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# Matching appropriateness of A58N70 and A58N72 Turbocharger with Commercial Haulage-Truck Engine

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## Abstract

Turbo-charger is castigated as the performance maker for commercial vehicle especially during the operating conditions at Maximum torque and higher loads. Complication lies in Turbo-matching and carried out by many methods. Automotive manufacturer added many components in supplier chain. This investigation adopts test based methodological approach to perform such turbo-matching. The simulation based method is used to obtain the initial operating conditions at various engine speeds by using manufacturer data. The same verified by Data-logger method through experimental observation of operating conditions at various routes namely rough road, highway and slope up at various specified speed also. Compressor map is used to depict the performance and evaluation of matching. The appropriate turbocharger is suggested.

**Key Words:** Turbocharger, Compressor, turbo-matching, Choke, Surge, Data-logger, Simulation.

## INTRODUCTION

Turbo charger is an accessory in the IC engines to boost pressure, especially at higher loads. Turbo charger also helps to reduce specific fuel consumption (SFC), downsizing the engine, reduce CO2 emission, etc.[1]-[5]. Due to the character of centrifugal compressor, the turbocharged engine yields lesser torque than naturally aspirated engine at lower speeds [6],[7]. Comparatively in diesel engine these problems very worse than petrol engine. Some of the system designs were made to mange this problem. They are: adopting the sequential system [8], incorporate the limiting fuel system, reducing the inertia, improvements on bearing, modification in aerodynamics [9], establishing electrically supported turbocharger [10], the use of positive displacement charger i.e., secondary charging system and use of either electric compressor or positive displacement charger with turbocharger [10],[11] facilitating the geometrical variation on the compressor and turbine [12], adopting the twin turbo system [13], and dual stage system [14]. It is noticed that the transient condition is always worst with the engine which adopted single stage turbo charger. The variable geometry turbine was introduced for reducing the turbo lag in petrol as well as diesel engines. But the system is not exact match for petrol engines [15]. Even though many research were done on this case still the problem is exist. [12],[15]-[18]. Though the advancements in system design like variable geometry turbine, common rail injection system, and multiple injections, the problem is still persist due to the limiting parameter say supply of air. [19] discussed in detail about the benefits, limitations of turbo charger in single stage, parallel and series arrangements. According to the literature the turbocharger matching is a tedious job and demands enormous skill. The turbo matching can be defined as a task of selection of turbine and compressor for the specific brand of engine to meet its boosting requirements. That is, their combination to be optimized at full load. The trial and error method cannot be adopted in this case because the matching is directly effects as well as affects the engine performance [5],[20],[21]. So it is difficult task and to be worked out preciously. If one chooses the trial and error or non precious method, it will certainly lead to lower power output at low speeds for partly loaded engines for the case of two stage turbo charger. It is because of the availability of a very low pressure ratio after every stage than single stage [21]. Some cases the turbocharger characteristics are not readily available, and in some cases, not reliable or influenced by the engine which is to be matched [19]. Nowadays the Simulator is used for matching the turbocharger to the desired engine. The simulator was used to examine the performance at constant speed of 2000 rpm of two stage and single stage turbo chargers, the aim of the study was to optimize the high load limit in the Homogeneous charge compression ignition engine. For increasing the accuracy of matching the test bench method is evolved. Test bench was developed and turbo mapping constructed for various speeds to match the turbocharger for the IC engine by Leufven and Eriksson, but it is a drawn out process [21]. The on road test type investigation is called Data Logger based Matching method is adopted in this research. [22] discussed the data-logger turbocharger matching method in detail and compared with the result of test best method and simulator based matching method. And proved the data logger method outputs are reliable. By use of the data logger method the performance match can be evaluated with respect to various speeds as well as various road conditions. The core objective of this research is investigating the appropriateness of matching of the turbocharger with A58N70 and A58N72 for the TATA 497 TCIC -BS III Engine by simulator method. The validation of the same by Data Logger based Matching method.

