Performance Analysis of Supercharging Process in Spark Ignition Engine

Prof.K.P.Agte[1], Sangram Khairnar[2], Amol Visave[3]

[1]*Professor, Mechanical Engineering SKNCOE Vadgaon, kpagte@sinhgad.edu*
[2]*Student, Mechanical Engineering, SKNCOE Vadgaon,sangramkhairnar@gmail.com*
[3]*Student, Mechanical Engineering SKNCOE Vadgaon,amolvisave00@gmail.com*

ABSTRACT

There are many inventions aimed at improving the performance of IC Engines. It is a known fact that the power output of an engine increases with an increase in amount of air or mixture in the cylinder. This paper studies the performance characteristics and effects of supercharging process in SI Engine. Most of the automobiles are overpowered, for most of the time these vehicles operate at less than speed. Full power is needed only for accelerating and hill climbing during the remaining time the excess weight of the vehicle is carried with loss of efficiency and the most important parameter of the engine is the shape and size which accommodates for its weight. A smaller engine can be used advantageously when used with supercharger, the supercharger being used only when excess power is required.

***Keywords**: SI Engines, Supercharger, Supercharged engine, performance.*

1. INTRODUCTION

The performance of the engine can be improved by-

- Increasing the speed of the engine.
- Use of higher compression ratio.
- Utilization of exhaust gas energy.
- Use of two stroke cycle.
- Improving volumetric efficiency.

The power output of the engine depends on the amount of air inducted per unit time, the degree of utilization of that air and the thermal efficiency of the engine. The amount of air inducted per unit time can be increased by increasing the engine speed or by increasing the density of air at intake .Increasing the engine speed increases the inertia loads and demands a rigid and robust engine. The engine friction and bearing loads also increase and the volumetric efficiency decreases with the speed of engine. The method of increasing the inlet air density, called supercharging, is
usually employed to increase the power output of the engine. This is done by supplying air at a pressure higher than the pressure at which the engine naturally aspirates air from the atmosphere by using a pressure boosting device called as supercharger. [1]

The supercharger gives boost to the engine, Boost is measured in Manifold Pressure (MAP).The boost increases with the increase in the density of the air charge. Which allows the engine to burn more air and fuel hence it generates more power. [3]

The increase in the amount of air inducted per unit time by supercharging is obtained mainly to burn a greater amount of fuel in a given engine and thus increase its power output. The objective of supercharging include one or more of the following:

1. To increase the power output for a given weight and bulk of the engine. This is important for aircraft, marine and automotive engines where weight and space are important. [2]
2. To compensate for the loss of power due to altitude .This is mainly related to aircraft engine which lose power at an approximate rate of one percent per 100 meters altitude .This is also relevant for other engines which are used at higher altitude. [1]
3. To increase the power of an existing engine when the demand for power increases. [1]

2. WORKING OF SUPERCHARGING

More air means more power and so the current demand for increased engine outputs is met by larger cylinders or by running at higher speeds to deal with the greater weight of air per unit time. With a normal (supercharged) engine it is atmospheric pressure which forces air through the carburetor into the cylinders on the induction stroke .As atmospheric pressure falls with the altitude, the weight of air available for combustion also falls off and power goes low. This natural fall off with the altitude can be avoided if we deceive the engine that it was still at sea level by blowing air into its induction system using some kind of pump .This process is called supercharging. The air is drawn in at the hub of the impeller, centrifugal force causes it to radiate outward. The air leaves the impeller at high speed, but low pressure. A diffuser -- a set of stationary vanes that surround the impeller -- converts the high-speed, low- pressure air to low-speed, high-pressure air. Air molecules slow down when they hit the vanes, which reduces the velocity of the airflow and increases pressure. [1]

