ONE DIMENSIONAL MODELING OF GASOLINE ALCOHOL DUAL FUEL COMBUSTION ENGINE

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ABSTRACT: In this study, experimental outcomes from a Spark ignition engine (SI) which fueled with E1 to E20 (Percentage of alcohol content in total fuel blend is various between 1% and 20%) were collated with recital of combustion codes for one dimensional analysis.1-D codes, which is called SRM-Suite (Stochastic Reactor Model) and Chemkin-Pro, were estimated from combustion, emissions and heat transfer point in an SI engine. The estimations are based on empirical data and working situations which were done at karadeniz technical university Research Labs in Turkey. A bunch of empirical data was employed for analysis in both of software's according to both expanded and decreased kinetic mechanisms. Simulation outcomes were collated to empirical data from heat release rate, pressure and emission point. The vicissitude of the H_2O_2, temperature and OH which weren't available experimentally were achieved by comparisons between two codes. Analysis demonstrates that each code has pluses and minuses. The advantages of SRM-. Suite are blow-by Crevice, ring gap, and probability density function (PDF) – based stochastic reactor modeling and these advantages helped with better convergence of the outcomes. But, Chemkin-Pro outcomes were logical and solution duration was much shorter than SRM-.Suite. Also it was clear that both decreased and expanded kinetic mechanisms had huge effect on analysis.

Key-words: One-dimensional simulation, Chemical kinetic mechanism, SI engine, SRM-Suite, Chemkin-Pro.

INTRODUCTION

The expanded - mechanisms which has been set for fuels with high number of carbon commonly behold high number of elements and chemical reactions. By employing new generation of computers it's possible to achieve solution in very short period of time even for cases which have developed mechanisms [1]. During the past years' lots of computer engineers have tried to develop a software

packages that be able to analyze 1-dimensional combustion to modeling of SI engines effectively. [2] One of the software's that was used in this study is Chemkin-Pro which aim of its develop is to determine the accuracy of chemical mechanisms with evaluating of delay that happens in the ignition. Beside that its capable of doing analysis according to various reactor types. First one is a 1-D IC reactor. As the Chemkin-Pro software is capable of simulating engine combustion 1-D reactor, it is possible to be integrated with several zone models and CFD modeling to achieve much expanded numerical outcomes. Second one is SRM-Suite its 1-D codes for analyzing combustion the main aim for developing this software was to analyze SI engines according to probability density function (PDF) based on stochastic reactor model. The model works on assuming statistical uniformity of the blend inside the cylinder by factoring in the turbulent mixing [3][4].

Table 1. Nomenclature, Abbreviations
1-D → One Dimensional
3-D → Three Dimensional
CAD → Crank Angle Degree
CFD → Computational Fluid Dynamics
EGR → Exhaust Gas Recirculation
VC → Exhaust Valve Closing Time
EVO → Exhaust Valve Opening Time
HRR → Heat Release Rate
IC → Internal Combustion
IVC → Intake Valve Closing Time
IVO → Intake Valve Opening Time
ŁMM → Łocalness Mixing Model
PDF → Probability Density Function
PRF → Primary Reference Fuel
RPM → Revolution Per Minute
SRM → Stochastic Reactor Model
Symbols
a, b, c → Constants for Nusselt Equation
C_{11}, C_{12}, C_2 → Constants of Woschni Correlation
Nu → Nusselt Number
P → Instantaneous Cylinder Pressure (bar)
Pr, Vr, Tr→Volume, Temperature and Pressure Evaluated at any Reference Condition
Re → Reynolds Number
Sp → Piston Speed
Vd → Displaced Volume
$\hat{W}$ → Average Cylinder Gas Velocity

Here an SI engine was evaluated under two various mechanisms in the same working situation employing Chemkin–Pro and SRM-Suite software's results of

both chemical mechanisms expanded for the same fuel were tested according their nearness to the empirical facts. Also, CPU analyzing times of codes were assumed as performance norm. To obtain the codes performances precisely, both decreased and expanded chemical kinetic mechanisms were employed [5]. In this study we compared computational outcomes to empirical results from CO, O_2, CO_2, heat release rate and pressure point.

