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Integrated Tri Turbine Turbocharger

Vikram R. Deshmukh
8th Semester Mechanical Engineering
PVG's College of Engineering and Technology

Rutuja A. Patil
8th Semester Mechanical Engineering
PVG's College of Engineering and Technology

Abstract:-With evolution pertaining in automobile industry at a rapid rate, incredible efforts are being directed to get maximum output with minimum input that is to increase the efficiency of the internal combustion engine to the maximum possible value. One such way is by supplementing the internal combustion engine with components such as turbochargers and superchargers. Turbochargers are the devices which use the exhaust gas velocity to run a compressor, which would in turn provide compressed air input to the engine. Many advancements in the turbo technology have been made over the years resulting in increased output and maximizing the efficiency. Twin turbo technology is one such advancement into turbo technology, which makes use of two turbo charger either in parallel or sequential configuration. However, both the setups have inherent disadvantage of turbo lag for parallel configuration and large space required, intricate piping and high cost for the sequential setup. The design put henceforth addresses both the problems by integrating three turbines (the no of turbines to be selected is solely dependent on the manufacturer and their needs) into a single turbocharger setup. The design has the advantage of minimum turbo lag at low rpm as, low boost threshold, high turbo boost at high rpm as well as a compact setup as compared to conventional twin turbo setup.

Keywords:-Efficiency, Turbocharger, Twin Turbocharger, Sequential, Turbolag

I. INTRODUCTION

Turbo lag is the time delay between opening the engine's throttle valve and when the turbo accelerates and delivers positive pressure (boost) to the engine when engine speed is above the boost threshold. The turbo does not react immediately to a change in throttle position or engine speed, it needs time to react and accelerate. This situation occurs to some degree in all turbocharged engines, but it is more prominent when a large capacity turbo with a large mass moment of inertia is fitted to a small capacity engine. Inertia is an objects resistance to a change in direction or speed. This means that a large, heavy turbine wheel will have more resistance to accelerate than a smaller, lighter version which is why reducing the mass and diameter of the compressor and turbine wheels is one way to reduce turbo lag. Turbocharged cars often experience lag at lower speeds, due the time required for sufficient exhaust pressure to build up and spool the turbo. A turbo's boost threshold is the engine speed (rpm) equivalent to the required exhaust gas flow for the turbo to produce boost, below this level the turbo simply will not produce boost and very little benefits will be achieved. Another way to minimize turbo lag, which also effects the boost threshold, is to fit a turbine housing with a smaller aspect ratio (A/R). A turbo with a smaller aspect ratio will be able to spool up faster and deliver greater boost pressure at a lower rpm when the exhaust gas pressure turning the turbine is reduced, but it will not provide a satisfactory amount of airflow at higher rpm. A larger aspect ratio on a turbocharger will allow for sufficient airflow at higher rpm but will considerably increase lag due to its difficulty spooling up at lower rpm.

II. BACKGROUND STUDY

Turbo lag is the time between mashing the throttle and feeling the rush of torque from a turbocharged engine. The lag comes from the time it takes the engine to create enough exhaust pressure to spin the turbo and pump compressed intake air into the engine and is longest when the engine is in a low-rpm, low-load cruising situation

A. Twin-Scroll Turbos

A twin-scroll turbo effectively brings together twin turbocharging into one neat package. Using two inlets for the exhaust gases instead of the conventional single inlet, this form of turbo is designed to operate at small and high exhaust gas flow rates, reducing the effects of turbo lag.

The first inlet to the turbocharger is designed for lower engine speeds where exhaust gas flow rate is low and is therefore small in diameter. This will maximize pressure on the impeller blades where most conventional turbos would be struggling to spool. The second inlet is consequently larger to deal with a high flow rate of exhaust gases.

B. Variable Geometry Turbos

This uses dynamic vanes within the turbo, which can open and close their relative angle to the central spinning shaft. This theoretically means that they can close right up to take advantage of lower engine speeds and then progressively open to then capitalize on the full potential of the vane surface area. The dangers of this technology are the risk of the vanes failing to open at the same rate as the increase in engine speed. If they were to stay shut, the turbocharger would input too much boost back into the cylinders and high RPM, which can easily end up in an engine blowout.

C. Nitrous

NOx is used to make the pressure within each cylinder sharply increase. Since that pressure is directly related with exhaust gas flow, the introduction of Nitrous to the combustion process makes for an instant pressure increase, which will translate through to the blades of the turbocharger, creating an instant and rapid spool.

D. Sequential Turbo

Two is normally always better than one and the same can be said for turbocharging. One small turbo and one large turbo work together to keep the engine boosted at as wide a range of RPMs as possible, reducing turbo lag. The small turbocharger only needs a small amount of inertia to get spooling and therefore boosts the engine at lower engine speeds. As the engine speed rises, the larger turbo is then introduced, using its larger vanes to increase the pressure of the recycled exhaust gases back into the combustion chamber.

