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Enhancing the Efficiency of Gasoline Engines using Solar Powered Supercharger

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Abstract— ***The world presently depends heavily on non-renewable sources of energy like crude oils. These conventional energy sources have certain limitations, that is, they will eventually run out, fuel prices can rise without warning and most importantly growing environmental concerns over the climate change associated with the release of CO_2 on burning fossil fuels[1]. Renewable energy is the key to a clean energy future. In the last few decades, solar energy is the fastest growing renewable energy source[2]. We can harness this energy of the sun in increasing the efficiency of our automobiles. Forced induction system (supercharger and turbocharger) in automobiles helps in the improvement of the efficiency of internal combustion engines by pushing extra atmospheric air into the cylinder which results in the proper combustion of fuel and thus reducing the smoke from the exhaust gas. Conventional Supercharger draws power from the engine and though the overall mechanical efficiency is increased but some energy is lost in powering the supercharger. The main purpose of this paper is to develop a solar-powered supercharger which will not consume extra power from the engine and thus increase the overall efficiency of the engine along with a reduction in CO_2 emission.***

Keywords— ***Solar powered supercharger, Forced induction system, Solar power, Supercharger, CO_2 emission.***

I. INTRODUCTION

There are around two billion internal combustion engines in use in the whole globe. The price of crude oil is increasing abruptly and there is a need for an immediate solution that can lower the fuel consumption of internal combustion engines without compromising the performance of the engine. Also, there are various environmental issues associated with the damaging effect of the exhaust gases from the automobile's engine. For an automobile designer, it is the prime objective to achieve these twin targets of improved engine efficiency and minimum exhaust emissions [3]. In the last few decades, researchers have done a lot of progress in improving the efficiency of the automobile engine along with controlling air pollutant emissions due to the burning of fuel. Out of all the modifications available for automobiles, Forced induction system provides the greatest improvements in the overall efficiency of the automobile's engine.

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High-quality supercharger or turbocharger can increase engine torque by 50% and reduce CO_2 emissions by 20%. Forced induction system improves the engine's performance by pushing extra atmospheric air into the engine cylinder than would be possible using conventional aspiration methods[4]. Due to increased airflow, fuel and air are mixed in a correct proportion which results in proper combustion of the fuel and thus exerting more force on the piston, which in turn, pushes stronger on the crankshaft and therefore producing additional power. Therefore, more power can be generated from the automobile's engine with the use of a forced induction system[5][6]. Also, because of the complete combustion of the fuel, greenhouse gas (CO_2) emission from the automobile reduces. Hence, forced induction technology helps in both increasing the fuel economy and reducing the carbon footprint from the environment. Superchargers are a kind of forced induction system which is powered by chain or belt drive from crankshaft connected to engine. Therefore, superchargers increase the overall mechanical efficiency of the vehicle's engine but some power from the automobile engine is consumed in running the supercharger.
The aim of this paper is to develop a supercharger which utilizes solar energy for its functioning and thus eliminating the dependency of it on the engine power for its working. Solar power is the source of unlimited clean energy. The sun provides far more energy everyday than we require for powering everything on earth. Being a sustainable energy source, it will never be exhausted and additionally no harmful emissions are discharged in utilizing solar power[7]. A solar powered supercharger can help in achieving a more fuel efficient and environmental friendly internal combustion engine. When solar powered supercharger is applied in the gasoline engine, the fuel efficiency can be increased to the point that they are comparable to the diesel engines of the same power output. This paper aims to provide a comprehensive study of the working of solar powered supercharger in gasoline engines.

II. WORKING OF CONVENTIONAL SUPERCHARGER

Superchargers are the forced induction devices that increase the pressure of the air before allowing it to go in to cylinder of the internal combustion engine. The process of pushing the extra atmospheric air into the automobile's combustion chamber is known as supercharging.
Superchargers are basically compressors/blowers which take atmospheric air at normal ambient pressure and forcefully push it into combustion chamber. Power to the supercharger is provided from the engine with the assistance of a chain or belt drive[8].

When the mean effective pressure increases, power output of automobile engine increases. Mean effective pressure could be increased by forcing air-fuel mixture or atmospheric air at a pressure much above than that of the atmosphere. Due to increased pressure, the density of air or air-fuel mixture increases and thus the mass of air or air-fuel mixture supplied to combustion chamber is more than the air or air-fuel mixture supplied at the non-pressurized condition. This results in availability of more oxygen for fuel combustion process than the conventional technique of supplying fresh air into combustion chamber.

Therefore, extra air or air-fuel mixture is pushed into the engine cylinder which may facilitate complete combustion to increase power output and thereby the efficiency of the engine. Also, because of the complete combustion, CO_2 emissions reduces. In this way, supercharger helps in achieving both more power output and less exhaust emissions simultaneously[9].

