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MONITORING AND ALERT SYSTEM: NEURO-FUZZY DECISION ALGORITHM BASED ON BIOLOGICAL SIGNALS ACQUIRED FROM VEHICLE DRIVERS

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Abstract: *The paper presents a system of monitoring and warning drowsy drivers in order to prevent accidents, based on EEG signals and eye state images. The drowsiness warning system is based on four main components, which learn, analyze and decide whether the driver is or is not in a drowsy or sleepy state.This result can be then used to warn the driver if he/she is in a drowsy state.*

Key-Words: *Driver drowsiness, EEG (Electroencephalography) signals, EOG (Electrooculography) signals, Artificial Neural Network*

1 INTRODUCTION

Driver sleepiness is a complex phenomenon involving a progressive decrease in attention to road and traffic requirements, having the effect of lowering driving performance, longer reaction time and an increased risk of crash involvement. Various studies have indicated driver fatigue as a factor in a large number of vehicle crashes. In a study published by the AAA Foundation for Traffic Safety drowsiness at the wheel was identified in 8.8% -9.5% of accidents examined and 10.6% -10.8% of accidents that resulted in significant damage to property, airbag deployment or injury. Based on research conducted by the Real Automóvil Club de España (RACE), driver drowsiness involves a high percentage (30%) of accidents. Recently, vehicle manufacturers (Volvo, Bosch Group, Mercedes) have developed systems to detect the driver's state of exhaustion.

The development of a system for detecting tiredness while driving, based on EEG (Electroencephalography), EOG (Electrooculography) signals measurement and eye state (closed or opened) image classification has been presented in [9]. Detection of driver fatigue based on images acquired while driving, presented in [10], was done by analyzing driver eye condition: open, half open and closed. We used for this purpose two types of artificial neural networks: 1 hidden layer network and auto-encoder network [1]. Developments in this field are supported by efforts to create brain – computer interfaces [2][6][12] for different applications.

An application of EEG signal acquisition and processing had been presented in [3][4][13].

In early studies [7][11] we approach the possibility of acquisition of EOG signals from three sensors.For the classification of driver fatigue we used artificial neural networks [5][8].

The objective of this study is to develop a system for fatigue of the driver detection by monitoring eye movements (EOG) and brain activity (EEG) in order to determine levels of alert and attention.

Biological data that are acquired by the sensors will be stored, processed and evaluated in real time, through a system able to detect early signs of fatigue, because the physiological variables are closely related to this phenomenon.

2 STRUCTURE AND OPERATION OF THE PROPOSED DECISIONAL SYSTEM

The drowsiness warning system is based on four main components, which learn, analyze and decide whether the driver is or is not in a drowsy or sleepy state. The first component is an Artificial Neural Network (Pattern Recognition ANN) which is able to process the spectrum of EEG signals.

As a result the network outputs the probability that the analyzed signal represents an active or drowsy state of the driver.

Other two components of the system are dealing with the images of the eyes of the driver.

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The first component is an Artificial Neural Network (Image Recognition ANN) which detects if the driver has the eyes closed or opened in a sequence of N images.

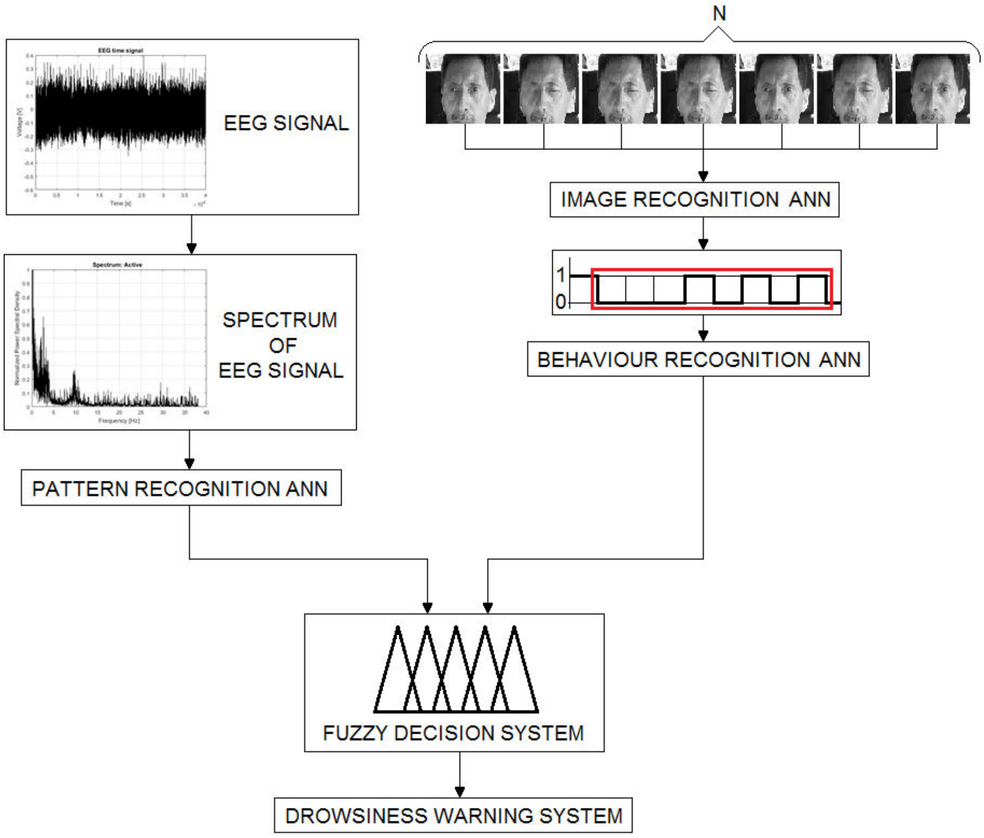

Figure1. Structure of the decisional system.

This network generates a numerical sequence which represents a certain behavior of blinking in the case of a drowsy state and another behavior in the case of an active state.
This analysis was described in a previous work of the authors [10].
The sequence containing the blinking behavior is then analyzed with another ANN (Behaviour Recognition ANN) as a time series signal.
The result of this processing is a number representing the probability that the blinking behavior is linked to an active or a drowsy behavior. The results of the Pattern Recognition ANN and Behavior Recognition ANN are used as inputs for a fuzzy logic decision component which will output the overall result of the system. This result can be then used to warn the driver if he/she is in a drowsy state.
The proposed system combines to types of sensing methods EEG signals and eye state images, regarding the state of the driver (drowsy or active).
Doing so, we can increase the success rate of detection of the driver's state.
Having in mind the complexity of the behavior and also the variation of behavior from individual to individual, the ANNs which are components of the system have to be trained by the driver who will use the system. This requires a number of training sessions before the operation of the system but crucially increases it's feasibility.
As the image recognition component of the system has been described in a previous paper of the authors [2], in this paper we will further describe the EEG signal analysis.

3 EEG SIGNAL ANALYSIS BY ANN

In order to train the ANN, EEG data were acquired from five subjectsby measuring 17 data samples for drowsy and 17 data samples for active state. EEG signals were acquired using a BST112 amplifier from VEB MESSGERATEWERK ZVONIZ. For A/D conversion of data, we used an NI-USB 6251 DAQ board.
The DAQ board has an accuracy of 15.259 μV. The electrodes material was Ag-AgCl and we placed the active electrode in the F3 point, using a conductive gel (figure 2).

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As voltage reference, the A1 point was used,the ground was located on the right leg. The data sampling rate was of 1000 Hz. The data acquisition and processing programs were written in MATLAB®.

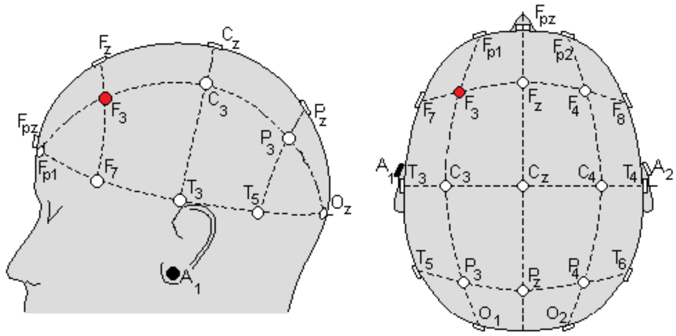

Figure 2. EEG electrode placement

An example of EEG signal is shown in figure 3. The signals had been processed using the Fast Fourier Transform as it is implemented in the MATLAB platform by the function fft(). The signals were also filtered with a low-pass filter to obtain only the frequency interval of 0 to 40 Hz as this is the range which is meaningful for the EEG signals. In figure 4 the spectral diagrams obtained for a drowsy state and an active state signal had been presented. The spectral data was used as input for the artificial neural network. We used 17 datasets for active and 17 datasets for drowsy state. 60% of the data was used for training, 15% of the data was used for validation and 15% for testing.

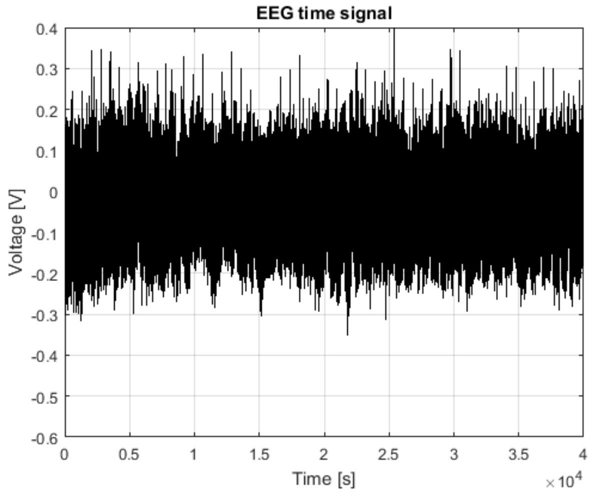

Figure 3. EEG signal – measured voltage vs. time

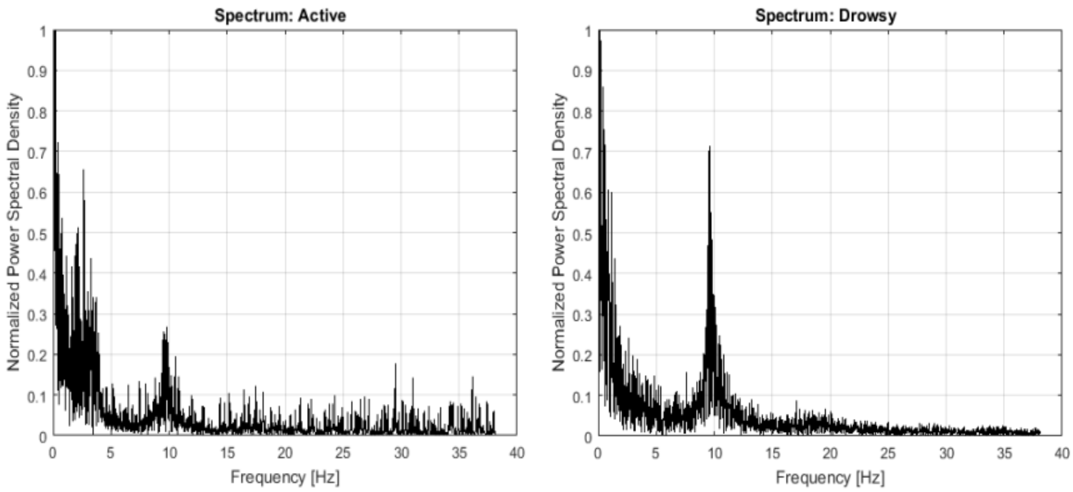

Figure 4. Frequency spectrum of the EEG signals: active state (left), drowsy state (right)

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In a pattern recognition we want to classify the inputs into a set of target categories. In our case we have two target categories defined by a target 2 by 34 vector.
For this application we used a two-layer feed-forward network, with sigmoid hidden and softmax output neurons which can classify vectors well, given enough neurons in the hidden layer. The network is trained with scale conjugate gradient backpropagation.

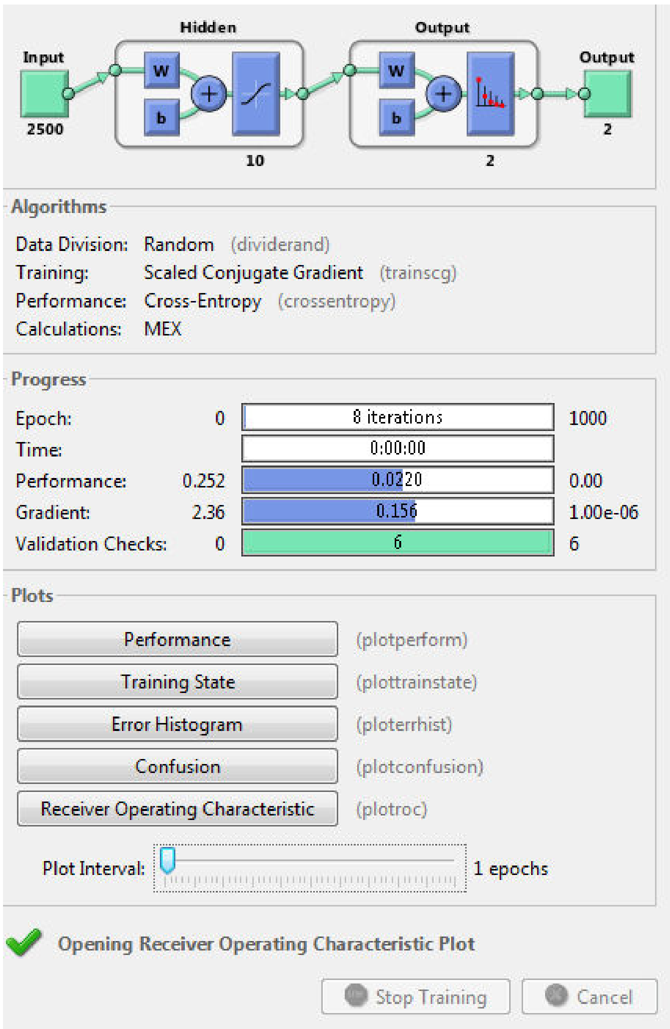

Figure 5. ANN Pattern Recognition module interface

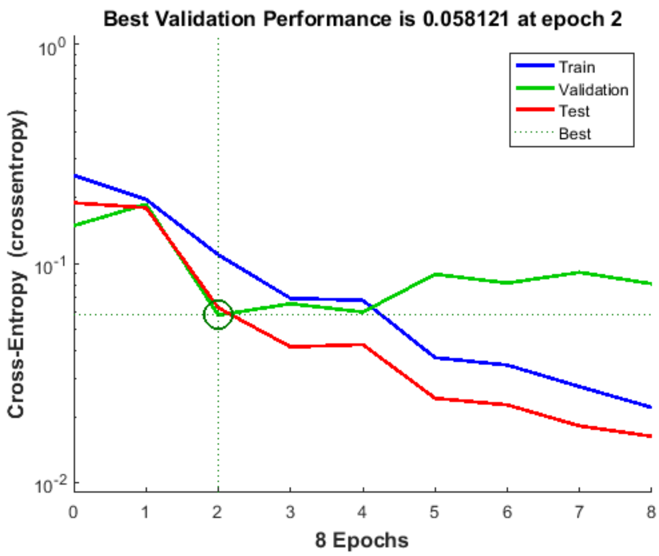

Figure 6. Diagram of training, validation and testing performance for 8 epochs

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It is recommendable to use normalized inputs (in a scale of 0 to 1) as it is shown in the diagrams in figure 4. Figure 5 shows the interface of the Neural Network Pattern Recognition module Interface. As it can be seen we used 2500 input neurons (the length of the spectrum data), 10 neurons in the hidden layer and 2 neurons in the output layer (the length of the target vector and also the number of classes).