EXPERIMENTAL AND MODELING PARAMETER

Experimental part of study was carried out at Karadeniz Technical University Laboratories in the Turkey. The engine used in the tests is a single-cylinder, four-stroke, water-cooled, variable compression engine. Engine specifications are given in detail in Table 1. [6].

Table 2. Engine Parameters

Number	Characteristics	Values (Dimension)
Cylinder Diameter	90	mm
Stroke	120	mm
Łength Of Connecting Rod	140	mm
Compression Ratio	9.25	
Engine RPM	2000	Rev/min
Intake Valve Diameter	30	mm
Number Of Values	4	
Intake Valve Opening Time	340 BTDC	CAD
Intake Valve Closing Time	108 BTDC	CAD
Exhust Valve Opening Time	120 ATDC	CAD
Exhust Valve Closing time	322ATDC	CAD

To catch SI engine situation practically the head of piston was lifted to reach the compression ratio of 15.06 as well inlet temperate into the cylinder raised to 250 C^o. Experimental steps were done when the pressure of intake manifold was 1bar. RPM of engine was taken as2000 to obtain steady combustion. The ethanol content which used in alcohol–gasoline fuel in the engine was various between 1% and 20%. These studies done under two categories: first mechanism is decreased and second mechanism is expanded.

1D COMBUSTION MODELING

Combustion simulation was done using both SRM-Suite codes and Chemkin-Pro, under module of SI engine. All of the study were done between two times it starts at the closing time of intake valve and ends at the opening time of exhaust valve.
The compression ratio is 9.25 for Chemkin-Pro .
The proportion of length of connection rod to the radius of crank assumed is 1.58.
Operating criterions were chosen on 2000 RPM .
Equivalent values were employed for decreased and expanded mechanisms and the test steps assumed as 0.1.
The temperature of inlet blend was assumed as 450 for reduced mechanism and for detailed mechanism it was assumed as 530k.

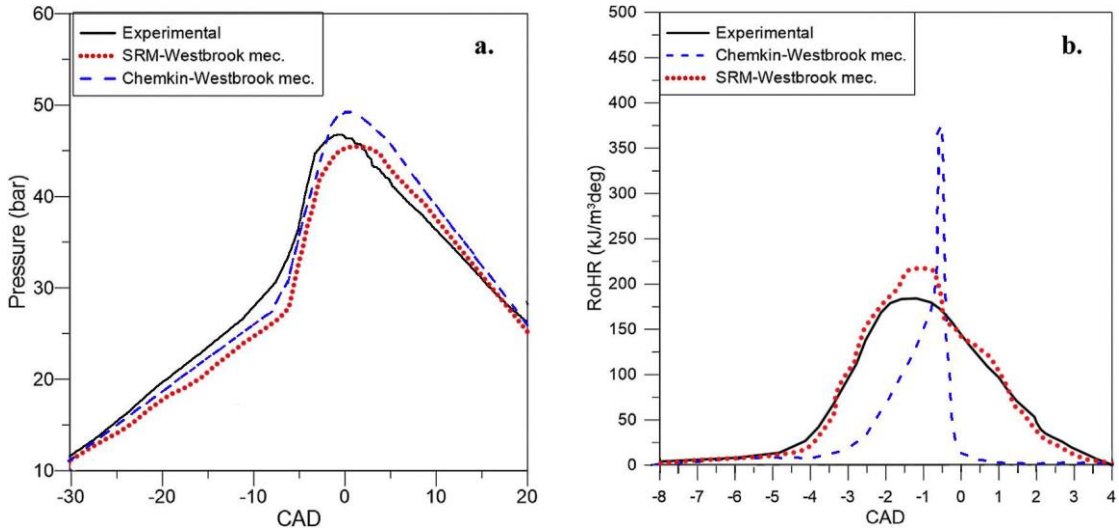

Figure 1. (i) Pressure Diagram Of Empirical And Simulating With Expanded Mechanism. (ii) Empirical And Simulating With Expanded Mechanism Of Heat Release Grade Diagrams

The pressure of intake assumed as 1.43 bar according to empirical information. The following equation was employed for simulating the heat transfer: [7]

$$Nu=a \times Re^{b} \times Pr^{c} \qquad (1)$$

According former researches for an SI engine constant parts of equation are assumed as:

a=0. 32, b=0.69, c=0.001.

