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Numerical and Experimental Investigation of Performance of a Spark Ignition Engine

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Abstract: In this study, Investigations have been done as experimental and numerical. Numerical model of gasoline engine has been designed. So, a gasoline engine performance test system has been modeled by 1-D numerical analysis program. Results of the analysis which has been used gasoline have been obtained for a total of five different engine speeds ranging from 1500 rpm to 4000 rpm at partial throttle opening from %10 to %50 with an increment %10. These conditions have been used for experiments, too. Performance and emissions of the gasoline engine based on engine speed have been revealed. Performance rates have been evaluated. Results have been shown with graphics.

Keywords: Spark ignition engine, engine performance, 1-D engine modeling, gasoline, torque.

1. Introduction

Developed in many studies relative to the energy efficiency in the automotive world are desirable more efficient use of energy resources and giving less damage to the natural balance with liquid fuels such as gasoline and diesel fuels inclusion different additions. Many fuel supplements like CNG, Methanol and LPG are used for each engine. All fuel supplements are used in both experimental and numerical studies. These supplements are investigated in terms of performance and emissions. Due to experimental studies require both high cost and extensive time, academic studies are tended to analysis programs which are taken faster and cheaper. These programs have near accurate results. This study aimed to obtain engine performance values and emissions values with both experimental and numerical investigations on a gasoline engine for pure gasoline. Thanks to 1-D numerical analysis program prevented experimental costs and it was faster data [1-2].

In the literature dealing with this issue, there are numerical and experimental studies with various content and approach.

Bedford et al. [3], have compared their analysis with experimental results with FLUENT software which is a numerical based package program for spark ignition engine and direct injection diesel engine. Thermal stress analysis of the components of the spark-ignition engine has attempted to improve reliability after ensuring the accuracy of the test results, and for the diesel engine, they have performed the task of confirming the accuracy of the combustion delay model.

Choi et al. [4], have studied on a model for stratified combustion in direct - injection spark ignition engines. The 3-D simulation was applied in the direct injection spark ignition engine geometry by STAR-CD program. The simulation results have provided important data to understand the combustion process in the engine.

Das et al. [5], Numerical and experimental comparisons have been made on the internal flow of a gasoline engine. Experimental particle image velocimetry has been used in their work with KIVA-3V multidimensional code with Particle Image Velocimetry (PIV). Studies have shown the utility of multidimensional modeling in understanding the in-cylinder flow of a gasoline engine.

Hooper, P. R. et al. [6], have simulated an engine by using Ricardo –Wave software. Fueling methods and core engine parameters have been modeled and compared, for multi-fuel operation.

Yontar, A. A. et al. [7], have numerically and experimentally investigated performance and exhaust emissions of Honda L13A4 motor at %75 throttle opening rate with respect to engine speed. The complete test engine was modeled by using Ricardo-Wave 1-D numerical analysis program. Experimental and model data have been compared. Effects of throttle opening rate on the performance and emissions have been presented.

2. Materials and Methods

In this study, Honda L13A4 motor is investigated. In the engine test setup, engine performance parameters are measured. Measurement results have been found with Eddy-Current dynamometer. Engine test system and engine test scheme are shown in figure 1.

