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Simulation based comparative study of Gasoline Direct Injection and Multi-Port Fuel Injection Engines

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Abstract— Since the discovery of IC engines, decades of research have been focused on improving the performance and efficiency of the engine. In the recent decade, there have been increasing concerns regarding the environmental effects engines have and hence there is a need for more fuel-efficient and fewer emissions in an engine. GDI engines have played a major role in the past decade to improve upon the fuel economy with cleaner emissions. On the other hand, a PFI engine that has a similar fuel system is used more widely in the market in high-performance vehicles. Though the market for GDI engines is increasing, it has not made a mark in regions other than Europe and the US where the emission norms are rigid. In this case, we have compared both these engines having similar dimensional attributes using a standard KTM Duke 390 engine which is a PFI engine and simulated the results using Lotus engine simulation software. The research has been carried out at various speed levels to observe the performance changes for changing RPMs. As this is a simulation-based study the results observed could inaccurately depict the practical scenario but these results could help in understanding the difference in these two fuel systems to the basic level.

Index Terms— Gasoline Direct Injection, Port fuel Injection, KTM Duke 390, Lotus Engine Simulation, Engine Performance.

1 Introduction

THIS research aims to develop a comparative study between various aspects of GDI engines and MPFI engines. In commercial terms MPFI engines are widely used due to their low cost and high power output whereas GDI engines being more fuel efficient and develop lesser emissions compared to most of the commercial engines.

This study majorly focuses on the comparison between the MPFI engines and GDI engines based on their performance criteria like Brake Torque, Brake Power, BMEP, BSFC and Volumetric efficiency keeping the dimensional attributes same across both the engines. This is a simulation based study using software named Lotus Engine Simulation V 5.07 developed by Lotus Cars Ltd.

The main objective of this study was to understand the difference in the performance criteria of two engines which are similar in architecture but serve different purposes like MPFI engine which gives a high power output and hence being less fuel efficient whereas GDI engine is more fuel efficient and produces cleaner emissions compared to MPFI.

The research aims to prove the above practical scenario though the simulation done on a standard KTM Duke 390 engine which is a single cylinder MPFI engine.the article is being submitted to and the manuscript identification number. Click the forward arrow in the pop-up tool bar to modify the header or footer on subsequent pages.

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2 Methodology

The methodology used for the research is comparative type of simulation based study where two systems are simulated under similar test conditions considering its principle differences in design and working. In this case MPFI engine and GDI engine are the two systems under consideration and the simulation is carried in as standard industrial purpose engine simulation software called Lotus Engine Simulation.

3 Research Design

Initially as a prerequisite to the simulation we need to gather the dimensional and material data for various parameters for the components like inlet valve, intake port, engine cylinder, outlet valve, outlet port. These data have to be entered into the software and then the test conditions have to be declared and later the simulation is to be performed.

The results of the simulation have to be compared and then it is to be analysed. Finally the research has to be concluded and compared with the research aims

4 Tools

Initially to gather the physical data from the KTM Duke 390 engine measuring tools such as bore gauge and vernier callipers and later the major tool used was Lotus Engine Simulation software where the Simulation of both the MPFI engine and GDI engines were carried out

5 Procedure

First the various physical measurements of the KTM Duke 390 engine were done. It mainly involved parameters from components like inlet port and valve, engine cylinder and exhaust port and valve. Later these values were fed into the Lotus Engine Simulation Software.

Step 1: Initially a standard engine module is imported from the side panel

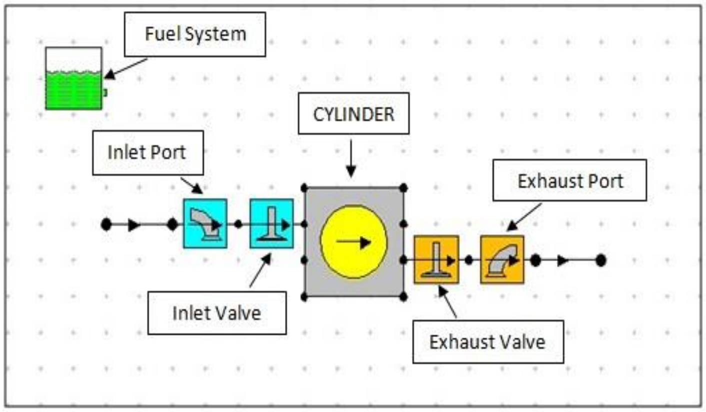

Figure 2: Full engine model in LES workspace

Step 2: Then the type of fuel is and fuel system is decided. In this case the fuel remains the same for both the iterations i.e. Gasoline and the fuel system is iterated between Port injection and direct injection