The temperature of cylinder boundary parts was assumed as 420 K.

The Chemkin-Pro employs woschini relations to calculate heat transfer:

$$W=c_1 \times s_p + c_2 (V_d \times Tr/P_r \times V_r)(P-P_m) \qquad (2)$$

For a SI engine constants are assumed as C_{11}=2.28 , C_{12}=0.308 ,C_2=3.24.

SRM -Suite models were arranged and modeled also within the time interim of the closing of intake valve and opening of exhaust valve .

The data entered in Chemkin-Pro assumed same with data entered in SRM-Suite modeling.

110 particles were employed to decently evaluate inside-cylinder feature and also weight factor assumed as 13. The time for mean mixing assumed as 5.5 ms also localness mixing model (ŁMM). is specifically suggested for SI engine demands because it factors in localness into calculation [8].

RESULTS

In expanded mechanism case entire time that CPU needed was 123,016 s and in decreased case it was 2851s for SRM-Suite software. It's totally different when we used Chemkin-Pro software for expanded case it was 3050 s and for decreased case it was 355 s. estimated out comes were tested compared to heat release rate pressure–crank angle change, temperature and mole fractions of C_2H_5OH, C_8H_{18}, CO, CO_2, H_2O and OH [9]. Empirical outcomes were collated to estimated data from heat release rate, pressure, temperature and fractions of CO, CO_2, and O_2 point. The data that isn't accessible empirically like C_2H_5OH, C_8H_{18}, CO, CO were obtained by employing computational amounts also variation of H_2O_2 and OH, that are middle species in SI combustion, were shown graphically by employing computations. In figure 1. i it's obvious that expanded case from peak pressure point, SRM-Suite has much better consistency with empirical data in pressure vs crank angle diagrams compared with Chemkin-Pro. Figure1. ii demonstrates the empirical heat release value against crank angle and estimated outcomes of expanded mechanism by employing SRM-Suite and Chemkin –Pro It's obvious in figure SRM-Suite outcomes are in much better compliance from inclinations and rates point than Chemkin-Pro when collated to empirical outcomes.
It's clear in figure 2 i that the decreased mechanism outcomes demonstrate less proper results than expanded mechanism when collated to the empirical outcomes, SRM - Suite and Chemkin - Pro pressure vs crank angle diagram demonstrates this fact that combustion began afterwards, but occurred faster when collated to the empirical results. If we analyze Figure 2. ii it demonstrates stalled and quicker burning in computational estimations. Broadly, from heat release rate and pressure point computational outcomes achieved by the expanded mechanism demonstrated better compliance with empirical out comes [10]. From heat release rate point SRM - Suite out comes demonstrated more consistency than Chemkin–Pro. In addition, both Chemkin - Pro and SRM - Suite run on the same basic correlations the major disagreement among

them is the significant participation of stochastic on results. Chemkin-Pro presumes that gas temperature stays uniform at the whole burning chamber so assumption results in abrupt pressure increase [11]. Beside this burning processes happen quicker compare with empirical actions due to the erasure of lots of middle reactions to decrease the CPU time remarkably. This process results to abrupt pressure increase and the variation in heat release grade [12]. Even so because of the effect of the decreased mechanism on CPU time it's possible to ignore the deviation. Figure.3 demonstrates computational increasing of temperature during the burning process. At most temperature for combustion values are among 2000K and 2100K. Figure.4 demonstrates depletion of fuel for each of pieces C_2H_5OH and C_8H_{18}. In case of decreased mechanism (Tsurshima), fuel was used rapidly and finished steadily. The reason for rapid fuel depletion of the decreased mechanism is lack of middle reactions. [13] It worth to say that whole of calculational studies demonstrated the same duration of time for depletion of fuels. Figure.5 demonstrates variation of CO andCO_2 vs crank angle. Commonly, the outcomes demonstrated identical tendency apart from the cases running on SRM-Suite expanded mechanism. It's not possible to test the exactness of the outcomes by collating with other results destitute of reasonable empirical values[14]. Figure 6. demonstrates variation of O'H and 'H$_2$O vs crank angle. While curves are analyzed it's clear that mole fraction of O'H varied for two mechanisms SRM-Suite expanded mechanism studies demonstrated faster appraisal of O'H which has less apogee amount [15].