## 1. MATERIAL AND METHODS

A logical science of combining the quality of turbocharger and engine and which is used to optimize the performance in specific operating range is called as turbo-matching. The Simulator method, data-logger method and Test Bed method is identified for this matching. Apart from the above three this research used the Simulator method and data-logger method for evaluating the performance of turbo matching. The trim size is a parameter, which can be obtained from the manufacture data directly or by simple calculation. That is the trim size is a ratio of diameters of the inducer to exducer in percentage. This parameter is closely related to the turbo matching. Various trim sizes are available, but in this study the trim size 70 and 72 are considered for investigation.

### A. SIMULATOR BASED MATCHING

Various kinds of simulation software are being used for turbo matching. In this research the minimatch V10.5 software employed for turbo-matching by simulation. The manufacturer data of the engine and turbocharger are enough to find the matching performance by simulation. The manufacturer data are like turbo configuration, displacement, engine speed, boost pressure, inter cooler pressure drop and effectiveness, turbine and compressor efficiency, turbine expansion ratio etc. The software simulates and gives the particulars of the operating conditions like pressure, mass flow rate, SFC, required power etc. at various speeds. These values are to be marked on the compressor map to know the matching performances. The compressor map is a plot which is used for matching the engine and turbocharger for better compressor efficiency by knowing the position of engine operating points. Based on the position of points and curve join those points the performance of matching will be decided.

### B. DATA LOGGER BASED MATCHING

This type of data collection and matching is like on road test of the vehicle. This setup is available in the vehicle with the provision of placing engine with turbocharger and connecting sensors. It is a real time field data gathering instrument called as Data-logger. It is a computer aided digital data recorder which records the operating condition of the engine and turbo during the road test. The inputs are gathered from various parts of engine and turbo charger by sensors. The Graphtec make data logger is employed in this work. It is a computerized monitoring of the various process parameters by means of sensors and sophisticated instruments. The captured data are stored in the system and plot the operating points on the compressor map (plot of pressure ratio versus mass flow rate). The Fig. 1 depicts the setup for the data-logger testing in which the turbocharger is highlighted with red circle.

### C. DECISION MAKING

The decision making process is based on the position of the operating points on the compressor map. The map has a curved region like an expanded hairpin, in which the left extreme region is called surge region. The operating points fall on the curve or beyond, is said to be occurrence of the surge. That means the mass flow rate limit below the compressor limit. This causes a risk of flow reversal. The right extreme region curve is called as Choke region. The points fall on the curve and beyond its right side is denoted as the occurrence of choke. In the choke region the upper mass flow limit above compressor capacity, which causes the quick fall of compressor efficiency, Chances for compressor end oil leakage and insufficient air supply. The all operating points fall in between those extreme regions i.e., the heart region holds good. It must be ensured at all levels of operation of the engine holds good with the turbocharger. The manufacturer of Turbocharger provides the compressor map for each turbo charger based on its specifications.

### D. ENGINE SPECIFICATIONS

**Table 1: Specification of Engine**

| S.No | Description | Specifications |
|---|---|---|
| 1 | Fuel Injection Pump | Electronic rotary type |
| 2 | Engine Rating | 92 KW (125 PS)@2400 rpm |
| 3 | Torque | 400 Nm @1300-1500rpm |
| 4 | No. of Cylinders | 4 Cylinders in-line water cooled |
| 5 | Engine type | DI Diesel Engine |
| 6 | Engine Bore / Engine Stroke | 97 mm/128mm. |
| 7 | Engine speed | 2400 rpm (Max power), 1400 rpm (Max Torque) |

The TATA 497 TCIC -BS III engine is a common rail type diesel engine. It is commonly used for medium type commercial vehicle like Tata Ultra 912 & Tata Ultra 812 trucks. The engine develops 123.29 BHP at 2,400 rpm and also develops the peak torque of 400 Nm between 1,300 and 1,800 rpm. The other specifications can be found in Table 1.

