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SIMULATION OF EFFECT OF INJECTION STRATEGIES ON PERFORMANCE OF A SPARK IGNITION ENGINE

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Abstract- Since the discovery of the fuel powered engines, tons of studies have been focused on enhancing the performance and effectiveness of the engines. In the very recent decades, there have been concerns with respect to the ecological impacts of contaminations emission by engines, and consequently, emphasized the need to utilize systems to improve fuel burning efficiency and lower engine related pollution. Direct, indirect and Port Fuel Injection gasoline injection system, have played a major role to increase fuel economy with cleaner emissions. In order to track the effect on the performance of the spark-ignition (SI) engine, three fuel system strategies were experimented using a simulation Lotus Engine software. Spark engine, one cylinder, four-stroke, various injection fuel systems, and changing compression ratios are the engine characteristics used in this modeling. The research has been done at various speed levels to determine the performance changes for these levels. The results show that when comparing between a GDI and MPFI fuel system with variable compression ratios between 10 and 12 the brake-specific fuel consumption value of GDI system was about 3% lower than the MPFI. There has also been a 6% increase in volume efficiency and a 2% increase in brake power.

Keywords: Multi Port Fuel Injection (MPFI), Gasoline Direct Injection (GDI), Lotus Engine Simulation.

1. INTRODUCTION

The current difficulties with spark ignition engines contain diminishing fuel utilization and emissions level. A few arrangements are attempted via auto makers, amid which fuel immediate injection system is painstaking by way of an acceptable strategy. In contrast to port type of fuel system engine, the direct injection engine displays a pinnacle potential in diminishing fuel utilization, whose can be attributed to the various aspects.

In the first place, the direct injection GDI technology can effectively address the port divider wetness issue that is inherent in the engine's port fuel injection setup, consequently working on the cold beginning execution and decreasing the fuel utilization and unburned hydrocarbon exhaust discharges during the engine operation cold and load. Second, the choked GDI arrangement of the engine can significantly diminish the pumping losses misfortunes associated with choking under fractional burdens. Third, delineated lean burning acknowledged by the GDI system can likewise get better motor productivity because of the increment of the particular hotness proportion of the blends and the decrease of hotness move.

Additionally, the impact of charge cooling of injection during acceptance stroke develops the volumetric effectiveness and diminishes the in-chamber temperature level toward the finish of pressure stroke which permits the use of a greater pressure proportion to acknowledge higher brake thermal efficiency. Furthermore, postponed, delayed injection in a gasoline direct of system injection system engine suction charge layer by a poor blend nearby the chamber wall holds the potential capacity to lessen the way of the end-gas auto-start [1-5]. indicate that the double-stage inoculations through suction strike could remove great hit by decreasing spray impingement on the cylinder lining or piston top. Additionally, it was suggested that a new double-fuel SI burning connotation could be achieved by putting GDI gasoline in the chamber to create the desired mixture and liquid alcohol fuel into the suction port to create a small temperature poor standardized charge.

This would result in a high compression ratio for the engine [6-7]. They inferred that engine execution could be improved by utilizing the GDI system. As indicated by Shim, et al. [8]. The GDI fuel infusion system further develops motor execution as far as lessening fuel utilization and controlling level emanations. [9] The direct injection fuel infusion scheme is further convoluted in plans and needs more proportion command over the fuel infusion processes and the combination of the air-fuel proportion than the MPFI system. This is on the grounds that, rather than pre-blending mixture fuel with air, fuel is quickly infused into the burning combustion room having a higher-pressure proportion than the MPFI system [10-13]. The point of this model investigation is to foresee the spark explosion engine's presentation, through a model study, involving Lotus programming to concentrate on various injection system impact the exhibition of engines.

2. MODELLING

2.1. Engine Specifications

A model study had been completed on the application of GDI and MPFI systems for little four-strokes single-chamber engines. The point-by-point determinations of the test engine is summed up in Figure 1 and Table 1. The engine model is built using these engine specifics. For engine portrayal resolves, every one of the aspects in lotus programming were thought of. Foreseeing and assessing the ignition, stream of gas and motor execution are the fundamental points of this software.