Step 3: In the engine model the Cylinder parameters of KTM Duke 390 are entered

TABLE 1
Dimensional Parameters of the Engine

Label	Duke 390 Cylinder
Bore (mm)	89.0000
Stroke (mm)	60.0000
Cyl Swept Volume (l)	0.37327
Total Swept Volume (l)	0.37327
Con-rod Length (mm)	105.00
Pin Off-Set (mm)	0.00
Compression Ratio	12.88
Clearance Volume (l)	0.031420
Phase (ATDC)	0.00

Step 4: The parameters for Port Flow Data and Intake Valve data is entered

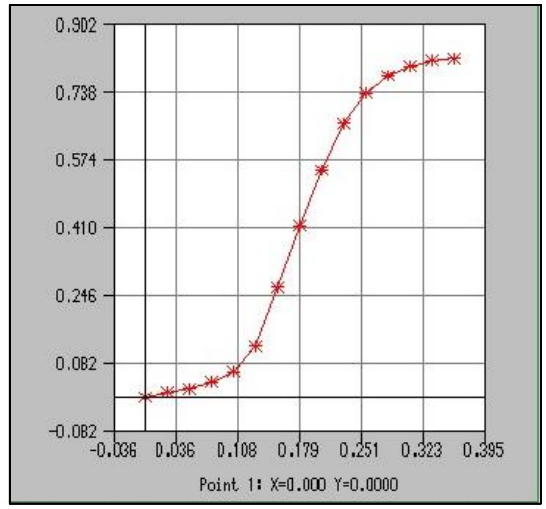

Figure 3: Graph of Valve lift vs. Flow Co-efficient for intake port

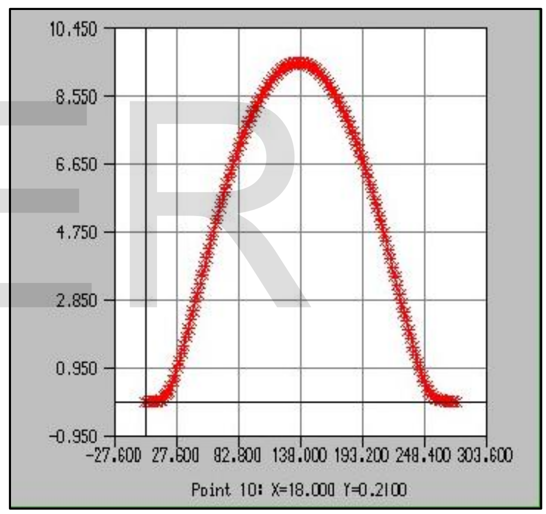

Figure 4: Graph of CAM angle vs. Lift for intake valve

Step 5: Similarly the Port flow data and Exhaust valve data is entered

Step 6: Finally the test conditions are defined which remains same for both PFI and GDI engines

6 Test Conditions

After defining all the above parameters the test is simulated for an RPM from 1000 to 10500 with an increment of 500 RPM under normal temperature and pressure conditions.

