

# **Conversion of Naturally Aspirated Genset Engine to Meet III A Norms for Tractor Application by Using Turbocharger**

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**ABSTRACT:** The small power diesel engines are most demanding product in Indian market for power genset and Tractor applications. The basic requirements of the end user in off-road market are good response, transient performance, better low speed torque, better fuel efficiency and smooth operation of the engine. Additional requirements needed to sustain the market are downsizing of the engine, higher power to weight ratio and increased life of the engine.

Turbo charging applied to off road diesel engines is a promising solution for enhancing rated power, low end torque, transient performance, better low-speed torque, optimized fuel efficiency and downsizing diesel engines. A trade-off is required to match some conflicting issues, i.e. overall dimensions, cost, emissions control and performance in order to sustain. Future Diesel engine emission standards will further restrict vehicle emissions, particularly nitrogen oxides.

In the present work, reference is made to 1.29L, 2 cylinder in-line diesel engine for genset application and its conversion to off-road application satisfying all the needs of the market is attempted by the application of turbo charging. The development methodology adopted to achieve high pressure ratio turbo charging is discussed along with operating limitations. Turbo charging the internal combustion engine has become a key point in both reduction of pollutant emissions and improvement in engine performance. The matching between turbocharger and engine is difficult in two cylinder engines because of the highly unsteady flow and off-design conditions the turbocharger works with.

An elaborate study is done on this 2 cylinder compact diesel engine for the optimization of performance with changes in nozzle geometry, static injection timing, change in injector end pressure, nozzle tip protrusion and exhaust gas recirculation to achieve TREM IIIA norms in naturally aspired engine. The emission values are documented in the present work and further the behavior of the engine and the ease of meeting emission norms by turbo charging and intercooling is also done to clearly indicate the need of supercharging in off-highway applications

**KEYWORDS:** Good response, Transient performance, Turbo charging, compact diesel engine, Trem III A.

## **I. INTRODUCTION**

A diesel engine (also known as a compression-ignition engine) is an internal combustion engine that uses the compression to initiate ignition and burn the fuel that has been injected into the combustion chamber. This contrasts with spark-ignition engines such as a petrol engine (gasoline engine) or gas engine (using a gaseous fuel as opposed to gasoline), which use a sparkplug to ignite an air-fuel mixture. The diesel engine has the highest thermal efficiency of any standard internal or external combustion engine due to its very high compression. Low-speed diesel engines (as used in ships and other applications where overall engine weight is relatively unimportant) can have a thermal efficiency that exceeds 50%.

## II. TURBO CHARGING

Engine power is proportional to the amount of air and fuel that can get into the cylinders. All things being equal, larger engines flow more air and will produce more power. If a small engine has to perform like a big engine, or make the bigger engine produce more power, ultimately more air is to be drawn into the cylinder.

## III. ENGINE DETAILS

The engine used is a 2 cylinder constant speed direct injection diesel engine capable of generating 11.8 kW. The technical specification of the base engine is shown below

|                     |  |
|---------------------|--|
| No of Cylinder      | 2                                      |
| Power Rating        | 11.8 kW @ 1500 rpm (16 bhp @ 1500 rpm) |
| Engine Speed        | 1500                                   |
| Bore and Stroke     | 95 mm * 91 mm                          |
| Cubic Capacity      | 1.3 ltrs                               |
| Cooling System      | Water cooled                           |
| Aspiration type     | Naturally aspired                      |
| Compression Ratio   | 18.3:1                                 |
| Fuel Injection pump | Bosch , Inline                         |
| Emission Norms      | CPCB- I                                |

## IV. EXPERIMENTAL SETUP

The experimental setup consists of engine, dynamometer, gravimetric fuel measurement system, rectifier (converts AC to DC according which is used to start the engine), water cooling system, inlet depression and exhaust back pressure control valve. Airflow meter, blow by meter, testo emission meter, smoke Meter and crankcase pressure measuring instrument are the other instruments used for testing. The various parameters such as speed, torque, fuel time, fuel temperature, lube oil temperature, lube oil pressure, engine coolant temperature, inlet air temperature, exhaust gas temperature are indicated in the control panel.