ISSN: 2321-8169
847 – 851

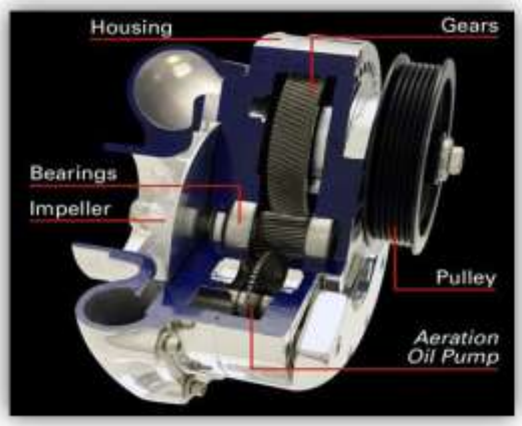

Fig-1: **Working of Centrifugal Supercharger.** [2]

3. THERMODYNAMIC CYCLE WITH SUPERCHARGING

Fig.2 shows diagram for an ideal Otto cycle supercharged engine. The pressure p_1 represents the suction pressure and p_5 the exhaust pressure. Area 8-6-7-0-1-8 represents work done by supercharger (mechanical driven) in supplying pressure air at a higher pressure p_1 while area 1-2-3-4-1 is the output of the engine.

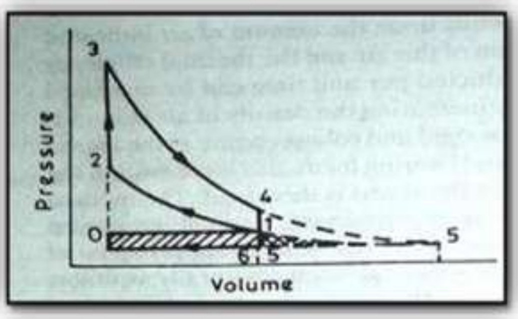

Fig.-2: gine. [1] **P-V Diagram for an Ideal Otto Cycle Supercharged En**

Area 0-1-6-7-0 represents the gain in work during the gas exchange process due to supercharging .Thus a part of the supercharger work is recovered .However the area 1-6-8-1 cannot be recovered . and represents a loss of work .This loss of work causes the ideal thermal efficiency of the supercharged engine to decrease with an increase in supercharging pressure .The gain in the output of the supercharged engine is mainly due to increase in the amount of air inducted for the same swept volume.An additional amount of air is also induced due to compression of residual volume to a high pressure.Supercharging also results in an increase in mechanical efficiency , and in better gas- exchange process.An engine should be designed from the start as a supercharged engine to obtain optimum performance with the desired life . [3]

4. SUPER-CHARGING OF SPARK IGNITION ENGINES

As far as spark-ignition engines are concerned, supercharging is employed only for aircraft and racing car engine. This is because the increase in supercharging pressure increases the tendency to detonate and pre-ignite. Apart from increasing the volumetric efficiency of the engine supercharging results in increase in the intake temperature of the engine. Increased intake pressure and temperature reduces ignition delay and increases flame speed. Both these effect result in a greater tendency to detonate or pre-ignite. For this reason, the supercharged petrol engines have lower compression ratio. The use of lower compression ratio and increased heat losses due to higher value of specific heats and dissociation losses at higher temperature results in a lower thermal efficiency for such engines. Thus supercharged petrol engine have a greater fuel consumption than naturally aspirated engines.

Fig.3 shows that performance of a supercharged petrol engine for different speeds. Knocking can be controlled in highly supercharged engine by injection of water in the combustion chamber. However, large amount of liquid needed for this purpose becomes prohibitive. Another alternative is to use intercooling of the charge before it is fed to the engine. [1]

ISSN: 2321-8169
847 – 851

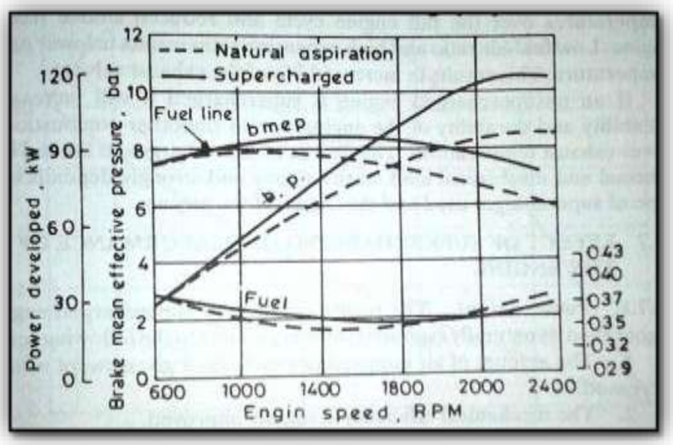

Fig-3: Effect of supercharging on a petrol engine. [1]

