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IMPROVING THE INJECTION CHARACTERISTICS OF FUEL NOZZLES

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Abstract: *Reducing the level of pollution in automobiles is mainly achieved by constructive optimization of the components of the injection system, which have the greatest influence in this regard, namely by improving the flow characteristics through the fuel nozzle holes. This improvement can be achieved by vibrations assisted abrasive finishing of the flow surfaces using abrasive fluxes. Through this process, a finishing - rounding - of the fuel flow holes is achieved, causing the removal of cavitation effect.*
Key words: *fuel injectors; pollution; performance; abrasive flux machining; injection characteristics.*

1. INTRODUCTION

In order to fulfill the requirements of the current legislation regarding the pollution caused by motor vehicles, it is necessary to constructively optimize the injection systems that have an important, fundamental role in making the engines work more efficiently to reduce environmental pollution.

In injection systems, the most important component involved in spraying the fuel mixture into the combustion chamber is the fuel nozzle. Its operation can be influenced by the occurrence of cavitation, which can cause erosion in the flow area, respectively in the passages with changes in their geometry [1].

This erosion can cause destruction of the nozzle tip and consequent damage to the motor mechanism [2].

The pollution produced by automobiles can be reduced by improving the flow characteristics through the orifices of the fuel nozzles, which can be achieved by hydroabrasive finishing of their inner flow surfaces [3].

The hydroabrasive finishing process uses an emulsion made of a fluid and abrasive microparticles.

This emulsion, grinding system, provides a very good finishing of the surface to be processed.

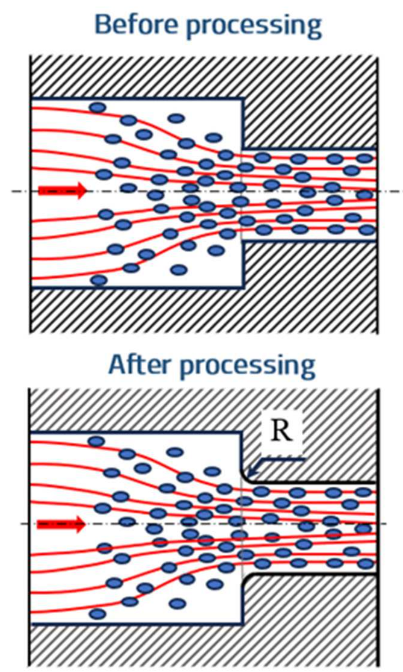


Fig. 1. Abrasive fluid flow lines before and after machining

A use of abrasive particles that have sharp edges causes a higher erosion rate compared to rounded particles [4]. Figure 1 shows the flow lines of the abrasive fluid as well as the action of the abrasive particles on the sharp edges of the fluid flow microchannels.

A very good fluid for this finishing process is the fluid used for injection equipment on diagnostic stands.

2. HYDROABRASIVE PROCESSING - MEANS OF IMPROVING INJECTION CHARACTERISTICS OF INJECTION NOZZLES

Hydro abrasive finishing is a process by which flow improvement is achieved through microchannels and can be used to finish the orifices of fuel injector nozzles.

From the analysis of the research in the field, it is found that an analysis of the injection characteristics after an erosive finishing processing of deep holes has not been carried out, in this study an analysis of them after erosive finishing is presented.

During the experimental studies, six nozzles type DLLA-150-P449 (having five holes with a diameter of 0,24 mm, with a length of 1,1 mm) [5], with intermediate treatment (51HRC), were processed with the help of the installation that is presented in figure 2, using an ISO 4113 oil emulsion and 7 µm SiC microgranules as the abrasive medium. The stand was designed and made before the research was carried out. The homogenization of abrasive particles in suspension is carried out with the help of an ultrasonic vibration homogenizer.

Fig. 2. Hydroabrasive machining plant

This study was carried out according to the experimental plan obtained with MINITAB software, presented in table 1.