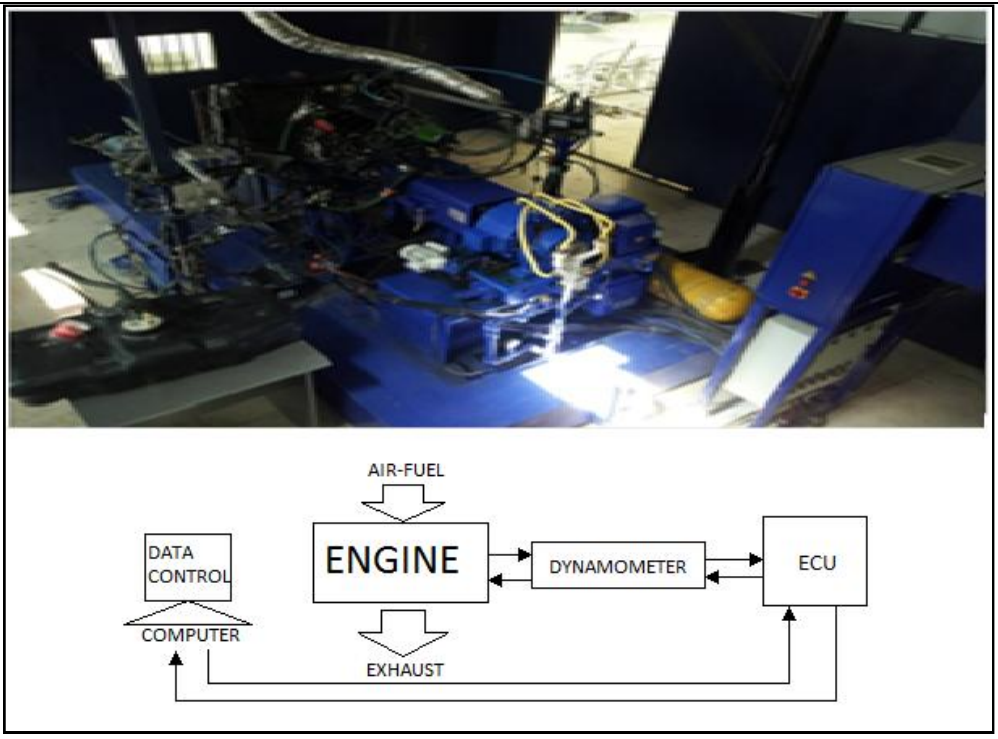

Figure 1: Engine test system and engine test scheme.

Features of used Honda L13A i-DSI engine are given in table 1.

Table 1: Features of used engine.

Number of cylinder	4
Volume of engine	1,339 cm3
Compression rate	10.8:1
Bore	73 mm
Stroke	80 mm
Engine power	63 kW (5700 rpm)
Engine torque	119 Nm (2800 rpm)

The same analysis matrix has been applied for experimental and numerical investigates. Used physical and chemical conditions in these investigates have been shown in table 2.

Table 2: Analysis matrix.

Compression rate			10,8:1
Air-fuel ratio			1.05
Engine speed			
1400	2000	3000	4000
Throttle opening			
10 / 20 / 30 / 40 / 50			

Experimental torque data which have been given from engine test system have been shown at partial throttle opening and at different engine speed in figure 2.

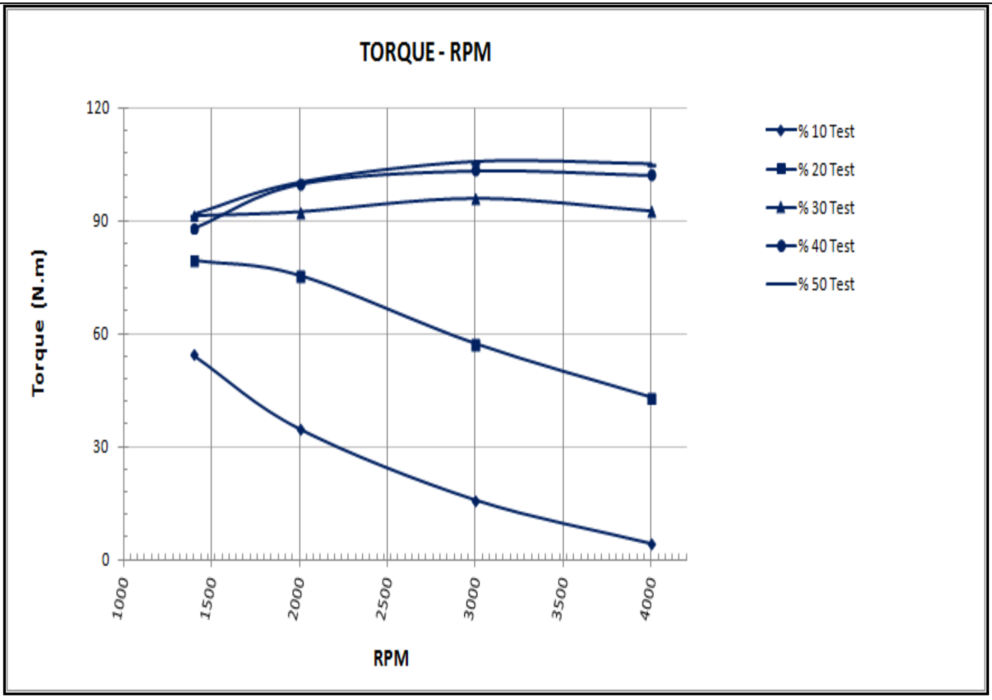

Figure 2: Experimental torque data.

3. 1-D Modeling

In the numerical study, gasoline engine and engine test system which have been used at experimental studies have been modeled by an analysis program (1-D Modeling Program) with all components. Both geometric and physical conditions of the components of the gasoline engine in this study have been determined. Specifications of all components which is belong to gasoline engine have been entered to this program. Analyses have been given based on partial throttle opening. So, throttle opening has been recognized from %10 to %50 with an increment %10. In addition, convergence criteria has been determined as 0.01, the number of loops is 300 and time step size is 0.5. The model is shown in figure 3.