### DYNAMOMETER

The engine is coupled to an Eddy current type dynamometer. It is connected to Engine by means of Cordon Shaft. The specification of the dynamometer is shown below

|                      |                                |
|----------------------|--------------------------------|
| Make                 | Benz system (Dynalec Controls) |
| Type                 | Eddy current                   |
| Model                | ECB 300                        |
| Capacity             | 200 Nm                         |
| Dynamometer Constant | 9549.3                         |
| BHP                  | (Torque x Speed)/Dyno constant |

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**PRESSURE MEASUREMENT**

U-tube glass manometer is used to measure pressure at required locations and the range required is shown below

| Parameter             | Sensor           | Range    | Fluid used     |
|-----------------------|------------------|----------|----------------|
| Inlet depression      | U-tube manometer | 0-300 mm | Water column   |
| Air after compressor  | U-tube manometer | 0-800 mm | Mercury column |
| Air after Intercooler | U-tube manometer | 0-800 mm | Mercury column |
| Exhaust back pressure | U-tube manometer | 0-300 mm | Mercury column |
| Lube oil pressure     | Transducer       | 0-10 bar | Strain gauge   |

**TEMPERATURE MEASUREMENT**

Thermocouple is used to measure temperature at required points. Digital indicators are available at the control panel.

| Sensor       | Type   | Range          |
|--------------|--------|----------------|
| Thermocouple | K type | -200 to 1000 c |

**EMISSION MEASUREMENT**

A portable emission meter is used to determine the exhaust emissions from the engine. Testo 350XL is the instrument used and is capable of measuring Carbon monoxide, Nitrogen oxides, Unburnt hydrocarbons in parts per million and it also measures oxygen and carbon di oxide content in percentage of exhaust flow.

**MEASUREMENT OF AIR FLOW**

An air flow meter is used to determine the mass of air that the engine takes. The specification of the air flow meter is shown below

| Make      | Range       | Sensitivity | Accuracy |
|-----------|-------------|-------------|----------|
| Sensyflow | 0-620 kg/hr | 0.1 kg/hr   | 5 % FSR  |

**TEST BED SETUP**

The experimental setup consists of The test engine Dynamometer Diesel tank Air filter Gravimetric fuel flow meter Sensyflow air flow meter Testo 350xl-flue gas analyser Temperature and pressure sensors Control panel.

**V. EXPERIMENTS ON TURBOCHARGED ENGINE**

A turbocharger was fitted in the engine and the performance with emission data were recorded to study the effect of turbo charging on engine exhaust emissions. In addition to the above, an attempt was also made to analyze the effect of varying combustion affecting parameters such as nozzle geometry, static injection timing, nozzle tip protrusion, and high pressure pipe change on the test engine. Table 4.3 shows the list of trials done to optimize the torque and power trend of the engine. Hence, these experiments are grouped together and are termed as torque shaping experiments.

**Torque trend shaping experiments**

| SI NO | INJECTOR  |            |              | SIT | NTP | HIGH PRESSURE PIPE |    |     | PURPOSE OF TRIAL   |
|-------|-----------|------------|--------------|-----|-----|--------------------|----|-----|--|
|       | Hole size | Cone angle | No. of spray |     |     | ID                 | OD | L   |  |
|       | mm        | deg        |              | deg | mm  | mm                 | mm | mm  |  |
| 1     | 0.19      | 142        | 5            | 13  | 2.5 | 1.8                | 6  | 260 | As it is –Torque back up 30% will result in high free acceleration smoke.                        |
| 2     | 0.21      | 142        | 5            | 13  | 2.5 | 1.8                | 6  | 260 | Injector trial- Increased hydraulic through flow to reduce torque back up.(torque curve shaping) |
| 3     | 0.21      | 142        | 5            | 13  | 2.5 | 2                  | 6  | 260 | HPP trial- Reduce residual pressure for reduced torque backup(torque cure shaping)               |
| 4     | 0.197     | 150        | 6            | 13  | 2.5 | 2                  | 6  | 260 | Injector trial- Increased hydraulic through flow to reduce torque back up.(torque curve shaping) |
| 5     | 0.197     | 150        | 6            | 13  | 1   | 2                  | 6  | 260 | NTP trials – bowl geometry matching to reduce smoke  |
| 6     | 0.17      | 144        | 5            | 10  | 2.5 | 1.8                | 6  | 260 | Injector trial   |