Table 1

Experimental research plan

StdOrder	RunOrder	PtType	Blocks	Volum fraction, [%]	Numer of passes	Volum, [l]
4	1	1	1	20	4	4
6	2	1	1	20	8	8
1	3	1	1	10	4	4
3	4	1	1	10	8	8
2	5	1	1	10	6	6
5	6	1	1	20	6	6

An abrasive fluid pressure of 80 bar was used in this study.

During the machining process, the duration of the machining process was measured, as well as the flow rate of the abrasive fluid, resulting in the following graphs of their variation, which are presented in figure 3.

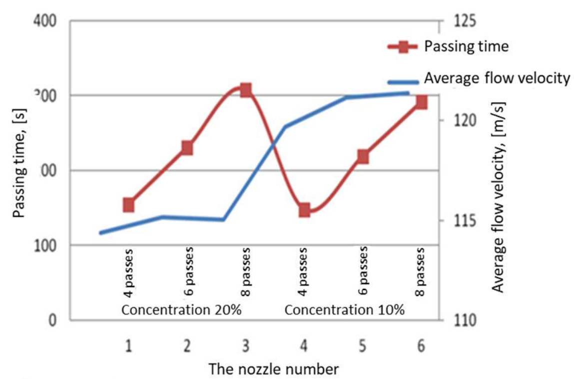
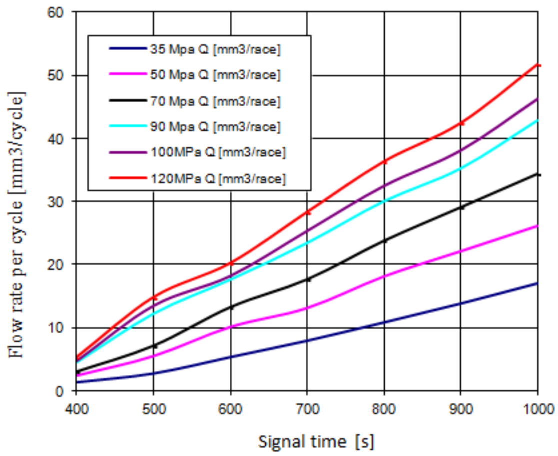


Fig.3. Distribution of the variation of the duration and flow rate of the abrasive fluid

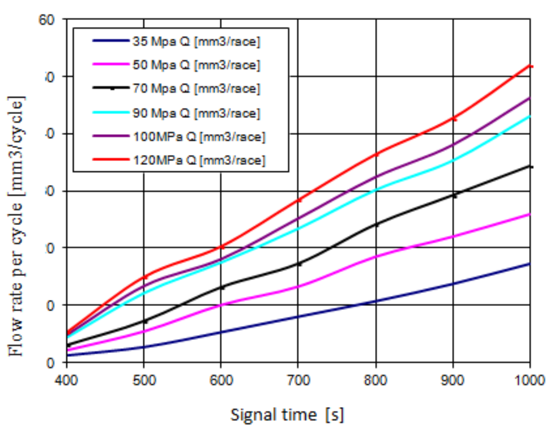
From the analysis of the distribution of the abrasive fluid flow parameters, figure 3, it is observed that an increase in the number of passes causes a reduction in the duration of the abrasive fluid flow through the hole and an increase in its speed. This is determined by the phenomenon of abrasive particle wear during chipping of the nozzle orifice surface.

Likewise, the decrease in the percentage of abrasive particles in the abrasive medium causes an increase in the speed and a decrease in the duration of the flow of the fluid through the hole.

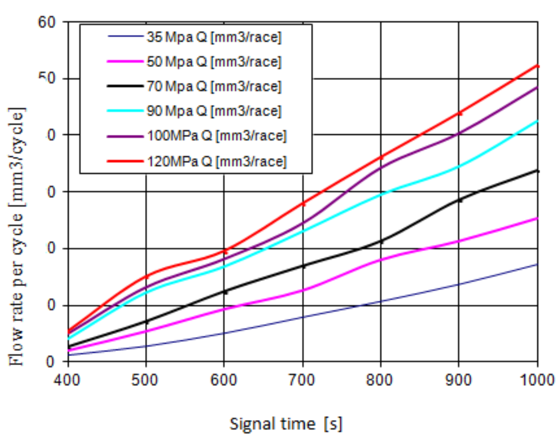
After processing the injector nozzles, the injection characteristics were checked for different operating conditions on the injector test stand. The injection characteristics are shown in figure 4.