Mass portion of 'H$_2$O$_2$ vs crank-angle obtained before, throughout and later than burning in an SI engine by employing empirical results. Empirical results were in concession with SRM-Suite Studies employing the method of Tsurushima. [16] Also the calculation outcomes for 'H$_2$O$_2$ were impossible to be ratified empirically. It is clear the alternation of SRM-Suite expanded mechanism demonstrated in CO, CO_2 and OH point is impossible to be seen in 'H$_2$O$_2$ [17]. It's obvious in Figure.6 ii, the developing of 'H$_2$O$_2$ starts in advanced compared with modeling with decreased method. As the consuming duration of 'H$_2$O$_2$ is approximately equal for whole studies, it indicates the ignition stall of engine overlap [18]

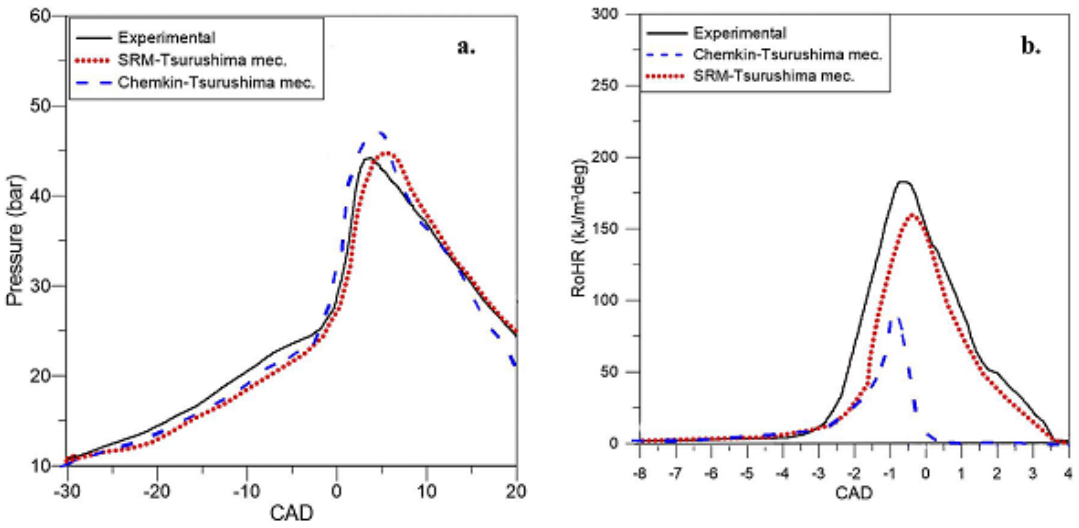

Figure. 2. (i) Pressure Diagram From Empirical And Simulating By Decreased Mechanism. (ii) Empirical And Simulating By Decreased Method Of Heat Release Grade Diagrams

