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Performance Analysis of Four Stroke Internal Combustion Engine with Supercharger

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Abstract:
This paper reports a review study of different paper that was made to determine whether the mechanical action of a high-speed supercharger improves engine performance. Most passenger automobiles are overpowered and probably 80 per cent of such vehicles operate at less than 55 km.p.h. for 90 per cent of the time. Passenger-car requires from 12 to 15 hp., but the engine carried is capable of developing from 50 to 55 hp.

The result is that the car is operated for the greater part of the time at one-third to one- quarter throttle opening. Full power is needed only for accelerating and hill-climbing; during the remainder of the time the excess weight of the engine and other parts must be carried at a loss of efficiency. Those smaller engines can be used advantageously when equipped with superchargers, the supercharger being used only when excess power is required. Curves and a table are given to show the results of comparative tests with and without a supercharger.

Keywords:
Boost pressure, internal combustion engine, Performance, supercharged engine, supercharger.

I.INTRODUCTION:

The current popularity of internal combustion engines, such as gasoline and diesel engines, originates from the combination of their attractive driving performance due to high toque levels and low fuel consumption. The decisive role of these characteristics has led to the development of charger technology, resulting in a remarkable increase in power density and mean effective pressure.

Turbo charging technology has been widely used in engines for different applications, ranging from small vehicles to large marine vessels, thanks to its technical advantages such as no demand for driving power from the engine and excellent charging effects during sac operation at mid to high engine speeds. However, there is a response time delay, especially for passenger car turbochargers, which can be problematic since mot driving is done under downtown conditions at mid to low engine speeds resulting in a "turbolag" when there is sudden acceleration[6].

In recent years, the motor vehicle industry aims at the small sized and high power density engine, while downsizing (small size and weight saving) and measuring the improvement in fuel consumption, and cleanization. The demand of economical minivehicle increases in recent years from such a background by low fuel consumption, and by the time it will especially exceed 30 percent of the automobile total number of possession in Japan of 2005, will grow up. However, power of a minivehicle is insufficient and there is indication of the user that acceleration power is weak and unsatisfactory, especially at the time of a start dash, gradability, and passing, etc. For the reason, Auto makers taking out with the high-output car.(as shown in below figure)[3].

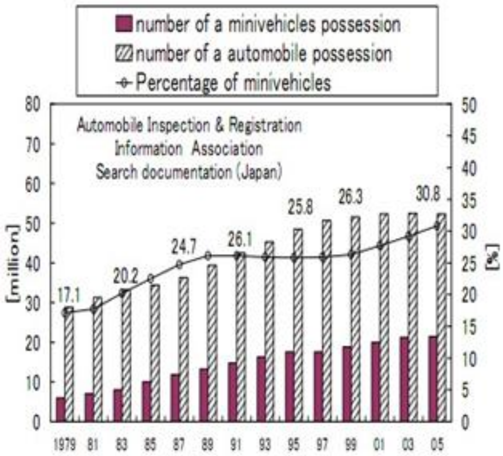

Fig. 1. Share of mini vehicle[3]

A supercharger is a belt or gear driven air pump used to increase the air density at the inlet of an engine to generate more power. A supercharger is connected directly to the crankshaft by a belt and therefore can provide an immediate boost and horsepower on demand [1]. As compared with the turbocharger engine, a supercharger is mechanically driven by the engine crankshaft. Since the engine speed and supercharger speed are in a fixed ratio to each other, boost pressure change with engine speed much more rapidly than in the case of a turbocharged engine [2]. In recent year considerable research for the development of supercharger has been made with various types of supercharger technologies in order to obtain a higher output performance of automotive engines[1].

