Faculty of Engineering
University of Kragujevac

Ministry of Science, Technological Development and Innovation

10th International Congress

Motor Vehicles & Motors 2024

ECOLOGY - VEHICLE AND ROAD SAFETY - EFFICIENCY

Proceedings

University of Kragujevac

Department for Motor Vehicles and Motors

International Journal for Vehicle Mechanics, Engines and Transportation Systems

October 10th - 11th, 2024
Kragujevac, Serbia

10^{th} International Congress
Motor Vehicles & Motors 2024

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Proceedings

October 10^{th} - 11^{th}, 2024
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Publisher: Faculty of Engineering, University of Kragujevac
Sestre Janjić 6, 34000 Kragujevac, Serbia

For Publisher: Prof. Slobodan Savić, Ph.D.
Dean of the Faculty of Engineering

Editors: Prof. Jasna Glišović, Ph.D.
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Cover: Nemanja Lazarević

USB printing: Faculty of Engineering, University of Kragujevac, Kragujevac

ISBN: 978-86-6335-120-2

Year of publication: 2024.

Number of copies printed: 100

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

CIP - Каталогизација у публикацији Народна библиотека Србије, Београд

629.3(082)(0.034.2)
621.43(082)(0.034.2)

INTERNATIONAL Congress Motor Vehicles and Motors (10 ; 2024 ; Kragujevac)
Ecology - Vehicle and Road Safety - Efficiency [Elektronski izvor] : proceedings / [10th] international congress Motor vehicles & motors 2024, October 10th - 11th, 2024 Kragujevac, Serbia ; [editors Jasna Glišović, Ivan Grujić]. - Kragujevac : University, Faculty of Engineering, 2024 (Kragujevac : University, Faculty of Engineering). - 1 USB fleš memorija ; 1 x 1 x 6 cm

Sistemski zahtevi: Nisu navedeni. - Nasl. sa nasl. strane dokumenta. - Tiraž 100. -
Bibliografija uz svaki rad.

ISBN 978-86-6335-120-2

a) Моторна возила -- Зборници b) Мотори са унутрашњим сагоревањем -- Зборници

COBISS.SR-ID 153339657

Publishing of this USB Book of proceedings was supported by
Ministry of Science, Technological Development and Innovation of the Republic of Serbia

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PREDGOVOR

U oktobru se na Fakultetu inženjerskih nauka Univerziteta u Kragujevcu tradicionalno održava skup istraživača i naučnika koji se bave proučavanjem motornih vozila, motora i drumskog saobraćaja. Od 1979. do 2004. godine održano je trinaest bienalnih MVM simpozijuma koji su 2006. prerasli u Međunarodni kongres MVM. Od tada je održano devet MVM kongresa, a oktobra 2024. godine Fakultet inženjerskih nauka je organizovao deseti međunarodni kongres MVM od 10. do 11. oktobra 2024. godine.

Na deseti kongres Motorna vozila i motori, MVM2024 dostavljen je veliki broj naučnih radova iz Srbije i inostranstva. Kongres tradicionalno podržavaju Ministarstvo za nauku, tehnološki razvoj i inovacije Republike Srbije, Univerzitet u Kragujevcu, Fakultet inženjerskih nauka i međunarodni časopis „Mobility and Vehicle Mechanics“.

Tema Kongresa MVM 2024 bila je „Ekologija – Bezbednost vozila i na putevima – Efikasnost“. Tokom ovog istraživačkog putovanja, učesnici su puno naučili kroz rad na različitim sekcijama, koje su pokrivale širok spektar tema u vezi sa inženjerstvom u automobilskoj industirji, od fundamentalnih istraživanja do industrijskih primena, naglašavaju interakciju između vozača, vozila i životne sredine i stimulišući naučnu interakcije i saradnju.

Međunarodni naučni odbor u saradnji sa organizacionim odborom izradio je podsticajan naučni program. Program je ponudio preko 54 prezentacije radova, uključujući predavanja po pozivu i radove u sekcijama. Prezentacije na ovom kongresu obuhvatile su aktuelna istraživanja u oblasti motornih vozila i motora sprovedena u 12 zemalja iz celog sveta.