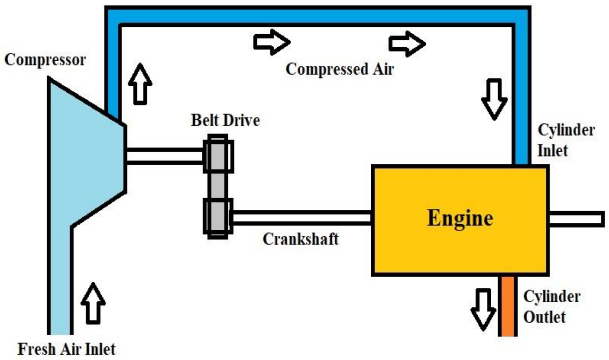

Figure 1. Working of Supercharger

Fig. 1. Explains the working principle of a supercharger. Fresh air from atmosphere enters the supercharger wherever it gets compressed and it's pressure increases. The compressor is coupled with the engine crankshaft with the help of belt or chain drive to get required power for its operation. Compressed air from the compressor then enters in to the combustion chamber. In combustion chamber, compressed air assists in complete combustion of the fuel and thus providing more power output and less exhaust emissions.

III. THERMODYNAMIC ANALYSIS OF SUPERCHARGER

The ideal Otto-cycle of a naturally aspirated engine is represented in fig. 2. The corresponding cycle for a mechanically driven supercharged engine is represented in fig. 3. The pressure of the compressed air is represented by p_1 in the fig. 3 and the pressure of the exhaust gas is represented by $p_5 = p_6$. The power output from the engine is represented by area enclosed by points 1-2-3-4-1. Also, area enclosed by points 7-1-5-6-7 indicates the positive gas exchange work. However, area 9-10-11-8-9 indicates the work supplied to mechanically driven supercharger from the engine. Thermodynamically, work done by a system is considered as +ve and work supplied to a system is considered as -ve. Therefore, the net power output of a supercharged engine is the summation of two positive work and one negative, i.e.,

W = Engine power output (+ ve) + Gas exchange work (+ ve)
- Power supplied to supercharger (- ve)

= area (1-2-3-4-1) + area (7-1-5-6-7) - area (9-10-11-8-9)

In supercharged engine, the negative work, i.e., the power supplied to the supercharger will increase with increase in supercharging pressure. This will result in a limit for supercharging. However, the net increase in the power output is due to increase in mass of inlet air. When fig. 2 and fig. 3 are compared, it can be concluded that the inlet air pressure in a supercharged engine, i.e., $p_1 = p_7$ is greater than the inlet air pressure in the naturally aspirated engine. Since the inlet air pressure is higher in the supercharged engine than the naturally aspirated engine, thus the density and thereby the mass of the inlet air coming in to the combustion chamber in the supercharged engine is also higher. And the increase of power output in a supercharged engine is primarily due to increase in mass of the inlet air for the same engine capacity.

