Analysis of Superchargers Implemented In Automobiles – A Review

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Abstract— **The following review paper shows the different analysis done by several researchers in the topic of Superchargers when implemented in automobiles. This review paper highlights the efforts done to determine the relationship between the mechanical action of a high-speed supercharger with the engine performance. Moreover the comparison between the performance of supercharged engine and naturally aspirated engine is also shown. The option for waste heat recovery can also be an important parameter to improve the cycle efficiency. Further several modifications in the design of combustion chamber have been proposed for enhancing the engine's performance.**

Keywords— *Naturally-aspirated engine, supercharged engine, roots supercharger, compression ratio, combined air cycle.*

I. INTRODUCTION

The four stroke, spark ignition (SI) engine pressure–volume diagram (p–V diagram) contains two main parts. They are the compression–combustion–expansion (high pressure loop) and the exhaust-intake (low pressure or gas exchange loop). The main reason for decrease in the cyclic efficiency at part load conditions is the flow restriction at the cross sectional area of the intake system. During the working cycle by partially closing the throttle valve, leads to increased pumping losses. Because of these factors, the pressure loop area which is important for a better combustion of fuel is greatly affected. Meanwhile, the poorer combustion quality, i.e. lower combustion speed and cycle to cycle variations additionally influence the pressure loop areas.

There are only three possible ways to improve the power output for an Internal Combustion Engine: - [5]

- Increasing the dimensions of the engine but it will cause increased weight and cooling problems.
- Increasing the speed of the engine but it is also not possible every time.
- Increasing the density of air entering in to the combustion chamber which increases the amount of oxygen and hence better combustion of fuel will be possible.

A supercharger is an air compressor that increases the pressure or density of air supplied to an internal combustion engine. This gives each intake cycle of the engine more oxygen, letting it to burn more fuel and do more work, thus increasing power. The motion for the working of the supercharger can be provided mechanically by means of a belt, gear, shaft, or chain connected to engine's crankshaft. The Fig. 1 shows the Roots supercharger (a type of supercharger generally used) connected to an Internal Combustion Engine. This type of supercharger possesses two lobes which contract the air entering into the combustion chamber. Hence the speed as well as the density of air will increase.

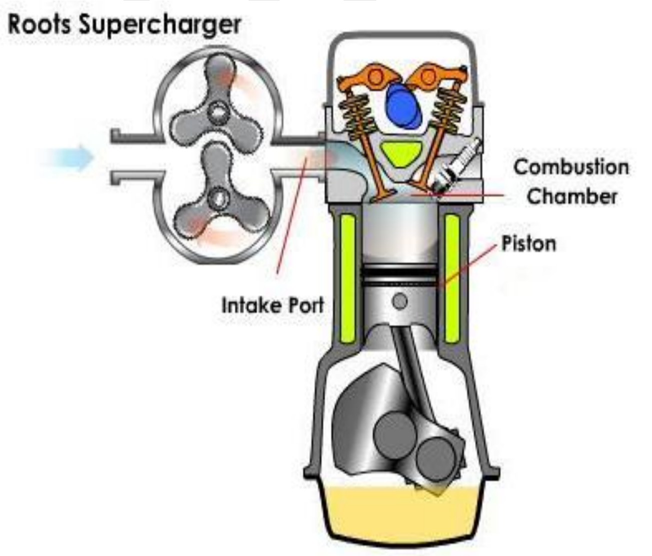

Fig. 1 Roots Supercharger connected to an internal combustion engine.

Implementing a supercharger with an internal combustion engine will reduce the exhaust emissions coming out of the IC engine. Also more amount of power can be generated using the same quantity of fuel which reduces the depletion of the conventional fuels such as petrol as well as diesel. Moreover, some modifications are needed within the combustion chamber to introduce a supercharger in order to achieve good combustion of the fuel.

II. LITERATURE REVIEW ON SUPERCHARGERS

M. Muhamad Zin, R. Atan, "Boosting Performance Enhancement For SI Engine - Experimental Study". [1]

In the following paper, the effects of pressure induced through the throttle on the performance of SI engine were studied. The acceleration of the operating speed depends on the air mass flow rate from the booster.