### E. TURBOCHARGERS SPECIFICATIONS

**Table 2: Specification of Turbo Chargers**

| S.N | Description | A58N70 | A58N72 |
|---|---|---|---|
| 1 | Turbo maximum Speed | 200000 rpm | |
| 2 | Turbo Make | HOLSET | |
| 3 | Turbo Type | WGT-IC (Waste gated Type with Intercooler) | |
| 4 | Trim Size (%) | 70 | 72 |
| 5 | Inducer Diameter | 48.6mm | 50.1 mm |
| 6 | Exducer Diameter | 69.4mm | 69.58mm |

The TATA Short Haulage Truck, turbochargers of A58N70 and A58N72 are considered to examine the performance of matching for TATA 497 TCIC -BS III engine. For example, if specification A58N70 means in which the A58 is the design code and N70 is the Trim Percentage in Percentage. The other specification is furnished in the Table 2.

## 2. EXPERIMENTAL OBSERVATION

The simulator and data-logger method is adopted to match the turbo Chargers A58N70 and A58N72 for TATA 497 TCIC -BS III engine. The matching performance can be obtained in the simulator by feeding necessary data from the manufacturer catalogue. The simulator simulates and presented the values of specific fuel consumption, pressure ratio and mass flow rate at various speeds as measure of performances for identifying the matching performance of the turbo-charger for desired combination. The simulator based matching observations are obtained and presented as observation samples in the Table 3 for turbo Charger A58N70 and A58N72 turbocharger respectively. In data-logger method the turbocharger is connected to the TATA 497 TCIC -BS III Engine of TATA 1109 TRUCK with sensors. The vehicle loaded to rated capacity 7.4 tonnes of net weight. The grass weight of vehicle is 11 tonnes. The experimental setup is shown in the Fig. I. The same operating speeds (1000, 1400, 1800 and 2400 rpm) were preferred to examine the matching performance on Highway, and slope up. The recorded observations were different routes like rough road, plotted separately for each route along with simulator solution in the following figures. The Fig.2 and Fig.3 are for Rough route for turbo Chargers A58N70 and A58N72 turbocharger respectively. Similarly Fig.4 and Fig.5 for Highway route and Fig.6 and Fig.7 for City Drive, Fig.8 and Fig.9 for Slope Up and similarly Fig.10 and Fig.11 are for Slope Down.

**Fig. 1: Experimental set up of Data-Logger method**

**Table 3: Simulated observations for A58N70 and A58N72 Turbo matching**

| S.No | Engine Speed (rpm) | Mass Flow Rate (Kg/sec.sqrt K/Mpa) | | Pressure Ratio | |
|---|---|---|---|---|---|
| | | A58N70 | A58N72 | A58N70 | A58N72 |
| 1 | 1000 | 9.534 | 13.265 | 1.856 | 1.284 |
| 2 | 1400 | 20.186 | 24.789 | 3.042 | 2.678 |
| 3 | 1800 | 27.958 | 32.265 | 3.548 | 3.224 |
| 4 | 2400 | 35.488 | 36.256 | 3.764 | 3.427 |

**Table 4: Data-logger – Rough Road Route observations for A58N72 and A58N72 Turbo matching**

| S.No | Engine Speed (rpm) | Mass Flow Rate (Kg/sec.sqrt K/Mpa) | | Pressure Ratio | |
|---|---|---|---|---|---|
| | | A58N70 | A58N72 | A58N70 | A58N72 |
| 1 | 1000 | 8.43 | 9.32 | 1.29 | 0.97 |
| 2 | 1400 | 16.27 | 17.23 | 1.9 | 1.77 |
| 3 | 1800 | 23.87 | 25.73 | 2.29 | 2.25 |
| 4 | 2400 | 28.49 | 29.72 | 2.51 | 2.38 |