Table 1. Engine qualifications

N	Part Name	Value	N	Part Name	Value
1	Cylinder	1	6	Density (kg/litre)	0.750
2	STROKE	4	7	Calorific Value of Fuel (kJ/kg)	43000
3	Bore	90 mm	8	Firing order	4-2-1-3
4	Stroke Length	85 mm	9	Fuel System	GDI, PDI
5	Compression Ratio	4-17.5	10	Con-Rod Length	130 mm

The subsequent equations were utilized in computing the performance characteristics for an engine [14].

$$bp = (2\lambda \times N \times Tb)/(60 \times 1000) \quad (1)$$

This is the engine's measured output. It is often achieved using a power absorption device, such a brake or dynamometer, that may be loaded to allow the engine's torque to be measured. The formula for the break power is:

$$bp = 2pNT$$
$$bmep = bp(2NT)/(vN) \quad (2)$$

The observed bp would be equal to the $bmep$ (Pb), which is the mean effective pressure acting on the pistons, i.e., $bp = Pb\ Al$ active cycles / min.

$$bsfc = mf / bp \times 3600 \quad (3)$$

To generate energy, an internal combustion engine needs both fuel and air. On a dynamometer, the fuel consumption is often expressed as a mass flow rate in kilograms per second (kg/s). Because it is unclear how much power we can derive from the fuel, this parameter cannot be used to gauge the engine's efficiency. Therefore, we can calculate the brake-specific fuel consumption (kg/J) by dividing the fuel mass flow rate (kg/s) by the engine output power (W):

$$m_{(a,act.)} = \langle 12\sqrt{h}\ /3600 \times \rho_{air} \rangle \quad (4)$$

Engine air consumption measured in milliliters per second at ambient temperature and atmospheric pressure, or Pa (mbar) Temperature (K) is to area of orifice (m^2).

$$m_f = \langle vf \times 10^{-6} / 1000 \times \rho_{air} \rangle \quad (5)$$

where, m_f is the mass of fuel spent per unit of time. A model of a SI engine was fabricated and researched.

The model is shown clear in Figure 2. The simulation begins with an inlet arrangement of the engine, including bay lines, ports and valves, throttle and the enter plenum. On the discharging part, exhaust valves, choke and plenum. Ordinary atmospheric climate defined as limit conditions for both admission and exit of the models. The created models were reenacted under consistent state circumstance, where the engine speed (rpm) begins from (1000 to 3500 rpm) with an increase of 500 rpm.

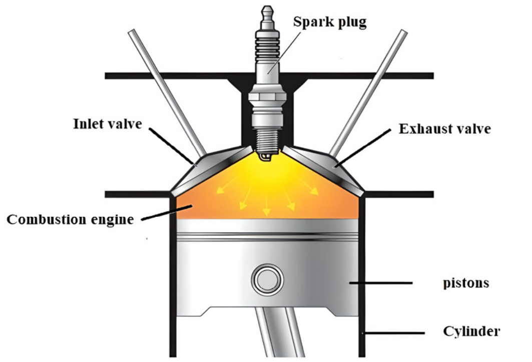

Figure 1. Traditional gasoline assembly of an engine

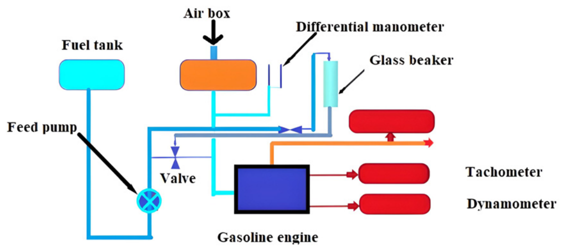

Figure 2. Lotus's schematic for an engine model

2.3. Injection Strategies Model

The procedure utilized for the study is comparative sort of simulation-based study on where two systems are simulated under similar test conditions but considering each one standard distinctions in working and design.

2.4. Test Circumstances

The test is conducted for an rpm range of 1000 to 3500 with an increment of 500 rpm under normal temperature and pressure circumstances once all the aforementioned parameters have been defined.