During the experimentation, the pressure was reached up to 4 bars as shown in Fig. 2, Fig. 3 and Fig 4. respectively. These figures show the effects of different pressure iterations with operating engine speeds. However on the other hand it remained at normal operating pressure which observed to be between 1 bar to 1.5 bar. The engine was run with a limitation of boundary speed and torque range. The engine could only tested up to 4500 rpm and the limit was strictly to follow to avoid unpredictable severe damage.

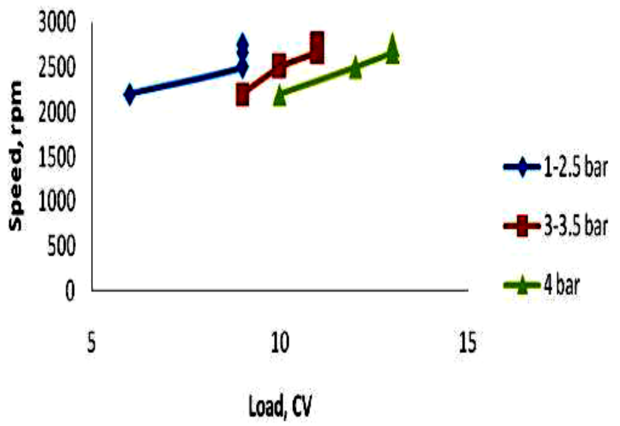

Fig. 2 Pressure iterations at Low operating speeds.

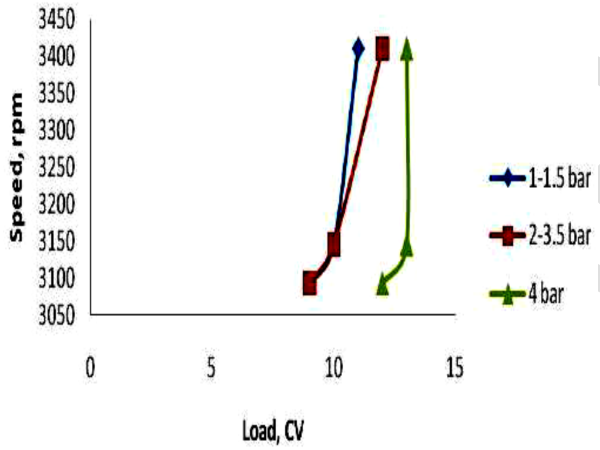

Fig. 3 Pressure iterations at Medium operating speeds.

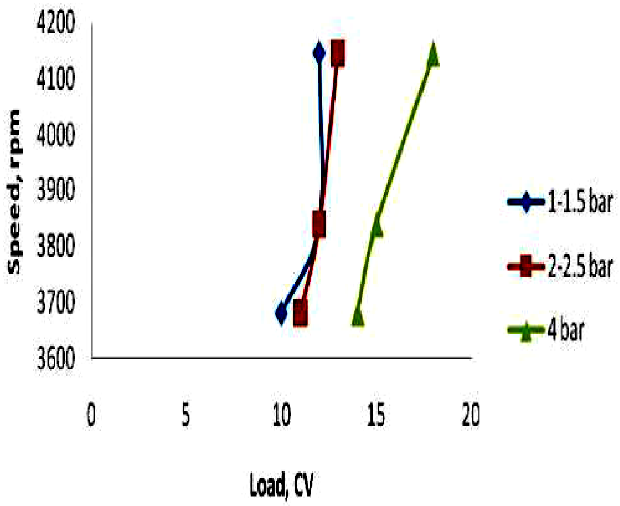

Fig. 4 Pressure iterations at High operating speeds.

Furthermore the authors also worked on finding the performance of naturally aspirated engine and supercharged engine by considering various parameters. Fig. 5 shows the torque comparison between natural aspirated engine and the supercharged engine. The trajectory however has influenced by uncertainty and disturbance Fig. 6 exhibits the results based on the optimum torque calculations from the result in Fig. 5.

