



Časopis Naučnog društva za pogonske mašine, traktore i održavanje
Journal of Scientific Society of Power Machines, Tractors and Maintenance

TRAKTORI

I

POGONSKE MAŠINE

TRACTORS AND POWER MACHINES

1/2

UDK 631.372

ISSN 0354-9496

Godina 29

Nov. 2024.



Novi Sad, Srbija

Trakt. i pog. maš., Trac. and pow. mach., Vol. 29, No. 1/2, p.1-81, Novi Sad, Dec. 2024.

Izdavač – Publisher



Naučno društvo za pogonske mašine, traktore i održavanje
Scientific Society of Power Machines, Tractors and Maintenance

Suizdavač – Copublisher

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Rešenjem Ministarstva za informacije Republike Srbije, Br.651-115/97-03 od 10.02.1997.god., časopis je upisan u registar pod brojem 2310
 Prema Mišljenju Ministarstva za nauku, Republike Srbije ovaj časopis je "PUBLIKACIJA OD POSEBNOG INTERESA ZA NAUKU"

Jurnal is published four times a year

Subscription price for organization is 40 EURO, for
 foreign organization 80 EURO and individual
 subscribes 15 EURO

Štampa – Printed by

Štamparija "Grafika Galeb" doo Niš, Matejevački put 13, 18000 Niš

Tiraž 100 primeraka



Časopis Naučnog društva za pogonske mašine, traktore i održavanje
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UDK 631.372

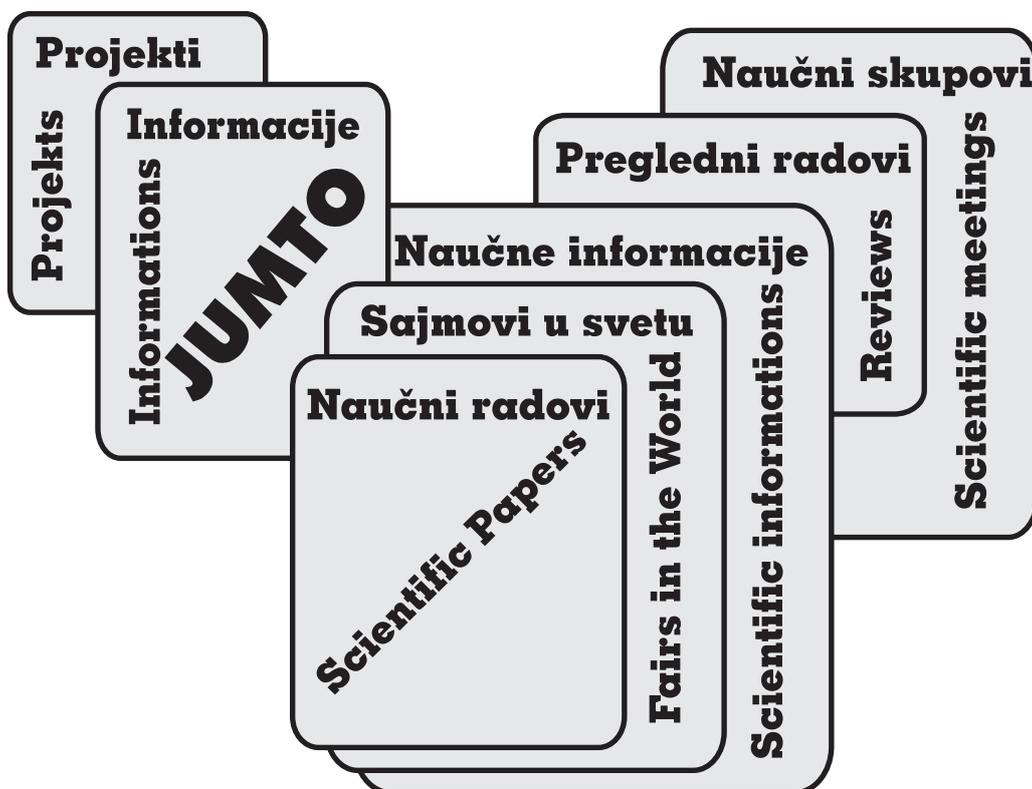
ISSN 0354-9496

Godina 29

Dec. 2024.