E. Electric Hybrid Turbo

Using an electric motor between the inlet and outlet of the turbocharger, a load is applied through the central shaft of the turbo to keep it partially spooled and ready for the exhaust gases to catch up and take over the spooling process. Used primarily in Formula 1, the engine is constantly on boost even when exhaust gas flow is slow, making turbo lag minimal.

III. DRAWBACKS OF THE EXISTING CONVENTIONAL SYSTEMS

- Twin scroll turbos face the basic challenge of complex design. The complex shape of the runners and the requirement for a second wastegate and dump tube (one for each side of the divided turbine) there is more mass and more parts which adds expense and complexity.
- Variable Geometry turbos vary the aspect ratio by varying the area of discharge of air onto the turbo. This increases the backpressure due to smaller nozzle area and hence reduces efficiency. The dangers of this technology are the risk of the vanes failing to open at the same rate as the increase in engine speed. If they were to stay shut, the turbocharger would input too much boost back into the cylinders and high RPM, which can easily end up in an engine blowout.
- Nitrous is a car busting substance which gives rapid spool. However, it increases the harmful emissions of nitrous oxides and compounds and decreases the reliability of the engine.
- Sequential turbos play vital role in changing the aspect ratio and proving boost at high and low rpm. However, the layout of the system is very bulky with two compressors and long tubing arrangements.
- In electric hybrid turbos there is need for extra external electric power supply to run the motor. In addition, precautions need be taken that the motor is properly insulated from the heat of the engine.

IV. SOLUTION

The solution for all the above-mentioned problems is to integrate three turbines into a single exhaust circulation housing. The thee turbines provided would be of different radius and hence would have different aspect ratios.

Three turbines of varying aspect ratios would result in less turbo lag at low rpm, as the turbine with least aspect ratio would be functional at low rpm. However, at high rpm only the turbine with highest aspect ratio would be functional hence resulting in high boost by the compressor. The turbine with moderate aspect ratio would be operational at mid rpm ranges.

Figure 1: Turbofan Setup

(Turbine design are for representative purpose only)
The above picture shows the three turbines of different radius mounted on a single shaft. This shaft will be connected to the compressor.

V. CONSTRUCTIONAL DETAILS

All the three turbines would be mounted with bearings on a single shaft. Separate synchronizers would be provided to each of three turbines to bring the turbine to the shaft rpm while the turbine is in the process of being selected for operation over another.

The synchronizers would be selected or engaged by the selectors, which would be hydraulically operated.

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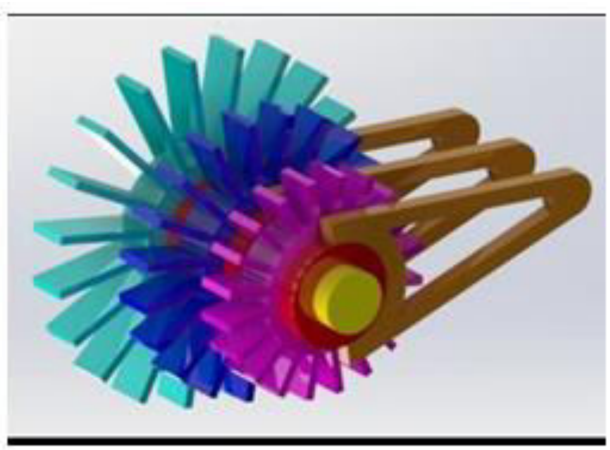

Figure 2: Turbofan Setup With Selector and Synchroniser

(Synchronizers and selectors are for representative purpose only)

The components shown in red represent the synchronizers and the brown coloured components are the selectors, which would engage and disengage the turbines.

All the components would be assembled in the casing, which would also serve the operation of providing exhaust to different turbines at appropriate rpm ranges.

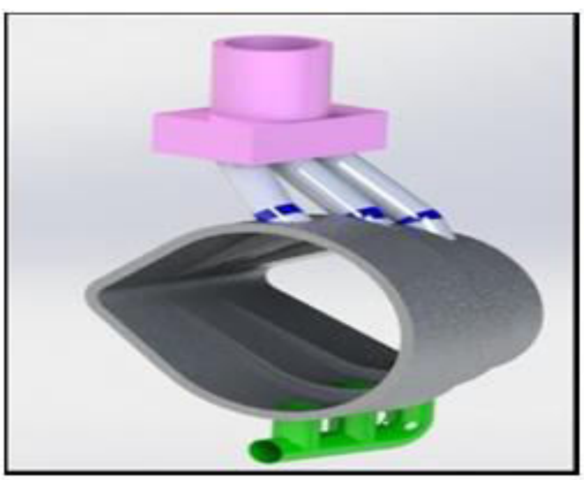

Figure 3: Casing Setup

The component in pink mark the entry point of the exhaust gases from the engine. These gases would then be passes upon to the turbine in operation with the help of tubing is provided.