5. EFFECT OF SUPERCHARGING

Power output –The Brake power will increase by a significant amount because of increase in supercharged pressure as more amount of fuel will be burnt within the same period as mass taken per stroke is increased.Also the power to weight ratio of the supercharged engine is much better than naturally aspirated engine. [1]

Mechanical efficiency- Due to packing of more air in the engine cylinder during supercharging, the gas load is increased which needs large bearings and robust components. Heavy load on the bearings increases friction force. However, the increase in the brake mean effective pressure is much more than the increase in frictional forces. Therefore the mechanical efficiency of a supercharged engine is improved as compared to an un-supercharged engine. Thus mechanical efficiency increases with the increase in the degree of the supercharging, but reduces with increase in engine speed.[2]

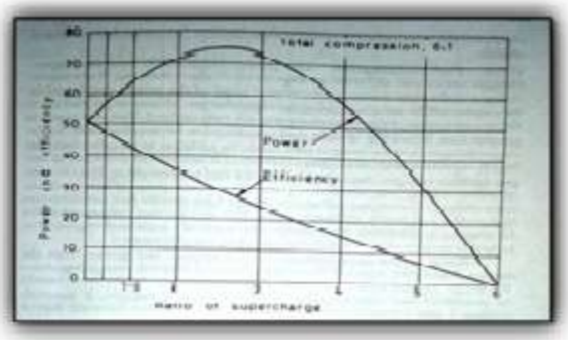

Fig-4: Effect of supercharging ratio on power and efficiency[4]

Fuel consumption - The power required to run the supercharger varies with different arrangements of supercharging. If the supercharger is directly run by the engine some of the power developed by the engine will be used in running the supercharger. Moreover, at part loads the compression of the supercharger is not fully utilized. This will result in greater loss , hence the specific fuel consumption for mechanically driven superchargers will be more at part loads. In addition to this, the fact that highly supercharged Otto engines use very rich mixtures to avoid knock and pre-ignition will give rise to higher specific fuel consumption. Thus in spite of better mixing and combustion due to reduced delay a mechanically supercharged Otto engine will almost always have specific fuel consumption higher than a naturally aspirate engine.[1]

6. SUPERCHARGING LIMITS

The power output of an engine is basically limited by knock, thermal and mechanical loads. Usually one of these limits is reached earlier than the other limits depending upon the type of engine and its design of the structure, the cooling arrangements, etc. For spark-ignition engines knock limit is usually reached first while for diesel engines the thermal and the mechanical load limits are reached first.

The degree of supercharging in SI engines is chiefly limited by the knock. This increase in pressure and usually in temperature also, because of supercharging reduces ignition delay and consequently the engine has a knocking tendency at these pressure. The knock limit is dependent upon the type of fuel used, mixture ratio, spark advance and the design features of the engine, of which the valve the valve timing and cooling system are important.

Different fuels have different knocking tendencies. Some are more sensitive to increased pressure, others to increase in temperature. Fig 5 shows higher useful compression ratio for different fuels used and Fig.6 shows mean effective pressure obtained with different fuels at different intake temperatures. It can be seen that for volatile petroleum fuel of high octane number the knocking and pre-ignition tendency is reduced at very rich and very lean mixture, and that fuels of same octane value have different response to supercharging.