II. PERFORMANCE:

M. Muhamad Zin, R. Atan[9], Performance of the SI engine was influenced by the pressure induced through the throttle. The acceleration of the operating speed depends on the air mass flow rate from the booster. The induced pressure was controlled by regulator and all of the temperatures were monitored from the engine test bench. The experiment can be categorized of two sections which are experimental test and source. The test fully operated using the test bench engine and the pressure charging was utilized from the pressure vessel laboratory equipment. The compatibility between both major categories was made up and suited the requirement.

At certain time, the pressure can reached up to 4 bar as shown in Fig. 2-3-4. 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. The pressure induced into the intake manifold could carry loads within certain range. Fig. 2 showed the pressure range at low operating speed. The range from 1 bar - 2.5 bar could carry load up to 9 CV and the patterns are the same for the other two pressure range which are 3bar, 3.5bar and 4 bar. The pattern identically can be predicted as the same with the hypothesis of high sustainable load of the engine could carry at the increment of operating speed and appropriate pressure.

Thedifference can be spotted among the pattern is shown at Fig. 2 where the pressure range was about 1bar to 2.5 bar and the range tends to decrease to 1.5 bar at the two categories operating speed which are medium and high. The overlapping load plotted at Fig. 3 and 4 described that mutual relation between pressure induced and operating speed could determine the appropriate load and thus lead to torque response. The more pressure induced towards speed increment however could not be predicted in this study whereby direct charging approach is boundaried by speed range limitation. Otherwise it is not possible to see the outcomes because it occurs as in Fig. 2-3-4 when the pressure induced could reach up to 4 bar. The load represents the torque responses in the performance outcome. The effect of boosting pressure towards torque is proportional to each other. The increasing boosting pressure however found difficult to validate especially the boosting pressure up to 4 bar and only interpreted throughout the experiment rather than theoretical validation. After few times iteration obviously the pressure induced were allowed by the experimental condition to boost the engine performance with the unexpected outcomes but unpredictable.

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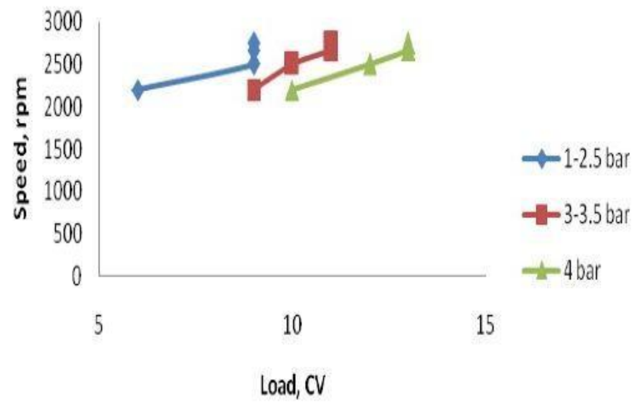

Fig. 2. Pressure iterations at constant low operating speed[9]

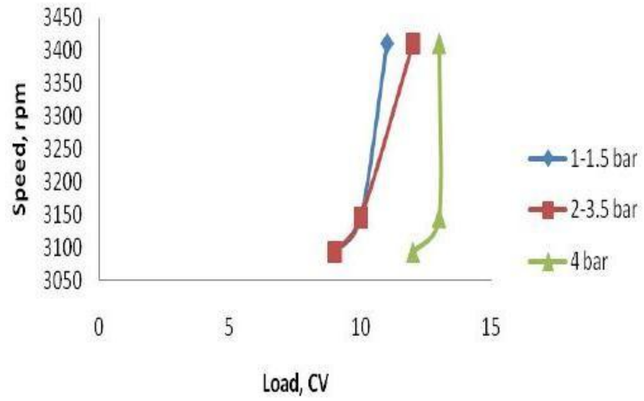

Fig. 3. Pressure iteration at constant medium operating speed[9]