Figure 7. Confusion matrix for the best training session

Figure 8. Error histogram for training, validation and testing

Best results were obtained after 8 training epochs. The results of the training are shown in the diagrams in figures 6, 7 and 8. The performance diagram shows an acceptable convergence (figure 6).
As it can be seen in the confusion diagram in figure 7 the classification was 100% successful, although the error histogram in figure 8 shows that were some errors of 0.3522.
However these errors did not influence the good results obtained.

4 CONCLUSIONS

In this paper we presented a general description of a system capable to decide over the drowsy or active state of a driver based on EEG signals and eye state images.
The eye state image analysis was described in a previous paper by the authors.
The EEG signal analysis using a feedforward neural network had been trained and tested obtaining a 100% classification results on a 34 signal data set obtained from 5 different individuals.
The results are promising as to be applied in vehicles supposing that wearing electrodes (with dry electrodes) can be accepted by vehicle drivers under a form of a cap or other appliances.
The fuzzy decision component of the system will be the subject of future research.
The described system can be also used as a black-box to store information that can be used in case of accidents.

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A STUDY ABOUT DEVELOPMENT OF ELECTRIC OIL PUMP CONTROLLER BASED ON THE AUTOSAR PLATFORM

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Abstract. *In hybrid vehicle, there have been two oil pumps, mechanical and electrical to supply oil pressure for transmission and new trend is to merge into electrical pump to improve fuel efficiency. Purpose of this study is to make standardization of firmware development process for Oil Pump Unit (OPU) and Electric Oil Pump (EOP) which is used for hybrid automatic transmission to supply proper torque. In old-fashioned non-Operating System (OS) firmware, it was convenient to calculate control timing for motor control, however the firmware was deeply dependent to specific MCU. It means that much of efforts and time are needed if new MicroController Unit (MCU) were applied. In this study, new development process for MCU firmware could be built based on AUTomotive Open System ARchitecture (AUTOSAR) platform. It also achieved similar motor control performance compared with non-OS based firmware by not utilizing standard AUTOSAR I/O driver & Real Time Environment (RTE) scheduling but by implementing Complex Device Driver (CDD).*

Keywords: *Hybrid, Oil Pump Unit (OPU), Electric Oil Pump(EOP), AUTOSAR, Transmission*

1 OPU/EOP SYSTEM IN HYBRID AUTOMATIC TRANSMISSION

1.1 System Configuration

In automatic transmission of hybrid vehicle, the OPU and EOP modules supply and lubricate oil to provide the clutch and brake with the torque needed to drive the vehicle and also cool some parts in the transmission. To supply the proper oil as shown in Figure1, the Transmission Control Unit (TCU) calculates the amount of oil needed, converts it to Revolutions Per Minute (RPM) and sends it to the OPU via Controller Area Network (CAN) protocol. The OPU is supplied with high-voltage from battery to drive the motor and drives the EOP made with three-phase Brush-Less DC (BLDC) motor through the hall sensor. The motor is driven with three-phase block commutation method and Insulated Gate Bipolar Transistor (IGBT) is used as power switching device [1]. When the OPU drives the EOP, the oil is supplied to the valve body module and hydraulic pressure is provided to the clutch and brake through the solenoid control [2].

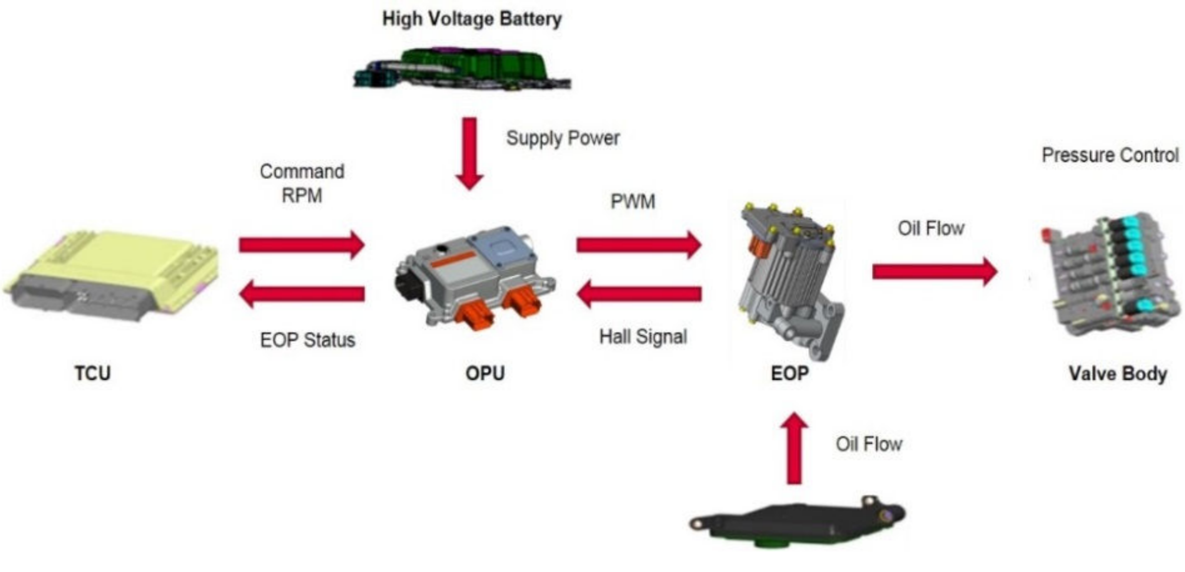

Figure 1. System overview [3]

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1.2 OPU Function Description

The OPU consists of four main functions which are coordination control between vehicle Electronic Control Units (ECU), motor drive control, system fault diagnosis, and protection & fail-safe mode [3].

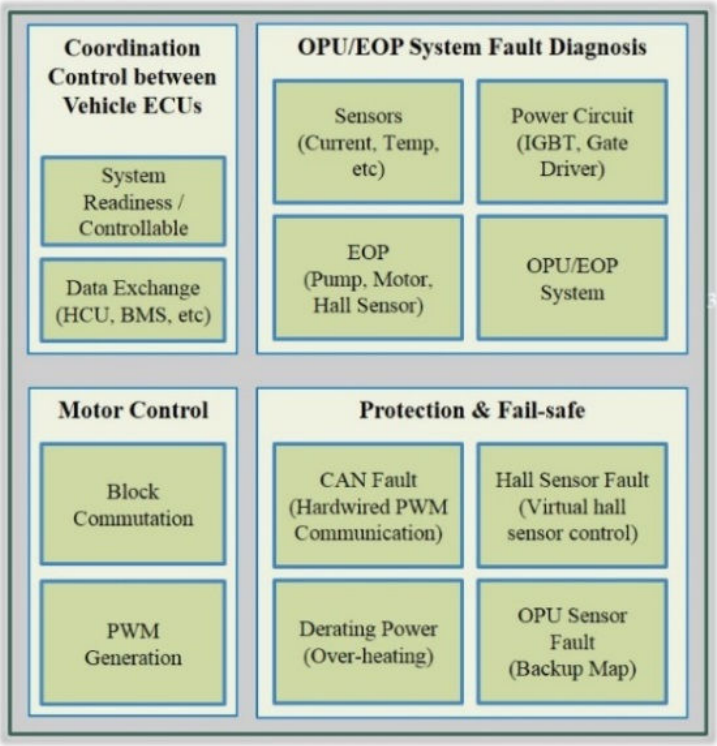

Figure 2. OPU main functions

The coordination control between vehicle ECUs is to exchange various information with vehicle ECUs for driving EOP and to judge various situations. The motor drive control drives three-phase BLDC motor with block commutation method based on the hall sensor input. The system fault diagnosis is to detect failure of power circuit, failures of various sensors such as hall / voltage / current / temperature and failure of the whole system. The protection & fail-safe mode is composed of several functions which are hard-wired Pulse Width modulation (PWM) communication when CAN fails and continuous driving motor when the hall sensor fails. Others are applying 'backup sensor map' data when various sensors fail and enhancing cooling during overheating as 'Derating Power' function.

1.3 OPU/EOP System Requirement

The most important challenge in applying the AUTOSAR to the OPU system is to design timing for motor control. In Table 1, it shows what is necessary to consider the timing required for the motor control based on the OPU system requirements [4].

Table 1.
OPU system requirements

Factor	Requirement
RPM Response Timefor OPU/EOP System	0.2s@ Δ2000rpm
Switching Frequency for Motor Driving	8 kHz
Current Limit Protection	Under 50A@270V

In the above requirements, the RPM response time can be achieved through gain tuning for the Proportional/Integral (P/I) controller but the motor control function should be performed as fast as possible within PWM switching frequency, 8 kHz (= 125μs). Because the motor control algorithm is executed every 125 μs, the execution time is closely related to the CPU load.

In order to smoothly execute other control logics besides the motor control, the execution time must be optimized so that sufficient margin can be achieved. To implement the current control function as shown in Figure 3, current value should be sensed by Analog to Digital Converter (ADC) at center of the PWM period and based on this current value the current control and the motor control algorithm are executed.

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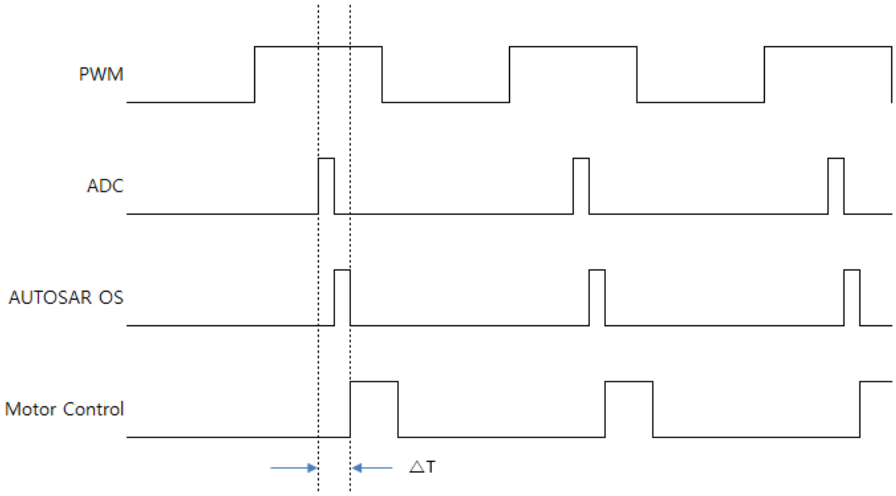

Figure 3. Optimized timing chart for motor control

When MicroController Abstract Layer (MCAL) Application Programming Interfaces (API) and AUTOSAR are applied, it takes a little long time for these control functions. This study will explain how to optimize the control timings as the Figure 3. This optimization effort should be done mandatory to implement field oriented control (FOC) algorithm for Brush-Less AC (BLAC) motor in further study.

2 AUTOSAR

2.1 AUTOSARoverview

The AUTOSAR is an open and standardized automotive software architecture, jointly developed by automobile manufacturers, suppliers and tool developers. It is partnership of automotive OEMs, suppliers and tool vendors whose objective is to create and establish open standard for automotive electrics/electronics architectures that will provide a basic infrastructure to assist with developing vehicular software, user interfaces and management for all application domains. This includes the standardization of integration from multiple suppliers, maintainability throughout the entire product life-cycle and software updates and upgrades over the vehicle's life as some of the key goals [5].

2.2 AUTOSAR Electric & Electronic Systems Trends

In order to increase the reusability of control & logic and to support the ISO 26262 specification, AUTOSAR is also applied to not only vehicle control units but also small ECU such as OPU and many automotive Tiers are adopting AUTOSAR platform to most of ECUs.
To follow this major trends up, we implemented OPU main functions into application layer of Figure 4.