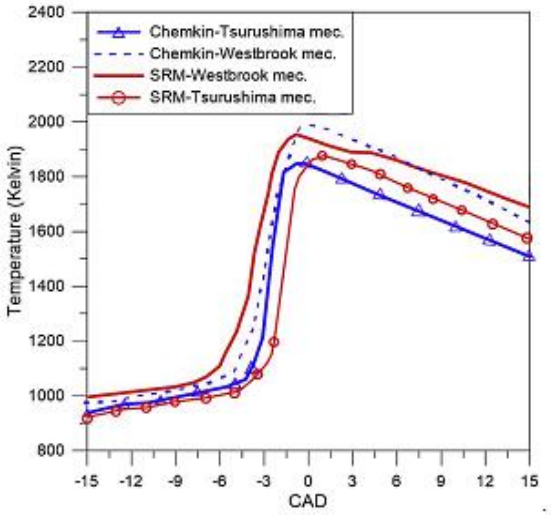

Figure. 3. Temperature Diagrams

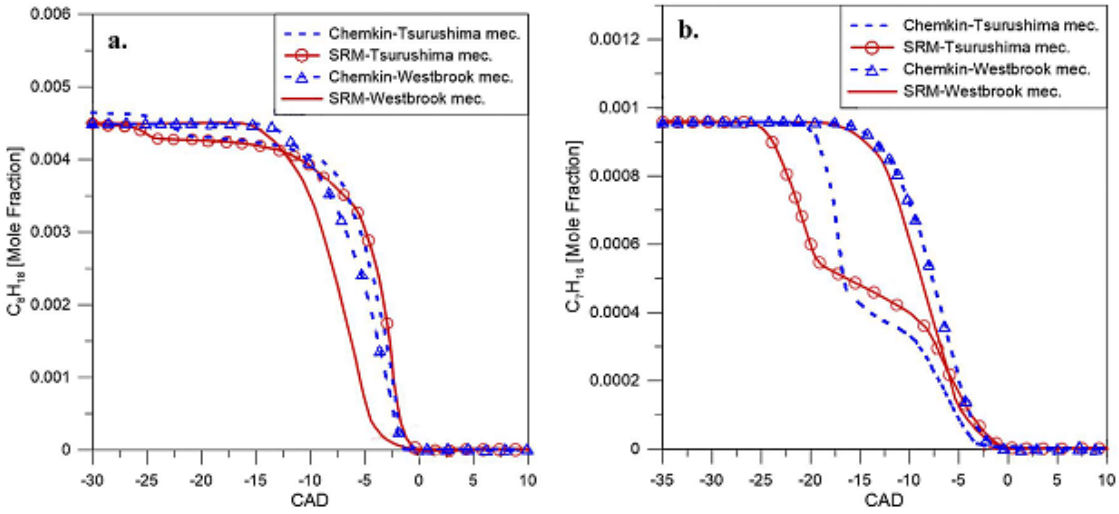

Figure. 4. C_2H_5OH (i) And C_8H_{18} (ii) Fuel Depletion Diagrams For Various Dissolvers Also Chemical Method Relaying On CAD.