2.5. Classifications for Gasoline Injection

Fuel injection systems come in a wide variety. A fuel injection system is another name for a gasoline injection system. Throttle body injection, multiport injection, indirect injection, and direct injection are the most common fuel injection systems used in automobiles. On top of the engine, in a throttle body assembly, are installed throttle body injection injector nozzles. Multiport port injection each cylinder intake aperture has injectors positioned there. An indirect injector fills the intake manifold with gasoline. Indirect fuel systems are the norm. Injection Direct gasoline is sprayed right into the combustion chambers of the engine and utilized by every diesel injection system [26-29].

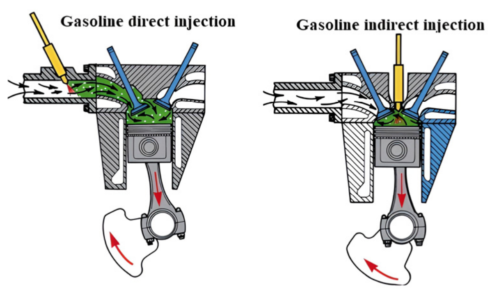

Figure 3. Types of injecting fuel sprays

3. RESULTS AND DISCUSSION

1) A more sophisticated variation of multiport systems is gasoline direct injection (GDI), in which fuel is injected directly into the combustion chamber rather than through the intake port. Direct injection boosts fuel economy, reduces pollutants, and improves combustion efficiency.
2) Although both systems use electronic fuel injectors to dispense fuel into the engine, there is a distinction in the location of the fuel's discharge. In port injection systems, the intake ports are sprayed with.
3) Throttle body injection, port fuel injection, sequential fuel injection, and direct injection are the four fundamental types of fuel-injection systems now in use. The main advantages of direct-injection technology are somewhat higher power and better fuel economy for most applications.

3.1. Performance Characteristics

Feeding system fueling are analyzed for comparison of their execution yields, which are volumetric, power, mean impact pressure and fuel consumption. The comparison results are shown in the following figures.

3.2. Fuel Systems Influence on Volumetric Efficiency

Figure 4 analyses volumetric proficiency versus different motor rates. the outcome shows that at lower speeds saw that volumetric effectiveness of GDI motors is higher than that of MPFI motors at fluctuated comp proportions. Although the volume of blend entering the chambers increases at higher velocities increments, plus the air -eco-friendliness increments; particularly when the GDI fuel system is utilized, prompting an improvement in the volumetric. When the engine speed rises, it takes less time to close and open the valves, resulting in more airflow and fewer friction losses. This results in the introduction of a lower charge mixture, which increases volumetric efficiency at higher engine speeds [21, 22].

The MPFI fuel system has displayed better brake power beginning from 1000 rpm upwards than for the direct fuel Injection. The best result was at 3500 rpm with its brake power about 15 kW then it begins to diminish when the engine speed increments, whereas MPFI actually giving power at that stage, which concurs with the what M.F. Hushim, et al. [13] found. Accelerating incited an extension in the strain differential between the motor chamber including increasing new charge mass movement and energy discharge at the start of the inlet stroke.

Figure 6 shows the varieties of brake torque observations among MPFI and GDI fuel system. Where brake power for MPFI system is higher at all engine speed rates with the most delivered brake power nearing 41 N.m at 3500 rpm at pressure proportion esteem equivalent CR 10. While the created brake power for GDI system is 39 N.m at 3500 rpm at the same pressure proportion. MPFI system has shown that it delivered better brake power contrasted with the GDI system.

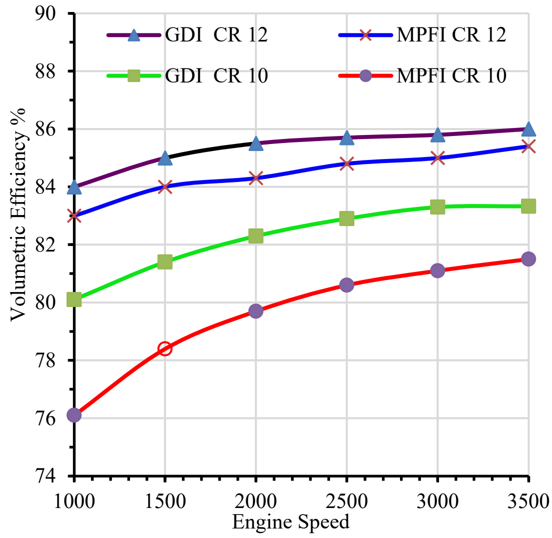

Figure 4. Volumetric efficiency of the GDI and MPFI systems at various engine speeds

