustion engines that are found on existing vehicles on the market. In this context, it is considered to be of interest to investigate the influence of injector's wear upon the process of fuel atomization. If non-conformities of the jet shape or large dimensional deviations of the atomized fuel droplets from normal values are found, then corrective measures must be adopted. The research will take into account the number of operating hours of the injectors. To achieve these goals, it is necessary to study how to form the jet of fuel by analyzing the phenomena of primary and secondary atomization.*

Keywords: *Atomization, gasoline jet, injector, drops.*

1. Introduction

Atomization is the process of dissolving liquid using devices called injectors. Spraying a liquid through an injector is a collection of drops with a variety of dimensions [1], which is the result of a moving atomization in a controlled manner.

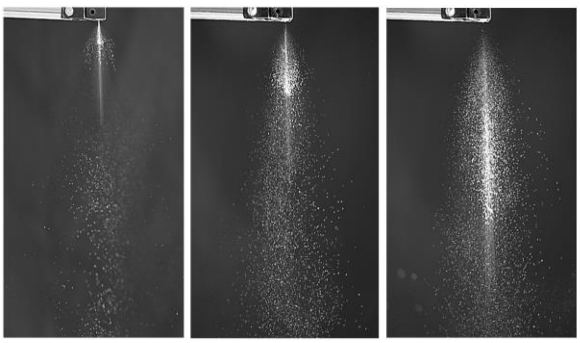
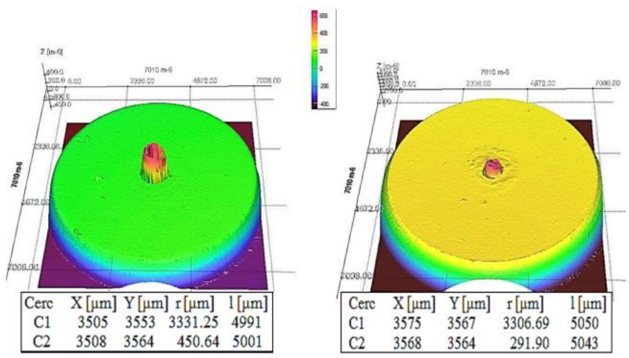


Figure 1: *Images of the atomized fuel jet in three stages of formation.*

The impact of wear and working regimes of injectors on the development, formation and dissolution of droplets of pulverized liquid will be analyzed.

It will be established whether the undesirable effects due to the wear phenomenon of the injectors can be countered by intervention on the injection mappings in the engine control unit, by performing simulations in Matlab Simulink.

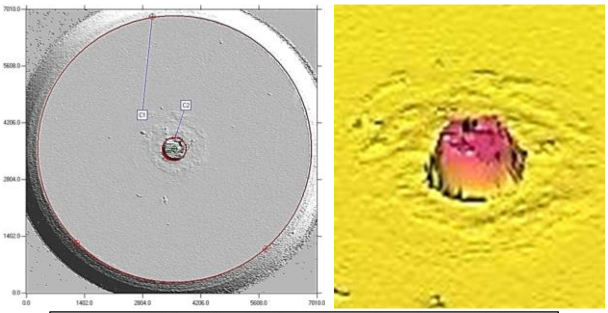


a. Injector with low wear. *b. Injector with high wear.*

Figure 2*: Injector scan images using laser profilometry.*

By analyzing the results shown in the two images in Figure 2, [3] it is noted that in the injector without wear, figure 2.a., the height of the injection needle is 620 μm and its radius of 450.64 μm compared to only 460 μm height and a radius of 291.90 μm to the worn one in figure 2.b.

It is easily observed from the details in figure 3, that deposits are formed around the injector needle (zone C1, C2) for the important wear injector.



	X [µm]	Y [µm]	r [µm]	l [µm]
C1	3575	3567	3306.69	5050
C2	3568	3564	291.90	5043

Figure 3: *Detail of the injector needle area with high wear (fig. 2.b).*

The experimental determinations shall be carried out on the basis of a test scheme to ensure that the operating modes essential to the operation of multipoint injection systems are achieved.