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Novi Sad, Srbija

Trakt. i pog. maš., Trac. and pow. mach., Vol.29, No.1/2, p.1-81, Novi Sad, Nov. 2024.

**Časopis Traktori i pogonske
mašine broj 1/2 posvećen je
XXXI-om naučnom skupu
“Pravci razvoja traktora i
obnovljivih izvora energije”**

**The journal Tractors and power
machines number 1/2 is devoted to
XXXI scientific meeting
“Development of tractors and
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Organizers of meeting

Mesto održavanja

Place of meeting

Poljoprivredni fakultet, Novi Sad, 06.12.2024.

Štampanje ove publikacije pomoglo je:
Ministarstvo prosvete, nauke i tehnološkog razvoja Republike Srbije
Pokrajinski sekretarijat za poljoprivredu, vodoprivredu i šumarstvo AP Vojvodine

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THE NUMERICAL INVESTIGATION OF THE COMBUSTION PROCESS OF THE DUAL FUEL IC ENGINE

Đurić, Ž.¹, Grujić, I.², Davinić, A.³, Stojanović, N.⁴, Dorić, J.⁵

SUMMARY

In the paper it was conducted the numerical analysis of the combustion process. In order of this it was created 3D model of the IC engine working space, which by geometry do not correspond to no one existing engine. The simulation it was conducted for the entire working cycle, that is, for all four strokes and for the combustion process, by application of computational fluid dynamics. In the simulation it was defined that the engine is turbocharged, and that uses two fuels, gasoline and methanol. According to the conducted analysis, as well as to the obtained results, it was found, that is necessary provide more intensive combustion, in order to increase the indicating efficiency. In order to provide this, were proposed actions for future researches, such are the earlier ignition, redesign of the shape of the combustion chamber and increment of the compression ratio.

Key words: numerical investigation, combustion process, dual fuel, IC engine, combustion chamber.

INTRODUCTION

The experimental work, is very important during the development of IC engines. However, in early stages of the development, the numerical analyses are good replacement, in order to see if development goes in right direction, or not. The main process in IC engines, from which depend all output characteristics of the IC engine, is the combustion process. From the combustion process, depend performances of the IC engine such is power, as well as raw engine emission. In order to achieve this, it is necessary to have a intensive combustion, which will provide good heat release (relatively short combustion with the 50% of combusted fuel

¹ Đurić Željko, senior assistant, University of Banja Luka, Faculty of mechanical engineering, Banja Luka, zeljko.djuric@mf.unibl.org

² Grujić Ivan, assistant professor, Faculty of Engineering University of Kragujevac, Sestre Janjic 6, 34000 Kragujevac, Serbia, ivan.grujic@kg.ac.rs

³ Davinić Aleksandar, associate professor, Faculty of Engineering University of Kragujevac, Sestre Janjic 6, 34000 Kragujevac, Serbia, davinic@kg.ac.rs

⁴ Stojanović Nadica, assistant professor, Faculty of Engineering University of Kragujevac, Sestre Janjic 6, 34000 Kragujevac, Serbia, nadica.stojanovic@kg.ac.rs

⁵ Dorić Jovan, full professor, University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovica

6, Novi Sad, Serbia, jovan_d@uns.ac.rs

near the Top Dead Centre (TDC)), as well as the complete combustion of fuel hydro-carbons. For the numerical analyses/simulation of working cycle of the IC engine and of combustion process, usually are using the Computational Fluid Dynamics (CFD) analyses.

