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Design and Fabrication of an Electrically Assisted Turbo Charger

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Abstract- **The electrically assisted turbocharger (EAT) is a novel technology that integrates an electric motor with a conventional turbocharger to enhance its performance, efficiency, and responsiveness. The EAT system uses the electric motor to assist the turbocharger during low-engine-speed conditions, providing instant boost pressure and improved engine responsiveness. This technology has the potential to significantly improve fuel efficiency, reduce emissions, and enhance overall engine performance.**

Keywords: **electrically assisted turbocharger, turbocharger peromance, fuel efficiency, emissions reduction, engine responsiveness.**

I. INTRODUCTION

An electrically assisted turbocharger (EAT) is an arrangement where an electric motor assists the gas-driven turbocharger in providing forced induction, particular at time when exhaust gas flow is insufficient to produce the desired boost. Some systems integrate the motor inside a turbocharger, while others use a separate electric supercharger. Like other forced induction devices, a compressor in the turbocharger pressurises the intake air before it enters the inlet manifold. In the case of a turbocharger, the compressor is powered by the kinetic energy of the engine's exhaust gases, which is extracted by the turbocharger's turbine.

II. LITERATURE SURVEY

[1] Manoj Sivaraman, Aakash AS, G Bharathiraja, V. Jayakumar, presented a paper and their contributions are as follows:

- The electric turbocharger works like a normal turbocharger which spools up and compresses air into the engine, but instead of connecting the compressor directly to the exhaust turbine, the exhaust turbine is connected to a high current alternator and runs a high-speed motor at the intake compressor.
- This reduces the spooling time of a turbocharger eliminating turbo lag which is in conventional turbocharger.
- The present work is focused on design and performance analysis on Electronic turbocharger to eliminate turbo lag.

[2] Woongkul Lee, Erik Schubert, Yingjie Li, Silong Li, Dheeraj Bobba, Bulent Sarlioglu presented a paper and their findings are as follows:

- This paper provides a comprehensive study on EFIS by investigating system level topologies, performance, various types of high speed machines, power electronics, and control techniques.
- The advantages and disadvantages of existing electric forced induction system are summarized and the new challenges and opportunities are also introduced.

[3] E. Winward, J. Rutledge,J. Carter, A. Costall, R. Stobart, D. Zhao, Z. Yang, presented a paper and their contributions are as follows:

- The Electric Turbocharger Assist device was based on a BorgWarner BV63 variable turbine geometry turbocharger with a bearing housing that was extended to accommodate a switched reluctance electrical machine.
- The ETA device was evaluated over a range of steady state and transient engine conditions with the ETA providing electric assist or electric regeneration.
- The response of the single stage ETA turbocharger matched a production 2-stage turbocharger on the same engine.

III. OBJECTIVES

- Reduce turbo lag: Turbo lag is a delay in the response of a turbocharged engine when the driver accelerates. This is because the engine needs to produce enough exhaust gas pressure to spin the turbine and force compressed air to the engine intake manifold. With the help of a motor, turbo lag can be reduced.
- Reduce emissions: When there is more air available for the fuel to burn inside the cylinder, complete combustion takes place and this causes less emissions
- Improve fuel efficiency: A turbocharger uses engine exhaust energy to breathe more air into the combustion chamber for a more efficient engine operation and more efficient usage of fuel.
- Increase boost pressure: Turbo boost pressure is the amount of air that the turbocharger forces into the engine. With the help of a motor, the amount of air forced into the engine can be reduced.

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- Better performance at low rpm: At lower RPM's enough energy is not available to rotate the turbine. This problem can be avoided by using a electric motor.