If a correlation can be found between the wear of the injectors and the non-compliance of the injection parameters, corrections in Matlab Simulink for multipoint injection systems will be simulated, analyzing the effects and the resulting parameters.

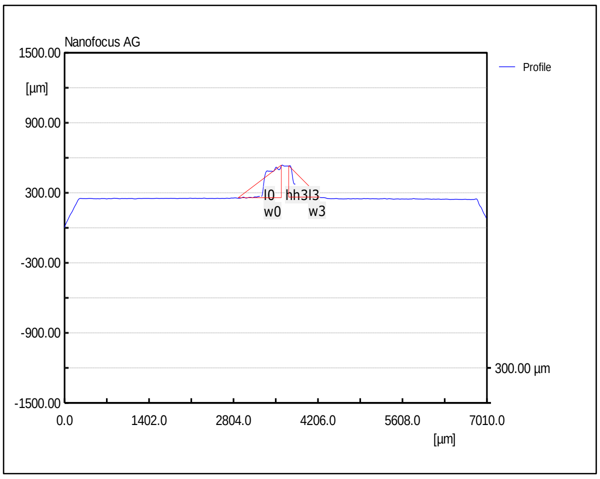


Figure 3.a: *High wear injector tip profile values (fig.3).*

Profile values:

Width w_0 = 714.6 μm

The height h_0 = 279.570 μm

Length l_0 = 767.3 μm

Angle = 21.37°

Width w_3 = 517.4 μm

Height h_3 = 268.817 μm

Length l_3 = 583.1 μm

Angle = 152.55°

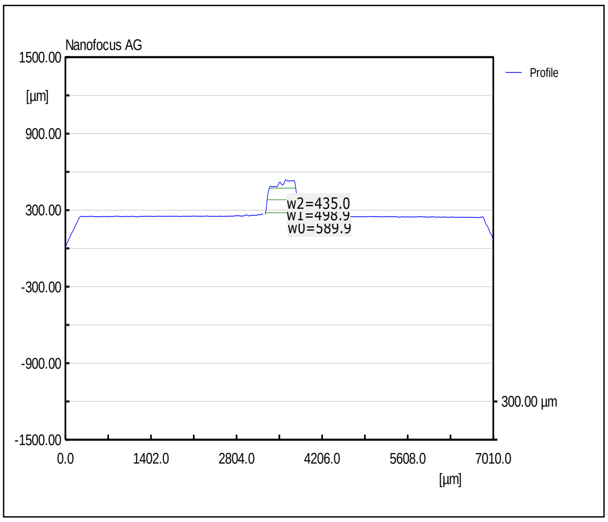


Figure 3.b: *High wear injector tip width values (fig. 3).*

Injector peak width values:

Width w_0 = 589.9 μm

Width w_1 = 498.9 μm

Width w_2 = 435.0 μm

2. Obtaining images of the atomized jet

At this stage, photo-video equipment will be used to allow after processing, extracting high-resolution images of the atomized fuel jet at different stages of formation.

2.1. Atomised fuel jet analysis at low wear injector tested at nominal pressure

The statistical analysis that provides the distribution of the size of the fuel droplets on the jet surface is shown in figure 4 where the images are arranged in order of sequence of time formation of the atomized fuel jet through an injector showing low wear.

This injector is also found in figure 2.a, which represents the profilometric scan of the tested injector tip.

For the study of the phenomenon of fuel atomization in multipoint injection systems the programming environment ANSYS CFX [4], [5] was used.

Simulation of sprayed jets has application in many fields, such as internal combustion engines, gas turbines, air conditioning systems, missiles, etc.