Zadovoljstvo nam je bilo što su nam uvodničari bili profesor Emrulah Hakan Kaleli (sa Tehničkog univerziteta Yıldız, Turska), profesor Ralph Putz (sa Univerziteta Landshut UAS, Nemačka) i profesori Nenad Miljić i Slobodan Popović (sa Univerziteta u Beogradu, Srbija). Izazovi i rešenja u korišćenju vodonika kao goriva za motore sa unutrašnjim sagorevanjem, korišćenje aditiva nanoborne kiseline dodatog u motorno ulje, kao i evropska politika o budućoj mobilnosti na putevima su bile teme uvodnih predavanja.

Sigurni smo da je ovaj program pokrenuo živu diskusiju i podstakao istraživače na nova dostignuća.

10. Kongres MVM 2024. finansijski je podržalo Ministarstvo za nauku, tehnološki razvoj i inovacije Republike Srbije.

Zahvaljujemo se iskusnim i mladim istraživačima koji su prisustvovali i prezentovali svoju stručnost i inovativne ideje na našem kongresu.

Posebnu zahvalnost dugujemo članovima međunarodnog naučnog odbora i svim recenzentima za njihov značajan doprinos visokom nivou kongresa.

Naučni i organizacioni komitet Kongresa MVM2024

FOREWARD

In October, the Faculty of Engineering University of Kragujevac traditionally holds gatherings of researchers and academics who study motor vehicles, engines and road traffic. From 1979 to 2004, thirteen, biennal MVM Symposiums have been held and they grew into an International Congress MVM in 2006. Since then, ninth MVM Congresses have been held, and in October 2024, the Faculty of Engineering organized the tenth International Congress MVM from 10th to 11th October 2024.

A large number of scientific papers from the Serbia and abroad were submitted to the tenth Congress “MVM2024”. Congress is traditionally supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, University of Kragujevac, Faculty of Engineering and the International Journal “Mobility and Vehicle Mechanics”.

The theme of the Congress MVM 2024 was "Ecology - Vehicle and Road Safety - Efficiency". Along this journey we learned from the various sessions, which broadly cover a wide range of topics related to automotive engineering from fundamental research to industrial applications, highlight the interaction between the driver, vehicle and environment and stimulate scientific interactions and collaborations.

The International Scientific Committee in collaboration with the Organising Committee built up a stimulating scientific program. The program offered over 54 presentations, including key-note speakers and paper sessions. The presentations to this conference covered current research in motor vehicle and motors conducted in 12 countries from all over the world.

We were pleased to have professor Emrullah Hakan Kaleli (from Yıldız Technical University, Türkiye), professor Ralph Pütz (from Landshut University UAS, Germany) and professors Nenad Miljić and Slobodan Popović (from University of Belgrade, Serbia) as the keynote speakers, addressing Challenges and solutions in using hydrogen as a fuel for internal combustion engines, using nanoboric acid (nBA) additive added in engine oil, as well as European policy on future road mobility.

We are sure this program will trigger lively discussion and will project researchers to new developments.

The 10th Congress MVM 2024 was financially supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia.

We would like to thank experienced and young researchers, for attending and bringing their expertise and innovative ideas to our conference.

Special thanks are due to the International Scientific Board Members and all reviewers for their significant contribution in the high level of the conference.

Scientific and Organizational committee of Congress MVM2024

CONTENT

INTRODUCTORY LECTURES

SECTION A
Power Train Technology

SECTION B
Vehicle Design and Manufacturing

SECTION C
Vehicle Dynamics and Intelligent Control Systems

SECTION D
Driver/Vehicle Interface, Information and Assistance Systems

SECTION E
Transport Challenges in Emerging Economies

International Congress
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Kragujevac, Serbia
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Motor Vehicles & Motors

MVM2024-049

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THE NUMERICAL INVESTIGATION OF THE WORKING CYCLE OF DUAL FUEL IC ENGINE

ABSTRACT: The numerical investigations have become the indispensable part of the development of new products, as well as, the part of modification of the existing products. For the numerical investigation of the IC engine working cycle, usually are using three-dimensional analysis, by application of computational fluid dynamics. In the paper it was investigated the working cycle of the turbocharged dual fuel IC engine. It was created a 3D model of one cylinder engine, with the displacement of 499 cm^3, and with the compression ratio 7.3:1. The analysis was conducted for the case of two fuels, with different injections type (gasoline injection into the intake port and methanol direct injection), as well as for the turbocharged IC engine, with 1.8 bar pressure at its inlet, at the engine speed of 6500 rpm. The obtained indicating power at the defined boundary conditions is 52 kW, with indicating efficiency of 0.3.