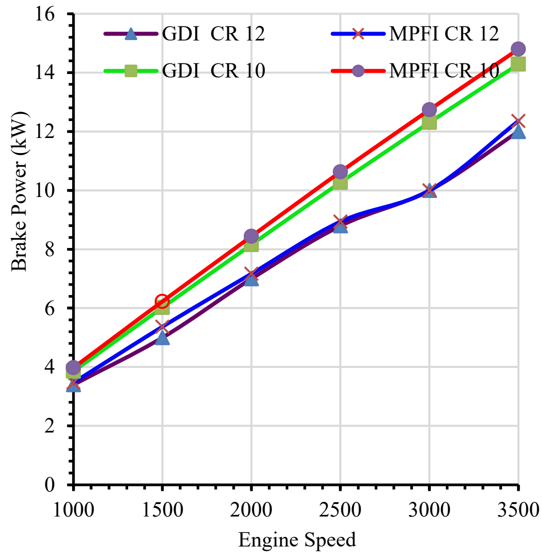

Figure 5. GDI and MPFI systems in relation to brake power at various engine speeds

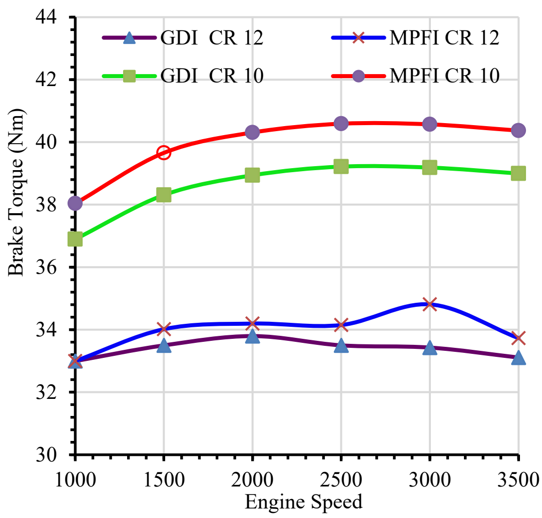

Figure 6. GDI and MPFI systems react to brake torque at various engine speeds

Figure 7 shows a contrast of *BSFC* between various filling fuel systems MPFI and GDI systems. Usually, for all types of injection to require low upsides of fuel consumption. Based on Figure 7, the MPFI systems consumes more fuel in opposite to GDI at all engine velocities particularly at the start of activity and higher rpm. There is additionally a drop in *BSFC* from 2000 to 2500 rpm for both engines demonstrating that at speeds close to 2000 rpm both motors have the least *BSFC* which is in agreement with the results of Y.S. Shim, et al. [9].

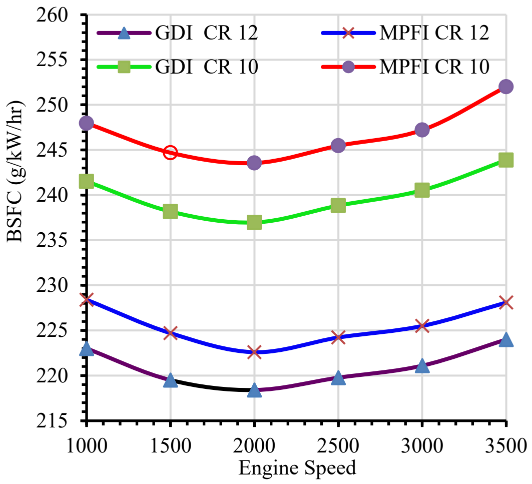

Figure 7. Fuel usage of the GDI and MPFI systems at various engine speeds

Figure 8 shows the influence of *bmep* behavior for GDI and MPFI fuel systems as displayed in. From the illustration, it tends to be noted that the scheme of the (*bmep*) follows the brake torque trend. justifying to be used to evaluate the engine working, (*bmep*) as it is an indication in other criteria it involved in. This shows fixed pressure effects on the piston over expansion stroke which creates power conveyed by the engine. For a fuel gasoline powered engine, it is capable to produce high *bmep* to create rise in power per in-chamber pressure. as shown in Figure 7 meaning, it has been set that the MPFI system has the ability of giving a rise in (*bmep*) in contrast with the Direct Injection fuel systems.

