METHOD FOR COMBUSTION CONTROL IN DIESEL ENGINES

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Abstract: The article considers different approaches to distribution of the amount of released heat among the stages of combustion for instance an ozone addition and changing of piston temperature. The research has proved for that the effect of reducing the heat loss during combustion can be achieved with exact ozone addition which was determined though calculation. On the basis of the forecast of the working flow of diesel engine it is estimated that the combustion characteristics can be changed with the piston temperature in order to reduce emission of nitric oxides.

Introduction

At the present stage further development of propulsion engineering has discrepant character. The construction of power unit is already bought to perfection. On the other hand we have performed analysis of the investments into development of the branch of power engineering [1, 2]. On that basis it was concluded that the level of efficiency is not growing higher even though the multi-billion investments into development, re-structuring and factory building are provided. We see the further development of propulsion engineering as a search of effective ways to control combustion on the basis of the fundamental description of the working flow of diesel engine and specifically of the combustion process.

The major contribution to the development of the fundamental description of hydrocarbon burning was made by soviet and American researches [3, 4]. When the developed by N. Semjenov theory of the clain and thermal explosion appeared, it has been established that the major influence on flame propagation are the promoters. However the working flow conditions are totally different from atmospheric condition. It should be noted that the aspect hasn't been considered in these studies [3, 4]. And it makes difficulties using the results which were obtained [3, 4] to indentify the qualitative impact of changes on the combustion process and its performance.

According to physical concepts [5, 6] considering the working flow of diesel the combustion process is a combination of three interrelated processes: fuel spraying and simultaneously its evaporation and combustion in the compressed air charge in the combustion chamber. In the experts' opinion a key determinant role in the processes is assigned to a macrostructure fuel spray which has geometrical characteristics. However it should be noted that a complex mathematical description of the thermodynamic processes is extremely complex [7]. So it is necessary to use of statistical methods for studying the process of spray, which makes some of the conventions in the physical model.

Purpose

Based on the available computational models [5,6] of the diesel working flow subject to the effect of ozone on the combustion process the use of ozone for combustion process will be considered as possible means to redistribute released heat over the phases of combustion for improving techno-economic and environmental performance of transport diesels. As well as on the basis of the forecast of the working flow of diesel engine a new physical model the heat boundary condition of piston is proposed. It can be allowed to change the combustion characteristic through piston temperature.

Theoretical overview

In this paper the effect of controlled combustion is based on increase in the adiabatic property of working gas. It can be made possible through releasing maximum quantity of heat in the combustion phase by which the specific volume of working gas loss is minimum. In Figure 1 the cooling system heat corresponds to the specific volume of working gas.

Figure 1 shows that redistribution of released heat can be achieved in order to change the combustion characteristics especially through the rate of heat release. The change of the rate of the heat release can be ensured through making variable the amount of evaporated fuel which must be generated in the ignition delay period. It provides different flows of the combustion processes which are depicted in the Figure 1.

Time regulation of the ignition delay period is based of the theory [4] of chain-thermal explosion. The period is required for saturation of promoters in a combustion chamber. The lower is the period, the lower is the amount of the evaporated fuel with contained the promoters [3] for next combustion stages. In this case the probability of chain break is decreased.