a)Flow rate evolution per cycle for raw nozzle

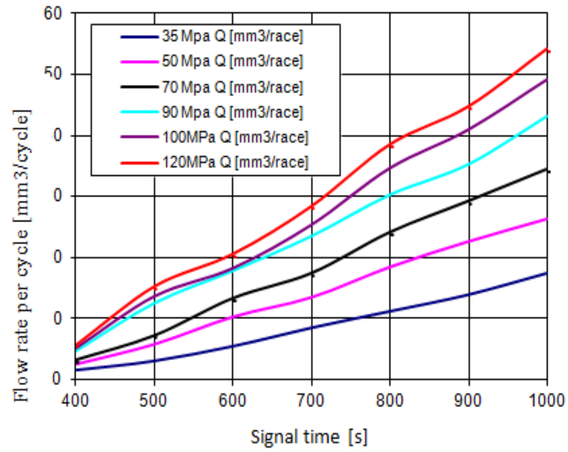


b) Flow rate evolution per cycle for nozzle no. 1 processed; 4 passes; c = 200 [cm^3/liter]SiC

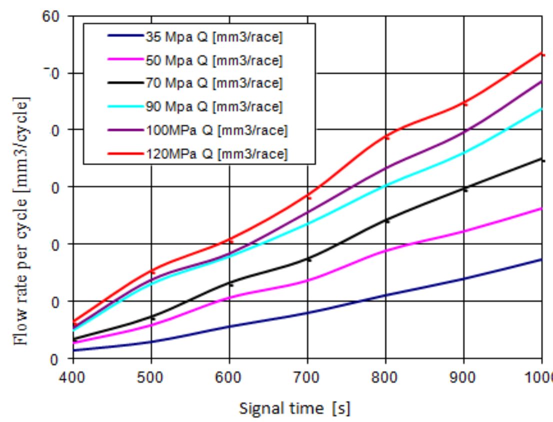


c) Flow rate evolution per cycle for nozzle no. 2 processed; 6 passes; c = 200 [cm^3/liter]SiC

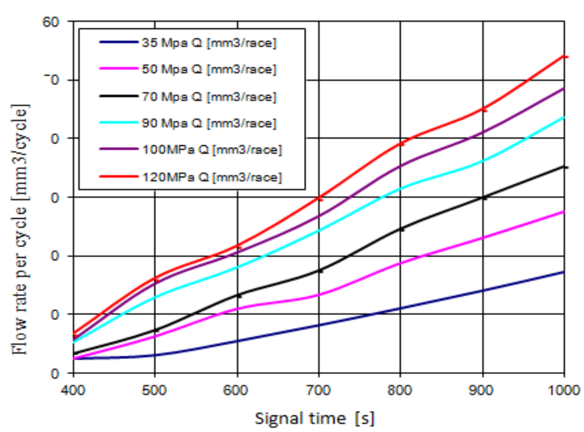
Fig 4. The injection characteristics of the nozzles



d) Flow rate evolution per cycle for nozzle no. 3 processed; 8 passes; c = 200 [cm^3/liter]SiC

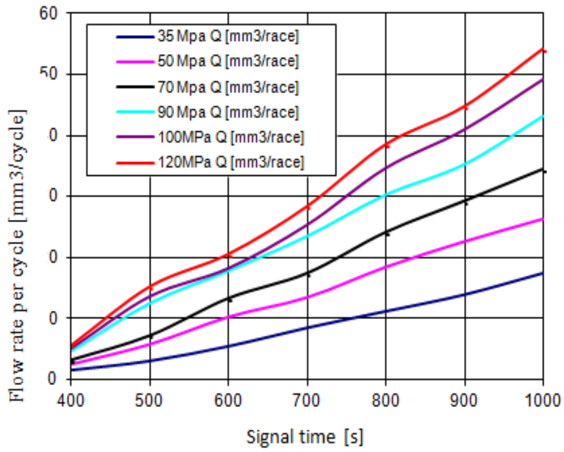


e) Flow rate evolution per cycle for nozzle no. 4 processed; 4 passes; c = 100 [cm^3/liter]SiC



f) Flow rate evolution per cycle for nozzle no. 5 processed; 6 passes; c = 100 [cm^3/liter]SiC