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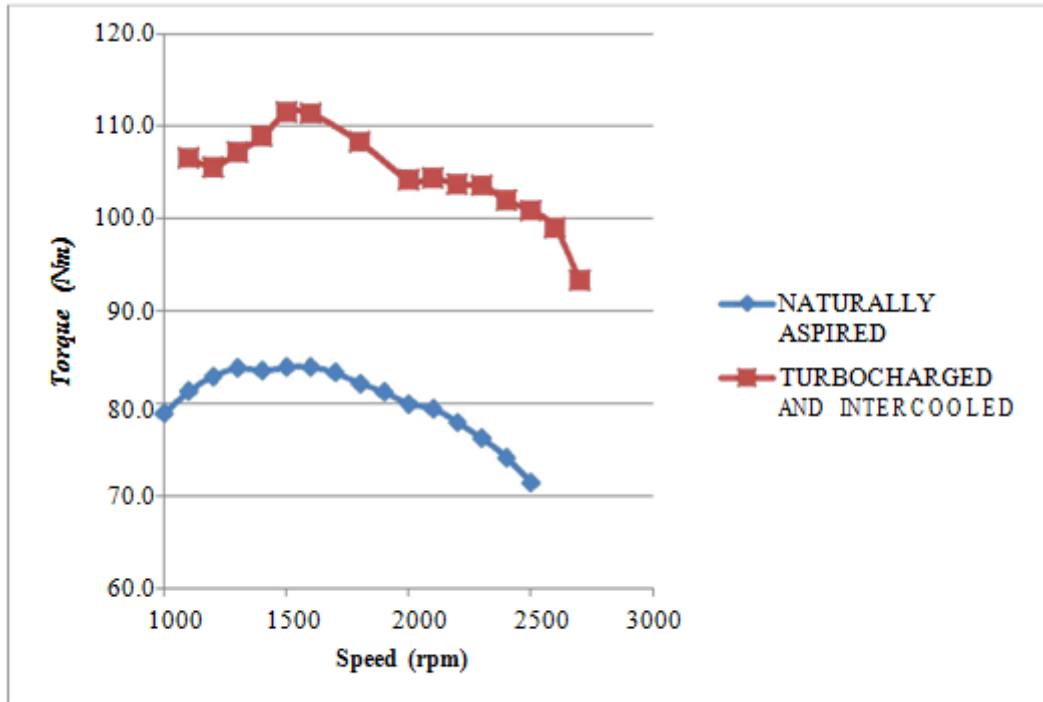
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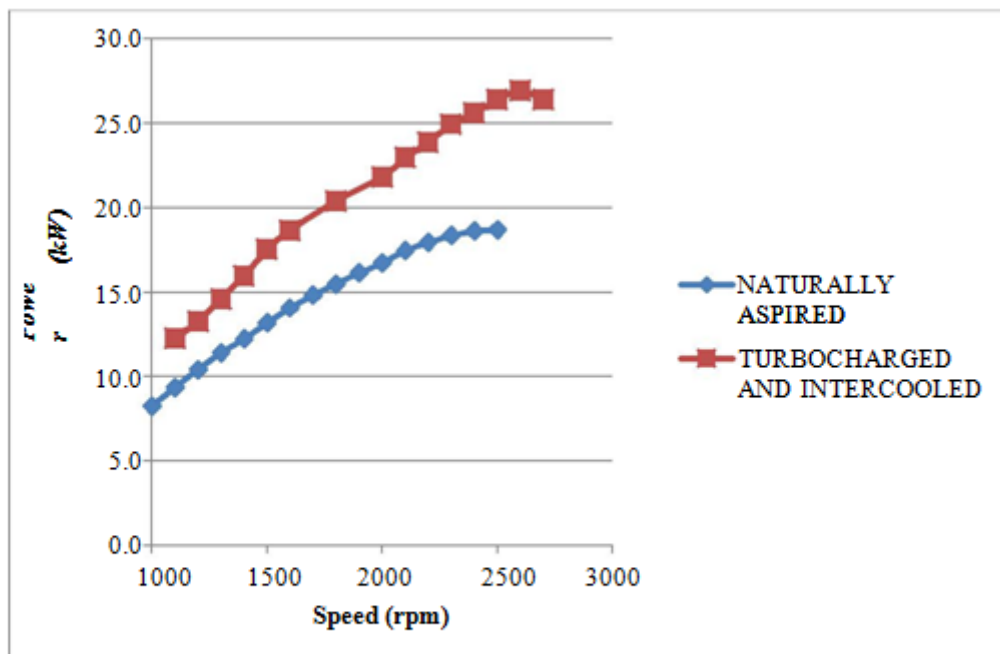
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**Comparison of Torque**



