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Enhanced Exhaust Heat Recovery using Brayton Cycle Turbocharging in Turbo Diesel Engines

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Abstract - *It is a well-known fact that most of the chemical energy obtained by the combustion of fuels are carried out by the exhaust gases. Recent studies and experiments have concluded that as much as 50% of the total chemical energy possessed by the burnt fuel is lost through the exhaust. It is this concept and the need for improving volumetric efficiency that gave birth to the idea of 'turbochargers'. Traditional turbocharging systems make use of the energy carried by exhaust gases by placing a turbine-compressor arrangement in the exhaust line of the automobile. The major problem with this system is the high back-pressures developed in the engine cylinders due to the obstruction provided to the exhaust flow by the turbine blades. The back-pressure results in higher operating temperatures, higher fuel consumption and overall lower engine performance. Hence, an effective solution to overcome this problem is required. The suggested project demonstrates an alternate method of turbocharging which could eliminate the problems produced by back-pressure to a large extent. The proposed system replaces the turbine-compressor arrangement from the exhaust line and places a heat exchanger which extracts heat from the exhaust and transfers this heat to pressurized air on the other side of the heat exchanger; it is this hot pressurized air that is used to drive the turbine-compressor arrangement. Since, the arrangement does not impede the flow of the exhaust it is expected that the back pressure will decrease resulting in the overall improvement of engine efficiency.*

***Key Words*: Brayton Cycle, Engine back pressure, Heat Pipe Heat Exchanger, Turbocharging.**

1. INTRODUCTION

An emerging topic of research in the field of Internal Combustion engines is waste heat recovery techniques. This field has been gaining popularity rapidly owing to the immense demand of energy efficiency in engines and the fact that most I.C engines are able to convert only 30% of the actual chemical energy in the fuel to useful work. It is estimated that a major part of the energy obtained through combustion is lost by means of heat carried by the coolant or the exhaust gas.

1.1 Conventional Turbocharging

Out of all the waste heat recovery systems one of the most common waste heat recovery systems seen nowadays is the conventional turbocharging technique. This technology works on the same basic principle of harvesting the thermal waste energy contained in the exhaust.

Conventional turbocharging systems basically make use of a turbine-compressor arrangement in the exhaust line of the engine where the exhaust gases are used to rotate the turbine that drives the compressor which in turn compresses the inlet air to the required boost pressure.

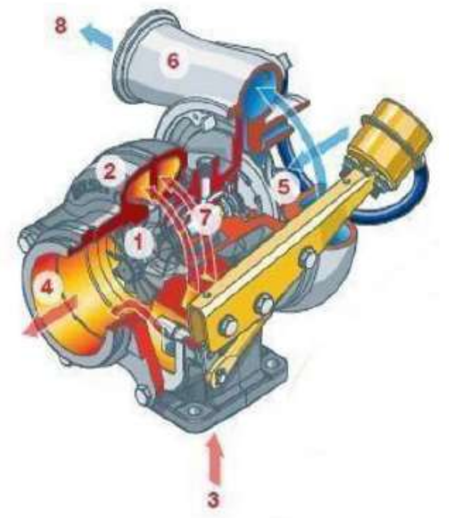

Fig -1: Conventional Turbocharger

A turbocharger is made up of two main sections: the turbine and the compressor. The turbine consists of the (1) turbine wheel and the (2) turbine housing. It is the job of the turbine housing to guide the (3) exhaust gas into the turbine wheel. The energy from the exhaust gas turns the turbine wheel, and the gas then exits the turbine housing through an (4) exhaust outlet area. The compressor also consists of two parts: the (5) compressor wheel and the (6) compressor housing. The compressor's mode of action is opposite that of the turbine. The compressor wheel is attached to the turbine by a (7) forged steel shaft, and as the turbine turns the compressor wheel, the high-velocity spinning draws in air and compresses it. The compressor housing then converts the high-velocity, low-pressure air stream into a high-pressure, low-velocity air stream through a process called diffusion. The (8) compressed air is pushed into the engine, allowing the engine to burn more fuel to produce more power.