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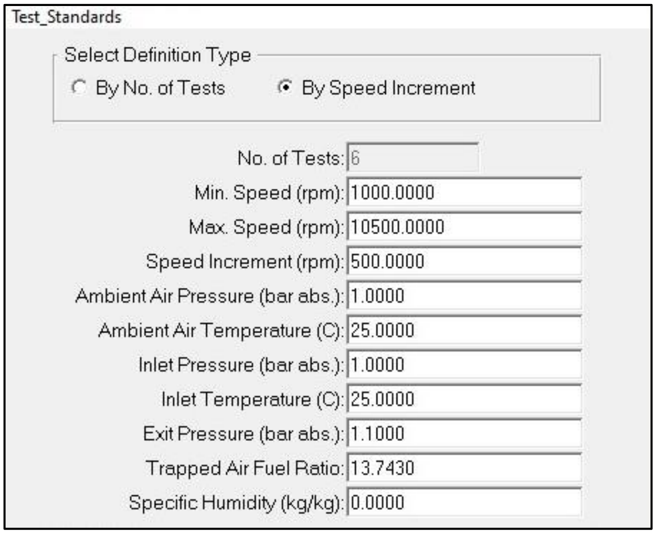

Figure 5: Overall Test Conditions for both the engines

7 Results

After running the Simulation for the above test conditions the Results were obtained and manually plotted in the tables below.

Table 2 contains the Performance results for MPFI engines with performance data entered against the speed from 1000 to 10500 RPMs with an increment of 500, while Table 3 contains the Performance results for GDI engines.

TABLE 2
Results obtained for MPFI Engine

Speed (rpm)	B.Power(kW)	B.Torque(Nm)	BMEP(bar)	BSFC(g/kw/hr)	V.Eff(%)
1000	3.47	33.17	11.17	227.39	83.1
1500	5.34	34.02	11.45	224.18	84.1
2000	7.16	34.2	11.51	223.64	84.3
2500	8.94	34.15	11.5	224.22	84.4
3000	10.62	33.81	11.38	225.52	84
3500	12.36	33.73	11.36	227.1	84.4
4000	13.89	33.17	11.17	229.33	83.8
4500	15.47	32.83	11.05	231.48	83.7
5000	17.19	32.83	11.05	233.7	84.5
5500	18.88	32.78	11.03	236.28	85.3
6000	20.42	32.49	10.94	238.96	85.6
6500	21.78	32	10.77	242.43	85.5
7000	23.16	31.6	10.64	245.92	85.7
7500	24.75	31.51	10.61	249.51	86.6
8000	26.42	31.54	10.62	253.07	87.9
8500	28.09	31.55	10.62	256.97	89.4
9000	29.79	31.61	10.64	261.06	91
9500	30.9	31.06	10.46	266.92	91.4
10000	31.59	30.17	10.16	273.24	90.9
10500	31.53	28.67	9.65	282.3	89.1

TABLE 3
Results Obtained for GDI Engine

Speed (rpm)	B Power (kW)	B Torque(Nm)	BMEP(bar)	BSFC(g/kw/hr)	V.Eff(%)
1000	3.43	32.77	11.03	222.39	84.3
1500	5.27	33.57	11.3	219.47	85.3
2000	7.06	33.71	11.35	219.07	85.5
2500	8.79	33.59	11.31	219.77	85.4
3000	10.47	33.32	11.22	221.11	85.3
3500	12.14	33.11	11.15	222.8	85.4
4000	13.7	32.7	11.01	224.9	85.1
4500	15.15	32.16	10.83	227.33	84.6
5000	16.71	31.91	10.74	229.78	84.9
5500	18.36	31.89	10.73	232.26	85.7
6000	19.96	31.77	10.69	235.03	86.4
6500	21.28	31.26	10.52	238.47	86.3
7000	22.5	30.69	10.33	242.3	86.1
7500	23.82	30.33	10.21	246.2	86.4
8000	25.27	30.16	10.15	250.22	87.4
8500	26.85	30.17	10.16	254.34	88.8
9000	28.53	30.27	10.19	258.62	90.6
9500	29.65	29.81	10.03	264.62	91.3
10000	30.45	29.08	9.79	271.23	91.3
10500	30.45	27.7	9.32	280.31	89.9

8 Analysis of Results

From the numerical data obtained in the Results we can compare the simulations of both MPFI engine and GDI engine using the Graphs as below.