The CFD is the type of the type of the analysis, which provides the calculation of fluid flow, pressure change, temperature change... [1], and all these parameters are exactly the parameters important for the IC engine work, which makes the CFD analyses excellent for the simulation of the IC engine working cycle. For example, the use of the CFD analysis in the are of the IC engines, provides the possibility to see the flow behaviour of different fuels. The fuels flow evaluation can be made according to the flow on the intake port [2], which will provide the information about the intake parameters necessary for the cylinder filling. Modern software's provides the simulation and analyses of the combustion process of many different fuels, for example natural gas or hydrogen [3], which is excellent for the development of engines which will work with alternative fuels. Also, the combination of CFD and cad software's provides no only the investigation of different combustion chamber, but also the investigation of different principes of injection, for example Direct Injection (DI) [4], manifold injection. These analyse, are even have the possibility to predict the emission, on the basis of the results of the combustion [5].

According to all listed, it can notice that the modern numerical analyses have many possibilities. This is the main reason why in this paper is used exactly numerical analysis. The main aim was to model the engine, and then to investigate the combustion process, in the case of the dual-fuel use, as well as for the engine work as the turbocharged one.

NUMERICAL ANALYSIS OF THE COMBUSTION PROCESS

In order to investigate the combustion process, it was conducted the numerical analysis of the entire cycle, that is the numerical analysis can be divided to the five stages, and that:

- ◆ Simulation of the intake stroke;
- ◆ Simulation of the compression stroke;
- ◆ Simulation of the combustion process
- ◆ Simulation of the expansion stroke, and
- ◆ Simulation of the exhaust stroke.

Generally, all five stages of simulation were conducted through one analysis. On the combustion process, the main influence have the intake stroke because during the intake stroke, enters the mixture into the cylinder (in the case of this analysis, it is defined mixture of gasoline and air, with air fuel ratio 1.1), as well as the compression stroke, because

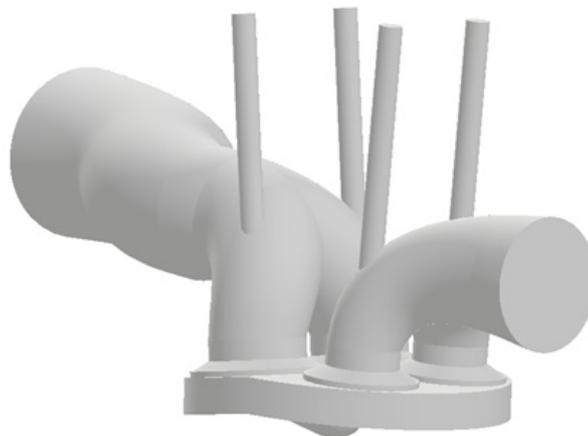


Fig. 1. The 3D model of IC engine used in the analysis

during the compression happen turbulences which are very important for the combustion behaviour, also, during the compression grow the pressure and temperature which values significantly influence on the combustion process. Also, in the case of this analysis, during the compression stroke is defined the injection of the secondary fuel, which in this case was methanol, and the defined mass of the injected methanol is 0.015 g. the methanol injection started at angle 550 degrees, and the injection duration is defined as 60 degrees The expansion stroke is important, in order to calculate the expansion polytropic coefficient, while the exhaust stroke don't have a great importance.

In order to conduct the analysis, first was created the 3D model of the working space of the engine (Fig. 1), which main characteristic are given in Tab. 1.

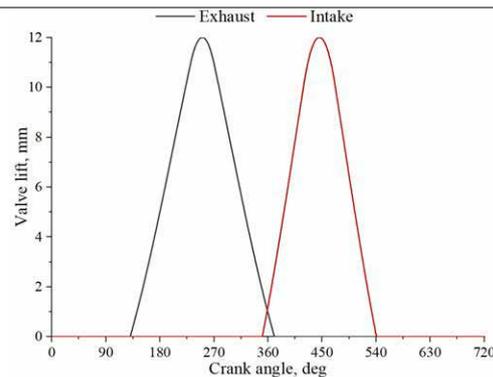
The next step in the analysis, it was to define the initial boundary conditions. The initial boundary conditions are given in Tab. 2.