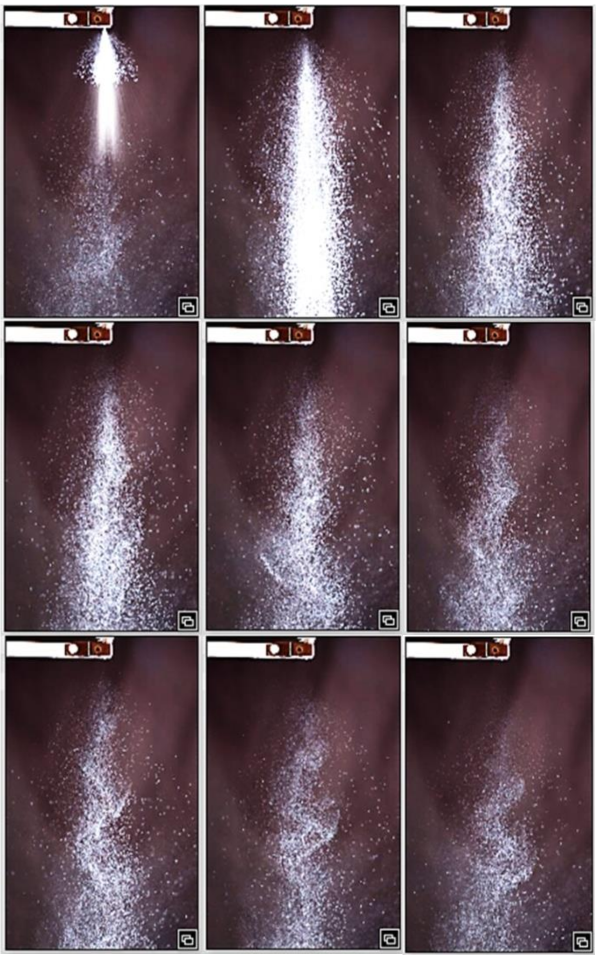


Figure 4: *Chronologically presented catches of an atomized petrol jet using a low-wear injector used at nominal working pressure.*

Validation of analytical results is done by modelling simulating the studied phenomena and in most cases provides satisfactory results.

In figures 5 and 6, an extract of the simulations performed during the experiments can be found, where the parameters of the atomized gasoline jet can be traced.

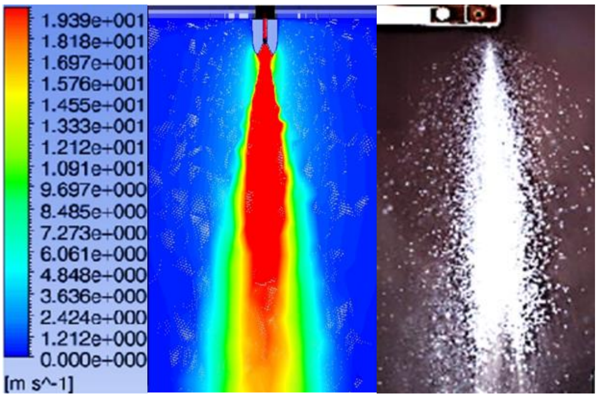


Figure 5*: Simulation of atomized fuel jet.*

Figure 5 gives the case for the onset of the injection and the time of its development, using ANSYS CFX.

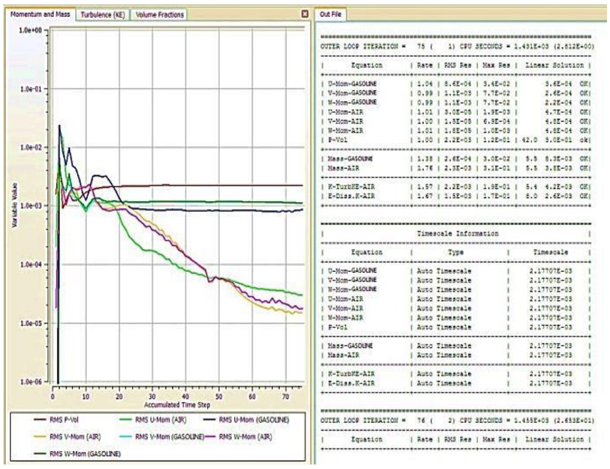


Figure 6: *Atomized fuel jet parameters.*

The data obtained by simulation shows a large difference between the speed of the liquid droplets and that of the gaseous medium, between the beginning and the end of the atomized jet. Thus, at the heart of the flow of fuel to the maximum speed, as shown in figure 5, is 19,390 *m/s*, which is at the periphery of the jet, the mean value of the velocity is 4,848 *m/s*, while the velocity of the air is out of 1,212 *m/s*. A decrease in the velocity of the droplets by the gas towards the periphery of the jet is attributed to the fact that during the atomization an increasing number of droplets are in contact with ambient air, showing a braking of the latter. This is explained by the high friction coefficients between the molecules of the gaseous medium and the surface of the liquid droplets.