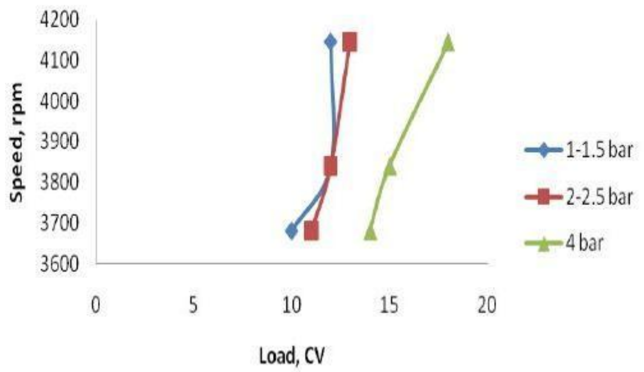

Fig. 4. Pressure iteration at constant high operating speed

Fig. 5 shows the torque comparison between natural aspirated engine and the charging approach. The trajectory however has influenced by uncertainty and disturbance. At certain portion we can see the inclination is at good set point but horizontally no increment at changing point and it is similar to the natural aspirated results.

Fig. 6 exhibits the result based on the optimum torque calculation from the result in Fig. 5. The power produce is once more than the natural aspirated. The results however affected by the air mass flow of the pressure induced.

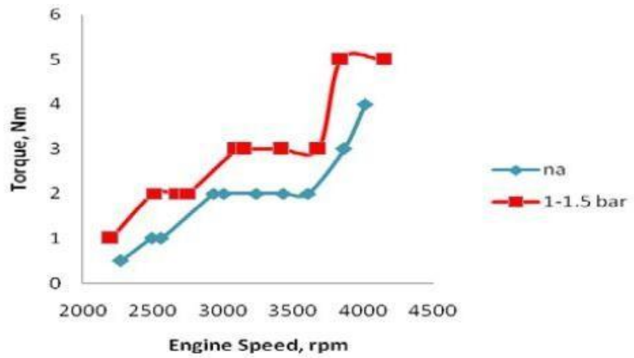

Fig. 5. Comparison of torque performance[9]

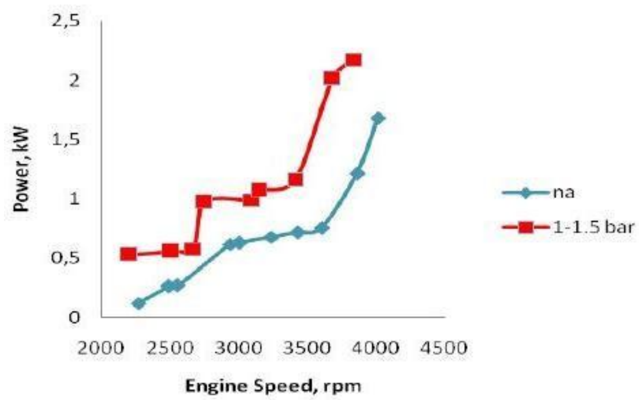

Fig. 6. Comparison of power performance[9]

Guzzella, L., Wenger, U. and Martin. R.[4], This paper describes work done on spark-ignition engine Downsizing and Super-Charging (DSC). Substantial DSC is shown to have a potential for good fuel-economy in SI-engines especially at part-load without compromising in pollutant emission levels. Built into a 4-passenger light-weight car a fuel economy of 67 M/gal (3.5 l/100km) in the European test cycle MVEG-95 was achieved with the potential to satisfy ULEV or Euro IV emission limits.Chang Sik Lee, Ki Hyung Lee, Dong Hyun Whang, Seo Won Choi and Haeng Muk [1], The supercharging experi- ment was carried out using the Roots type supercharger. The supercharger mainly consists of the rotor housing, non-contact rotors, side housings and drive gear system.