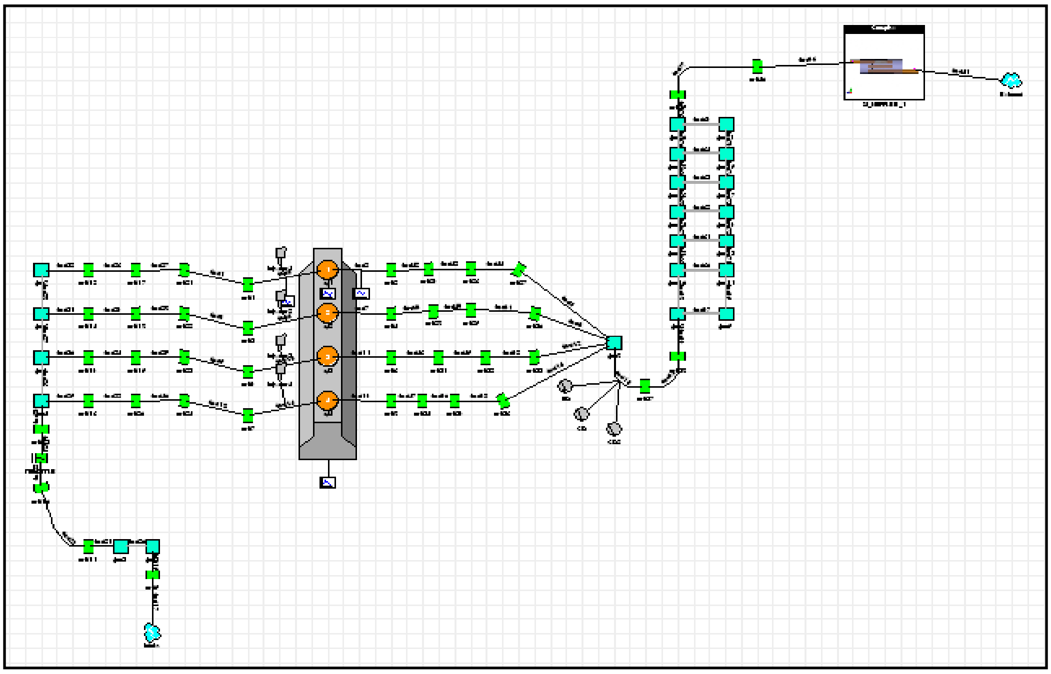

Figure 3: 1-D Modeling of The Gasoline Engine.

As a result of, performance values of a spark ignition engine have been obtained by the numerical model. The Numerical analysis results which have been obtained from the engine model have been evaluated and reported in the following section as compared with experimental results. Numerical torque data which have been given from 1-D model have been shown at partial throttle opening and at different engine speed in figure 4.

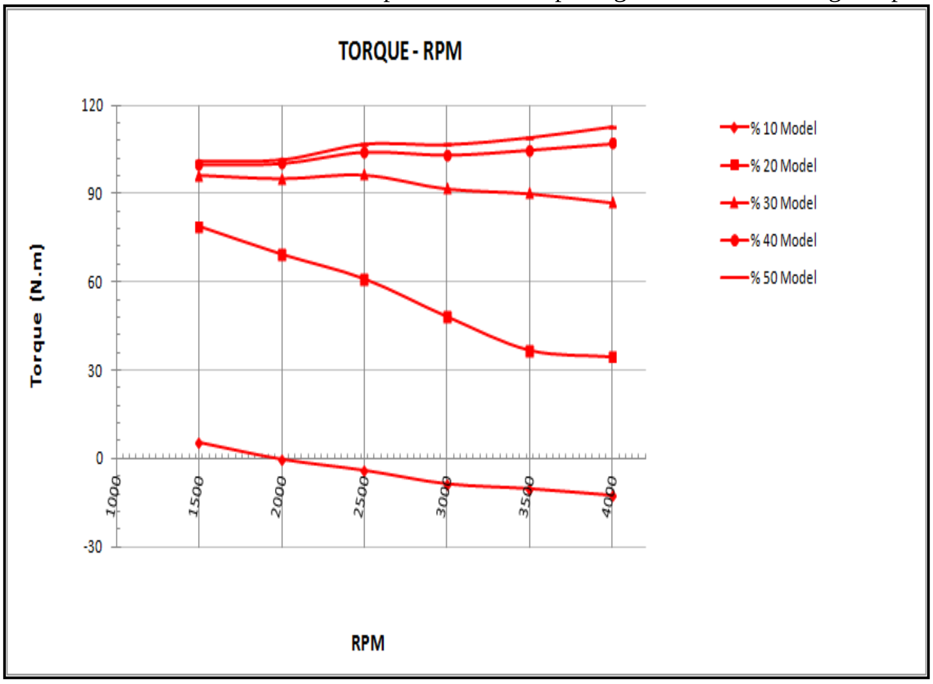

Figure 4: Experimental torque data.