KEYWORDS: numerical investigations, IC engine, turbocharged, dual fuel, gasoline and methanol.

INTRODUCTION

Today, in the modern engineering, it is unthinkable to work on the development of new product, or even on the modification of existing one, without the application of numerical analysis. In the case of the IC engine, all output parameters depend from the working cycle of the engine. The working cycle of IC engine is reflected by many physical-chemical reactions from which depend the output parameters. So, the ideal type of the analysis in the case of IC engine working cycle simulation, are so-called Computational Fluid Dynamics (CFD).

In order to conduct the successful CFD analysis of the IC engine working cycle, it is necessary to include in the engine geometry all parts which influence on the engine working cycle, such is the combustion chamber, the intake and exhaust ports, as well as the intake and exhaust valves [1]. It exists several types of IC engine CFD analyses. The most complicated is the analysis of the entire working cycle. However, in the case of the analysis, and the optimization of combustion chamber, usually are using so-called cold-flow analyses. The purpose of these analyses is to see how the shape of the combustion chamber influences on the air/fuel mixing, turbulences etc [2]. The great advantage of the use of CFD amylases, over the experimental work, is the possibility to visualize the entire simulated process. So, the use of CFD analyses provides the visualization of all five events in fours stroke engine and that:

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intake, compression, expansion, exhaust and combustion [3]. One more advantage of the CFD analyses is the easy possibility of the implementation of different fuels. For example, in the software can be easy defined fuel such are Natural gas and Hydrogen [4], while the experimental work will demand many modifications in order to apply different fuels on the test engine. At the end it should say, that from the research aspect, the ideal variant is to have the results obtained from CFD as well as from the experimental work [5], and in this way it can compare and to see if the CFD model is appropriate, and did it can be used in future with fully trust.

The main aim of this paper is to create the geometry of engine, that by geometry is not the same as any existing IC engine, and to simulate its working cycle for the case of dual-fuel use. The simulation will be conducted for the maximum power regime. On the basis of these initial results, it can get idea for the future researches.

3D MODEL AND BOUNDARY CONDITIONS

In order to conduct the numerical analysis, the 3D model of the engine was developed. In order to conduct the CFD analysis of the IC engine working cycle, for the analysis it is only necessary to create the working space of the engine. So according to this, it was created the 3D model of the working space with all elements which influence on the working cycle, and this are:

- Shape of the combustion chamber (cylinder, piston head shape, and cylinder head shape).
- Shape of the intake port.
- Shape of the exhaust port.
- Shape of the intake valves.
- Shape of the exhaust valves
- Position of the injector in cylinder.
- Position of the spark plug.

The 3D model of the engine is given on the Figure 1, while the engine characteristics are given in the Table 1.

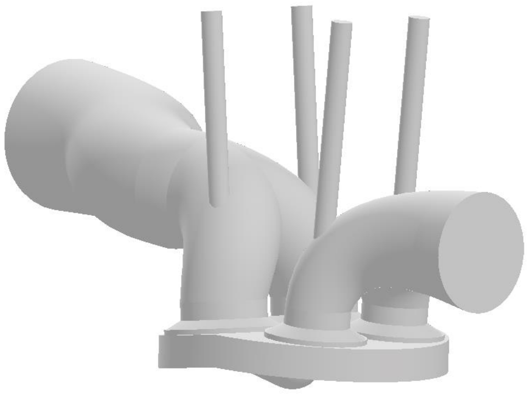

Figure 1 The 3D model of IC engine used in the analysis

Table 1 IC engine characteristics

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	-

The IC engine model, is the model created by authors, it is not the model of the working space of an existing IC engine. The main ide it was to create the IC engine with approximately 500 cm^3 displacement in one cylinder, which will correspond to the 2.0 L four-cylinder engine or to 3.0 L six-cylinder engine, etc.