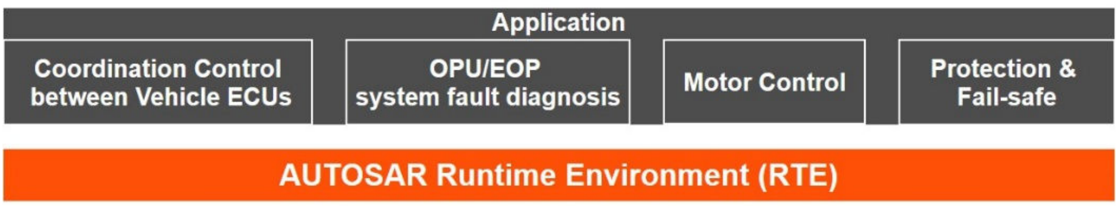

Figure 4. OPU main functions in application layer of AUTOSAR

3 METHODOLOGY

In this study, the microcontroller (AURIXTM TC222) & MCAL (MC-ISAR_AS4XX_AURIX_TC22X) of the Infineon Technologies and AUTOSAR solution (RTATM) &Model Based Design (ASCETTM) of the ETAS Co. Ltd. were applied to new OPU system. Infineon provides MC-ISAR low-level drivers based on the AUTOSAR MCAL layer. With the MC-ISAR AUTOSAR drivers a system supplier can use one set of standardized basic software drivers over different applications within one configuration tool.
One task every 125 uS was generated by RTE so that the motor control algorithm could be periodically activated at 8 kHz referring to Figure 5.

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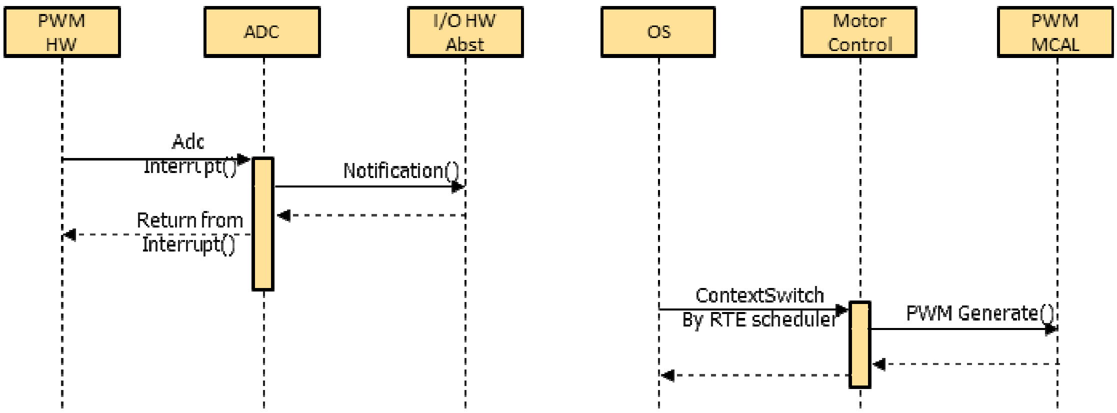

Figure 5. Functions flow of context switch by RTE scheduler

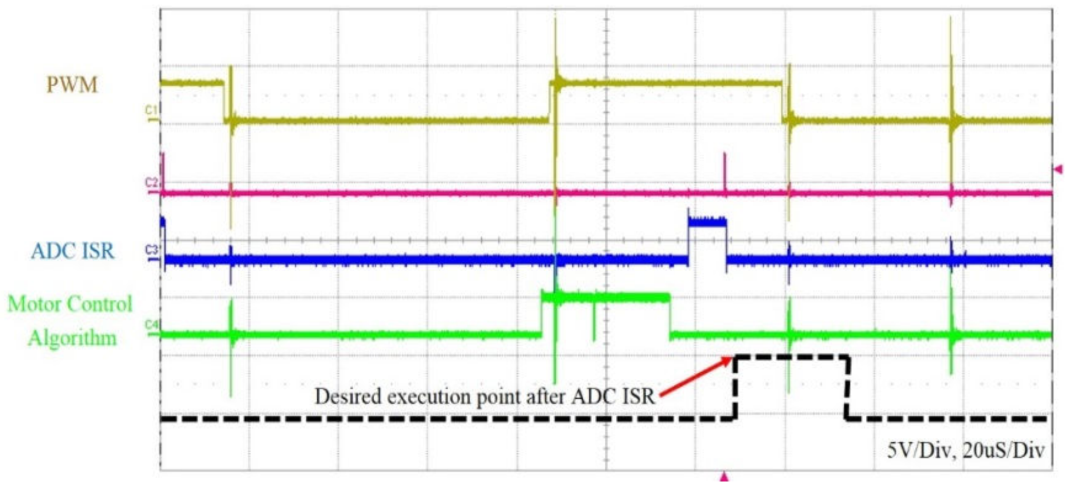

Figure 6. Timing between ADC ISR and motor control algorithm with RTE

As shown in Figure 6, the ADC Interrupt Service Routine (ISR) and the task scheduler generated by RTE was not synchronized and the motor control function was not executed immediately after the ADC ISR. Due to this reason, current limit function of the motor did not operate properly.

In additions, with the PWM duty update API function provided by the MCAL, total execution time of the API function was too long as shown in Figure 7. To resolve above limitations, new control logic was developed so that the logic directly can activate the motor control task in the ADC ISR as the chart of Figure 8. Furthermore, the PWM CDD was developed in order to shorten PWM duty update time. architecture what we implemented is shown in Figure 9.

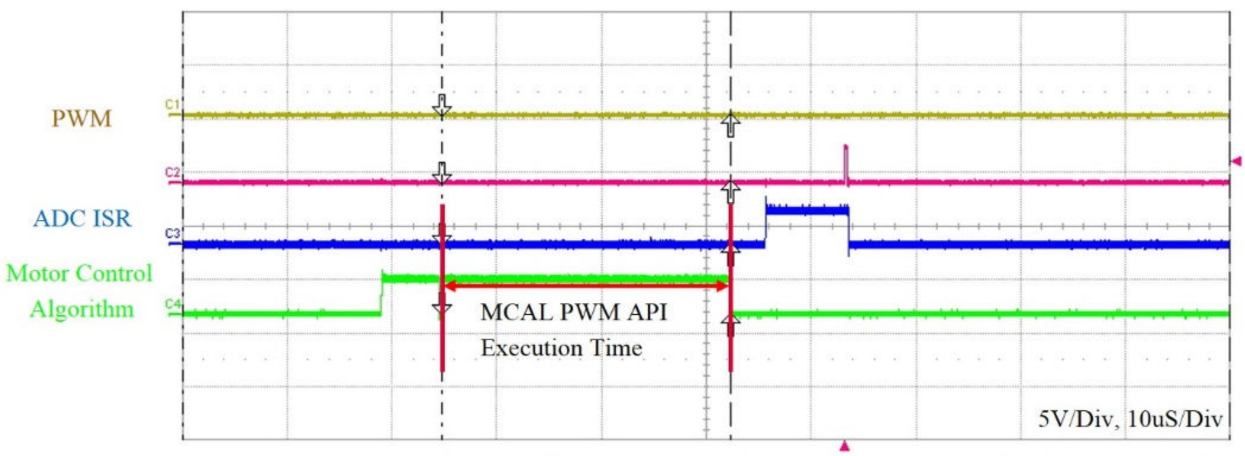

Figure 7. Timing with MCAL PWM API function

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Through this CDD the shadow register of counter register of Timer Output Module (TOM) in Generic Timer Module (GTM) could be accessed, not using MCAL API function. As a result, four major functions required by the OPU as application software components were implemented and the function flow was changed to meet the above control timing required by OPU system. The AUTOSAR software

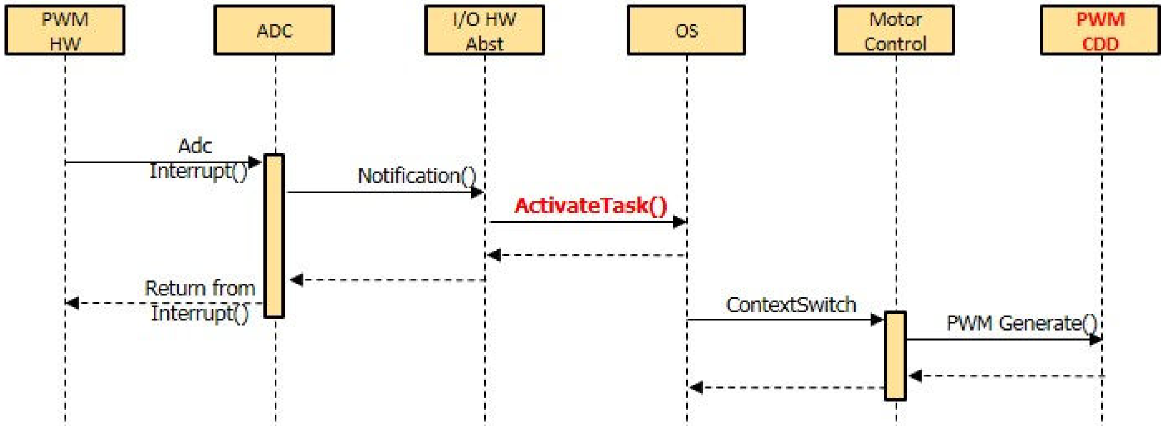

Figure 8. Functions flow of direct task activation

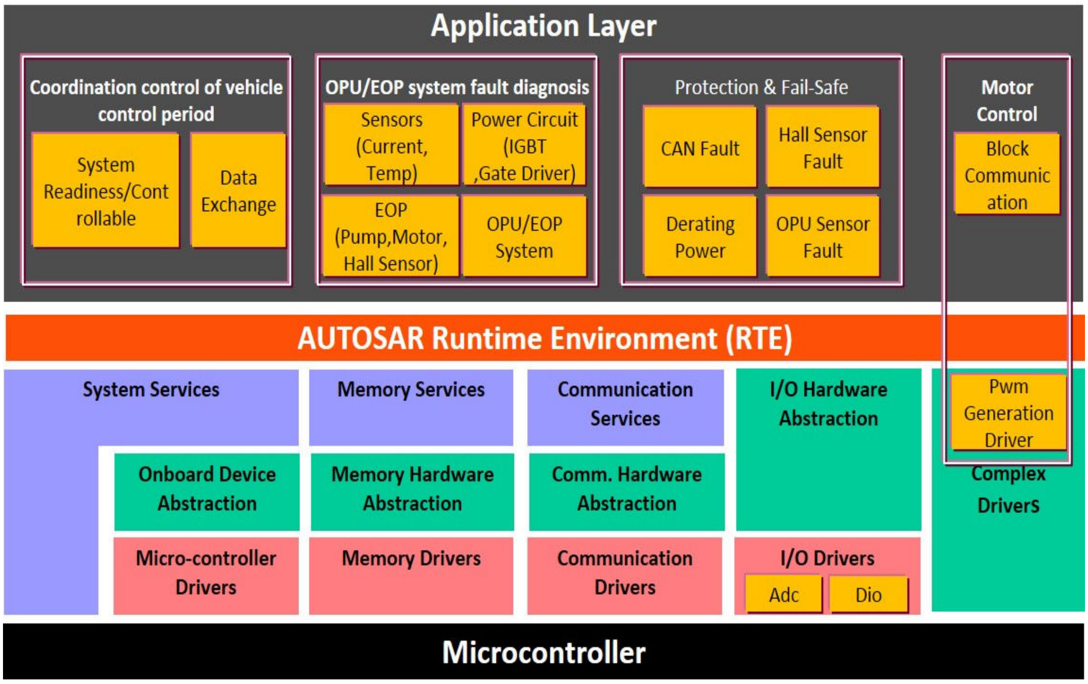

Figure 9. The AUTOSAR layered OPU software architecture [6]

4 CONCLUSIONS

To control EOP system based on the AUTOSAR platform, the most important consideration is to control timing of each logics.
Under this consideration, following timing waveform was measured and short execution time of the motor control was achieved:
– the OPU AUTOSAR OS performed that the motor control algorithm was synchronized with PWM as Figure10.
– to optimize PWM update routine in the motor control executed every 125 μs made the MCU load be reduced efficiently.
– with this OPU AUTOSAR OS, it met target RPM response performance (in Table 2) by achieving to 0.16 Sec/Δ2000rpm in Figure 11. It is closely related with automatic transmission performance.