2.2. Atomised cone jet analysis at high wear injector tested at low pressure

In figures 7 and 8 are shown images of the atomized jet of gasoline from the combustion chamber, at the injector with high wear, in which the accumulation of fuel on the surface of the intake valve is noted.

The evolution of the atomized jet of gasoline is shown where, at the injector with high wear, a pressure is applied much lower than the nominal value of 294 *kPa*, which is similar to alleged malfunctions at the petrol pump, or pressure losses on the fuel supply system of the internal combustion SI engine, [2].

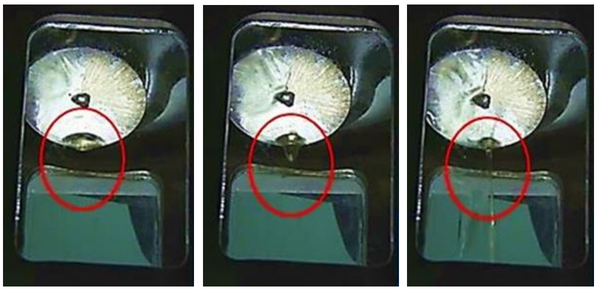


***Figure 7**: Evolution of fuel accumulation in the combustion chamber for the high wear injector, [2].*

This is due to deposits in the area around the needle and partly on the injector needle shown in figure 2.b. Using the same test parameters five chronologically consecutive images were obtained as shown in figure 8, illustrating the defective evolution of the shape of the atomized fuel jet.

***Figure 8**: Presentation in five stages of the evolution of the atomized fuel jet at the studied injector.*

3. Conclusions

Figure 4 concludes the chronological formation of an atomized liquid fuel jet under laboratory conditions in order to form a homogeneous mixture of fuel air necessary for the correct operation of SI internal combustion engines.

In the case of the use of the injector with low wear, it is noted that the simulation in ANSYS of the atomized jet of gasoline is very accurate in comparison with the image of the atomized jet during the experiment.

This result dictates for future studies the development of an algorithm for simulation of an atomized fuel jet that shows a defective evolution of the shape of the fuel jet using an injector that has high wear and tear as shown in figure 3 or differences in fuel pressure in the supply system that equips internal combustion engines.

As we can see in figure 8, the shape of the atomized liquid jet under the presented conditions does not lead to the development of a homogeneous mixture of combustible air necessary for the correct operation of SI engines.

The first step to correct the quality of this jet is the use of an air jet, which leads to the dissolution of existing droplets of different sizes. Then we consider several variants of controlling the temperature of the atomized liquid during the tests as well as the temperature of the environment of the atomized jet wrapping of the sprayed fuel.

References

[1] [Ashgriz, 2011] Ashgriz, N., (*Handbook of Atomization and Sprays, Theory and Applications*), University of Toronto Dept. Mechanical & Industrial Engineering, 2011.

[2] [Beniuga, 2016] Beniuga, M., Mihai, I., „*Studies concerning the effect of large droplets creation during fuel atomization*”, Proc. SPIE 10010, Advanced Topics in Optoelectronics, Microelectronics, and Nanotechnologies VIII, 100101N , doi: 10.1117/12.2243005, pp. 10010N-1÷10010N-7, 2016.

[3] [Suciu, 2016] Suciu, C., Beniuga, M., „*Optical investigation of electromagnetic fuel atomizers*”, Proc. SPIE 10010, Advanced Topics in Optoelectronics, Microelectronics, and Nanotechnologies VIII, 1001014, doi:10.1117/12.2243347, pp. 10010l4-1÷100140-6, 2016.

[4] ANSYS Fluent 12.0 Guide, 2009.

[5] ANSYS Fluent Theory Guide, 2013.