After the created 3D model of the engine, are defined boundary conditions. Boundary conditions which are defined, are the initial temperatures of engine pars, as well as the initial pressure at intake, in cylinder and at exhaust. The defined boundary conditions are given in Table 2.

Table 2 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

Besides the boundary conditions from Table 2, also it also necessary to define the valve timing/lift. The valve timing/lift is calculated on the basis of kinematic characteristic of created camshaft, which 3D model, which also was created by authors. Based on the dimensions and shape of the cams, it was determined the valve timing/lift, shown on the Figure 2.

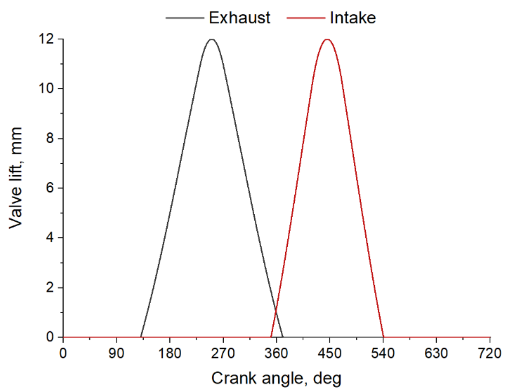

Figure 2 Valve lift

Also, in the analysis it was defined the engine speed, which in this case was 6500 rpm, the air-fuel ratio for the air-gasoline mixture was 1.1, and the injected amount of methanol in cylinder is 0.015 g. After all these conditions were defined, the analysis was conducted in ANSYS software package.

RESULTS AND DISCUSION

The analysis was conducted for the entirely working cycle, that is for the all four strokes of the engine, as well as for the combustion, Figure 3.

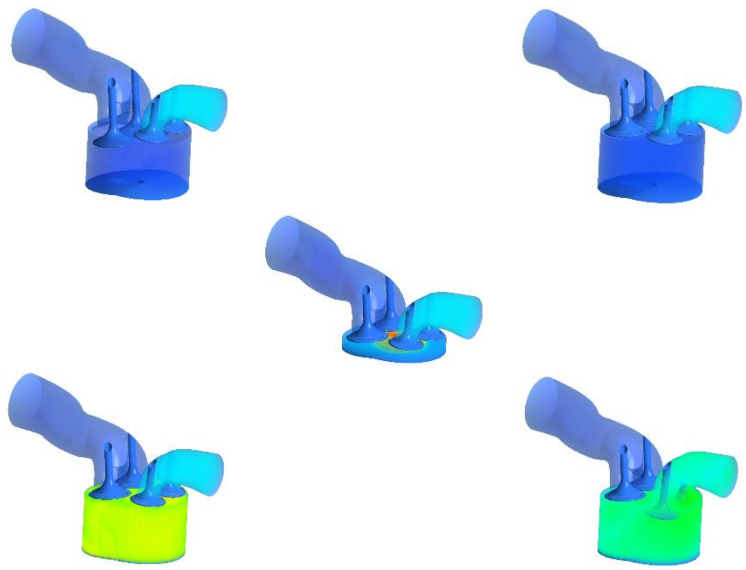

Figure 3 Parts of the simulation, intake stroke (upper left), compression stroke (upper right), combustion (in the middle), expansion stroke (bottom left) and exhaust stroke (bottom right)

The colours from the Figure 3, correspond to the temperature colours, which appeared during the simulated working cycle. That is, as the results are obtained cylinder pressure and temperature, which are and main parameters of the working cycle of the engine. The obtained values for cylinder pressure and temperature are shown on the Figure 4.