IV. DESIGN AND FABRICATION

Design of Turbocharger
Main Components:

- Turbine
- Compressor
- Shaft
- Compressor Wheel
- Turbine Wheel

Factors considered for the design

- Flow rate and pressure ratio
- Efficiency (adiabatic, polytropic, and isentropic)
- Turbine and compressor matching
- Shaft design and material selection
- Materials selection
- Manufacturing processes

Turbine Design

- Type of Flow: Mixed flow
- Blade Angle of Impeller: -22^0

Compressor Design

- Type of design: Radial flow
- Blade Angle of Impeller: 60°

Shaft Design

- Diameter: 7mm
- Length: 20mm

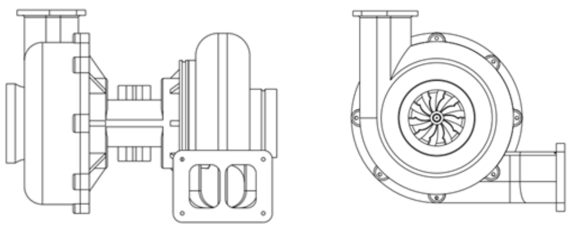

Fig- Assembly Drawing

Additive Manufacturing
Fusion Deposition Technique:

Step 1: The Preparation

- A geometrical model of conceptual design is created on CAD software which uses STL formatted files.

- It can then imported into the workstation where it is processed.
- The CAD file is sliced into horizontal layers after the part is oriented for the optimum build position.
- The necessary support structures are automatically detected and generated.
- The slice thickness vary between 0.172 mm to 0.356 mm depending on needs of the models.

Step 2: The Build

- The nozzle is heated to melt the plastic filament and is mounted to a mechanical stage which can move in both horizontal directions.
- As the nozzles is moved over the table in the required geometry, it deposits a thin bed of extruded plastic to form each layer and create a two-dimensional cross section of the model.
- The plastic hardens immediately after being squirted from the nozzle and bonds to the layer below.
- The platform then descends where the next layer is extruded upon the previous layer, this continued until the model is completed.
- The temperature of the system is maintained just below the melting point of the plastic.

Step 3: Post-processing
Once all the layer is drawn and the model is complete, the model is then removed from the platform and the support structures are removed from the part.

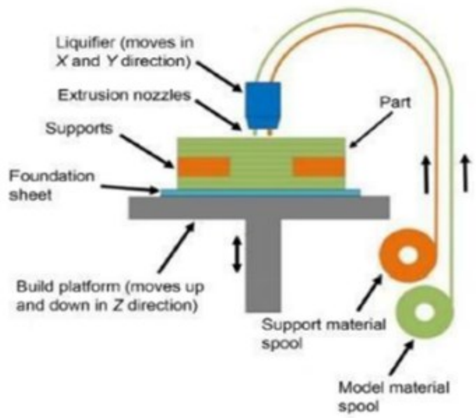

Fig-Fusion Deposition Modelling

Principle:

- The principle of the FDM is based on surface chemistry, thermal energy, and layer manufacturing technology.
- The material in filament (spool) form is melted in a specially designed head, which extrudes on the model.
- As it is extruded, it is cooled and thus solidifies to form the model. The model is built layer by layer, like the other RP systems.

- Parameters which affect performance and functionalities of the system are material column strength, material flexural modulus, material viscosity, positioning accuracy, road widths, deposition speed, volumetric flow rate, tip diameter, envelope temperature, and part geometry.
- Fused Deposition Modeling is an additive manufacturing process that can quickly produce geometrically complex parts through the melting, depositing, and solidifying of thermoplastics, layer by layer.
- Due primarily to its many cost -effective applications, Fused Deposition Modeling has emerged the most popular3D Printing method since its creation in the 1980s.

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V. PARTS OF THE TURBOCHARGER

Parts of the Turbocharger

- Turbine Section
- Compressor Section
- Central Housing
- DC Motor/Generator
- Arduino Board
- Battery

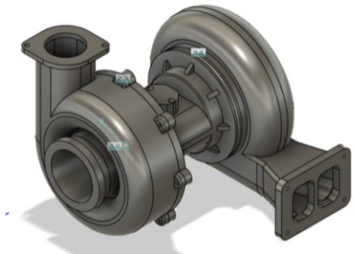

Fig-Turbocharger

- Turbine Section: Turbine section consists of the turbine wheel and turbine housing. The pressure energy available in the exhaust gases is converted into Kinetic energy by the turbine housing and is used for rotating the turbine wheel.