The supercharger is a non-contact rotor type with theoretical flow rate of 3.83xl0~^{4} m^3/rev. The engine is a three cylinder, inline, overhead valve gasoline engine with a total cylinder displacement of 7.96 x 10"^{4} m^3. To maintain the rotors at their proper speed, one rotor shaft is driven by the other through a pair of gear train. The gears are located in a closed chamber and lubricated with gear oil, which has been developed for high speed operation and high temperature conditions of the supercharger. In order to obtain the performance characteristics of the supercharged gasoline engine, the experimental apparatus consists of test engine with supercharger, power measuring system and combustion analyser system The experiments were performed on a supercharged gasoline engine directly coupled to an eddy current type dynamometer. The combustion analyser system was composed of the crank angle position detector, pressure measuring system, and data processing device. The rotation of the test engine was controlled by an eddy-current dynamometer system. In order to prevent the knock of the engine, the intercooler was adapted in this system for better cooling efficiency of the inlet air.

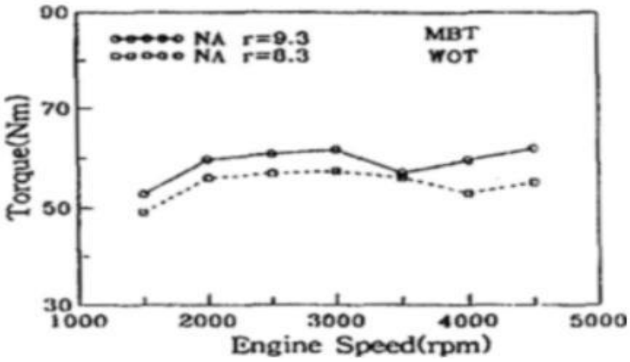

Fig. 7. Effect of a compression ratio on naturally aspirated engine torque[1].

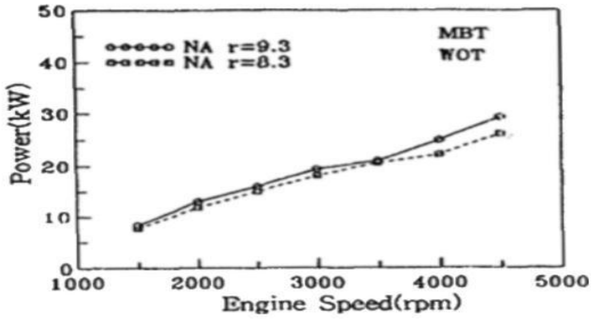

Fig. 8. Effect of a compression ratio on naturally aspirated engine power[1].

Figure 7-8 shows the comparison of the engine torque curve against engine speed for the naturally aspirated engine with compression ratio of 8.3 and 9.3. The engine torque increases with the increase of compression ratio at all engine speed also the effect of compression ratio on the output performance characteristics of the test engine. It can be seen that the output power of engine increases in accordance with the increase of compression ratio. This is the reason why the thermal efficiency of the gasoline engine strongly depends on compression ratio. That is, an increase in compression ratio increases the compression temperature and pressure at TDC, which will increase the burning velocity for the same rpm. The increased compression ratio and the associated increased burning velocity will result in higher performance for the higher compression ratio engine compared with the lower compression ratio engine.

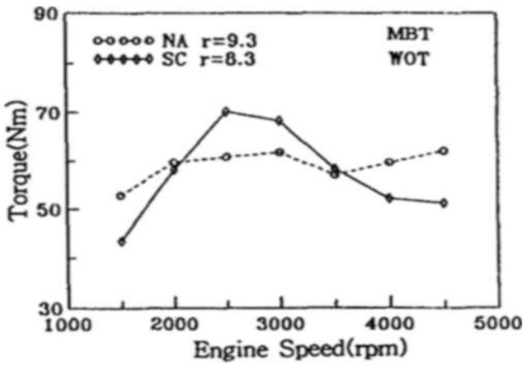

Fig. 9. Comparison naturally aspirated and supercharged engine torque[1].