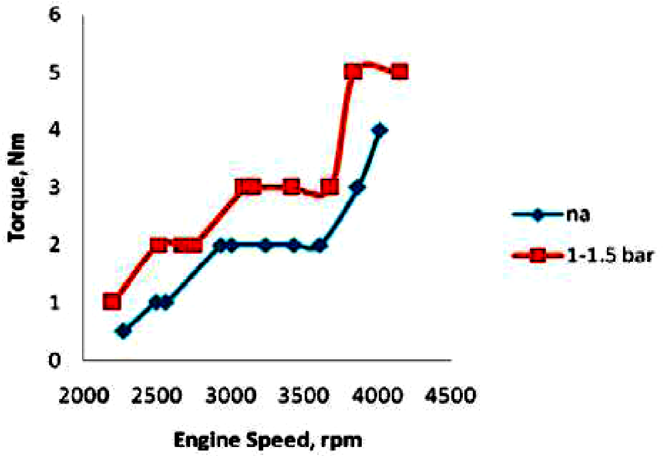

Fig. 5 Comparison of Torque with various engine speeds.

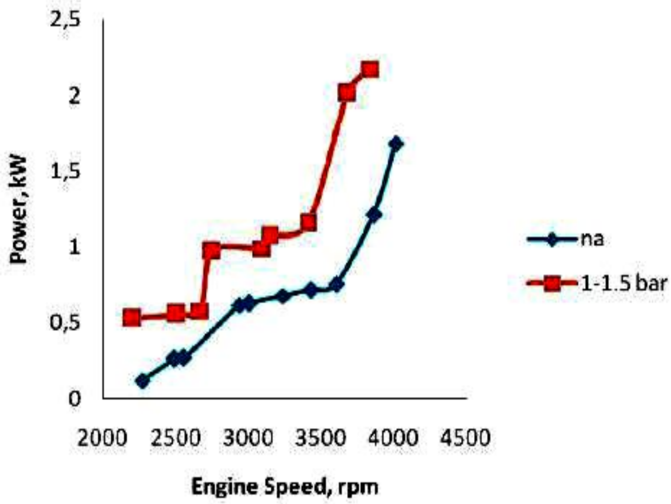

Fig. 6 Comparison of Power with various engine speeds.

From the results obtained we find that, the supercharged engine performance was mainly dependent on the mechanical loss to drive the supercharger at low speeds. In addition, at high speeds, the supercharged engine performance was more influenced by the compression ratio than mechanical loss.

Chang Sik Lee, Ki Hyung Lee, Dong Hyun Whang, Seo Won Choi and Haeng Muk, "Supercharging Performance of a Gasoline engine with a supercharger". [2]

In this paper the authors have worked on the roots super charger when implemented in four stroke IC engine. The results obtained are shown in Fig. 7 and Fig. 8 describe the effects of compression ratio on naturally – aspirated engine. The compression ratios for the performance of the engine were considered in the range of 8.3 to 9.3.

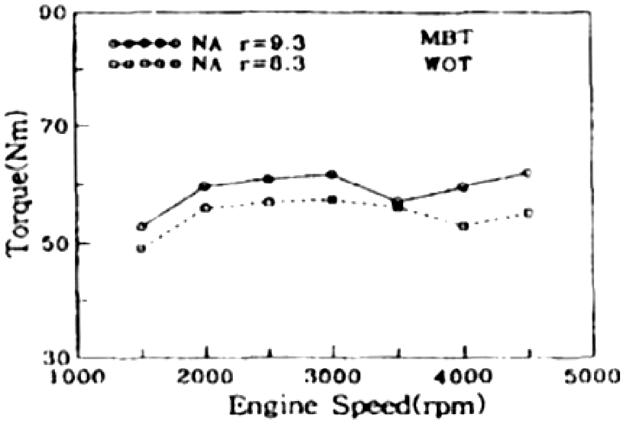

Fig. 7 Effects of Compression Ratio on Torque for a Naturally – aspirated engine.