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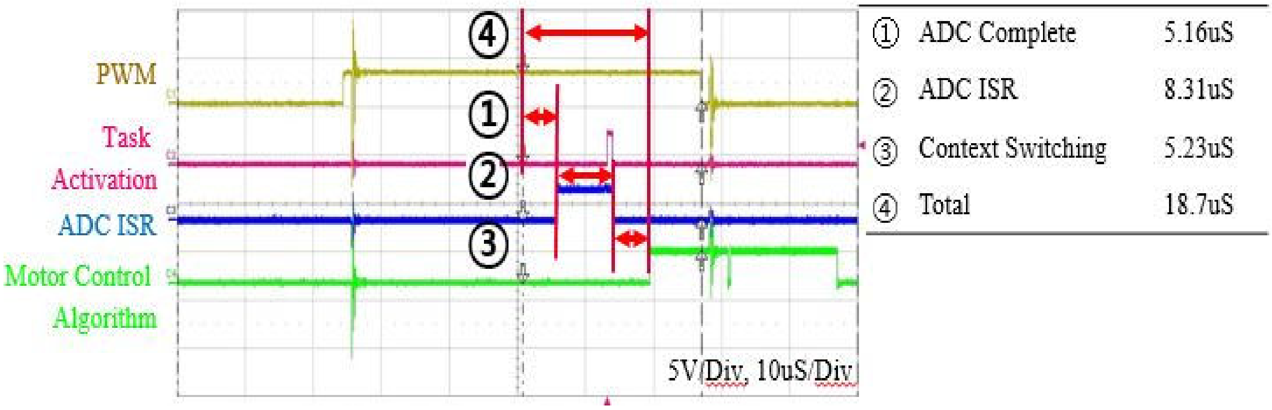

Figure 10. Result of major timings in EOP system

Table 2.
Execution time of PWM update logic

Control Function	RTE Scheduler	Direct Task Activation
Motor Control	Not synchronized with ADC ISR	Synchronized with ADC ISR
PWM Update	27.6 µS (API)	15.6 µS (CDD)

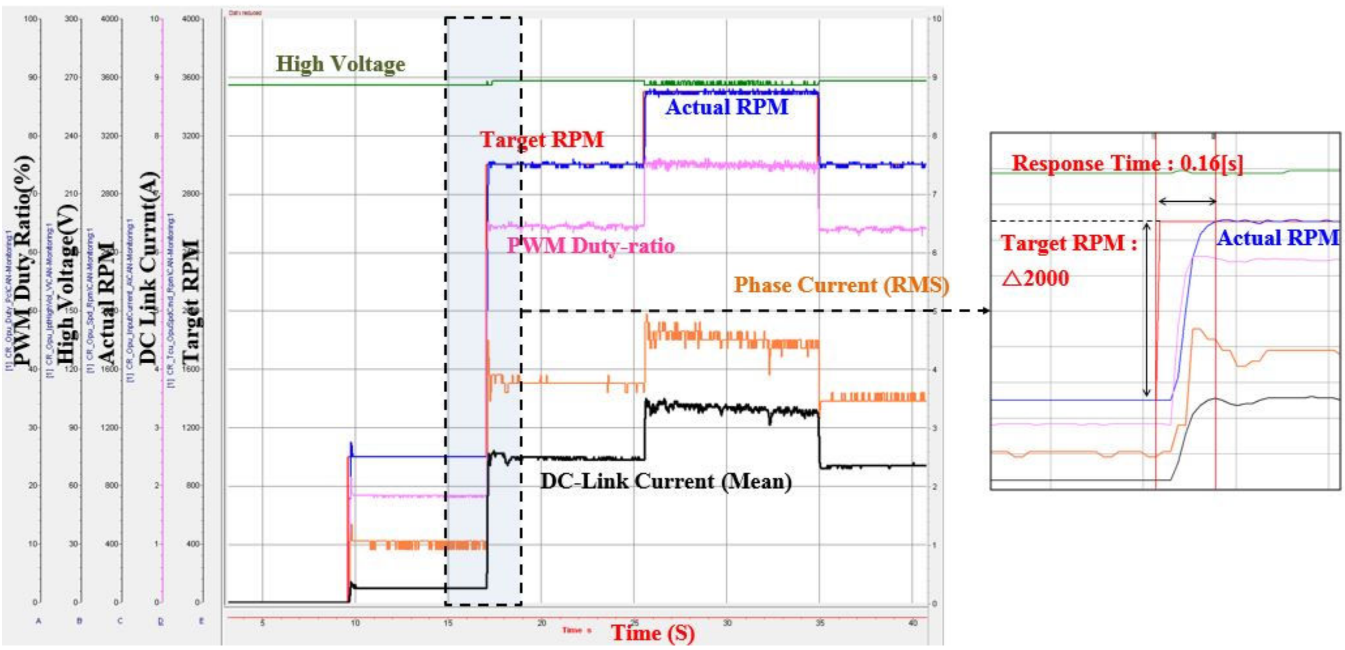

Figure 11. RPM response according to TCU RPM command

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EXPERIMENTAL INVESTIGATION ON THE EFFECT OF FUEL ADDITIVES WITH TAMARIND BIODIESEL ON THE PERFORMANCE AND EMISSION CHARACTERISTICS OF DIESEL ENGINE

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Abstract. *The present research work focuses on the influence of different oxygenated fuel additives as ignition improvers on performance and emission characteristics of diesel engine fueled with tamarind seed methyl ester (TSME 20) biodiesel blend. Three oxygenated fuel additives are considered in this study, namely Diethyl ether (DEE), Di-methyl carbonate (DMC) and N-amyl alcohol (NAA) at various concentrations (5% and 10%) on volume basis. The experiments were conducted on the four-stroke single cylinder water cooled diesel engine at constant speed (1500 rpm) with different loads of 0%, 25%, 50%, 75% and 100% for the diesel and fuel additive biodiesel blends. From the experimental outcomes, TSME 20 with DEE fuel additive generated enhanced performance and lower tail pipe emissions among the other tested fuels. However, the specific fuel consumption and the oxides of nitrogen were marginally increased. Hence, the use of oxygenated fuels to TSME 20 biodiesel blend could be seriously considered as a potential alternative to diesel that can effectively address global energy crisis as well as ensure environmental conservation.*

Keywords: *Tamarind seed methyl ester; fuel additives; performance and emissions*

1. INTRODUCTION

The use of energy is increasing day by day and fossil fuels are contributing much of its increment especially in transportation sector. In future, it is estimated that oil will remain the dominant energy source considering its importance in transportation and industrial sector. In-order to conserve fossil fuels from continuous usage for future generations, biodiesel came into existence. Biodiesel, which is a renewable fuel, has brought a wide revolution in fuel processing technology due to its large availability and low emission characteristics. Viswanath and Vijayabalan [1] conducted experiments on Diethyl ether mixed with waste plastic oil and concluded that the addition of DEE to plastic oil has improved the engine characteristics in every aspect. It gives better performance and cleaner emissions when compared to plastic oil. Manickam et al. [2] reported that among the oxygenated alternatives which could work as better ignition improver was diethyl ether (DEE) with advantages of more cetane number and oxygen content. Conclusions drawn from their investigations reported that the brake thermal efficiency of 20% KME (Karanja methyl ester) with 10% and 15% DEE increased by 0.94% and 1.76% respectively at full load compared with neat KME. Purushothaman and Nagarajan [3] conducted experiments on a single cylinder compression ignition engine successfully using DEE with orange oil. Similar research reported by Agarwal et al. [4] with the use of fuel additives in biodiesel blends and noticed the significant reductions in emissions than the diesel fuel and marginal improvement in engine performance. Wei et al. [5] examined the influence of n-pentanol as oxygenated fuel additive on the direct injection compression ignition engine and shown enhanced engine characteristics. Pandian et al. [6] reported about the utilization of Pongamia-diesel blends to estimate the performance characteristics of the double cylinder diesel engine using exhaust gas recirculation and Di-methyl carbonate as a fuel additive and concluded significant reduction in the smoke emissions. From the existing literature study, it is noticed that the use of various oxygenated fuel additives at different concentrations, significantly enhances the performance and combustion characteristics. Also, considerable reductions in CO, HC and smoke emissions.
Therefore, current study exploits the influence of different oxygenated fuel additives in tamarind seed methyl ester-diesel blend to explore the performance and emission characteristics in the diesel engine without any modifications.

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2. BIODIESEL PREPARATION

"Tamarindus indica" is likely indigenous to tropical Africa. Its scientific name is “Tamarindus indica”. Today, India is the biggest maker of tamarind. The crude oil extracted from the tamarind seed is having higher viscosity and density when compared to diesel.
Transesterification is the process of separating the total glycerol and fatty acids from the vegetable oil in the existence of catalyst.
Transesterification process has been used widely to reduce the viscosity of the vegetable oils, which in turn improves the physical properties of fuels and improving the engine performance parameters. In this process, the branched heavy triglyceride molecules of vegetable oils are broken into smaller and straight chain molecules that is similar to the diesel particles.
Various chemical reactions involved in transesterification process are presented below and the transesterification chemical reaction process is depicted in Figure 1.
Properties of tamarind seed methyl ester and its biodiesel blends are presented in Table1.

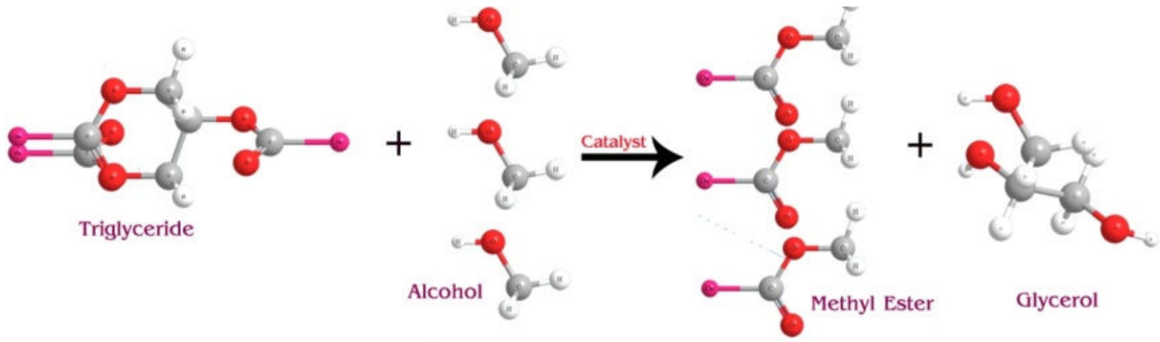

Figure 1.Transesterification chemical reaction mechanism

Table 1.
Properties of tamarind seed methyl ester and its biodiesel blends

Properties	Diesel	TSME	TSME20
Density (kg/m3) @ 15 °C	830	884	843
Viscosity (cSt) @ 40 °C	3.05	7.27	3.86
Calorific Value(MJ/kg)	42.50	38.70	41.76
Specific Gravity	0.830	0.884	0.843
Flash Point(°C)	56	159	74
Cetane Number	43	52.4	45

3. EXPERIMENTAL SETUP

Experimental investigations were conducted on a four stroke, single cylinder, natural aspirated, water cooled direct injection compression ignition engine.
Schematic arrangement of the experimental test setup is as shown in Figure 2.
These diesel engines are prominently utilized as a part of irrigation applications and versatile generators in India. The Kirloskar TV1 make diesel engine is used for investigation.
The prescribed injection timing by the manufacturer was 23° BTDC with standard injection pressure of 200 bar. The governing mechanism was used to control the diesel engine speed under different load operation. The technical details of the experimental setup are given in Table 2.
The tail pipe exhaust of direct injection diesel engine contains of different elements such as hydrocarbons (HC), carbon monoxide (CO), oxygen (O2), carbon dioxide (CO2) and nitrogen oxides (NOX) emissions.
The concentrations of exhaust emissions (CO, CO2, HC, O2 and NOX) were measured with an AVL 444N five gas analyzer.

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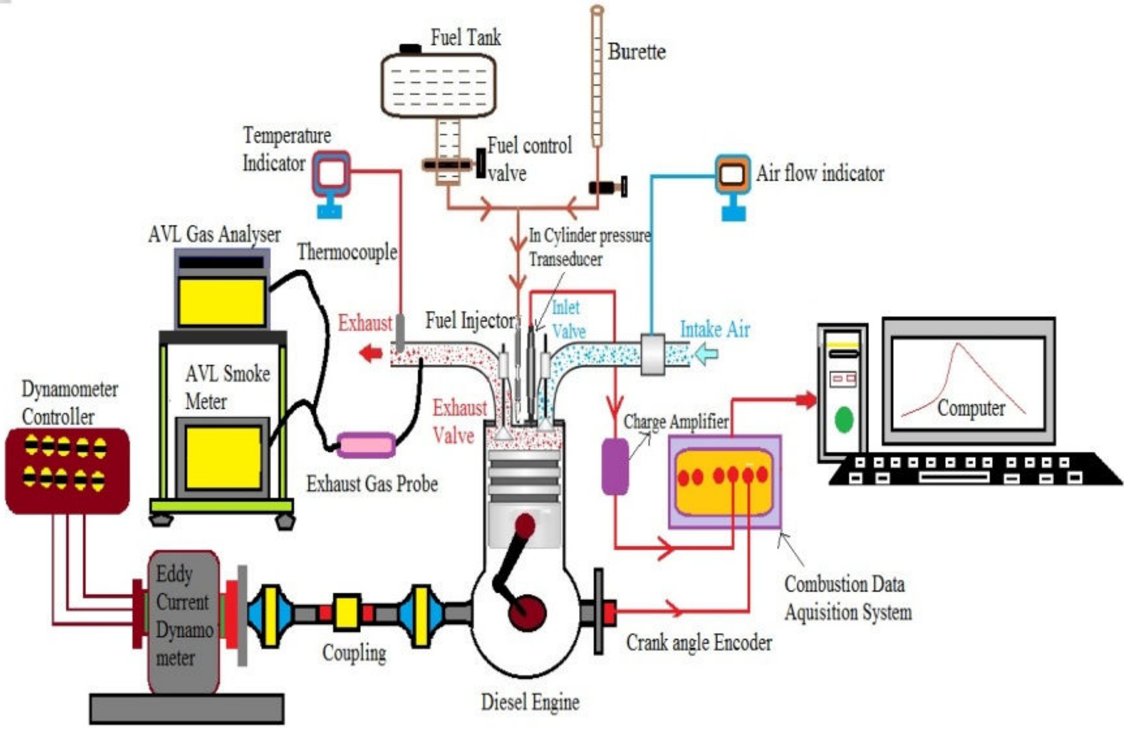

Figure 2. Schematic layout of experimental engine set up

Table 2.
Technical specifications of the diesel engine setup

Parameter	Specification
Make	Kirloskar TV1
Rated Power	5.2 kW
Rated Speed	1500 rpm
Bore	87.5 mm
Stroke	110 mm
Compression ratio	17.5:1
Injection timing	23º BTDC
Injection pressure	200 bar

4. RESULTS AND DISCUSSION

4.1 Engine Performance Characteristics

The variation of brake thermal efficiency with respect to brake mean effective pressure for diesel, TSME 20, and TSME 20 with DEE, DMC and NAA at 5% and 10% concentrations by volume is depicted in Figure 3 (a). BTE represents the efficient conversion of chemical energy fuel into mechanical energy available at the engine shaft to the heat energy supplied. The BTE for the tested fuels are obtained as 34.42%, 34.14%, 35.68%, 36.18%, 33.32% and 33.48%, 33.25% and 33.06% of diesel, TSME 20, TSME 20 with DEE, DMC and NAA blends. It is also noticed that, the addition of 10% DEE to TSME 20 biodiesel blend shown significant improvement in brake thermal efficiency, which is 5.11% over diesel and 5.97 % over the TSME 20 at full load condition. The brake specific fuel consumption for fuel additives added to TSME 20 is analyzed with diesel fuel as shown in Figure 3 (b). The specific fuel consumption of all the tested fuels is slightly increased with increased in load. The brake specific fuel consumptions of tested fuels are 0.245 kg/kWh, 0.256 kg/kWh, 0.248 kg/kWh, 0.241 kg/kWh, 0.265 kg/kWh, 0.268 kg/kWh, 0.274 kg/kWh and 0.281kg/kWh of diesel, TSME 20, TSME 20 DEE 5%, TSME 20 DEE 10%, TSME 20 NAA 5%, TSME 20 NAA 10%, TSME 20 DMC 5% and TSME 20 DMC 10% at peak load operation, respectively.
The experimental results revealed that the increases in BSFC for the oxygenated fuel blends are more than the TSME 20 and diesel fuel at maximum load condition except DEE addition.