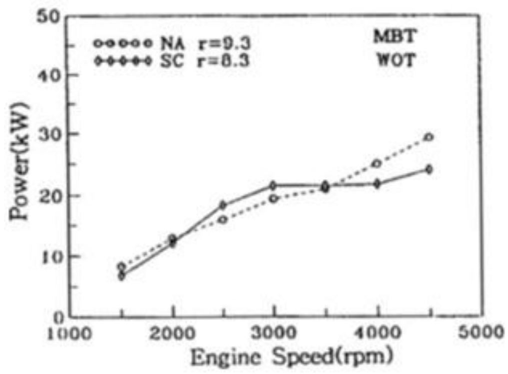

Fig. 10. Comparison naturally aspirated and supercharged engine power[1].

The effect of supercharging on the engine torque can be seen on Fig. 9-10. It was found that the effect of supercharger brought about the increase of the brake power 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 compression ratio decreasing. An illustration of the engine power corresponding to Fig. 7, which is selected as the stabilized torque during two hundred cycles, is shown in Fig. 8. These results indicate that the supercharged engine performance was mainly dependent on the mechanical loss to drive the supercharger at low speed. In addition, at high speed, the supercharged engine performance was more influenced by the compression ratio than mechanical loss.

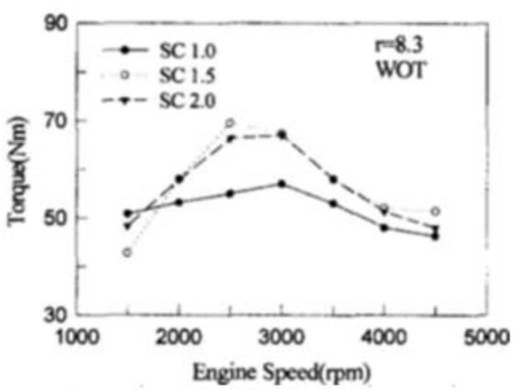

Fig. 11. Effect of pulley ratio on engine torque[1].

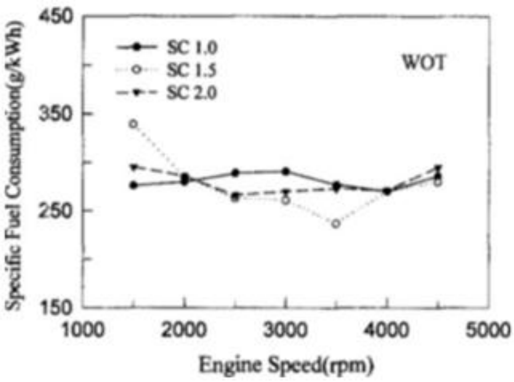

Fig. 12. Effect of pulley ratio on fuel consumption[1].

Figures 11-12 show the influence on the change of the reduction ratio for the drive system of supercharger pulley ratio on the brake torque and brake fuel consumption rate of the test engine with a supercharger. In order to investigate the influence of the variation of pulley reduction ratio on the supercharging performance, the driving reduction ratio between the crank pulley and supercharger pulley was tested from 1:1 to 2 : 1.

As shown in figures, the supercharger pulley ratio had influence on the engine torque and fuel consumption. Especially, the torque of ranges between 2,000 rpm to 3,000 rpm dramatically increased for pulley ratios of 1.5 and 2.0 and the brake fuel consumption rate decreased at the same regions. Therefore the selection of the pulley ratio between a supercharger and an engine is important due to its influence on the engine performance as shown in Figs. 11 and 12.

The over-boost of inlet air is undesirable from the point view of engine performance. Boost pressure control can be made by release of compressed air, control of pulley ratio, and various inlet port system. As shown in above figures, the optimum pulley ratio and minimum consumption rate of fuel at a medium engine speed range was proved to be the pulley ratio 1.5 : 1.