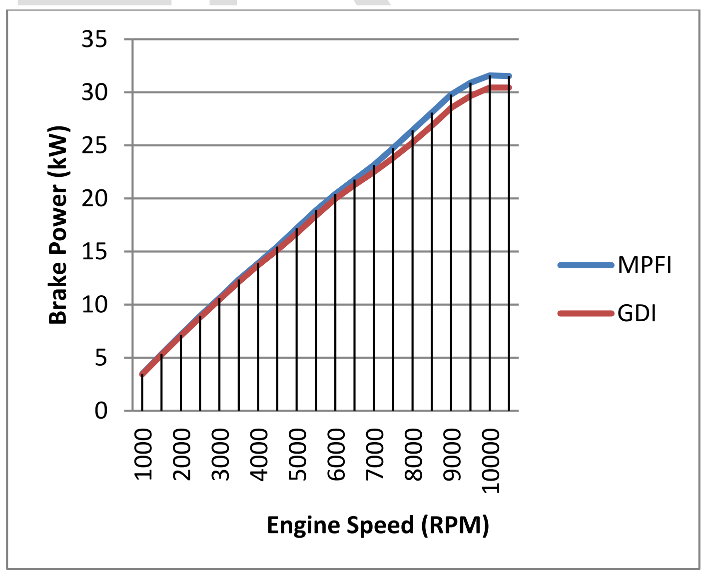

Figure 6: Comparison of Brake Power (kW) between MPFI and GDI engine

In Figure 6, we can see that for RPMs from 1000 to 3500 the Brake Power increases linearly and remains the same both for MPFI and GDI engines. The lines start diverging after 4000 RPM up until 10500 RPM where we see, for higher RPMs MPFI produce more

Power compared to GDI engine. At 10500 RPM we observe that MPFI produces 3.5% more Brake Power (kW) than GDI engine.

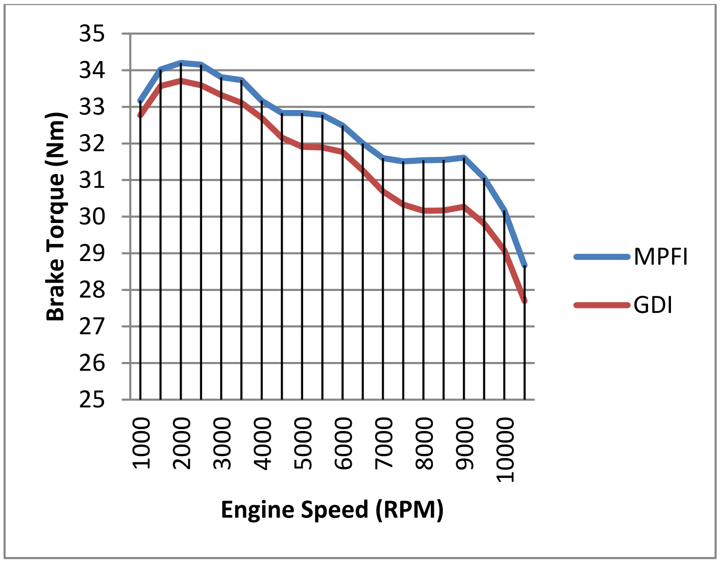

Figure 7: Comparison of Brake Torque (Nm) between MPFI and GDI engine

In Figure 7 both the engines follow similar but independent paths. MPFI has higher Brake Torque at all the RPMs compared to GDI. At 8000 RPM we see that Brake Torque of MPFI is 4.4% higher than that of GDI engine which is the maximum difference. Hence this states that MPFI has higher torque at all the speeds.