The part highlighted in blue represent the position of butterfly valve, which would decide which turbine would receive the exhaust gases. During operation of one turbine, the other two valves would be completely closed.

The part represented in grey colour is the main turbine casing which would serve the purpose of circulating the exhaust gases at the turbines to obtain maximum operating rpm.

The component highlighted in green would act as the waste gate outlet tubes, which would extract the excess amount of exhaust if any.

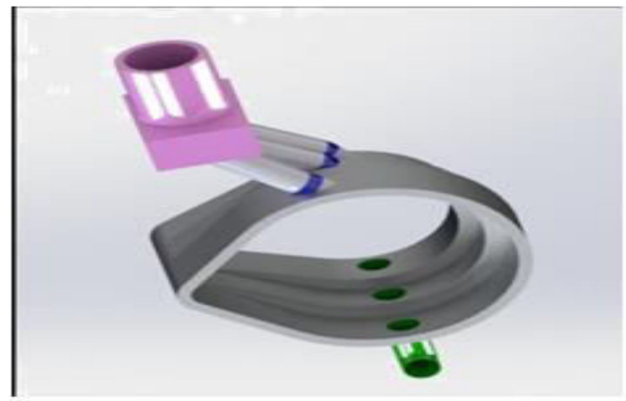

Figure 4: Casing Setup

The passages marked in yellow represent the inlet port of exhaust gases to their representative turbines. The inlet would be set at a specific angle to exert maximum force on the turbine.

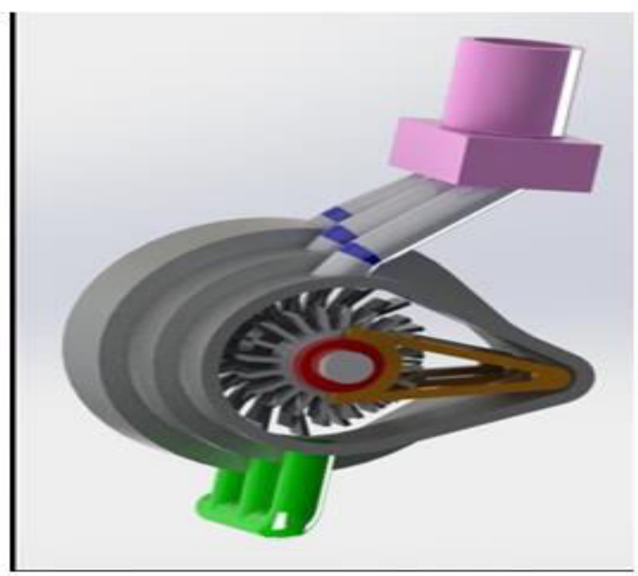

Figure 5: Turbocharger

The whole turbocharger assembly is shown above. The shaft would be connected to the compressor via the bearing support.

One important aspect of the casing not shown here is that all the three turbines would be separated from one another by separating walls which would result in the exhaust gases interfering with only the required turbine.

VI. WORKING OF THE SYSTEM

The turbines would become operational as soon as the engine is turned on and the exhaust gases are provided to the turbocharger.
In accordance to the type of engine used, the aspect ratios of the turbines would be selected as per the following factors:

- The aspect ratio of the smallest turbine would be selected to reduce the turbo lag at low rpm and hence reduce boost threshold.

- The aspect ratio of the mid-sized turbine would be selected to provide moderate boost in mid rpm range operation.

- The aspect ratio of the biggest turbine would be selected to provide max boost at high rpm ranges.

As the smallest turbine becomes operational at low rpm, due to small aspect ratio the turbo lag would be reduced to a minimum as per selection of radius of turbine.

As soon as the engine revs into mid rpm ranges, the selector on the smallest turbine would disengage the synchronizer and the butterfly valve in its input would be closed simultaneously.

As soon as this process is over the butterfly valve on the mid-sized turbine would open providing it with exhaust, simultaneously the selector would engage the synchronizer on the turbine bringing it to the shaft rpm in the process. Thus, this turbine would become operational and provide boost for mid rpm engine rpm.

The same process would be repeated for engaging the biggest turbine.

The whole process of changing the operating turbine would be monitored by an electronic control unit, which would get its input by the various pressure detecting sensors, the engine rpm sensors as well as the flow rate sensors for operating the butterfly valve, selectors, and the wastegates.

VII. CONCLUSION

The conclusion that can be drawn by studying the above design is that by using three (or as per requirement two) integrated turbines in a single turbocharger casing various flaws shown by the sequential and parallel setups of twin turbo charging can be improved upon and hence the efficiency of the internal combustion engine can be improved.

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