4. Results of Experimental and 1-D Model

That graphs have been obtained from experimental and numerical have been shown below. The graphics is shown in figure 5 as overlapped to observe more clearly the difference between experimental and numerical studies.

It is given graph comparing with experimental and numerical in terms of torque in gasoline engine. (Figure 5.)

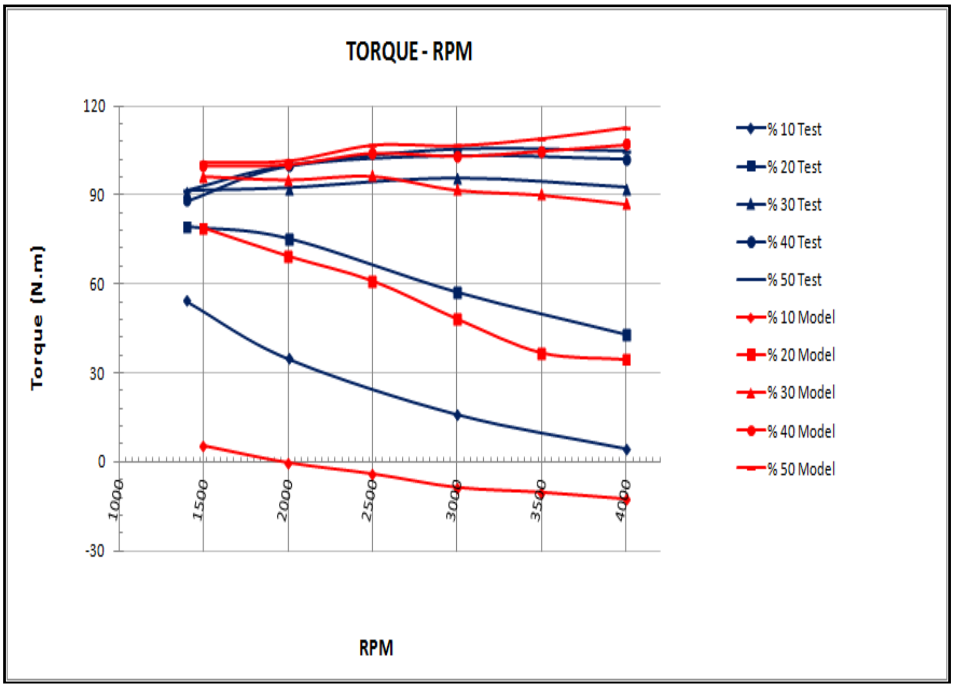

Figure 5: Engine speed – torque and comparison of experimental and numerical studies

Engine shows different responses at %10 and %20 throttle openings, because air-fuel blend is entered as very little. This condition is caused that turbulence of combustion is formed unexpectedly different. As it has seen, engine torque makes the peak point between 2500 rpm and 3000 rpm under load conditions where continuity can be achieved more easily. That is, in terms of performance, the highest value for those conditions is achieved. This result may not always be true for the 10% and 20% throttle openings due to the reasons mentioned earlier. After 3000 rpm, torque values decreases due to increase of friction and thermal losses. Action of torque values associate for experimental and numerical studies. Model results at increased throttle openings are even closer to experimental results. Even so, because of heat transfer, friction losses and combustion model selection model, results are shown below the experimental results for all throttle openings. In compare of experimental and numerical results, there are deviations due to physical conditions in experimental studies. Variability of the temperature and moisture content of the environment, heat transfer and friction losses, failure to achieve temperature, density and continuity of engine fluids such as cooling water, fuel and oil can affect the experimental results. The overlap of engine catalog, experiment and model results at these levels is considered as an analogy to the validity of numerical study.

As shown above, it is presented some similarities between experimental and numerical results.

5. Conclusions

In this study, effects of both experimental and numerical studies on the engine performance as a function of engine speed have been revealed and evaluated. The main reason for the differences;

The cycle executes in a closed system

- Heat transfer losses of the system
- Friction losses of the system
- The high octane number of gasoline
- The high thermal efficiency of gasoline
- The high minimum calorific value of gasoline
- Intake air pressure is 1 Atm
- Cylinder pressure equal to atmospheric pressure in exhaust stroke
- Advance angle is ‘0’ in combustion

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