**Comparison of Power**

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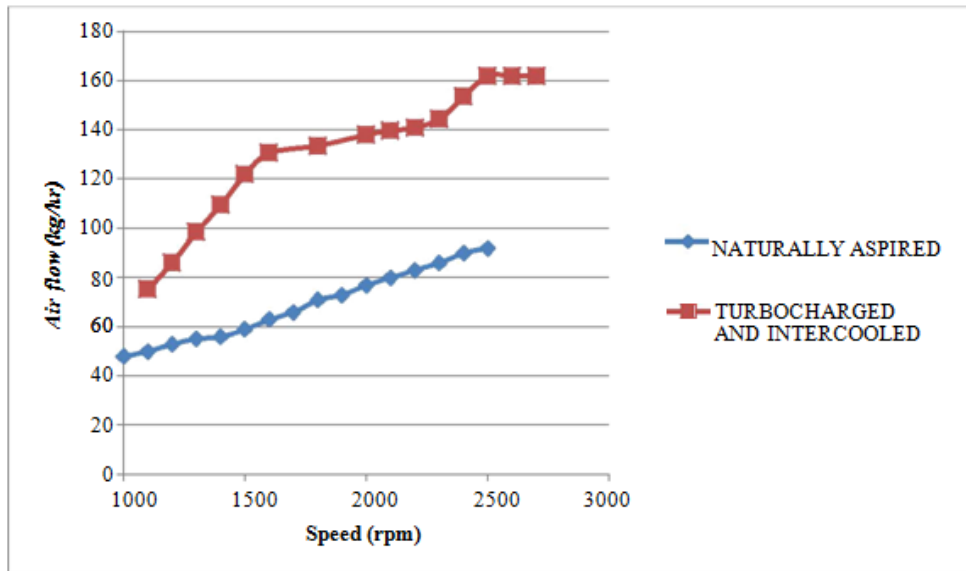
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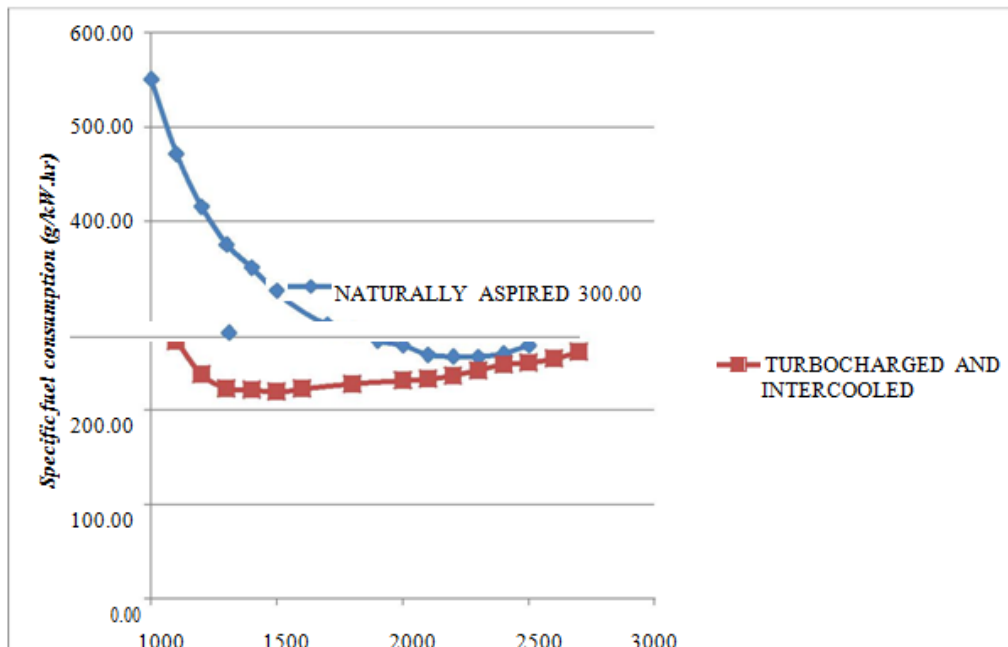
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Variation of Air Flow with Speed