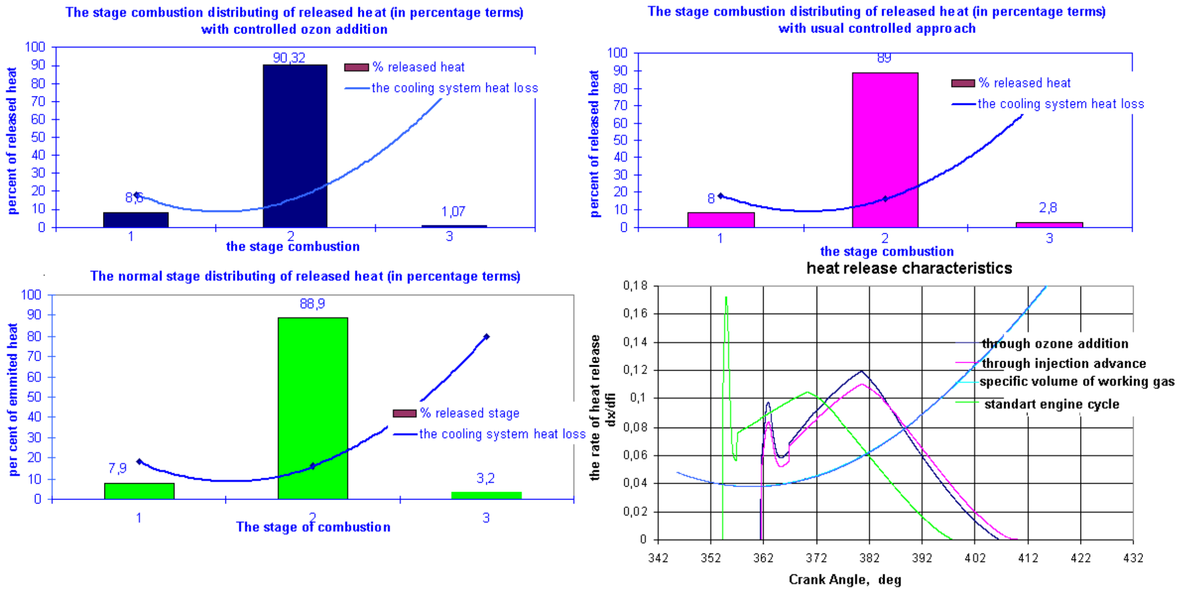

Figure 1: The results of forecasting of redistributing heat release through the combustion characteristics (the rate of heat release)

We analysed the result of simulation of diesel engine cycle to indentify the factors which have the strongest influence on the law of heat release as well as on the stage combustion distributing of the released heat. This analysis has been done taking into account that:

– It has many factors which have a dramatic impact on the released heat.

– The result of influence of the factors is considerably contradictory. In order to find out the solution it is necessary to consider a complex mathematical description.

For the reasons discussed above we reached the point to apply the control criterions [8]. It has given us the chance to arrive at the general solution of the issue as well as to satisfy most of all requirements. For one of the factors which exerts primary control over the rate of released heat is the relative amount σ_a of the evaporated fuel which can be estimated as a ratio of the evaporated fuel mass to whole fuel mass which must be sprayed in combustion chamber.

In our opinion the amount σ_a can have a determining influence on the ratio of released heat. Furthermore the amount conditional accounts for the number the «promoters'» which is necessary for the further combustion stage.

During a similar ignition delay period the longer is the amount σ_a, the longer is probability of chain break. It means in order to provide the further combustion process with necessary number of promoters it must be sprayed more fuel in the ignition delay period that limits the range of control combustion boundaries the comparison of which is given in Figure 2.