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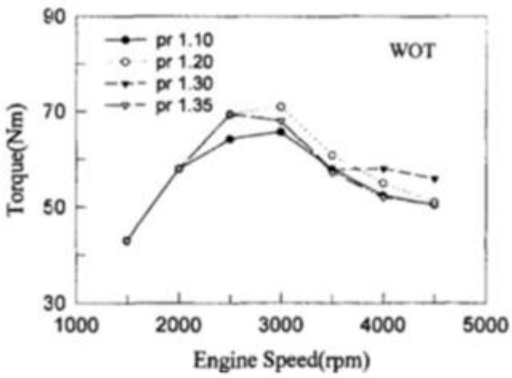

Fig. 13. Effect of pressure ratio on engine torque[1].

The effect of pressure ratio of the supercharger on the engine torque was investigated. Figure 13 showed how the engine brake torque versus engine speed plots changed with various pressure ratio of supercharger. It can be seen that maximum brake torque occurs in the operating range of medium speed from 2,500 rpm to 3,000 rpm under the condition of pressure ratio of 1.2[1].

Gh. Al. Radu, C.I. Leahu [10], In order to determine to what extent the supercharge with a pressure waves compressor of type Comprex represents an alternative to the supercharge with a turbocharger, this paper presents comparatively the values of ecological and economical parameters obtained from experimental research of a Diesel engine supercharged consecutively with turbocharger and with aggregate of type Comprex driven with a constant speed by an electric motor. Supercharging using a Comprex unit driven with a constant speed brings environmental and economical performances for the engine thus supercharged, a fast response in acceleration and a functional simplicity of the supercharged system.

In addition, due to the constant driving speed of Comprex, this supercharge solution presents both a functional simplicity with low manufacturing costs and a very fast response in acceleration. In the operating mode (speed and load), the values obtained with the latter method being bigger with a percentage in 14-40 % range for the load F of 49 N.

Because the quality of the supercharge process is reflected in the energy and environmental performance of the engine, the percentage deviation of the values for specific fuel consumption, smoke emissions and HC - acquired in the supercharge process with Comprex being driven by the speed of 12500 rpm are presented below, in order to validate the superiority of the supercharge process made with Comprex, compared with the values obtained from turbo supercharge.Conclude that the supercharge with an aggregate of type Comprex, driven with a constant speed of 12500 rpm, for the investigated operating modes, gives the engine improved (significantly, sometimes) energy, economy and environmental performances, compared with those obtained from the same engine but equipped with a turbocharger.

It is necessary to mention that during the experimental investigations of engine supercharged with Comprex driven by a constant speed of 12500 rpm, the power consumption for driving the Comprex unit was also measured, its average value being around 1.86 %, which represents a reduced amount of the consumed power utilized to drive the supercharging unit. Milburn, S.[5], A variable, positive displacement supercharger, (VPDS™) is being developed for Diesel and spark ignition engines. Benefits include reduced emissions, improved fuel economy and low speed torque improvements. Christensen, M., Johansson, B., Amnéus, P., and Mauss, F.[7]. The low Indicated mean effective pressure achieved with naturally aspirated Homogenous charge compression ignition (HCCI) limits future commercial use of the Homogenous charge compression ignition concept.

To clarify the effect of supercharging on Homogenous charge compression ignition, especially on the HC(hydro carbon) emissions and on the upper load limit, a series of tests was carried out. Boost pressures up to 2 bar were used. The boost pressure was generated by an external air compressor. It was decided to use a four-stroke engine operating at low engine speed.

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The engine speed was set to 1000 rpm during all experiments. Three fuels were used during the experiments: iso-octane was selected to serve as a reference fuel, ethanol is of interest as a future replacement for gasoline and natural gas is also of interest as an alternative fuel and was interesting since it is a gaseous fuel and hence has no heat of vaporization. The octane number of the three fuels are 100, 106 and 120, respectively. Two different compression ratios were used, 17:1 and 19:1. Gross indicated efficiency – The gross indicated efficiency was evaluated by measuring the fuel flow and the indicated mean effective pressure during the compression and expansion strokes only. This means that the effect of supercharging on the gas exchange process is absent. Figures 14-15 show the gross indicated efficiency for the different cases. Figure 14 shows a higher gross indicated efficiency for ethanol running at a 19:1 compression ratio than at 17:1.