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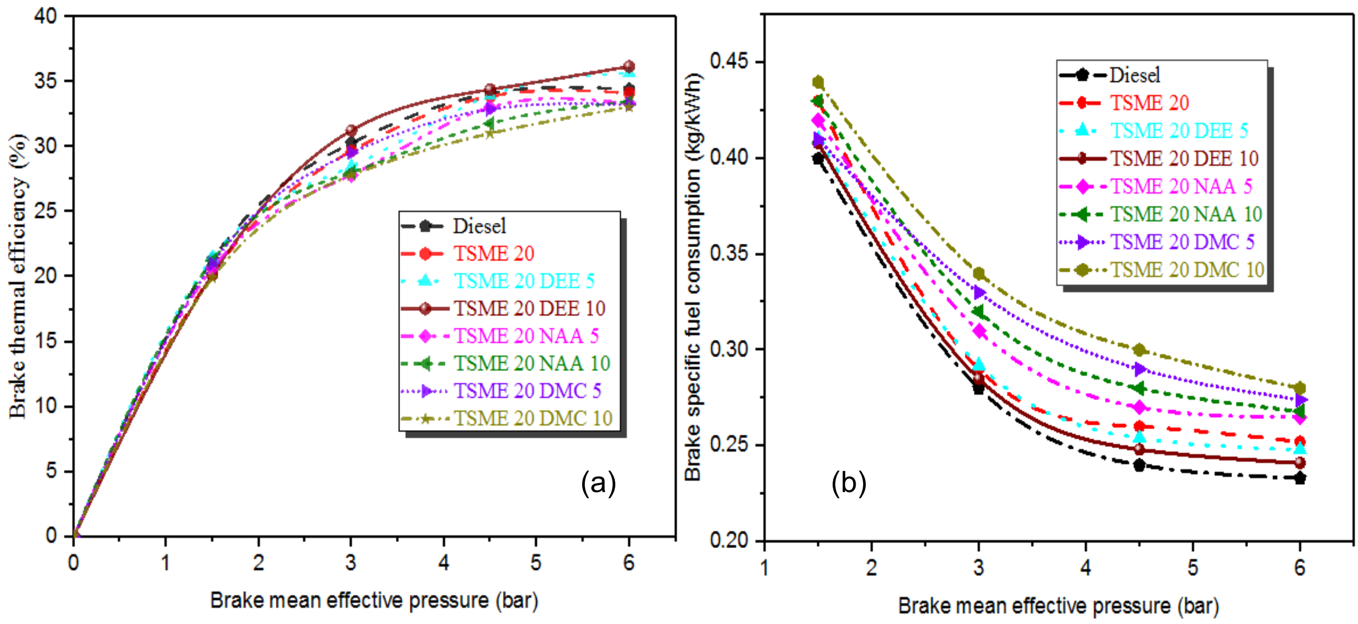

Figure 3. Variation of BTE (a) and BSFC(b) with BMEP

4.2 Exhaust emission characteristics

The variation of carbon monoxide emissions with respect to BMEP for fuel additive biodiesel blends along with diesel and TSME20 as shown in Figure 4 (a). The CO emissions formed for the diesel, TSME 20, TSME 20 with DEE 5%, DEE 10%, TSME 20 with NAA 5% and 10% and TSME 20 with DMC 5% and 10% are 0.137%, 0.161%, 0.123%, 0.117%, 0.142%, 0.151%, 0.154% and 0.147% respectively at full load. It is found that CO formed for DEE 10% TSME 20 blend is minimum of 0.117%, which is 17% lower CO emissions than diesel fuel and 37.6% lower CO emissions over the TSME 20 blend. Similar results were reported by Kalligeros et al. [8].

The variation of hydrocarbon emissions with respect to brake mean effective pressure for diesel, TSME 20, and TSME 20 with DEE, DMC and NAA at 5% and 10% concentrations by volume is depicted in Figure 4(b). It is mainly formed due to deficient combustion process. From the figure, it is noticed that the addition of oxygenated fuel additives to TSME 20 biodiesel blend significantly reduced the hydrocarbon emissions when compared to diesel fuel at all load operation of the engine.

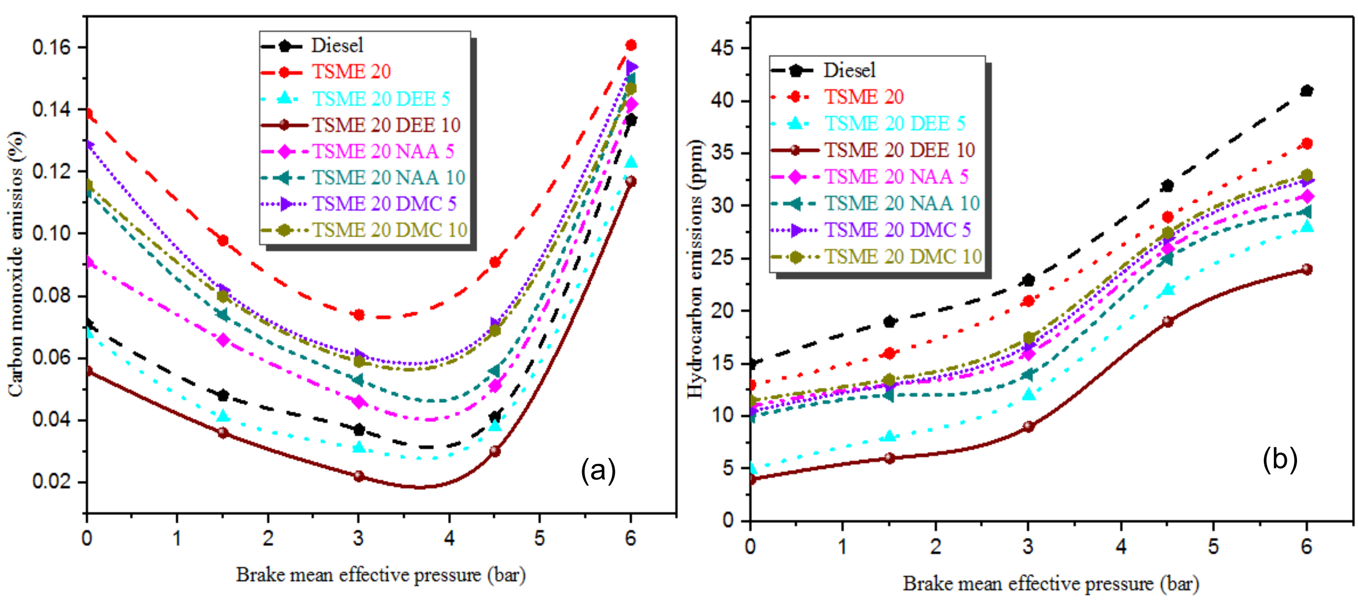

Figure 4. Variation of CO (a) and HC emissions (b) with BMEP

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Also, TSME 20 with 10% DEE has shown 41.46% of HC emissions reduction when compared to diesel fuel and 33.33% of HC emissions reduction over the TSME 20 biodiesel blend at peak load operation of the diesel engine. The use of DMC and NAA to TSME 20 blend has shown marginal decrease in HC emissions when contrasted with diesel and TSME 20 blend.
The main reason for decreased HC emissions for the oxygenated fuel additive biodiesel blend is due to higher cetane number and availability oxygen, leads to better combustion air-fuel mixture in the engine cylinder. The formation of the oxides of nitrogen mainly depends on the presence of oxygen and elevated temperature while burning of air-fuel mixture in the engine cylinder.
Figure 5 shows the variation of oxides of nitrogen (NOX) emissions for the diesel, TSME 20 and TSME 20 with oxygenated fuel additive biodiesel blend at various engine load operations.
From the experimental results, it is found that NOX emissions are higher for TSME 20 with 10% DEE biodiesel blend when compared to other tested fuel additive blends and also with diesel fuel.
The NOX emission of TSME 20 with DEE 10% biodiesel blend is 3.8% higher than diesel fuel and 7.55% higher than TSME 20 blend at full load operation.
The experimental test results were very close agreement with the results as reported by Ibrahim [14].

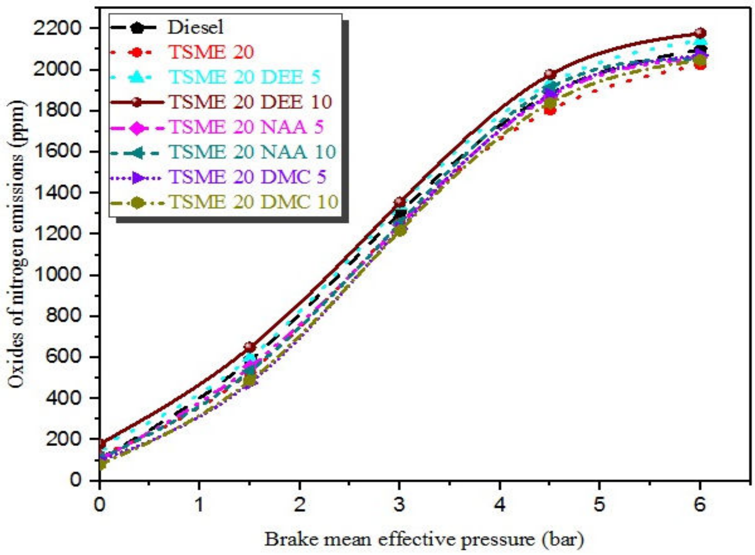

Figure 5. Oxides of nitrogen emissions (NOX) variation with BMEP

5 CONCLUSIONS

The comprehensive experimental investigation has discussed the influence of oxygenated fuel additives on the performance, combustion and emission characteristics of a diesel engine fueled with TSME 20 blend. TSME 20 DEE 10% blend shown enhanced brake thermal efficiency and reduction of exhaust emissions when compared to diesel and also other blends tested in this study.
It is mainly due to higher oxygen availability, low viscosity, and density of DEE nature.
The emissions of fuel additive blends at all load conditions were lower than the diesel.
However, there was a marginal increment in brake specific fuel consumption and the oxides of nitrogen emissions. The CO and HC emissions are lower in the case of TSME 20 DEE blends than that of diesel.
However, the NOX emissions are higher for DEE biodiesel blends when compared to other oxygenated blends and also with diesel.

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THE SIMULATION OF THE GAS EXCHANGE PROCESS FOR THE INTERNAL COMBUSTIN ENGINES WITH OPPOSITE PISTONS

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Abstract: *The internal combustion engines with opposite pistons present the possibility to create a dynamic balanced motor mechanism, having a smaller number of cylinders compared to conventional engines. The gas exchange process has a special importance both in the general development of the engine and the development of the combustion chamber. The simulation of the gas exchange process is done by using some simulating programs: GT Power and Computational Fluid Dynamics (CFD).*

Key-Words: *Internal combustion engines, The simulation of the gas exchange process, GT Power, Computational Fluid Dynamics*

1. INTRODUCTION

The engines with opposite pistons present the possibility to create a dynamic balanced motor mechanism, having a smaller number of cylinders compared to conventional engines [1][5].
Also, the total stroke of the motor mechanism is divided between the two ones of the pistons.
The two pistons are moving in opposition to each other in a cylinder. As a result, at the same engine's rotational speed, the mean piston's speed is considerable reduced, reducing also the frictions between the engine's parts. On the other hand, if one keeps the piston's mean speed, the rotational speed of the engine doubles. This results in a doubling of the engine's power.
In the case of the two stroke engine with opposite pistons, one can adopt the exchange gas process with a uniflow scavenging, one of the pistons governing the exhaust port while the second piston is governing the intake port. Also, this type of mechanism presents the possibility to implement, relatively simply, an asymmetric distribution diagram in relation to the TDC (Top Dead Center) [6][7][8].
The simulation of the gas exchange process will be done for an opposite pistons engine, having two opposite cylinders.
The concept of this engine has been patented in the year 1999 by one of the authors, under the denomination of EM100D, Prof. eng. Peter Hofbauer PhD: „Internal combustion engine with a single crankshaft and having opposed cylinders with opposed pistons", U.S. patent n. US 6,170,443, B1, Santa Barbara, 1999 [2][3].
The simulation and the optimization of the gas exchange process will be done with the aid of some simulation programs in two stages [9][10].
In the first stage one will realize the one dimensional simulation of the entire gas exchange process, with the aid of the simulation program. In the second stage, for a more accurate simulation, one will use the 3D simulation programs (Computational Fluid Dynamics – CFD) [4].

2. THE SIMULATION OF THE GAS EXCHANGE PROCESS USING THE SIMULATION PROGRAM GT POWER

Following this simulation, one will obtain the first estimation of the gas exchange process, together with the variation of the pressures and the pressures inside the whole system. In Figure 1 is presented the scheme of the gas exchange system, realized by the one dimensional simulating program GT Power.