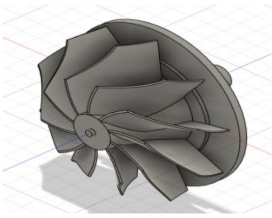

Fig-Turbine

- Compressor Section: The compressor consists of the compressor wheel and compressor housing. The compressor wheel draws in air axially and delivers it radially at a higher velocity. The compressor housing converts higher velocity air into higher pressure.

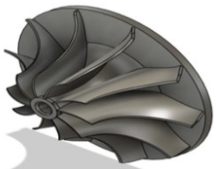

Fig-Compressor

- Central Housing: The central housing consists of shaft which connects the turbine and the compressor. A DC motor is coupled to the shaft.

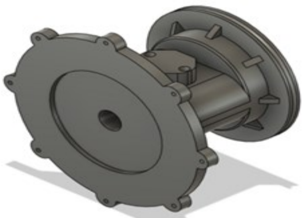

Fig-Central Housing

- DC Motor/Generator: A DC motor/generator is an electrical machine that converts electrical energy into mechanical energy and vice-versa. In a DC motor/generator, the input electrical energy is the direct current which is transformed into the mechanical rotation or Mechanical rotation is converted to electrical energy.

Fig-DC Motor/Generator

- Arduino Board: Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins, 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller, it is connected to a computer with a USB cable to get started.

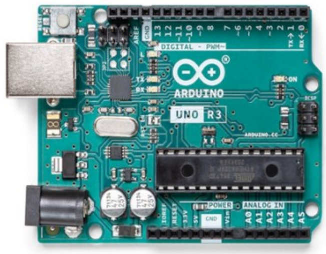

Fig-Arduino Uno

- Battery: The Battery used is a Lithium-ion Battery. A lithium-ion or Li-ion battery is a type of rechargeable battery that uses the reversible intercalation of Li+ ions into electronically conducting solids to store energy. In comparison with other commercial rechargeable batteries, Li-ion batteries are characterized by higher specific energy, higher energy density, higher energy efficiency, a longer cycle life, and a longer calendar life.

Fig-Li ion Battery

The Program used to run the DC motor/generator is as follows:

```
const int motor1Pin1 = 2;
const int motor1Pin2 = 3;
```