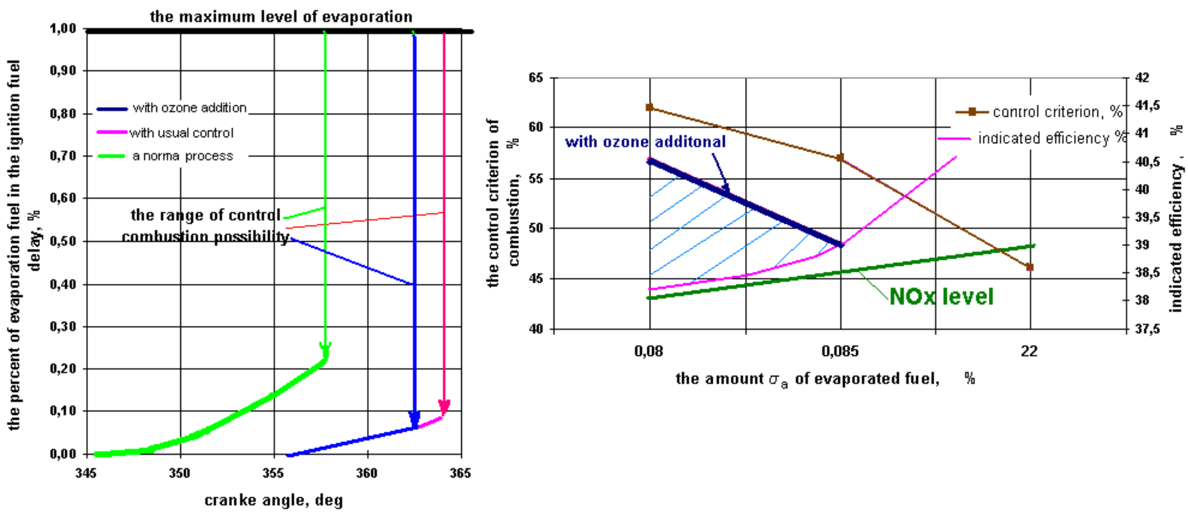

Figure 2: The principal regulation of fuel ignition

In Figure 2 it is shown that the lower is the amount of σ_a, the lower is the criteria control of combustion. The amount σ_a is used to bring down the emission of NO_x, despite the fact that the indicated efficiency is decreased. However the Figure 2 has got the hatched area which the efficiency is increased in contrast. It can be achieved through ozone addition which provides accessory promoters in «cool» flame period. The promoter saturation for the working gas in the ignition delay decreases the probability of breaking the new chain and generally reduces the period.

$$RH + O_3 \rightarrow R\dot{O}_3 + O\dot{H}$$

$$O_3 \rightarrow O_2 + \dot{O}$$

This effect can be also achieved to reduce the activation energy of working gas. Herewith the distinctive property of the use of ozone in the air charge is more heat in the intracylinder space at the moment when the specific volume of working gas is minimum. The other ways to control combustion have no the effect. It is reflected in the table 1.

Table 1: Comparison of the different controlled approaches

Parameter	Conventional signs	Value		
		Normal process	With usual control	With ozone addition
The relative amount of evaporation fuel	σ_a	22,0	8,5	8,0
The control criteria	φ	46	61	62
The indicated efficiency	η_i	41,6	39,4	40,4

As part of our research it is established that the ozonization of the air flow charge of diesel engine can bring about some difficulties which are caused first and foremost by chemical instability of ozone, especially under a gas-turbine boost which are used as the major means of increasing power of diesel engine. We have found that it is necessary to ensure that the ozone concentration in air-flow charge is estimated as $(0{,}8 - 1{,}0) \times 10^{-5}\%$.

It should be noticed that the estimated volume is optimal for economic considerations.

Relying on measurement made[9] of the use of fuel ozonization we have investigated diesel engine performances which are the concentration O_3 (to 1% in fuel volume) dependent such as the SFC dependence on the concentration as well as smoking of exhaust on the concentration of O_3.
In our view the fuel ozonization is reasonable on the following counts:

– to ensure against inevitable loss in indicated power for ozone generation;

– to ensure against problems of the sitting of ozonator in a engine unit.

The results of using of fuel ozonization are present in [9]. Based on its it is reasonable to say that the SFC was reduced per 4 g/kW*h as well as the smoke of exhaust was reduced per 17%. It can be achieved through ozone saturation of fuel from 0,01 to 0,5 mg per a liter of fuel.

All the same principal problem of the fuel ozonization is chemical stability of ozone fuel the structure of which is essentially time dependent.

One of the major distinctive properties of real engine cycle is the influence of diesel construction of the combustion chamber and 3D direction of fuel spray which are interrelated in the space of the chamber.

For the reason discussed above it seems to be justified to have an influence on the rate of released heat through control the piston temperature because of the ignition delay period is temperature of working gas dependent. The longer is the average piston temperature, the lower is a convective heat transfer from working gas to a surface of a piston during the ignition delay period of change. The increase in the piston temperature is associated with bringing up the coefficiency of convective heat exchange for the engine cycle [10].

It has negative influence on NO_x emission. If the average piston is reduced more than it is enough for chemical-thermal energy transformation during «cool» flame period, it can cause the rise of NO_x emission again because of spacing out the delay period and also increasing the amount σ_a.

To find out the optima for the piston temperature is necessary to determine the boundary conditions for a piston surface which mates with working gas in a combustion chamber. The boundary conditions are:

– the temperature of working gas;

– the temperature of ignition spray which touches the piston surface;
– the coordinate of the fuel spray head;

– the coefficient of convective heat exchange for the engine cycle;

– the coefficient of convective heat exchange nearby flame.

We have analyzed the result of dependences of NO_x emission on the piston temperature and reached the point that the optimal piston temperature exists. The principal dependence of NO_x emission on the piston temperature is shown on Figure 3.