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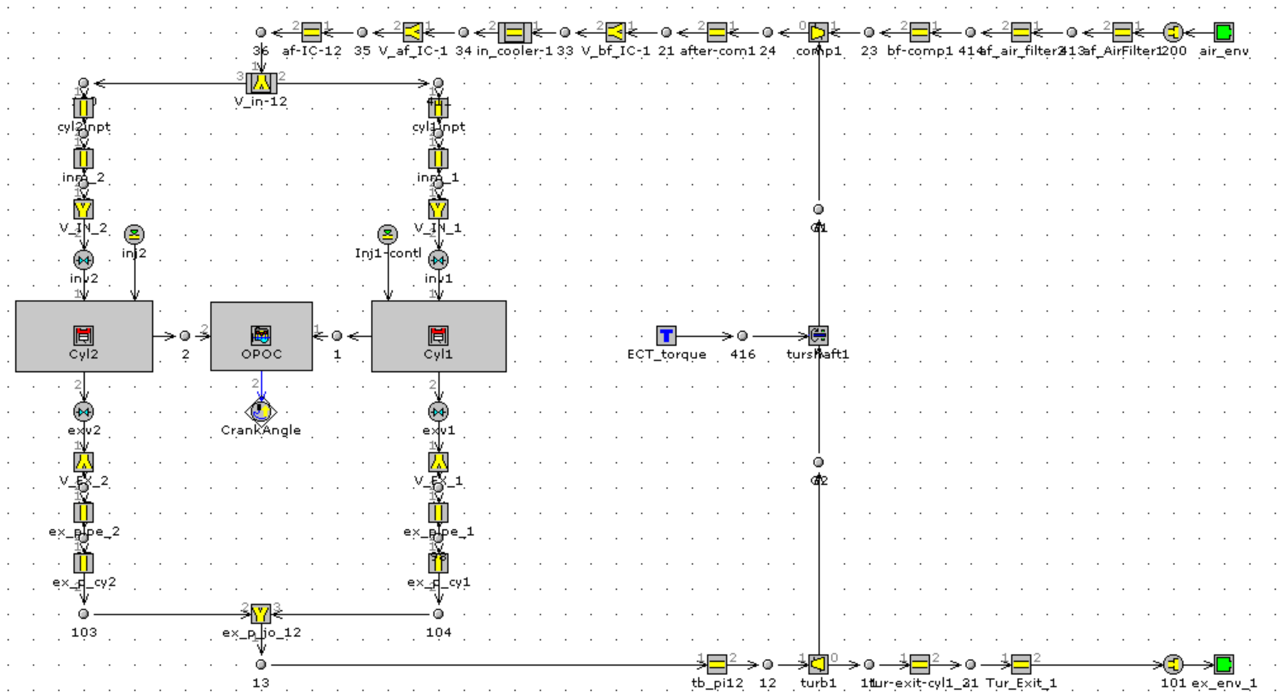

Figure 1. The scheme of the gas exchange system, realized by the one dimensional simulating program GT Power

In this scheme one can observe that in the one dimensional simulation all the components of the gas exchange system are taking to consideration, starting with the air filter at the beginning of the intake system and ending with the noise dumper at the end of the exhaust system. Between the air filter and the noise dumper all the volumes and the lengths of the connecting pipes, as well as the volumes around the intake and the exhaust ports of the cylinder were taken into consideration. The intake and the exhaust ports are considered to be one dimensional orifices at which one estimates, for beginning, the flow coefficients. One of the very important intake parameters in the one dimensional simulation is the scavenging curve. This curve is estimated at the beginning of the simulation that will iterative be rectified following the tridimensional simulation. The estimation of the initial scavenging curve is made taken into consideration the previous experiences in the field and the speciality literature.
In Figure 2 are presented the ideal scavenging curves, scavenging in ideal mixture conditions, the typical scavenging in counter current and the scavenging curve in uniflow estimated for the EM100 engine. With this curve starts the process of the one dimensional simulation.

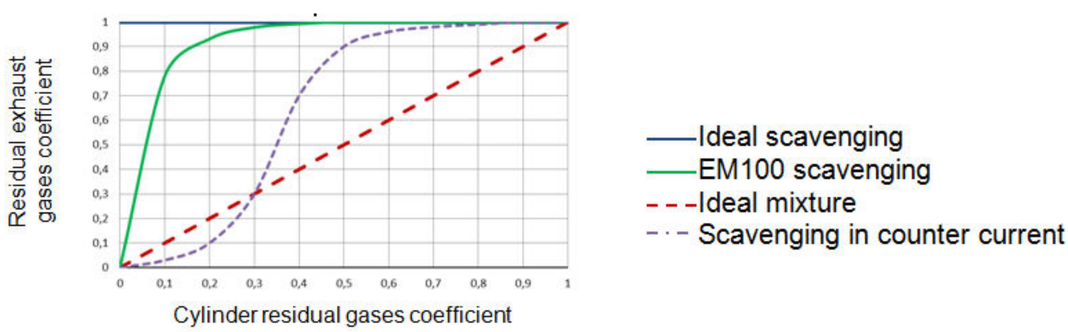

Figure 2. Comparison between different scavenging curves

In the graph in Figure 2 the scavenging process takes place from right to left, from the point {1.1}.
The residual burned gases are discharged through the exhaust ports as the fresh charge enters in the cylinder through the intake ports, with any part of the fresh charge being lost through the intake ports.
In the moment in which the first molecules of fresh air reach the exhaust ports, the residual gases are totally eliminated from the cylinder and the exhaust ports close.

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In the case of the perfect mixture scavenging, the curve signifies the existence of a process of instantaneous homogenous mixture process between the fresh charge that enters in the cylinder and the residual gases. As a result, the gases that leave the cylinder through the exhaust ports are a homogenous mixture of fresh charge and residual gases. These two curves are theoretical and present interest only from analytical point of view, in order to compare and study different real scavenging curves. The results of particular interest obtained following the one dimensional simulation are the variation of the pressure in the close proximity of the intake and the exhaust ports, of the instantaneous flows and of the total mass of fluid (residual gases and fresh air), that passes through the ports.
With the aid of these parameters one can make a qualitative estimation of the gas exchange process through the previous presented parameters. In Figure 3 are presented the results of the one dimensional simulation for three different rotational speeds, at full load for the engine EM100D.

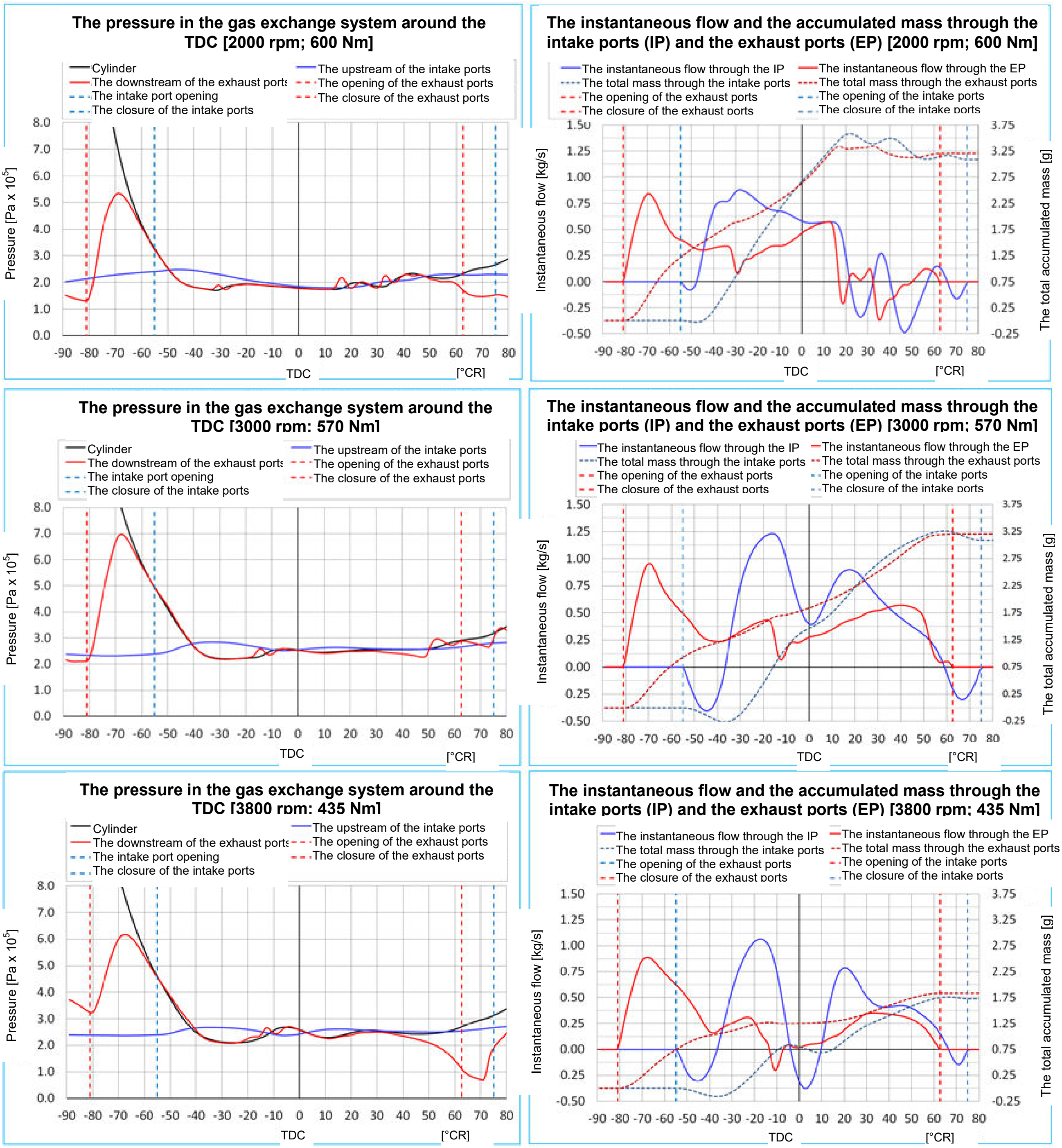

Figure 3. The results of the one dimensional simulation for the EM100D engine

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One can observe the fact that the pressure waves are closely related to the engine's rotational speed and load, as well as on geometrical characteristics of the gas exchange system.
A great air volume in the vicinity of the intake ports helps to the uniformization of the intake pressure. Also, the volume in the immediate vicinity downstream of the exhaust ports significantly influences the exhaust pressure.
The cylinder's pressure is the result of the interaction between the two pressures and because of the waving nature of the entire exhaust gas system, the difference between the three pressures is not constant as size and sense.
The instantaneous flows through the intake and the exhaust ports varies in relatively great limits, from positive values to negative ones, depending on the pressure difference from the their upstream and downstream.
This fact affects the quality of the separation surface form between the fresh air and the exhaust gases, generating an unwanted mixture between the two fluids

3. THE SIMULATION OF THE GAS EXCHANGE PROCESS WITH THE AID OF THE SIMULATION PROGRAM COMPUTATIONAL FLUID DYNAMICS

In the second stage, for a more accurate simulation, one will use the aid of the 3D (CFD) simulation programs. In this stage it is considered a narrower part of the gas exchange system, in order to reduce the time necessary for this simulation and the computing power and computer requirements.
In the case of the 3D simulation one takes into consideration the cylinder's geometry, the intake and the exhaust ports geometry and the volumes around the intake and the exhaust ports.
At the intersection between the respective volumes and the intake and the exhaust manifolds the geometry for the 3D simulation is interrupted, following that on the interrupting surfaces to apply the border conditions resulted from the one dimensional simulation.
Depending on the desired accuracy, one can also consider parts of the intake and the exhaust manifolds, in order to ease the stability of the computing model.
In Figure 4 is presented the 3D geometry used in the three dimensional simulation.

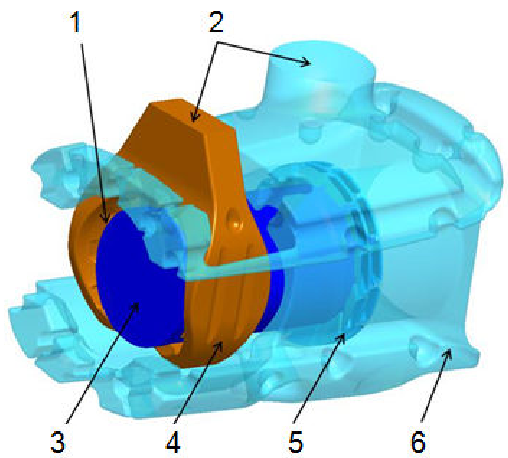

Figure 4. The 3D geometry used for the three dimensional simulation (CFD)
1 – exhaust ports; 2 – connecting surfaces of the intake and exhaust collectors; 3 – engine cylinder; 4 – air volume around exhaust ports; 5 – intake ports; 6 - air volume around intake ports

For the three dimensional simulation the programs Fluent and Converge have been used.
By introducing the pressures obtained in the first stage of the simulation as input data for the 3D simulation, one can view the intake process, the size and the direction of the fluid molecules speed, determining at the same time more accurate flow coefficients for the intake and the exhaust ports, in Figure 5, Figure 6 and Figure. 7 are presented some of the results of the three dimensional simulation for one operating point of the engine (3800 rpm, at full load).
In Figure 5 is presented the scavenging process in two perpendicular sections (vertical and horizontal) in which the blue color simulates the fresh air and the red color the exhaust gases.