Tab. 1. The characteristics of the 3D model of the engine

Parameter name	Value	Unit
Cylinder bore	95	mm
Piston stroke	70	mm
Connecting rod length	80	mm
Displacement	499	cm ³
Compression ratio	7.3:1	-
Number of intake valves	2	-
Number of exhaust valves	2	-

Tab. 2. Initial boundary conditions

Parameter name	Value	Unit
Piston temperature	180	°C
Cylinder temperature	160	°C
Cylinder head temperature	140	°C
Intake valves temperature	50	°C
Exhaust valves temperature	500	°C
Intake port temperature	32	°C
Exhaust port temperature	650	°C
Intake port pressure	1.8	bar
Cylinder pressure	1.2	bar
Exhaust port pressure	0.97	bar
Engine speed	6500	rpm



How it can see, the initial boundary conditions are related to the initial temperatures of engine parts, as well as to the initial pressures in certain places of the geometry. According to the intake port pressure, it can see, that the analysis it was conducted for the case of turbocharged engine. The Figure from the Table 2, represents the valve lift profile, defined in the analysis. This is quite important parameter because it influences on the mass of the mixture which will enter during the intake stroke. After the boundary conditions are defined, the analysis is conducted, and results are processed.

RESULTS AND DISCUSSION

In order to investigate the combustion process, of the IC engine, it is necessary to have only the main working parameter of the engine, and that is the cylinder pressure. The obtained cylinder pressure is given on the Fig. 2.

In order to calculate the heat release rate, also known as the combustion speed, or differential combustion law, it was used the Equation 1.

$$\frac{dQ}{d\alpha} = \frac{K}{n-1} \cdot (n \cdot p_i \cdot (V_{i+1} - V_{i-1}) + V_i \cdot (p_{i+1} - p_{i-1})) \quad (1)$$

The expansion polytropic coefficient is calculated based on the pressure and volume change during the expansion stroke, according to the Equation 2, and in this case the calculated value of the polytropic coefficient is 1.25.

$$n = \frac{\log\left(\frac{p_1}{p_2}\right)}{\log\left(\frac{V_2}{V_1}\right)} \quad (2)$$

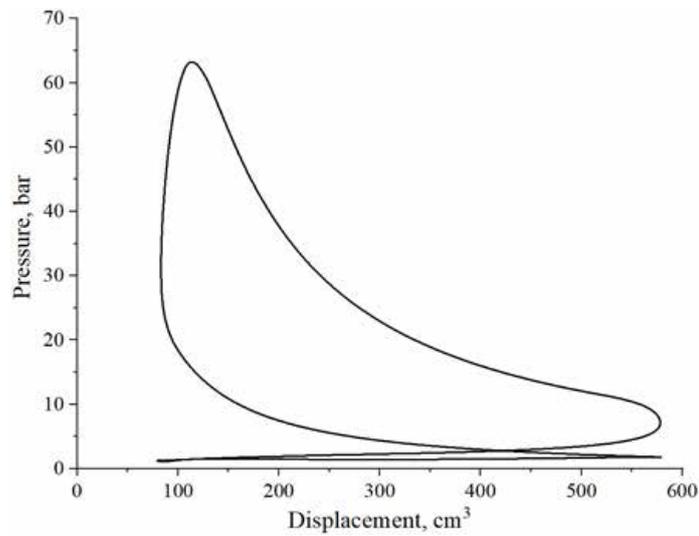


Fig. 3. The cylinder pressure

By application of the Equation 1, were calculated values of the heat release rate, which are represented on the Fig. 3.