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```
 void setup() {
 pinMode(motor1Pin1, OUTPUT);
 pinMode(motor1Pin2, OUTPUT);
 digitalWrite(motor1Pin1, HIGH);
 digitalWrite(motor1Pin2, LOW);
 delay(30000);
 digitalWrite(motor1Pin1, LOW);
 digitalWrite(motor1Pin2, LOW);
 delay(1000);
 }
void loop() {
}
```

Working:
After the ignition, the DC Motor/Generator, connected to the compressor, will run up to 30sec and stop, this is done using Arduino Uno Microcontroller. The compressor draws in atmospheric air via the compressor chamber. This air is used to burn the fuel inside the engine cylinder. After DC Motor/Generator stops, there will be exhaust gases available in the engine that causes the turbocharger to spool up. The turbine, which shares the shaft with the DC Motor/Generator and the compressor, rotates because of the exhaust gases. This causes both the compressor and the shaft of DC Motor/Generator to rotate. The compressor draws in air and the cycle continues like a traditional Turbocharger. The Rotational Kinetic energy is converted to electrical energy by the DC Motor/Generator. This energy is stored in the rechargeable Lithium ion Battery.
The Electronic Control Unit consists of DC Motor/Generator, Arduino Uno Microcontroller, H Bridge and Battery. The DC Motor/Generator is connected to the Arduino Uno via an H bridge. An H-bridge is an electronic circuit that switches the polarity of a voltage applied to a load. These circuits are used to allow DC motors to run forwards or backwards. A program is fed to the Arduino Uno such that the DC Motor/Generator runs for 30secs and stops. The Motor/Generator is connected to a Lithium Ion Battery which stores the electrical energy of the Generator.

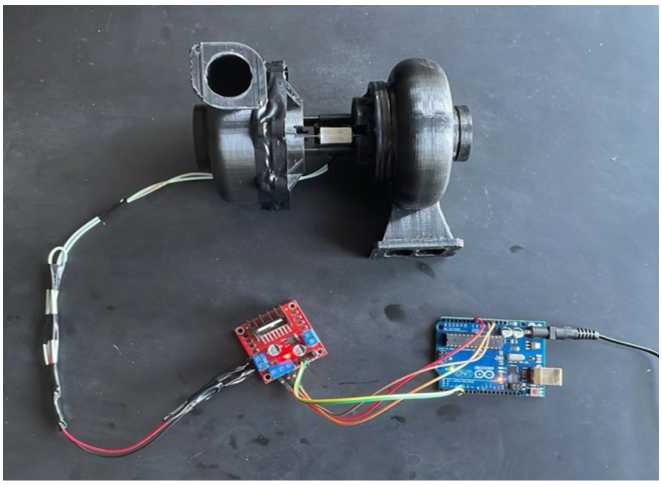

Fig – Final Model

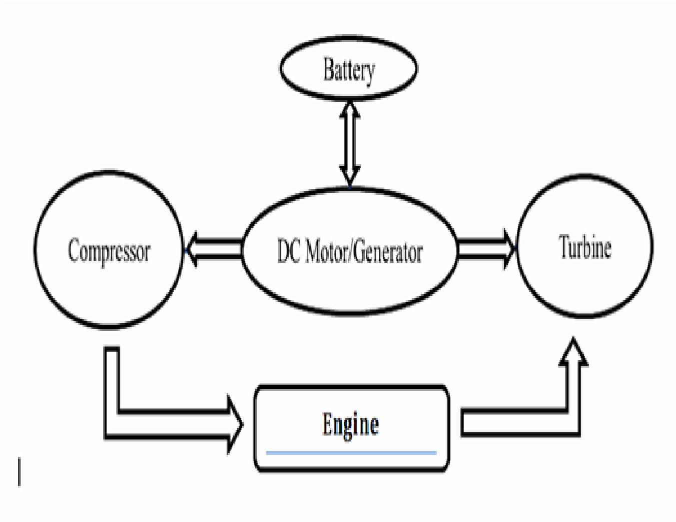

Fig – Block Diagram of Working of the Turbocharger

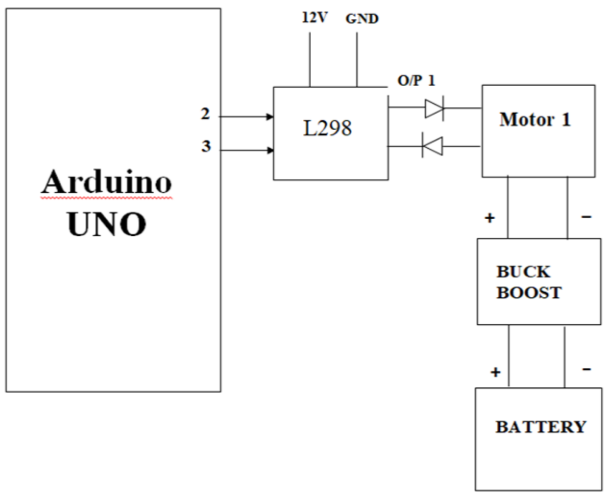

Fig – Circuit Diagram of ECU

VI. CONCLUSION

The Electrically Assisted Turbocharger (EAT) is a game-changing technology that offers a promising solution for enhancing turbocharger performance, efficiency, and responsiveness. By integrating an electric motor with a conventional turbocharger, EAT systems can provide instant boost pressure, improved engine responsiveness, and increased fuel efficiency. The benefits of EAT technology are numerous, including:

- Improved fuel efficiency: EAT systems can reduce fuel consumption by up to 10% compared to conventional turbochargers.
- Increased engine responsiveness: EAT systems can provide instant boost pressure, improving engine responsiveness and acceleration.
- Reduced emissions: EAT systems can reduce emissions by up to 20% compared to conventional turbochargers.
- Improved engine performance: EAT systems can improve engine performance by 15% compared to conventional turbochargers.

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