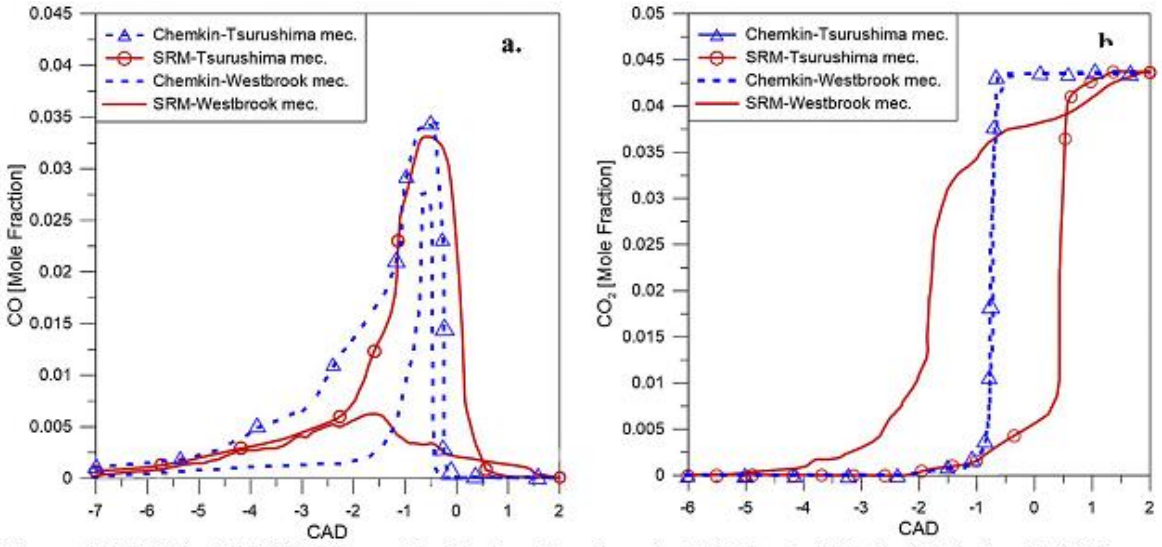

Figure. 5. CO (i) And CO_2 (ii) Diagrams For Various Dissolvers As Well Chemical Methods Relaying On CAD

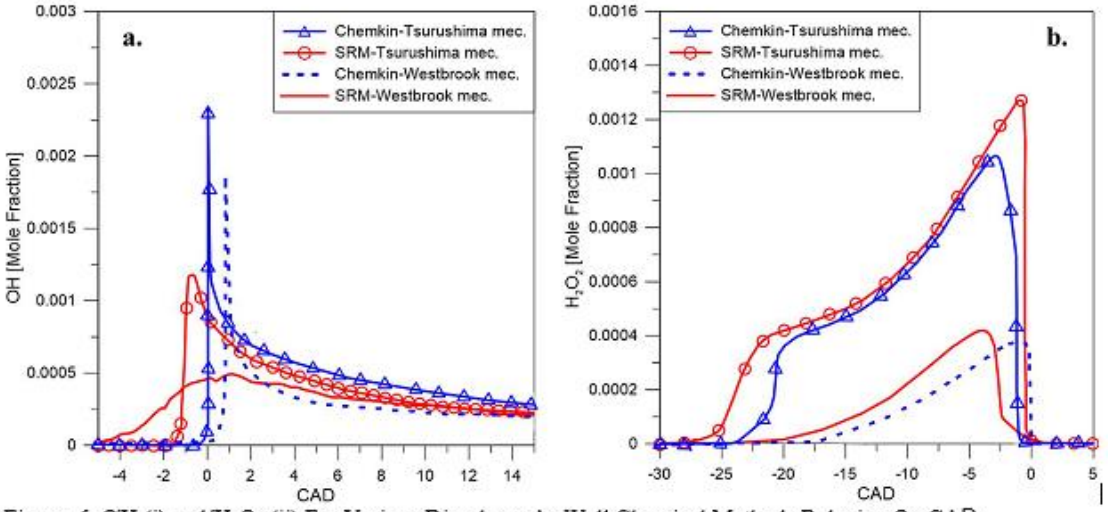

Figure. 6. OH (i) and H_2O_2 (ii) For Various Dissolvers As Well Chemical Methods Relaying On CAD

In Figure.7 empirical and some estimational outcomes of CO, CO_2 and O_2 are demonstrated. In CO case, Chemkin-Pro demonstrated better concession with the empirical data compared with SRM-Suite for either decreased and expanded methods. In CO_2 and O_2 case, whole estimated outcomes are in agreeable compliance with empirical outcomes.