Fig. 4. The injection characteristics of the nozzles-continued



g) Flow rate evolution per cycle for nozzle no. 6 processed; 8 passes; c = 100 [cm^3/liter]SiC

Fig. 4. The injection characteristics of the nozzles-continued

To analyze the quality of nozzle processing, the graph of the percentage ratio of the maximum flow rate of the pre-machined nozzles in relation to that of the unprocessed nozzles was drawn, which is presented in figure 4.

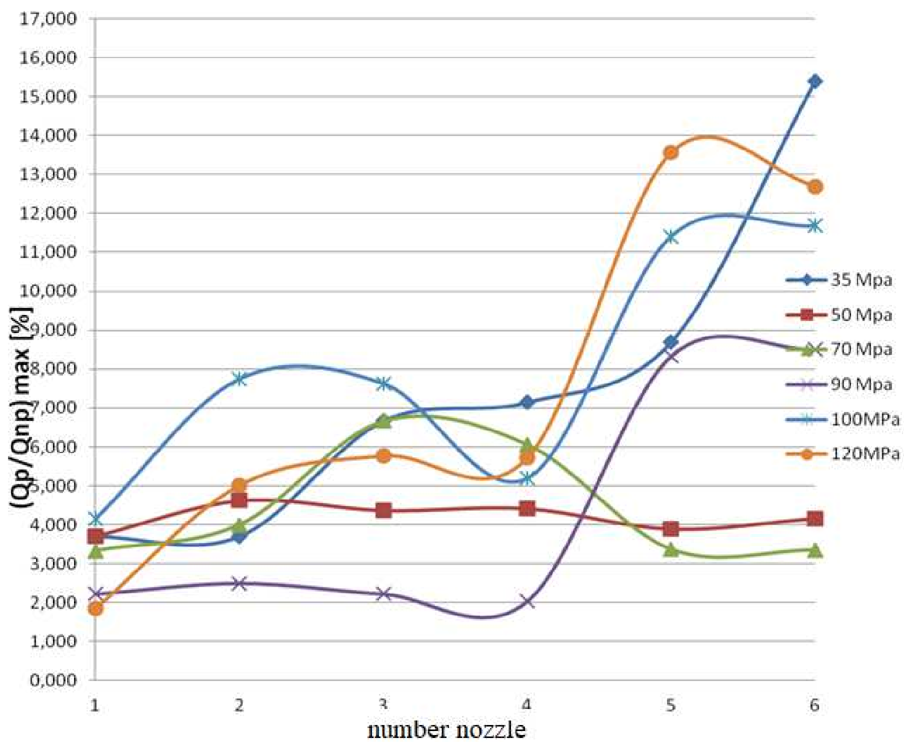


Fig. 5. Graph of the percentage ratio of the maximum flow rate of pre-machined nozzles in relation to that of non-machined nozzles

From figure 5 it can be seen that nozzle number 5 has a superior injection characteristic compared to the other machined nozzles.

The percentage ratio of the maximum flow rate of machined nozzles in relation to that of non-machined nozzles expresses the rounding effect of the of the injection nozzle hole in the entrance area of the fluid flow, [6].

To study the effect of rounding the nozzle hole, the radius of rounding was determined using the LEICA microscope, obtaining the results shown in table 2.