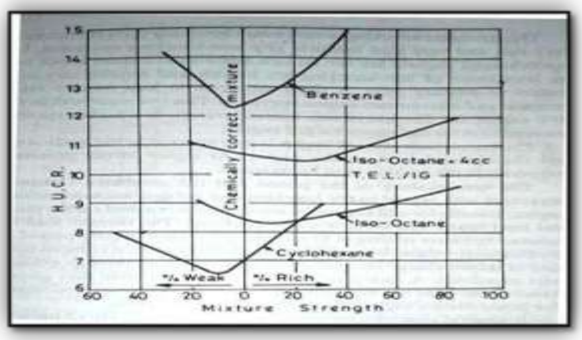

Fig-5: H.U.C.R .v/s mixture strength curves for different. [1]

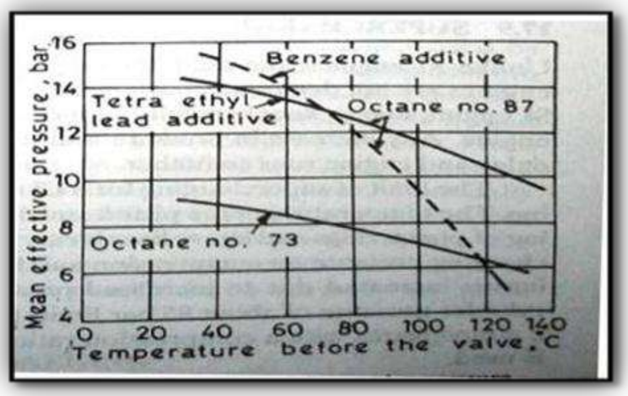

Fig-6: Highest mean effective pressure near the knock limit v/s temperature. [1]

The strongest knocking occurs near chemically correct mixtures ratios. Very rich and very lean mixtures give non- knocking operation. Usually supercharged engines are run on rich mixtures to control knock because the lean limits of non-knocking are narrow and require very accurate control of mixture ratio. A slight reduction in lean mixture results in irregular and intermittent engine operation. This can occurs with as early as 20% excess air. The use of rich mixtures results in a higher specific fuel consumptions for the supercharged engines. The knock limit of an SI engine is also affected by the ignition timings and the thermal load on the engine. At higher intake pressure and temperature the ignition must be retarded. In general, supercharger pressure of the order of 1.3 to 1.5 bar are used. That corresponds to about 30 to 50% supercharging. [1]

7. MODIFICATIONS TO BE DONE IN ENGINE

The power output of a naturally-aspirated engine can be increased by supercharging. However, certain modifications will make the engine more suitable to supercharging This modification include increase in the valve overlap period to allow complete scavenging of the clearance volume and increase in clearance volume by decreasing the compression ratio. A highly supercharged engine needs a very rich mixture to avoid knock and pre-ignition. Hence an arrangement for increased fuel supply is also to be provided to avoid knock and pre-ignition.

8. CONCLUSION

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 enhanced to promote faster burning, the severity of end-gas knock could be minimized. This would allow further increase in compression ratio and/or manifold absolute pressure, resulting in increased performance and efficiency.

1. The supercharged engine performance was mainly dependent on the power 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 power loss.
2. In most of the cases engine performance investigations using the supercharger indicate that the output and torque performance can be improved in comparison with the naturally aspirated engine.
3. Limit of supercharging is imposed due to maximum permissible pressure and temperature and thermal stress in the cylinder.
4. Supercharging can be an alternative for engines where more power and torque is desired on the verge of more fuel consumption.

9. REFERENCES

[1] Prakash Kumar Sen, Rohit Jaiswal, Shailendra Kumar Bohidar, "Performance Analysis of Super-charging process in SI Engine and CI Engine and Application of Supercharger", International Journal of Advance Research in Science and Engineering ,ISSN-2319-8354(E), April 2015.

[2] Prashant N Pakale, S U Patel, "Performance Analysis of IC Engine using Supercharger and Turbocharger- A Review", International Journal of Research in Engineering and Technology, ISSN-2321-7308, February 2015.

[3] Pasala Venkata Satish, Samanthula Naveen, Hepsiba Seeli, Sri Harsha Dorapudi, "Performance Analysis of Supercharging a Single Cylinder SI Engine", International Journal of Scientific and Engineering Research, December 2015.

[4] Automobile Engineering by K K Jain and R B Asthana.