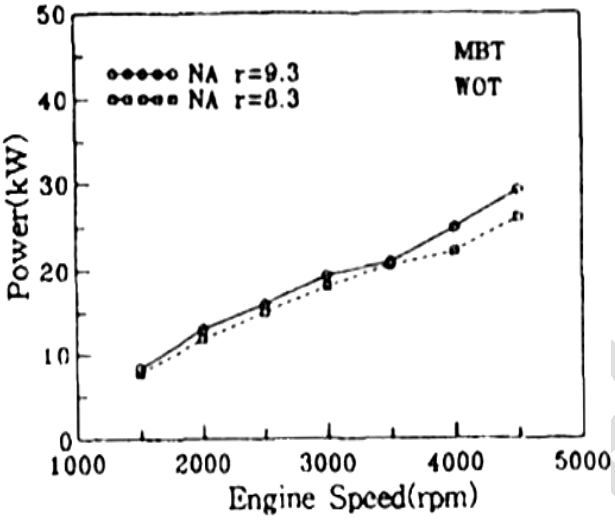

Fig. 8 Effects of Compression Ratio on Power for a Naturally – aspirated engine.

Also in the current work, the authors have compared the naturally-aspirated engine with the supercharged engine. The parameters selected for comparison were engine torque and power. Fig 9 and Fig 10 shows this comparison.

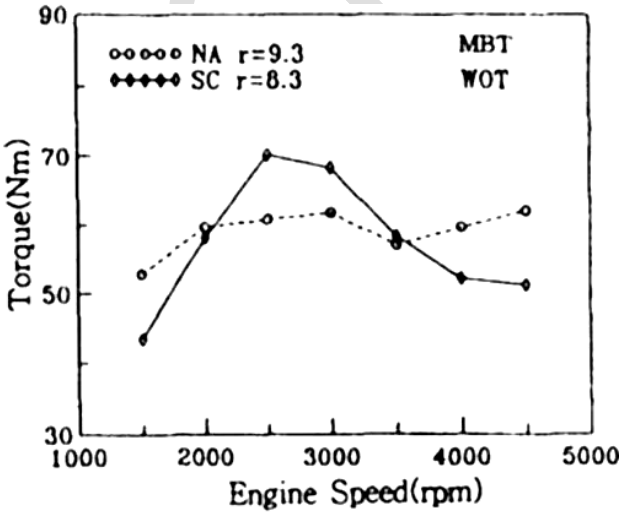

Fig. 9 Comparison of Naturally – aspirated engine and supercharged engine in terms of Engine torque.

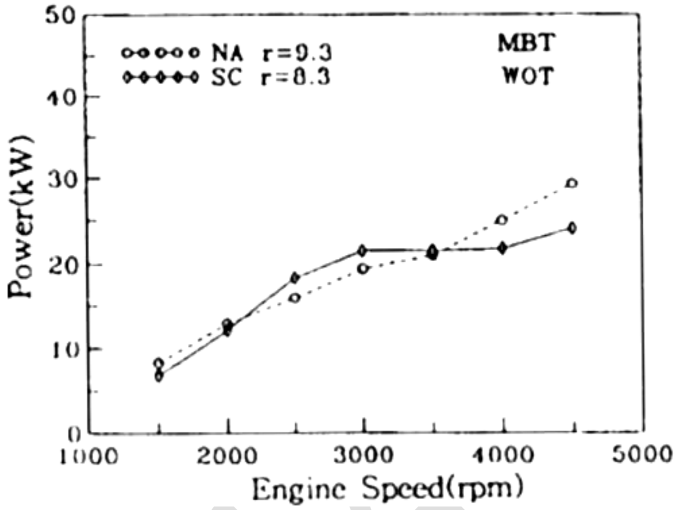

Fig. 10 Comparison of Naturally – aspirated engine and supercharged engine in terms of Power.