Table 2

The value of the rounding radius of the nozzle holes

Number the nozzle	N	1	2	3	4	5	6
Abrasive concentration [dm3/liter]	-	0,2	0,2	0,2	0,1	0,1	0,1
Number of passes	-	4	6	8	4	6	8
Range value [mm]	0,015	0,02	0,025	0,035	0,02	0,022	0.026

Table 2 shows that an increase in the concentration of the abrasive, respectively the number of passes of the abrasive fluid, causes an increase in the radius of rounding, which improves the flow.

After carrying out the experimental study, the multiple linear regression method was used to process the data resulting from this study to qualitatively express the dependence between the rounding radius and the volume fraction, respectively the volume of the abrasive flow.

Method

Null hypothesis All data values come from the same normal population
Alternative hypothesis Smallest or largest data value is an outlier
Significance level α = 0.05

Grubbs' Test

Variable	N	Mean	StDev	Min	Max	G	P
Raza, [mm]	6	0.02467	0.00565	0.02000	0.03500	1.83	0.093

Fig. 6. Applying the Grubbs

Applying the Grubbs test shows that the results are not affected by measurement errors, figure 6.

Next, the normality test was performed with a level of significance of 0.05, figure 7.

From figure 6 it can be seen that the radius values have normally distributed values.

The resulting linear regression relationship is:

$$R = 0.00292 + 0.0004 \cdot Fv + 0.002625 \cdot V \quad (1)$$

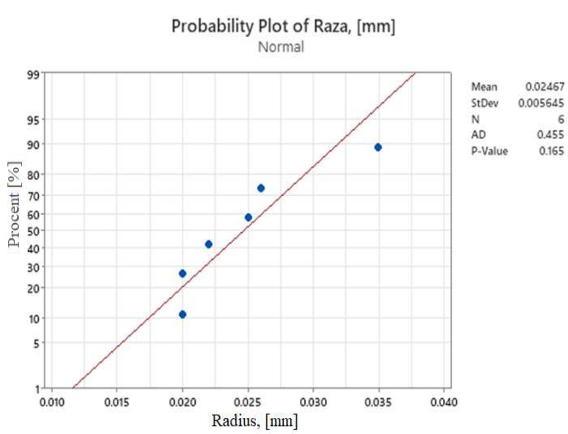


Fig. 7. Normal probability grid distribution of rounding radius

in which,

R - rounding radius [mm];

Fv - volume fraction [%];

V - volume of abrasive flow [l].

The value of the coefficient of determination:

$$R^2 = 84{,}26\ [\%]$$

indicates that the previous equation explains 84.26% of the variability of the analyzed process. The remaining 15.74% is due to the influence of factors that were not considered in the analysis performed.

As the weight of the two independent factors considered:

- the volume of abrasive flux used in processing has a weight of 69.19%, and
- the volume fraction has a weight of 15.06%.

3.CONCLUSION

The following conclusions can be drawn from the analysis of the conducted study:

- the erosion effect is influenced by the percentage of abrasives in suspension and the number of its passes through the flow holes, respectively an intensification of the erosion effect is achieved by increasing the percentage of abrasives, thus decreasing the quality of the finished surface;
- the abrasive flow finishing process is dependent on several factors, which makes it difficult to improve it;
- a superior injection characteristic of the injection nozzles is obtained for a percentage of suspended particles of 100 cm3/liter and for six passes of the abrasive fluid;
- by using the hydro abrasive finishing of the flow micro holes of the injection nozzles, an improvement of the surface quality is achieved.

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ÎMBUNĂTĂȚIREA CARACTERISTICILOR DE INJECȚIE ALE DUZELOR DE COMBUSTIBIL

Rezumat: Reducerea nivelului de poluare la automobile se realizează în principal prin optimizarea constructivă a componentelor sistemului de injecție, care are cea mai mare influență în acest sens, respectiv prin îmbunătățirea caracteristicilor de curgere prin orificiile duzelor de combustibil. Această îmbunătățire se poate realiza prin finisarea abrazivă asistată de vibrații a suprafețelor de curgere, utilizând fluxuri abrazive. Prin acest procedeu se realizează o finisare - rotunjire - a orificiilor de curgere a combustibilului, determinând înlăturarea apariției cavitației.

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