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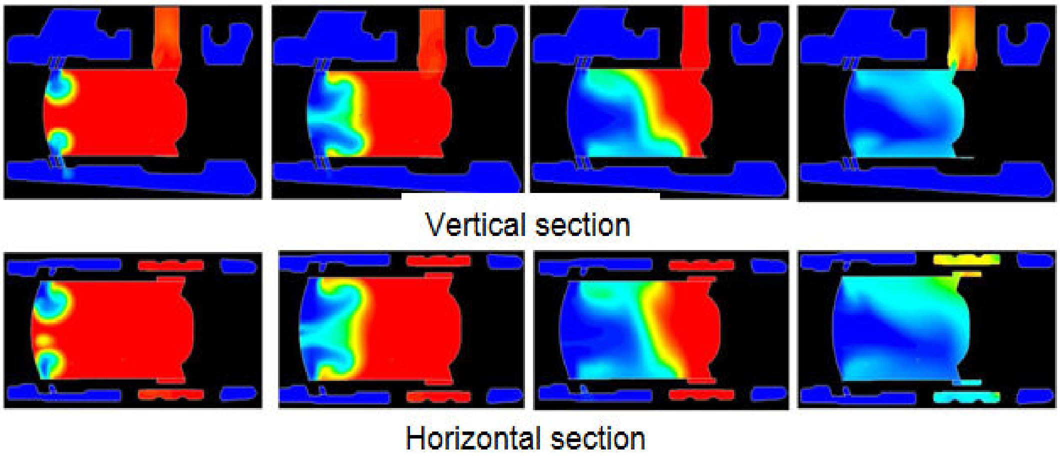

Figure 5. The results for the three dimensional simulation of the scavenging for the EM100D engine

One can observe that the separation surface between the fresh air and the exhaust gases is not ideal but, because of the radial configuration of the ports and the volumes in their immediately vicinity, this surface is more regular and has a smaller area compared to a counter current scavenging.
The results obtained after the three dimensional simulation do not match after the first iteration with the results obtained after the one dimensional simulation because of the necessary approximations, made for the input data at the one dimensional simulation (Figure 8).
As a result, more iterations must be done, by using de scavenging curve and the flow coefficients for the ports obtained in the 3D simulation as input data for the 1D simulation.
Generally, two or three iterations are sufficient in order to obtain an acceptable difference between the 1D and the 3D simulations and, as a result, the calculation model can be considered to be calibrated. The next step consists in the modification of some parameters that influence the gas exchange to reach the final architecture that offers the best compromise between the scavenging quality, the energetic and the environmental performances of the engine and energy consumed for the scavenging.

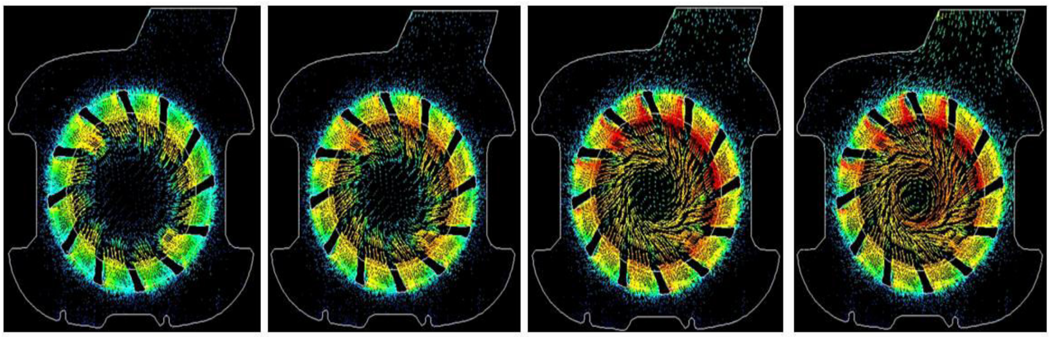

Figure 6. The speed vectors of the fresh air in the intake process through the intake ports

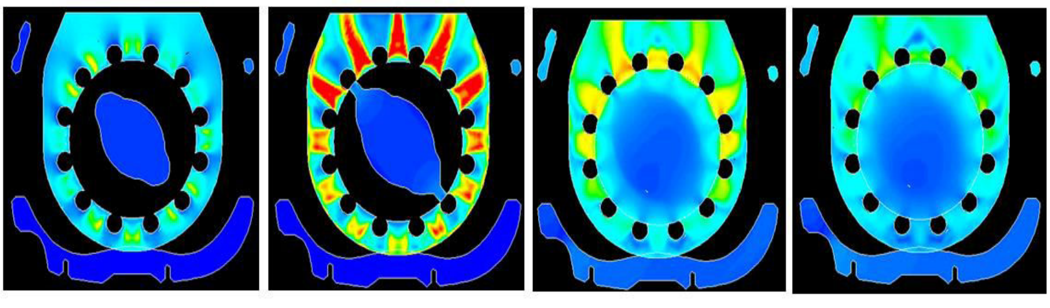

Figure 7. The speed of the residual gases through the exhaust ports during the scavenging process

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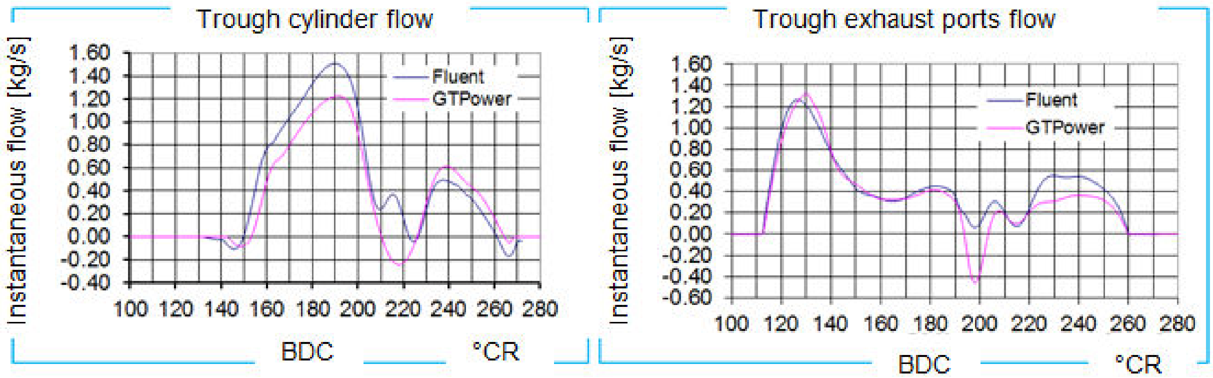

Figure 8. The differences between the 1D and the 3D simulations for the EM100D engine

The Table 1 presents the variation of some parameters of the scavenging process, depending on the exhaust ports height of the right side cylinder.

Table 1.
The variation the scavenging process parameters, depending on the exhaust ports height of the right side cylinder

Right side cylinder – 3.800 rpm, at full load					
Exhaust ports height [mm]	Type of simulation	Quantity of air delivered [g]	Total quantity of gas retained [g]	Quatity of fresh air retained [g]	Scavening coefficient [%]
30	GT Power	2.590	2.624	2.377	90,58
	CFD – 10 Ports	3.110	2.832	2.576	91,00
27	GT Power	2.480	2.606	2.302	88,35
	CFD – 10 Ports	2.872	2.778	2.490	89,63
	CFD – 12 Ports	2.678	2.762	2.461	89,08
25	GT Power	2.379	2.552	2.217	86,87
	CFD – 10 Ports	2.730	2.706	2.410	89,08

In Figure 9 is presented the influence of the intake ports height on some energetic and scavenging parameters of the engine. The engine's power has been calculated for a two EM100D modules assembly, with an air excess factor λ=1.35.

4. CONCLUSIONS

The calculus and the optimization of the gas exchange process in the case of two stroke engine involves a great effort and a high volume of the simulation's iterations, with the modification of the parameters, one by one, in order to understand their influence on the scavenging.
This effort has as general purpose the development of the engine but, at the same time, has a great importance in the development of the burning chamber.
The intake and the exhaust ports height influence the compression and the expansion ratio of the engine.
The quality of the air/ burned gases mixture, also the speed and the direction of the air movement at the end of the compression stroke determine the architecture of the burning chamber and, in the end, the energetic and the environmental performances of the engine.

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The multitude of parameters which have a major influence on the gas exchange further complicates the data of the problem, so a special attention is needed in the choosing, the designing and the optimization of each part of the exhaust gas system.
The calculus and the optimization of the gas exchange process at the uniflow scavenging EM100D engine has demonstrated the fact that is possible to obtain a good filling of the cylinder with fresh air. Theoretical, in the case in which a good filling of the cylinder with fresh air is realized, comparable to the filling of four stroke cylinder the power of the opposite pistons doubles.
The experience has shown that the direct solutions finally take out the indirect ones, and the gas exchange in the cylinder, without requiring other supplementary strokes of the pistons, is a direct solution.
As a result, the effort for the research and the development of this process is justified, in the perspective of obtaining some major advantages in the development of the internal combustion engines.

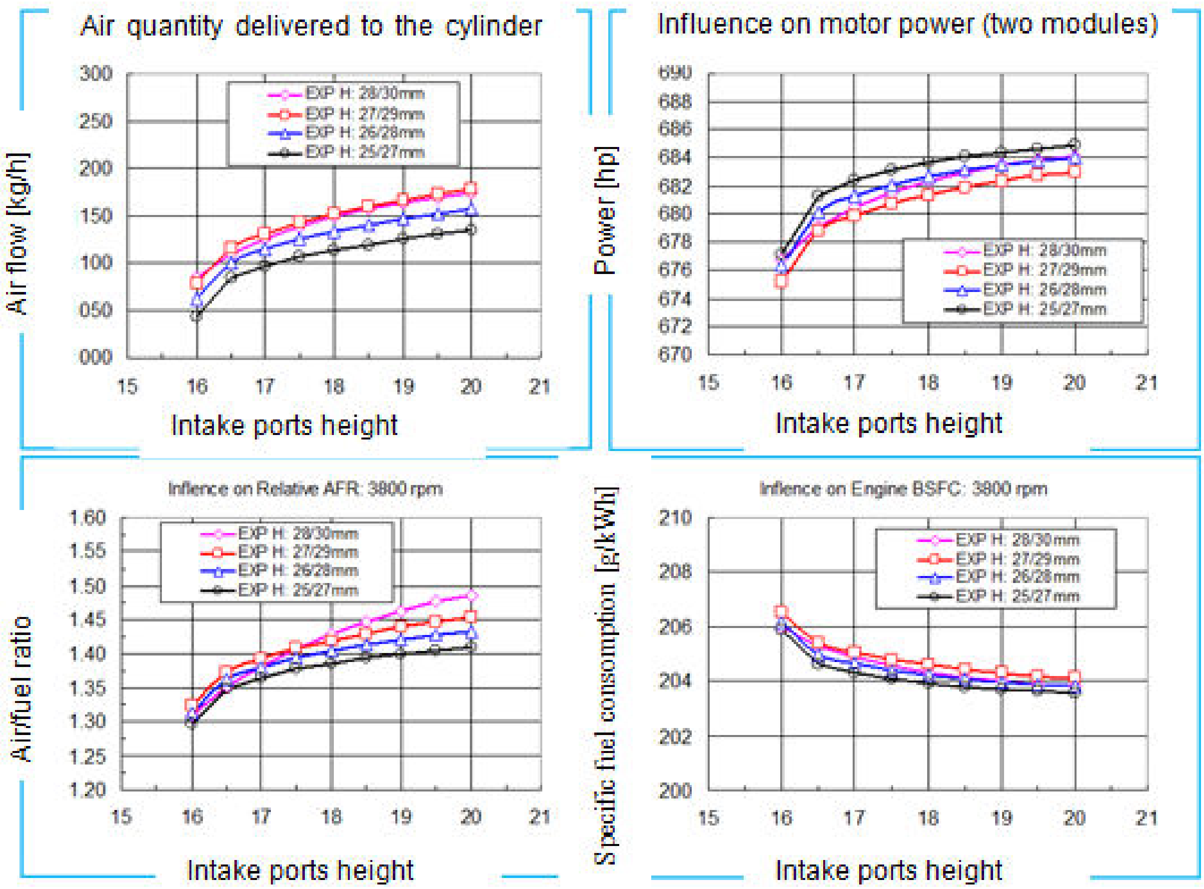

Figure 9. The influence of the intake ports height on the energetic and scavenging parameters of the EM100D engine

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ASSESSMENT OF THE ENERGY BALANCE OF BIOFUELS FOR MOTOR VEHICLES

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Abstract. *In order to reduce pollutant emissions from internal combustion engines, international regulations allow the use of biofuel blends as fuel for internal combustion engines. Another method of reducing pollutant emissions is the use of natural gas (compressed or liquefied) or propane (liquefied petroleum gas). The performance of internal combustion engines is affected by the use of those fuels instead of fossil fuels in an unmodified engine. The paper analyses the variation of engine parameters using alternative fuels.*

Keywords: *alternative fuels, combustion, emissions*

1 INTRODUCTION

Increased industrialization, depletion of petroleum resources and modernization of the world have caused researches to search and develop alternative fuel sources.
Biodiesel is one of the promising alternative fuels. Biodiesel is made from vegetal oil (rapeseed oil, sunflower oil, soybean oil) or animal fat using chemical processes [1].
Extending the use of alternative fuels can lead to soil protection and greenhouse gas reduction.
Biodiesel has a lower aromatic compound, about 10% oxygen content and is sulfur-free.
These characteristics can contribute to the reduction of carbon dioxide, carbon monoxide, unburned hydrocarbons and soot emissions [2][3][4][5].
Biodiesel is safe to storage and handle because it has a high flash point and a lower volatility [6][7].
The major disadvantage of biodiesel is its viscosity. Higher viscosity can lead to a poorer atomization, smaller cone angle, increase average droplet diameter and longer tip penetration [6][7].

2 EXPERIMENTAL SETUP

The tests were made on a Renault K9K engine. The engine specifications are presented in Table 1.
A schematic diagram of the engine test bed is presented in Figure 1.
The engine was mounted on a Horiba Titan 250 test bench. The engine test bed is equipped with an electric Dynas3 LI250 dynamometer, which is designed for operated within a range of 0-8000 rotations per minute. It can measure engine power up to 250 kW with an accuracy of ±2%.