It was found that the effect of supercharger brought about the increase of the brake power and torque at the range between 2,000 rpm and 3,500 rpm. At the low speed range less than 1,500 rpm, the engine torque was decreased due to friction loss and mechanical drive loss of the supercharger. In the case of high range more than 4,000 rpm, the engine torque also decreased with the decrease in compression ratio.
Engine performance investigations using the supercharger indicate that the output and torque performance can be improved in comparison with the naturally aspirated engine at speed range from 1,500 rpm to 3,000 rpm in most of the cases.

Jianqin Fu , Qijun Tang , Jingping Liu , Banglin Deng , Jing Yang , Renhua Feng, “ A combined air cycle used for IC engine supercharging based on waste heat recovery”. [3]

The concept of waste heat recovery is also very important to reduce the consumption of fuel in case of IC engines. The Fig. 11 shows a modification in an IC engine which is supercharged and the heat of the exhaust is also utilized.

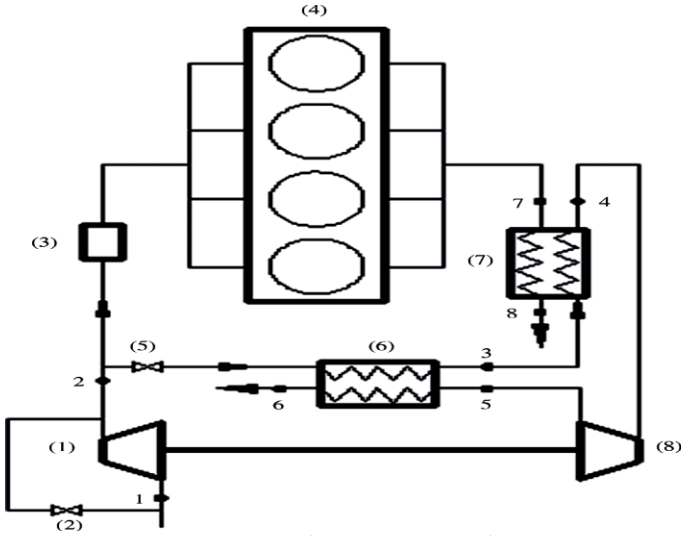

Fig. 11 Schematic Diagram of combined air cycle for I.C. Engine supercharging.

The list of the components in the schematic diagram is as follows - (1) Compressor (2) By-pass valve (3) Inter-cooler (4) I.C. Engine (5) Valve (6) Regenerator (7) Heat exchanger (8) Turbine. With the combined air cycle adopted, the energy balance of IC engine system is changed and redistributed. Owing to the change of PMEP (it is changed from negative to positive), the total fuel utilization efficiency of IC engine can be respectively promoted by 8.9% and 4.1% at most, when compared with the Naturally-aspirated engine and turbo charged engine.

Murari Mohon Roy , Eiji Tomita , Nobuyuki Kawahara , Yuji Harada , Atsushi Sakane, "Performance and emissions of a supercharged dual-fuel engine fuelled by hydrogen-rich coke oven gas". [4]

This paper presents the performance and emission analysis of a supercharged dual fuel engine. A four-stroke, single cylinder water cooled engine with the specifications as listed in Table 1 was used for the analysis.

Table 1 Engine Specifications

Engine type	4-stroke, single cylinder, water cooled
Bore × stroke	96 × 108 mm
Swept volume	781.7 cm3
Compression ratio	16
Combustion system	Dual-fuel, direct injection
Combustion chamber type	Shallow-dish
Injection system type	Electronically controlled common-rail
Nozzle hole × diameter	4 × 0.10 mm
Engine speed	1000 rpm

This is a dual-fuel engine where the primary gaseous fuel source (coke oven gas in this case) is pre-mixed with air as it enters the combustion chamber. This homogenous air-fuel mixture is ignited by a small quantity of diesel fuel, known as the pilot that is injected towards the end of the compression stroke. The diesel fuel ignites in the same way as in CI engines, and the gaseous fuel is consumed by flame propagation in a similar manner to SI engines. This ignition system has the advantages of a large energy source and stable ignition compared to the SI system. Gaseous fuel is consumed by flame propagation in a similar manner to SI engines. This ignition system has the advantages of a large energy source and stable ignition compared to the SI system.