1.2 Drawbacks and limitation of conventional systems

The conventional system of turbocharging suffers from two fundamental defects:

1.2.1 Back Pressure

Engine exhaust back pressure is defined as the exhaust gas pressure that is produced by the engine to overcome the hydraulic resistance of the exhaust system in order to discharge the gases into the atmosphere.

The major problems with increased back-pressure are:

- Increased pumping work
- Reduced intake boost pressure
- Cylinder scavenging problems
- Higher peak temperature-resulting in higher NOx emissions
- Higher specific fuel consumption

1.2.2 Turbo-lag

Turbo-lag basically refers to the time required for the turbo to spool up i.e. the time required for the required boost pressure to be achieved, this occurs mainly because of the finite time required for the pulse of exhaust gas to reach the turbine, hence making the turbocharger very unresponsive and sluggish at low speeds.

Variable geometry turbocharger are capable of reducing the turbo-lag to a large extent but is generally expensive and still has the disadvantage of back-pressure.

2. LITERATURE REVIEW

The proposed project basically deals with turbocharging and the concept of waste heat recovery from the exhaust of automobiles. There have been several studies on the topic of waste heat recovery from exhaust and also regarding the different methods of turbocharging.

Obviously these studies are of most importance as they focus on improving the overall performance of automobiles-which is crucial given the fact that the world's reserves of fossil fuels is rapidly depleting and pollution control and exhaust emission levels is of prime importance. The studies conducted in the relevant fields of turbocharging and waste heat recovery are as follows:

1. 'A comparative study on various turbocharging approaches based on I.C Engine exhaust gas energy recovery' – Jianqin Fu et al (Journal for Applied Energy Elsevier 2014).
2. 'Experimental investigation on heat recovery from diesel engine exhaust using finned shell and tube heat exchanger and thermal energy storage' – V. Pandiyarajan et al (Journal for Applied Energy-Elsevier 2011).

These are the two major studies that have been found to be relevant to the project proposal and the entire project is mainly based on these two references – though there have been several other studies that are of equal importance and they have been referred o during the development of this project proposal.

A very important development in the field of waste heat recovery is the BMW 'Turbosteamer'. The 'Turbosteamer' technology salvages heat from the radiator and engine exhaust while utilizing the steam produced from this heat in order to run a RANKINE CYCLE. So, obviously there are great similarities between the BMW turbosteamer and the proposed turbocharging model.

3. METHODOLOGY

The following methodology was followed in the course of the design of the proposed project:

1. Identifying the problem -the high amount of unutilized heat energy carried out by the exhaust.
2. Identifying the current methods of waste heat recovery – commercially available turbochargers, phase change materials, Rankine cycle, Brayton cycle, Thermoelectric generators etc. Whose waste heat recovery capabilities are being researched thoroughly.
3. Identifying the major problem related to present turbocharging systems – mainly back pressure, turbo-lag, low pressure boost at low rpm etc.
4. Suggesting an alternate design for turbocharging which could eliminate back pressure and facilitate more waste heat recovery from the exhaust.
5. After thorough research, the design was proposed to be based on either the RANKINE cycle or the BRAYTON cycle.
6. Considering the ease of demonstration and the fact that turbochargers are basically GAS turbines – the BRAYTON cycle was finalized as the basis of the new design.
7. Once the BRAYTON cycle was finalized, the major components involved were identified and decided upon, a heat pipe heat exchanger was decided to be used to extract heat from the exhaust for the BRAYTON cycle, owing to its ease of construction and relative compact nature.
8. Determine the approximate ratings of the required components for the budget estimation (components include Garrett GT 1544 turbocharger or equivalent, heat pipe heat exchanger, compressor to pressurize the working fluid of the BRAYTON cycle turbocharger)

4. DESIGN OF THE TURBOCHARGING SYSTEM SETUP

The system which is to be designed for demonstration and experimental purposes as shown below:

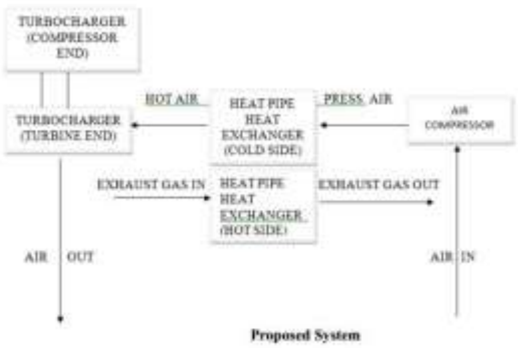

Fig – 2 Proposed System

In our new system we remove the back pressure on the engine by removing the exhaust line from the turbocharger turbine end and passing it through a heat exchanger. On the other side of the heat exchanger compressed air from an air compressor is passed. The compressed air absorbs heat from the heat exchanger and its pressure and temperature increases. This high pressure and high temperature air is fed into the turbine of turbocharger. The air gets expanded on the turbine blades rotating the turbine. Since the turbine is rotated this in turn rotates the compressor and compresses the intake air to the engine.

After calculation heat pipe heat exchanger for 2000 W was designed and fabricated. The experiment was conducted on a four cylinder four stroke diesel engine.

5. RESULTS AND DISCUSSION

The back pressure on the engine due to the turbocharger in the exhaust line is reduced by using the new design. The turbo lag can be reduced as an external air compressor is used to run the turbine of the turbocharger. The back pressure is reduced by a considerable amount when compared to the conventional turbocharging method because of the reduction in resistance to flow of exhaust gas by the heat pipes when compared to the turbine of the heat exchanger.

6. CONCLUSIONS

The proposed system of turbocharging has several benefits such as:

1. Reduced back pressure – because the exhaust flow is not obstructed by the turbine. This leads to more efficient working of the turbocharger, lesser operating temperatures and less specific fuel consumption.
2. Reduced Turbo-lag - Since the system has the air compressor end (which is responsible for the circulation of working fluid) coupled directly to the engine camshaft, the turbo tends to spool up almost instantly providing required boost pressure even at low speeds of operation.
3. Reduced NOx emissions due to lower operating temperatures.
4. Tuning of the turbocharger in order to get the required boost pressure is much easier for the operator.

The benefits of the proposed system of turbocharging have been mentioned previously. This design is useful mainly because of two factors:

6.1 Increased Fuel Efficiency

The proposed system of turbocharging, because of lesser backpressure and better waste heat recovery as compared to a conventional turbocharger, will have a lower specific fuel consumption thereby resulting in better fuel efficiency of the engine. This is extremely important in the modern day scenario of automobiles mainly because of the fact that the world's fossil fuel reserves are extremely limited and being depleted at a very rapid rate. This necessitates the need of finding more energy efficient methods of automobile design.

6.2 Reduced Emissions

Diesel engines are notorious for the high amounts of oxides of nitrogen that are emitted. NOx is extremely detrimental to the environment and has several harmful effects such as acid rain, eutrophication, and harmful effects on human health. Unfortunately, it is estimated that more than 50 percentage of the total NOx in the environment comes from I.C. engines specifically the diesel engines due to their high operating temperatures and pressures.

Over the years the regulations for the acceptable limits for NOx emissions has become extremely stringent all of which signal the need of reducing this harmful pollutant. The proposed design of turbocharging is expected to fulfil this requirement to a great extent.

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REFERENCES

[1] Jianqin Fu et al, "A comparative study on various turbocharging approaches based on I.C Engine exhaust gas energy recovery", Journal for Applied Energy, Vol:113, 2014, pp: 248-257.

[2] V. Pandiyarajan et al, "Experimental investigation on heat recovery from diesel engine exhaust using finned shell and tube heat exchanger and thermal energy storage", Journal for Applied Energy,

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