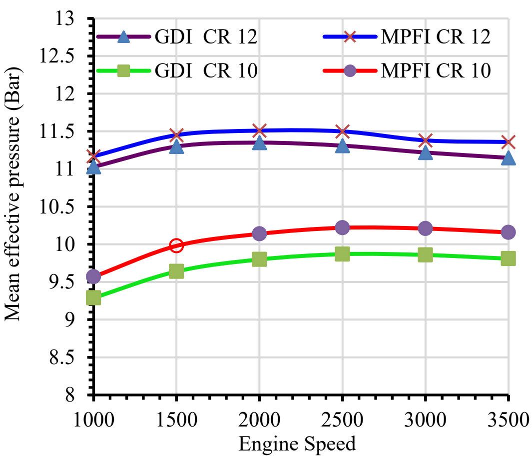

Figure 8. GDI and MPFI systems interact with the brake pedal pressure at various engine speeds

4. SUMMARY AND PROGNOSIS

The simulation by lotus engine programming of injection techniques contextual investigation conditions is introduced to observe the outgiving of the engine, fuel utilization and different boundaries. The single, four-stroke, gasoline engine characteristics used in this presentation are and variable pressure proportions. The simulation examination has uncovered that the GDI system had the best injection methodologies associated with MPFI engine at fluctuated pressure proportion (*CR*: 10 and 12). The results of simulation study are encouraging for additional investigations in a conservative method that has been not difficult to utilize, prudent, and has stayed away from the troublesome work expected in tests, that had been utilized. The findings of this study are summed up as follows:

1. Fuel injection systems have a significant influence on the SI engine performance.
2. The simulation program is a trustworthy method to accurately forecast when the engine SI will operate. An improvement of volumetric productivity has been accomplished at GDI work *CR* = 12 and *CR* = 10 when compared with the MPFI.
3. Brake power (bp) and Brake torque have improved with greater fuel Injection. The extreme increment (*bp*) reached, was 16% and (BT) 41% for gasoline fuel with MPFI system *CR* = 10 when compared with the GDI system,
4. An enhancement of 4% for fuel depletion was achieved at GDI system *CR* = 12 in comparison with the MPFI system at the same compression ratio.
5. When comparing the GDI system to the MPFI system at the same compression ratio, a 4% improvement in fuel depletion was made.

The *bmep* has improved with greater gasoline fuel at various speeds of the engine. The *bmep* has improved by 11. 5% when running the engine by MPFI system *CR* = 12 when compared with the GDI system *CR* = 12.

5. CONCLUSION

A high tumble flow design, cooled EGR, high compression ratios, over-expansion cycles with VVT, boosting, high-pressure injection, and other design elements have improved GDI engines over the past 20 years to make them more efficient and provide clean combustion. The best methods for reducing deto-knock have been determined to involve enhancing the fuel/oil characteristics and improving the combustion system, while fuel impingement and pool fire phenomena are principally responsible for in-cylinder soot generation. Therefore, based on the research above, it is clear that the MPFI and GDI engines used in the simulations have considerably different performance characteristics. Though a larger disparity is anticipated in practice, we can still see that some practical understandings could be drawn from the simulations. Additionally, GDI practically has different physical characteristics from MPFI engines, making it impossible to compare them directly. Nevertheless, this research was made to help us comprehend some important distinctions based on the software results found between these two engines.

NOMENCLATURE

1.Acronyms

SI. Engine Spark-Ignition Engine

2. Symbols / Parameters

bp: Brake Power
BSFC: Brake Specific Fuel Consumption
bmep: Brake Means Effective Pressure of Engine
η_v: Efficiency Volumetric of Engine
$m_{(a,act.)}$: Air Consumption
m_f: Fuel Mass Flow Rate

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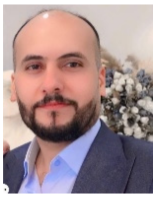

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