Variation of specific fuel consumption with Speed

| Trial | ENGINE          |                    | PUMP |          |         |         | NOZZLE    |            |               | RESULTS        |        |       |       |        |
|-------|-----------------|--------------------|------|----------|---------|---------|-----------|------------|---------------|----------------|--------|-------|-------|--------|
|       | Rating          | Cam shaft          | SIT  | Plunger  | Plunger | Element | hole size | cone angle | No. of sprays | Seating washer | Nox    | Co    | Smoke | SFC    |
|       |                 |                    |      | diameter | lift    |         |           |            |               |                |        |       |       |        |
| 1     | 18.4kW@2500 rpm | regular            | 15   | 8        | 9       | LLA     | 0.17      | 144        | 5             | 2.5            | 9.210  | 6.404 | 3.2   | 249.52 |
| 2     | 18.4kW@2500 rpm | regular            | 11   | 8        | 9       | LLA     | 0.21      | 142        | 5             | 2.5            | 7.090  | 2.730 | 4.1   | 273.11 |
| 3     | 18.4kW@2500 rpm | regular            | 13   | 8        | 9       | LLA     | 0.21      | 142        | 5             | 2.5            | 8.070  | 3.120 | 3.6   | 260.00 |
| 4     | 18.4kW@2500 rpm | regular            | 15   | 8.5      | 9       | PE      | 0.21      | 142        | 5             | 2.5            | 10.410 | 3.190 | 3.1   | 249.38 |
| 5     | 18.4kW@2500 rpm | regular            | 15   | 8.5      | 9       | PE      | 0.17      | 144        | 5             | 2.5            | 12.330 | 2.404 | 1.89  | 235.02 |
| 6     | 18.4kW@2500 rpm | regular            | 12   | 8.5      | 9       | PE      | 0.17      | 144        | 5             | 2.5            | 10.740 | 2.800 | 2.747 | 240.00 |
| 7     | 18.4kW@2500 rpm | regular            | 12   | 8.5      | 9       | PE      | 0.19      | 142        | 5             | 2.5            | 9.961  | 3.761 | 1.82  | 241.00 |
| 8     | 18.4kW@2500 rpm | TINER (lift 0.7mm) | 12   | 8.5      | 9       | PE      | 0.17      | 144        | 5             | 2.5            | 8.48   | 18.11 | 8.5   | 296    |
| 9     | 25.7kW@2500rpm  | regular            | 17   | 8.5      | 9       | PE      | 0.197     | 150        | 6             | 1              | 11.400 | 1.100 | 1.2   | 237.00 |
| 10    | 25.7kW@2500rpm  | regular            | 15   | 8.5      | 9       | PE      | 0.197     | 150        | 6             | 1              | 10.310 | 1.200 | 1.4   | 239.00 |
| 11    | 25.7kW@2500rpm  | regular            | 12   | 8.5      | 9       | PE      | 0.197     | 150        | 6             | 1              | 7.830  | 1.600 | 1.83  | 249.00 |
| 12    | 25.7kW@2500rpm  | regular            | 8    | 8.5      | 9       | PE      | 0.197     | 150        | 6             | 1              | 6.44   | 2.54  | 2.36  | 240.00 |

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