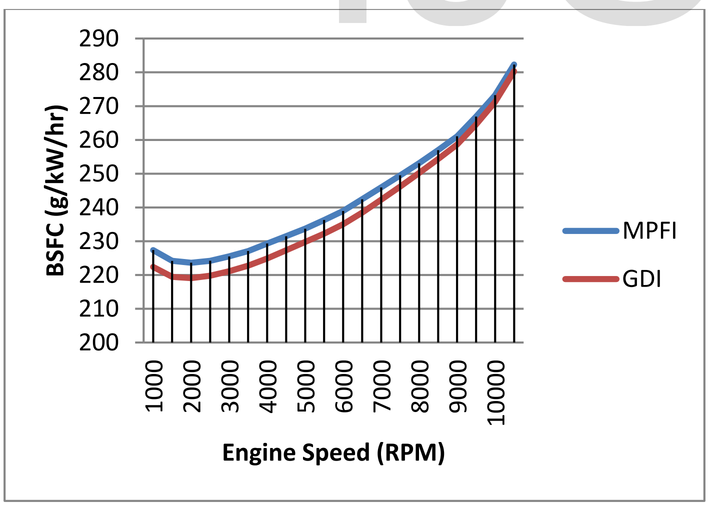

Figure 8: Comparison of BSFC (g/kW/hr) between MPFI and GDI engine

In Figure 8 we see that at lower RPM there is 2.2% higher fuel consumption in MPFI compared to GDI engine. At increasing RPMs we see that the graph is converging. There is also a drop in BSFC from 1000 to 2000 RPM for both the engines proving that, at speeds near 2000 RPM both the engines have the lowest fuel consumption.

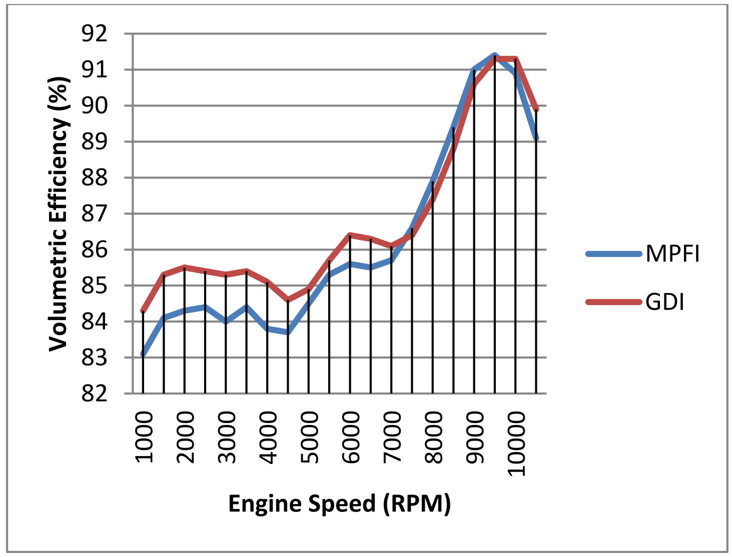

Figure 9: Comparison of Volumetric Efficiency (%) between MPFI and GDI engine

In Figure 9 we see that initially at lower speeds we see that volumetric efficiency of GDI engines is higher to that of MPFI engines. We observe that at higher RPMs above 7000, the MPFI engine is more efficient. For both the engines there is a sudden rise in efficiencies above 7000 RPMs. Both the engines reach their Peak efficiencies at 9000 RPM and then a sudden decline in volumetric efficiency is observed in both the engines.

9 Conclusion

Hence from the above analysis we could see very significant difference between the performance characteristics of MPFI engine and GDI engine involved in the simulations. Though a larger difference is expected in practical case we can find that the simulations were able to conclude some of the practical understandings.

Moreover GDI practically have different physical attributes and cannot directly be compared to MPFI engines but this research was designed for us to understand some key differences based on the software results obtained between these two engines.

References

[1] A. R. Shinde[1], J. B. Patil[1], N. K. Chougule[1], S. H. Gawande[2], "Design and Analysis of Performance Oriented Road Legal Muffler".

[2] Nicholas James Beavis, "Numerical studies of gasoline direct injection engine processes".

[3] Shijin Shuai[1], Xiao Ma[1], Yanfei Li[1], Yunliang Qi1[1], Hongming Xu1, "Recent Progress in Automotive Gasoline Direct Injection Engine Technology".

[4] Zhi Wang, Jian-Xin Wang, Shi-Jin Shuai, Guo-Hong Tian, Xinliang An, and Qing-Jun Ma, "Study of the effect of spark ignition on gasoline HCCI combustion".

[5] Shijin Shuai[1], Xiao Ma[1], Yanfei Li[1], Yunliang Qi[1], Hongming X[1], "Recent Progress in Automotive Gasoline Direct Injection Engine Technology".