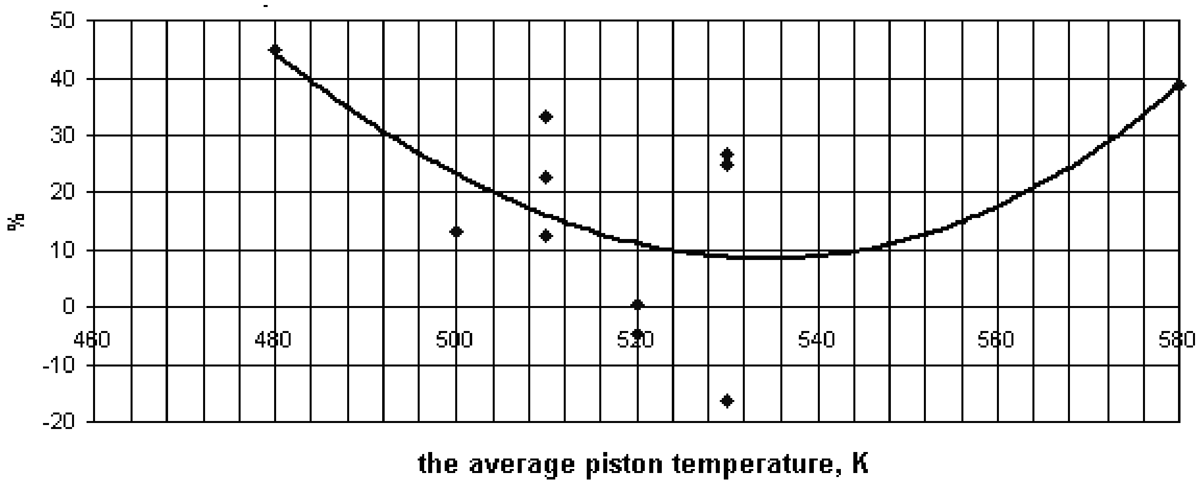

Figure 3: The percent deviations of NO_x from allowable level Euro 4 through using the AGR

Conclusions

In this paper major approaches which exert primary control over combustion are proposed. The described approaches to combustion control can give the chance to find out the general solution for complying with strict requirements of perspective development of diesel engines.

The further research is supposed to be carried out to find any ways to influence structural transformations of hydrocarbons during the cold flame. These ways of influence are supposed to provide the least value of self-ignition temperature for air-fuel mixture for providing the multifuel capability.

References

1. A global view of engine building.[Electronic resource]/ Marketing Automobile Magazine « Autobusiness ».–Mode access:http:// http://www.abiz.ru.

2. Romanov K. Engine-driver of growth as CMO /[Electronic resource]/ Magazine « The Russian stock market ». - Mode access: http://www.rcb.ru/rcb/2007-22/8832

3. Egerton, A. The limits of flame propagation at atmospheric pressure I. The influence of 'promoters'/ A. Egerton, J. Powling //The Royal Society[Electronic resource].–1948.–Mode of access: http://www.rspa.royalsocietypublishing.org/subscriptions.–Date of access: 25.11.2009.

4. Semjenov, N. The Chain reaction / N. Semjenov // The Physics- Successes.- Leningrad, 1930.- V.10.-P.191-233

5. Razleytsev, N. Simulation and optimization of the combustion process in diesel engines /N. Razleytsev.– Kharkiv, 1980.–169p.

6. Kuleshov, A Multizone model for the calculation of combustion in a diesel engine 1. The distribution of fuel in the jet // Vestnik MSTU after N. Bauman.-2007.- Special Issue on Internal Combustion Engines.-P.18-31.

7. Volochko, A. Methods of optimizing the workflow engine in the calculation of highly accelerated thermally stressed state of the piston / A. Volochko, A. Izabela, H. Viarshyna, A. Pilatau // Mechanics of machinery and materials.–2009.–№2.–P.70-75.

8. Charomsky, A. Testing, investigation and calculation of aircraft engine.-M.,-1934.-320p.

9. Golubenko A., Nozhenko E., Mogila V., Vasiljev I., Ignatjev O.: Ozonization influence on energy and ecological characteristics of locomotive diesel engine // Int. Sci. J. “Transport Problems”. – Gliwice, Volume 3, Issue 4, Part 2, 2008. – P. 39 – 46.

10. Izabela, A., Pilatau A., Physical model of optimization of thermal state highly accelerated piston engine // The news of the Automobile and Road Institute.-2010.-№1.-P.133-146.