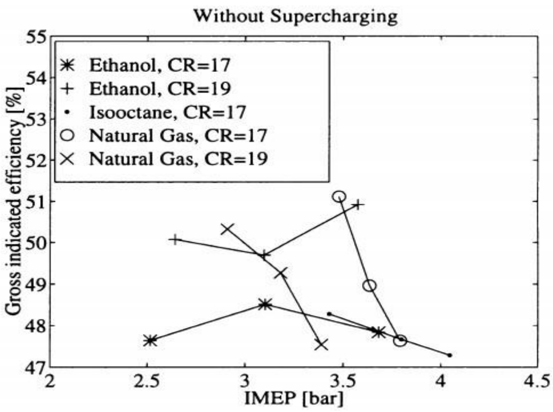

Fig. 14. Gross indicated efficiency without supercharging[7].

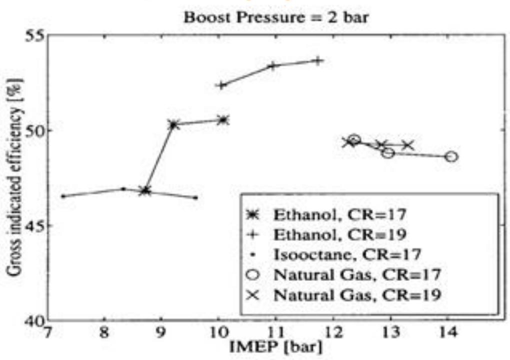

Fig. 15. Gross indicated efficiency with supercharging[7].

Net indicated efficiency – The net indicated efficiency is obtained from the fuel flow and the indicated mean effective pressure during all four strokes. The gas exchange process is thus included here. This means that the net indicated efficiency is lower than the gross indicated efficiency for the cases without supercharging. For the supercharged cases, the net indicated efficiency is higher than the gross indicated efficiency, due to the use of an external supercharging system. Figures 16-17 show the obtained net indicated efficiency. Ethanol gives the best result but natural gas has gained somewhat on its lower PMEP. In a production engine the power required for super- charging would be taken from the engine itself, resulting in a lower efficiency. Some of this power loss, however, returns to the engine as a decrease in pumping work.

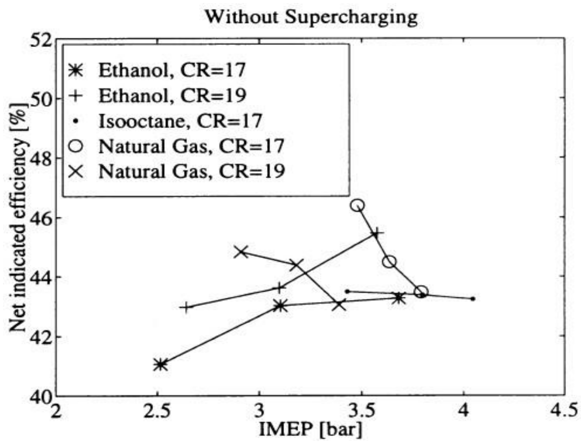

Fig. 16. Net indicated efficiency without supercharging[7].

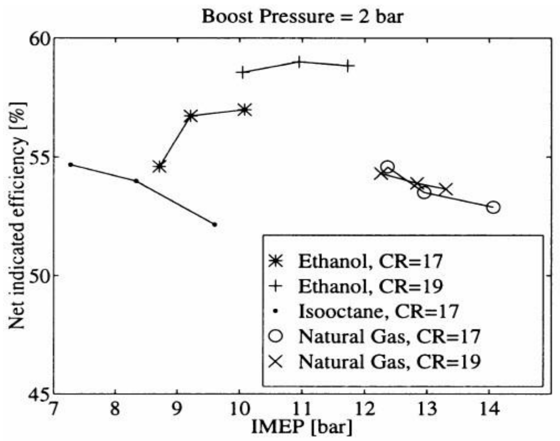

Fig. 17. Net indicated efficiency with supercharging[7].