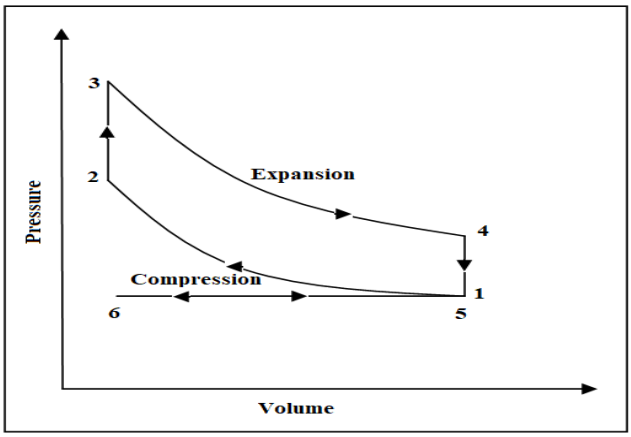

Figure 2. Ideal Otto cycle of a naturally aspirated engine

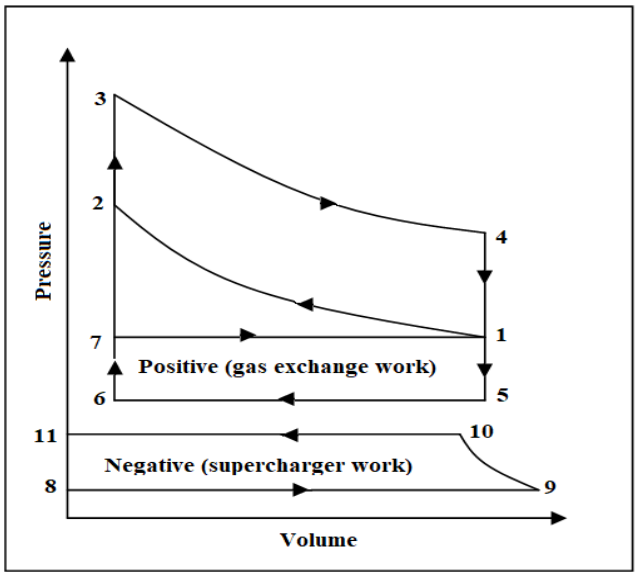

Figure 3. Ideal Otto cycle of a supercharged engine

IV. ELECTRIC SUPERCHARGER

The basic working principle of an electric supercharger is same as that of a conventional supercharger i.e., they too are designed for pumping air into the engine cylinder at a pressure higher than that of atmosphere. A conventional supercharger is driven by using mechanical arrangements. In almost every automobile application, the supercharger is driven with the help of chain or belt drive coupled with the engine crankshaft. However, the electric supercharger is operated by an electric motor[10][11][12]. It helps in controlling the operation of supercharger depending upon the load conditions, i.e. to shut down entirely or power up immediately within fraction of seconds when required.

On the other hand, working of the conventional supercharger is completely dependent on the speed of driving engine. Thus, conventional supercharger consumes more energy and reduces efficiency of the engine unless it is coupled with multi-speed gearbox. This indicates that electric in which an electric supercharger is used along with a battery. Supercharger has an upper hand from conventional supercharger in terms of efficiency. This paper aims to develop a system of supercharger and solar energy is employed to charge the battery and thus a more energy efficient and environment friendly internal combustion engine can be developed.

V. METHODOLOGY

As we have already discussed that the conventional supercharger derives its power from engine crankshaft with the help of belt or chain drive. It means that some of the energy from engine is wasted in powering up the supercharger.

As solar power is a free and clean source of energy, we can utilize it for running our supercharger. This proposed solar powered supercharger system eliminates the dependency on engine power for its operation. Also, the extra energy lost in driving the conventional supercharger is saved which results in increasing the net efficiency of the engine.

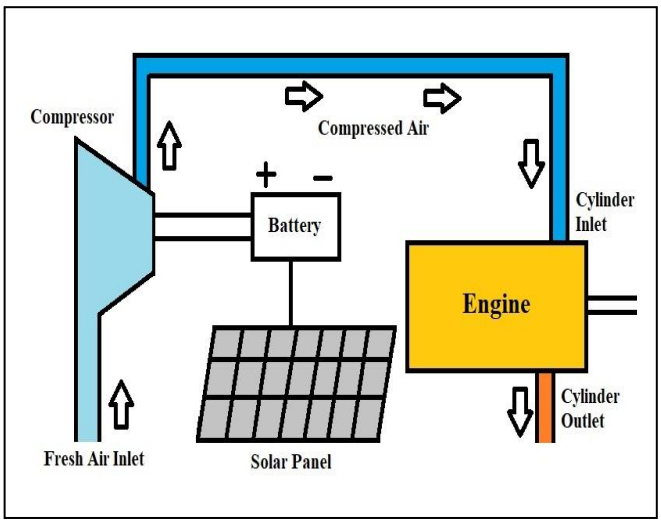

Figure 4. Working of solar powered supercharger

The working principle of the solar powered supercharger is illustrated in Fig. 5. In this system, the compressor (supercharger) gets power from battery which is connected to a solar panel. Solar panel is an assembly of photovoltaic solar cells[13]. Electrical energy can be generated from solar energy by using photovoltaic solar cells which works on the principle of the photovoltaic effect. It converts energy sunlight into direct current electricity. However, single photovoltaic cell will not produce desired amount of electricity. Thus, a number of photovoltaic cells are arranged on a frame and connected with each other in a proper electric circuit to form a photovoltaic module or solar panel. These solar panels can be installed at the roof of automobile and a battery should be connected with it to supply electricity continuously to the supercharger even in the absence of sunlight. If the above discussed supercharger is installed in a gasoline engine then its efficiency can be comparable to the diesel engine.

VI. RESULTS

There are a range of benefits of solar powered supercharging as compared to the conventional supercharging technology in the internal combustion engines such as:

- Efficiency of solar powered supercharger is higher than the conventional supercharging system, i.e., more power output for the same capacity engine.
- As additional air is pushed in the engine cylinder, complete combustion of the fuel is possible which results in smoke reduction from exhaust gases.
- Solar powered supercharger produces variably pressurized intake charge depending upon the load conditions.
- Quicker response, i.e. it shut down entirely or power up immediately within fraction of seconds when required.
- Dependency on engine power is eliminated in solar powered supercharger; therefore, more power output can be generated as compared to conventional supercharger.

VII. CONCLUSION

- In order to decrease the carbon footprint, the essential working components of the automobile must be less dependent on the conventional fossil fuel based mechanism.
- The solar powered supercharged system can be a significant step in the development of energy efficient and more carbon neutral internal combustion engine.
- It is concluded that it is possible to replace the conventional supercharger with a solar powered supercharger for a commercial automobile which can increase the engine torque by 50% and reduce CO_2 emissions by 20%.

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