Table 1.
Engine properties

Engine type	Renault K9K four stroke
Number of cylinders	4
Bore (mm)	76
Stroke (mm)	80.5
Total displacement (cm3)	1451
Compression ratio	15.3
Maximum power	72 kW at 3700 rpm
Maximum torque	200 Nm at 2700 rpm
Fuelling	Common-rail direct injection

The engine was fuelled with a blend from mineral diesel and 6% and 10% of biodiesel obtained from waste oil. The characteristics of fuel are presented in Table 2.

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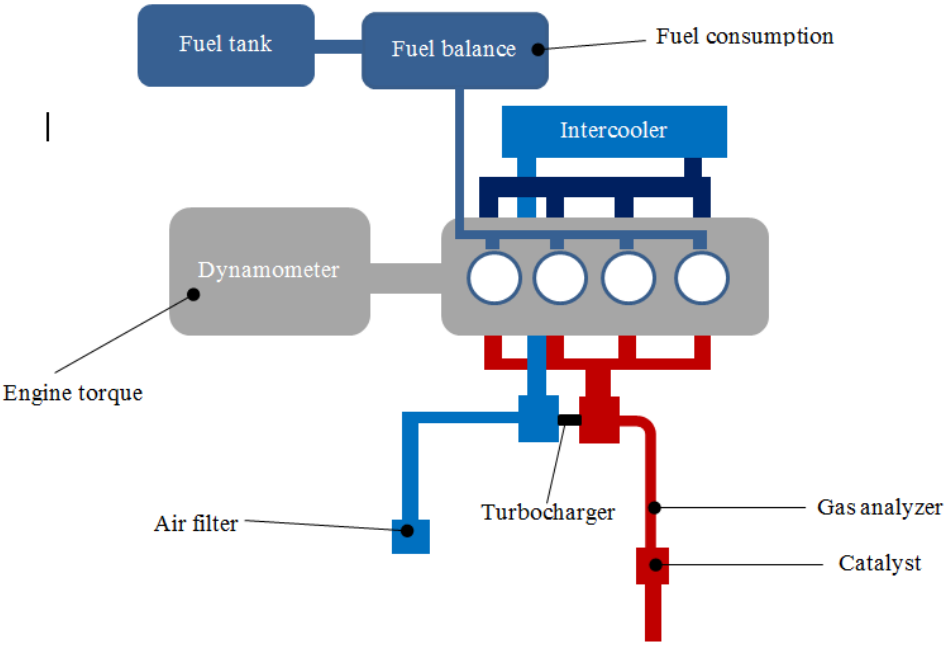

Figure 1.Schematic diagram of the engine test bed

Table 2.
Fuel properties

Properties	Diesel	B6 waste oil	B10 waste oil
Density (at 20 °C), kg/m3	840.2	842.7	844,4
Viscosity (at 20 °C), mm2/s	5.34	5.27	6.15
Cetane number	51.1	54.2	58.9
Flash point, °C	67	71	71
Net calorific value, MJ/kg	43.16	42.56	42.19

The in-cylinder pressure was measured with Kistler 6005 pressure sensor installed at glow plug hole of cylinder (Figure 2). The crankshaft angle was measured using AVL 365 sensor that is mounted on the crankshaft pulley (Figure 3). This is an optic sensor that using the beam of light passing through the slots. The tests were made for full load of the engine

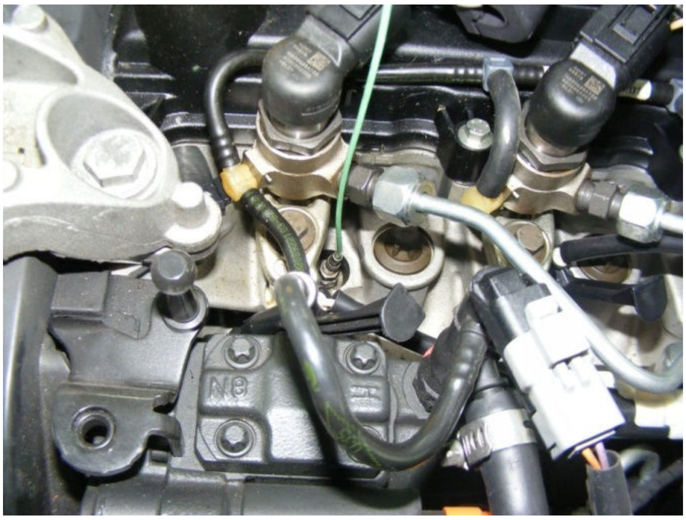

Figure 2. In-cylinder pressure sensor

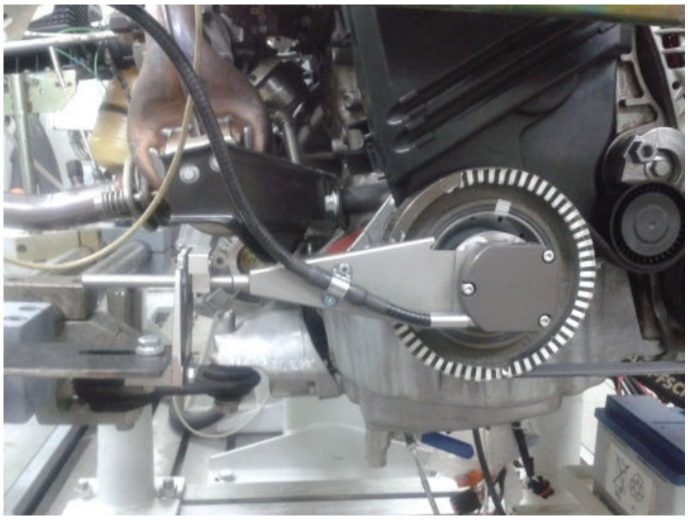

Figure 3. AVL 365C position sensor

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3 EXPERIMENTAL RESULTS

The ignition delay is defined as the period between start of the fuel injection and the start of combustion. The start of injection was considerate the moment when the injector starts to be energized with power. The start of combustion was considerate the moment when the in-cylinder pressure raise more than the pressure from cylinder when is no fuel injected. The ignition delay has an important impact on the heat release rate and on engine noise and emissions. The ignition delay is composed from physical delay and chemical delay. The physical delay depends on fuel's properties and composition and the chemical delay depends on cylinder pressure, cylinder temperature and fuel properties.
Usually, the chemical delay is longer than the physical delay.
In Figure 4 is presented the ignition delay when engine running at full throttle.

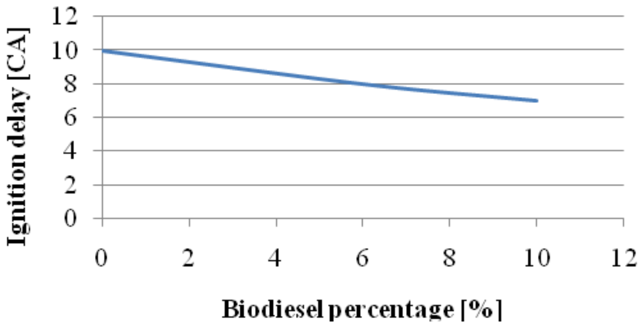

Figure 4. Variation of the ignition delay

The start of injection was the same for all test (13^o CA before Top dead Center and the end of injection was at 15^o CA after Top Dead Center) as can be seen in Figure 5.
In all tests, the ignition delay was shorter for biodiesel blends that for mineral diesel. Also, the ignition delay decreases with the increase of speed and load. This is the effect of high oxygen content in biodiesel. Another reason is the in-cylinder temperature that increases when the engine is fueled with biodiesel. The biodiesel blends have a higher bulk modulus, higher sound velocity, higher density and higher cetane number that mineral diesel. These characteristics lead to an early start of injection and a shorter ignition delay. Heat release rate is used to characterize Diesel engine combustion. The lower volatility and higher viscosity of biodiesel blends can contribute to a poor fuel atomization and in a reduction of heat release rate (Figure 6). The first phase of heat release is higher for biodiesel blends that for mineral diesel and may be due to the higher cetane number of biodiesel and supplementary oxygen contained by biodiesel. The cylinder pressure variation is important for the analysis of combustion process. The maximum pressure cylinder is smaller with 0.8% for B6 and with 2.8% for B10. Because the biodiesel blends have a higher viscosity and density as mineral diesel, spray characteristics are affected because is minimized the atomization. Both of these factors can lead to a smaller maximum pressure when the engine is fueled with biodiesel blends.

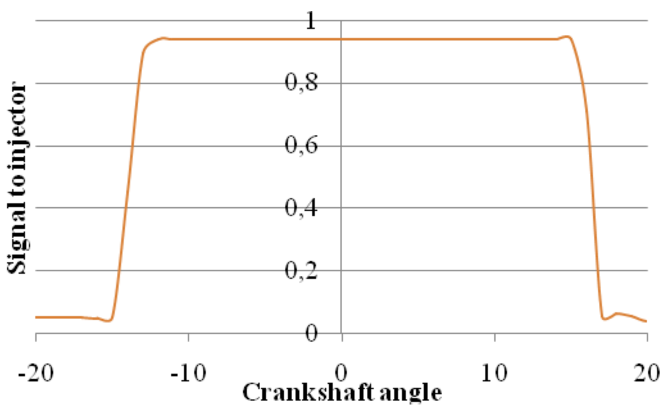

Figure 5. The law of injection at full load and 3700 rpm

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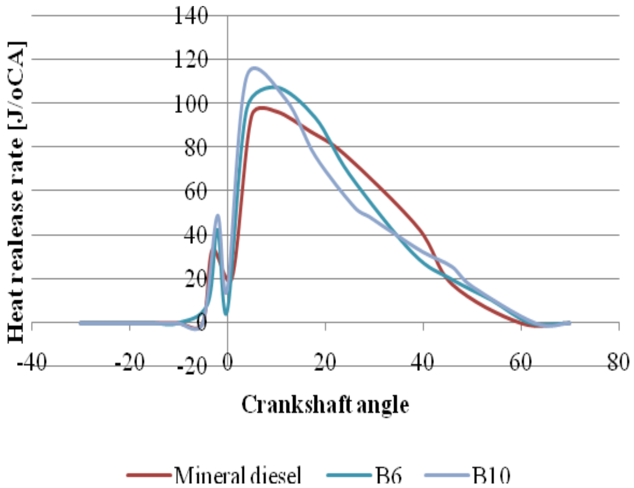

Figure 6. Heat release for tested fuels

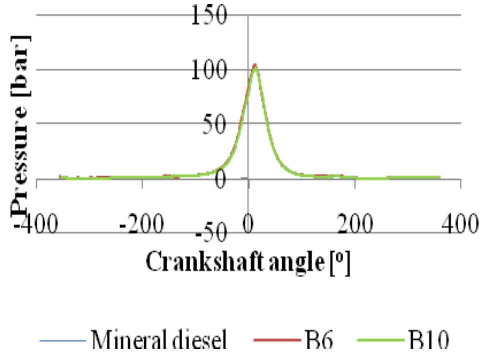

Figure 7. Cylinder pressure

4 CONCLUSIONS

Waste oil biodiesel and its blends have a higher cetane number, increased oxygen content, higher viscosity and density compared with mineral diesel fuel.
These properties have an important impact on combustion:

- The ignition delay is shorter for biodiesel blends and it decrease with the increase of biodiesel percentage;
- The maximum in-cylinder pressure decrease with the biodiesel percentage in blends;
- The result of tests shows that waste oil biodiesel can be used in engine in small percentage. For larger percentage it is necessary to modify the law of injection for engine (start of injection, duration of injection).

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The Scientific Journal of SIAR
A Short History

The engineering of vehicles represents the engine of the global development of the economy.
SIAR tracks the progress of the automotive engineering in Romania by: the development of automotive engineering, the development of technologies, and road transport services; supporting the work of the haulers, supporting the technical inspection and of the garage; encouraging young people to have a career in the automotive engineering and road haulage; stimulation and coordination of activities that promote an environment that is suitable for continuous education and improving of knowledge of the engineers; active exchange of ideas and experience, in particular for students, master students, PhD students, and young engineers, and dissemination of knowledge in the field of automotive engineering; cooperation with other technical and scientific organizations, employers' and socio-professional associations through organization of joint actions, of mutual interest.
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The insurance of a favorable framework for the initiation and the development of cooperation of the specialists in this field of activity allows for an efficient and easy exchange of information, specific knowledge and experience; it supports the cooperation between universities and between research centers and industry; it speeds up the process of implementing the new technologies, it simplifies the identification of training and specialization needs of the personnel involved in the engineering of motor vehicles, transport, and road safety.
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Total number of issues: 30 Type: Open Access
The above constitutes series nr. 1 of SIAR scientific magazine.

2. Ingineria automobilului (in English: ***Automotive Engineering***)
ISSN 1842 – 4074
Period of publication: as of 2006 Format: print and online, Romanian
Frequency: Quarterly Electronic publication on: www.ingineria-automobilului.ro
Total number of issues: 52 Type: Open Access
(including the September 2019 issue)
The above constitutes series nr. 2 of SIAR scientific magazine (Romanian version).

3. Ingineria automobilului (in English: ***Automotive Engineering***)
ISSN 2284 – 5690
Period of publication: 2011 – 2014 Format: online, English
Frequency: Quarterly Electronic publication on: www.ingineria-automobilului.ro
Total number of issues: 16 Type: Open Access
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4. *Romanian Journal of Automotive Engineering*
ISSN 2457 – 5275
Period of publication: from 2015 Format: online, English
Frequency: Quarterly Electronic publication on: www.ro-jae.ro
Total number of issues: 19 (September 2019) Type: Open Access
The above constitutes series nr. 4 of SIAR scientific magazine (English version).

Summary – on September 30, 2019

Total of series:	*4*
Total years of publication:	*25 (11: 1990 – 2000; 14: 2006 – 2019)*
Publication frequency:	*Quarterly*
Total issues published:	*82 (Romanian), out of which, the last 35 were also published in English*