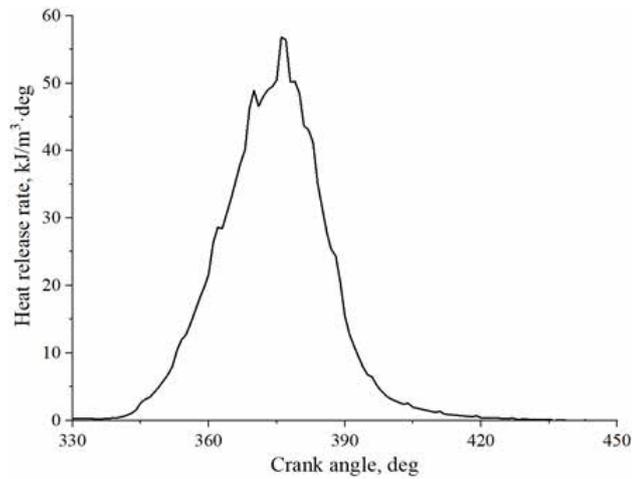


Fig. 3. The heat release rate during the combustion process

It can be seen that in the heat release rate there are several discontinuities. This is caused by the poor mixing of the injected methanol and the mixture of gasoline and air, or by late ignition. This can be improved by earlier ignition, increasing the compression ratio, as well as by changing the geometry of the combustion chamber. The combustion chamber can be changed in order to increase the turbulence, which can be partially achieved by increasing the compression ratio. Higher turbulence will lead to more intensive combustion. While a higher compression ratio will also contribute to higher temperatures, which will lead to better vaporization. However, in the case of this analysis, the lack of defined parameters has affected the combustion process stretching, which can be seen from the integral combustion law, Fig. 4.

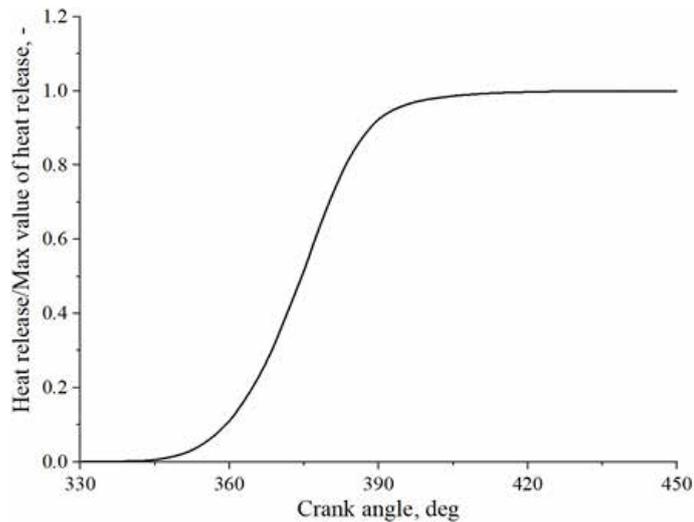


Fig. 4. The integral combustion law

According to the integral combustion law it was found that the 50% of the fuel, was combusted approximately at 15 degrees After Top Dead Centre (ATDC). In order to achieve better efficiency, the achieved indicating efficiency in this case is 0.3, it is necessary to get closer this point to the TDC. In order to do this, it should provide more intensive combustion, by earlier mentioned actions.

CONCLUSION

If we take into the consideration, that the analysis, was conducted for the non-existing engine, and that the initial boundary conditions are defined according to the experience acquired on the experimental work with one fuel, on real engines, it can be said that the obtained results are quite well. The main problem which affected on the efficiency, is not enough intensive combustion. In order to make the combustion more intensive, the for future analysis should change the geometry of the combustion chamber, that is to change the shape of the piston head. The piston head should be constructed as such to provide high-intensity turbulences during the compression stroke, which will lead to more intensive combustion. Also, it should increase the compression ratio, in order to achieve better initial conditions for the combustion start, that is, higher temperature. At the end, it should investigate the influence of the ignition timing, that is to consider earlier ignition, especially at such high engine speeds, where the duration of the working cycle is quite short

ACKNOWLEDGMENT

Paper is financially supported by The Ministry of Science, Technological Development and Innovation of the Republic of Serbia, Contract No. 451-03-65/2024-03/200107

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Rad primljen: 02.10.2024.

Rad prihvaćen: 14.10.2024.