Fig. 12 (a) shows energy supplied by the pilot diesel fuel, by the coke oven gas and the total fuel energy per cycle. The pilot diesel fuel energy was constant, and energy from the coke oven gas increased from 1.55 kJ/cycle to 2.72 kJ/cycle, and the total fuel energy increased from 1.67 kJ/ cycle to 2.85 kJ/cycle when the overall fuel-air equivalence ratio was increased from 0.35 to 0.65. Fig 12 (b) shows diesel share in total energy for various fuel-air equivalence ratios. The percentage share of diesel fuel changed from about 4.5% to 7.5%. The rest 92.5–95.5% energy was supplied by the coke oven gas.

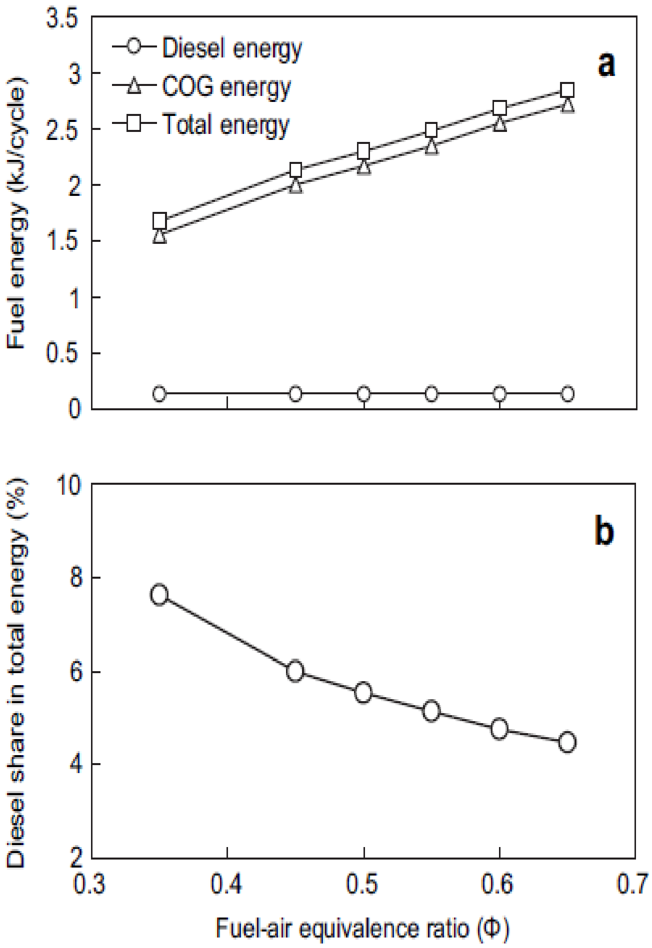

Fig. 12 Schematic Diagram of combined air Energy supplied by different fuels and percentage share of diesel at various equivalence ratios.

The two-stage combustion was found as a condition of higher engine power and a precursor of knocking combustion. The main combustion at the maximum IMEP conditions (with strong two-stage combustions) was found much faster than that of the normal combustions at other IMEP conditions with or without EGR conditions.

III. CONCLUSION

From the analysis of experimental results in papers reviewed, the effects of supercharging on the engine performance can be summarized. Experimentation and competition results have proven that the performance of downsized engines can match that of their larger counterparts, with the aid of intake boosting. Various other important observations marked are as follows:-

For low speed engines, the performance of supercharged engine is mainly dependent on the mechanical losses which are developed to drive the supercharger. Contrary to that for high speed engines, the performance of supercharged engines is more affected by compression ratio rather than the mechanical losses. In between the engine speeds from 1500 rpm to 3000 rpm, the output and torque performance of a supercharged engine can be improved. Power increase with increase in supercharged pressure as more amount of fuel will be burnt within the same period as the mass taken in per stroke is increased. By using some modification in naturally aspirated engine, supercharged application get influences in all field of internal combustion engine by obtain more power from given size of the engine. Limit of supercharging is imposed due to maximum permissible pressure and temperature and thermal stress in the cylinder.

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