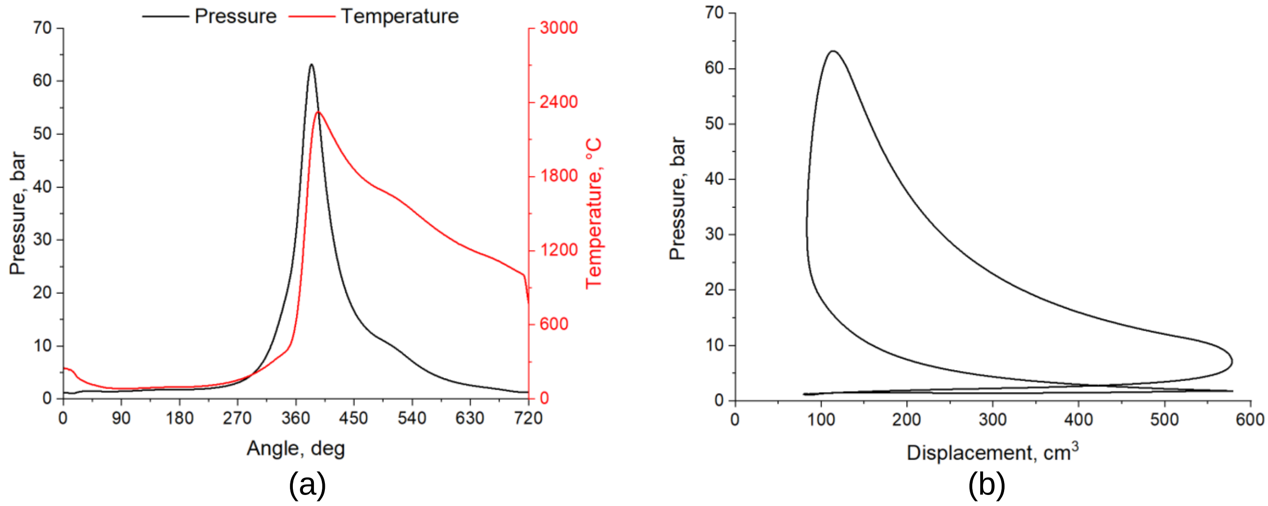

Figure 4 The results of (a) cylinder pressure and temperature and (b) cylinder pressure in p-V diagram

According to the obtained cylinder pressure, firstly is determined the indicating work of the engine, by application of Equation 1.

$$w_i = \frac{1}{V}\int_0^{4V} pdV \qquad (1)$$

Where the V is cylinder displacement and p is cylinder pressure. The obtained value for the indicating work is 1940000 J/m^3, that is, 1.94 kJ/dm^3. On the basis of the indicating work, it can be calculated indicating power, according to the Equation 2.

$$P_i = \frac{n \cdot w_i \cdot V}{120} \qquad (2)$$

Where the n is engine speed. On the basis of the Equation 2, the calculated indicating power is 52436 W, that is, approximately 52 kW. The indicating efficiency is calculated according to the Equation 3.

$$\eta_i = \frac{w_i \cdot V}{m_g \cdot H_{lg} + m_m \cdot H_{lm}} \qquad (3)$$

Where the m_g is gasoline mass while the H_{lg} is lower calorific value of gasoline, and m_g is methanol mass while the H_{lm} is lower calorific value of methanol. By application of Equation 3, it was obtained the value for indicating efficiency 0.3.

According to the obtained values of indicating parameters, it can be said that are obtained quit high values for the indicating work, as well as for the indicating power. However, the indicating efficiency is a little bit lower, which indicates on greater heat loses. This was happened due to the stretchered combustion process, which can be confirmed by the position of maximum cylinder pressure value, which was obtained at 24 degrees after top dead centre (ATDC). This can be regulated by the defining a little bit earlier ignition, especially in the case of high engine speed, as it was in this case. Also, in order to increase the efficiency, a compression ratio should be increased.

CONCLUSIONS

For the research, it was developed a working space of the on cylinder, with the displacement of 499 cm^3, and compression ratio 7.3:1. The research it was conducted by application of CFD analysis, and that for the turbocharged, dual fuel engine. The simulation was performed for the regime of maximum power, where it was defined the maximum engine speed of 6500 rpm. The boundary conditions of the simulation are defined according to the earlier experience in engine testing. The parameters which were observed are the indicating parameters of the engine work, that is, indicating work, indicating power and indicating efficiency. The obtained value for the indicating work is1.94 kJ/dm^3, the value of obtained value for the indicating power is 52 kW and the obtained value for the indicating efficiency is 0.3. A little bit lower indicating efficiency indicates that exist increased heat lose, that is, that are not achieved maximum possible performances. This can be improved by the regulation of ignition timing, which will significantly improve the performances. So, in future researches should seek the optimal value for the ignition timing. Also, it should modify the geometry of the engine working space, in order to increase the compression ratio, which will increase the efficiency and improve the indicating performances.

ACKNOWLEDGMENTS

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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ISBN 978-86-6335-120-2