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Combustion efficiency – The combustion efficiency was evaluated from the exhaust gas analysis (HC and CO). Figures 18-19 show the combustion efficiency. Figure 18 shows that the combustion efficiency increases with engine load. This is due to the use of a richer mixture and hence higher temperature. For the super- charged cases, Figure 19, this trend is less obvious. Pressure effects on combustion can play a larger role here. For all cases, the highest combustion efficiency is yielded with ethanol as fuel. Natural gas is better than iso-octane without supercharging but has a major drop at 2 bar inlet pressure. For both ethanol and natural gas, the combustion efficiency is increased with a higher compression ratio.

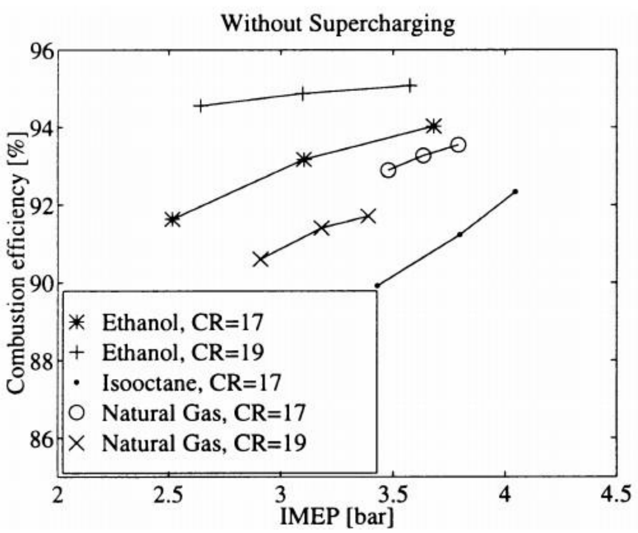

Fig. 18. Combustion indicated efficiency without supercharging[7].

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. However, the extent to which swept volume can be reduced in any downsized application is combustion limited.

If the combustion in high speed, small bore engines could be better understood or even enhanced to promote faster burning, the severity of end-gas knock could be minimized. This would allow further increases in compression ratio and/or manifold absolute pressure, resulting in increased performance and efficiency.

1. These results indicate that the supercharged engine performance was mainly dependent on the mechanical loss to drive the supercharger at low speed. In addition, at high speed, the supercharged engine performance was more influenced by the compression ratio than mechanical loss.
2. 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.
3. Limit of supercharging is imposed due to maximum permissible pressure and temperature and thermal stress in the cylinder.
4. An increase in brake mean effective pressure(BMEP) about 30% to 35% are easily obtainable in any supercharged engine compared to naturally aspirated engine.
5. 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.
6. Small size engine with charging approach similarly tend to be at par with the downsized turbocharged engine if it undergoes serious improvement and method. A better improvisation is almost control approach with experimental procedure and the parameters are likely more organized to be set as the outcomes. The appropriate pressure induced into the intake manifold is within 1bar-1.5bar.
7. Knock has been highlighted as being the single most important limiting factor in defining the performance for downsized boosted engines.
8. 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.

Acknowledgment:

We would like to sincerely acknowledge the encouraging efforts of our faculty of government engineering college Bhuj. I wish to express my sincere thanks to all my friends for their goodwill and constructive ideas.

NOMENCLATURE

BSFC brake specific fuel consumption
MAP manifold absolute pressure
MBT maximum brake torque
NA normally aspirated
OHC overhead camshafts
PFI port fuel injection
RON research octane number
SC supercharged
SI spark ignition
WOT wide open throttle

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