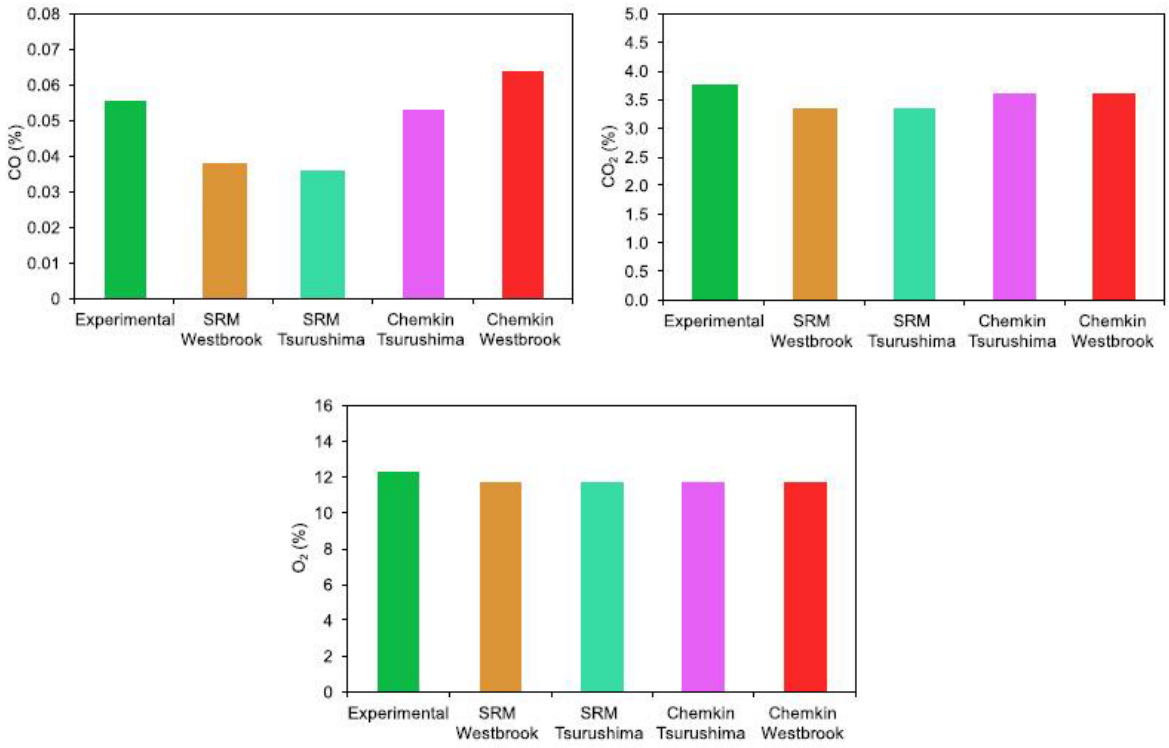

Figure. 7. Empirical And Estimated Amounts Of CO, CO_2, And O_2.

CONCLUSION

In this study I have researched and optimized the effect of fuel ethanol in gasoline combustion engines from emission and performance point. At the first level, I surveyed the engine performance for pure gasoline fuel; then I used a mixture of ethanol and gasoline in which the amount of ethanol varies from 1% to 20 %. The engine RPM was chosen as 2000 and the engine parameters, when it works with 100% gasoline fuel, were compared to when ethanol-gasoline fuel were blended. From the performance and emission value points it was obvious that 8% ethanol-gasoline blend is the desirable amount. It is clear that from performance and CO point, there is a good agreement between the results and literature researches. From performance and emission point it can be easily perceived that the gasoline-ethanol blend has advantages over pure gasoline. However, for obtaining the most decent value of gasoline-ethanol blend all of the engine parameters should be evaluated in an advanced optimization software in which the meantime factors in the gasoline-ethanol such as cost, engine performance and emission. If this conditions are met this study will be useful and practical.

In this study all of the engine parameters were defined variable, at the same time, engine performance and emission values were optimized together.
If renewable sources are used to produce ethanol the cost of product will be high. Despite this, it is preferable to use gasoline-ethanol blend from performance and emission point under aforementioned conditions since passenger cars emissions have turned to be the main problem in air pollution and governments, therefore, pass strict rules about passenger cars which result in emission every year. From software point of view each, SRM-Suite and Chemkin-Pro have pluses and minuses: The major strong point of SRM-Suite codes is that it employs PDF method that ease CFD procedure when it sustains estimation ability of three dimensional CFD codes. Chemkin-Pro software presumes a bulk volume empirical outcomes. SRM-Suite factors in simulation of piston position and blow-by, so it makes possible to give better estimation outcomes when collated to Chemkin-Pro.

Also if we go through results it's obvious that expanded mechanisms are more sustainable and near to empirical data from intake temperature and emissions point nevertheless the expanded method has some weak points. One is that it rises CPU time it's different for both codes .in fact the expanded method rises CPU time up to 10 times for Chemkin-Pro and almost 100 times for SRM-Suite.

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