**Table 5: Data-logger – Highway Route observations for A58N70 and A58N72 Turbo matching**

| S.No | Engine Speed (rpm) | Mass Flow Rate (Kg/sec.sqrt K/Mpa) | | Pressure Ratio | |
|---|---|---|---|---|---|
| | | A58N70 | A58N72 | A58N70 | A58N72 |
| 1 | 1000 | 8.52 | 9.39 | 1.31 | 0.97 |
| 2 | 1400 | 16.39 | 17.28 | 1.87 | 1.77 |
| 3 | 1800 | 23.94 | 25.79 | 2.3 | 2.25 |
| 4 | 2400 | 28.91 | 29.77 | 2.51 | 2.38 |

**Table 6: Data-logger – City Drive observations for A58N70 and A58N72 Turbo matching**

| S.No | Engine Speed (rpm) | Mass Flow Rate (Kg/sec.sqrt K/Mpa) | | Pressure Ratio | |
|---|---|---|---|---|---|
| | | A58N70 | A58N72 | A58N70 | A58N72 |
| 1 | 1000 | 8.49 | 9.43 | 1.32 | 0.99 |
| 2 | 1400 | 16.31 | 17.32 | 1.95 | 1.83 |
| 3 | 1800 | 23.78 | 25.84 | 2.33 | 2.29 |
| 4 | 2400 | 28.37 | 29.86 | 2.56 | 2.41 |

**Table 7: Data-logger – Slope –Up observations for A58N70 and A58N72 Turbo matching**

| S.No | Engine Speed (rpm) | Mass Flow Rate (Kg/sec. sqrt K/Mpa) | | Pressure Ratio | |
|---|---|---|---|---|---|
| | | A58N70 | A58N72 | A58N70 | A58N72 |
| 1 | 1000 | 8.58 | 9.51 | 1.31 | 0.96 |
| 2 | 1400 | 16.34 | 17.76 | 2.00 | 1.85 |
| 3 | 1800 | 23.98 | 25.95 | 2.37 | 2.3 |
| 4 | 2400 | 28.98 | 29.93 | 2.58 | 2.46 |

**Table 8: Data-logger – Slope –Down observations for A58N70 and A58N72 Turbo matching**

| S.No | Engine Speed (rpm) | Mass Flow Rate (Kg/sec.sqrt K/Mpa) | | Pressure Ratio | |
|---|---|---|---|---|---|
| | | A58N70 | A58N72 | A58N70 | A58N72 |
| 1 | 1000 | 8.47 | 9.27 | 1.30 | 0.98 |
| 2 | 1400 | 16.32 | 17.12 | 1.95 | 1.73 |
| 3 | 1800 | 23.89 | 25.47 | 2.31 | 2.18 |
| 4 | 2400 | 28.42 | 29.59 | 2.5 | 2.34 |

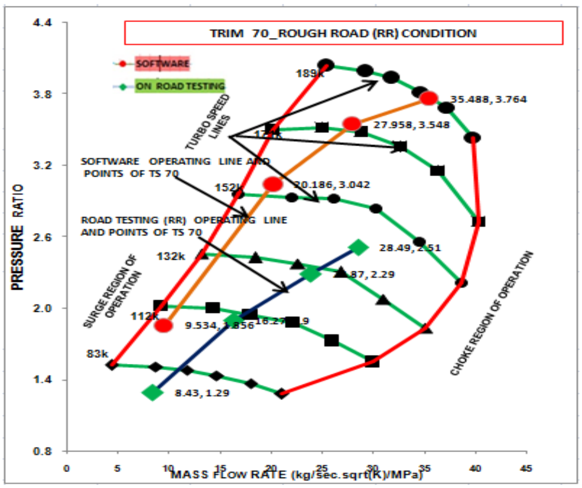


Figure 2: A58N70 Turbo-match-Rough Road

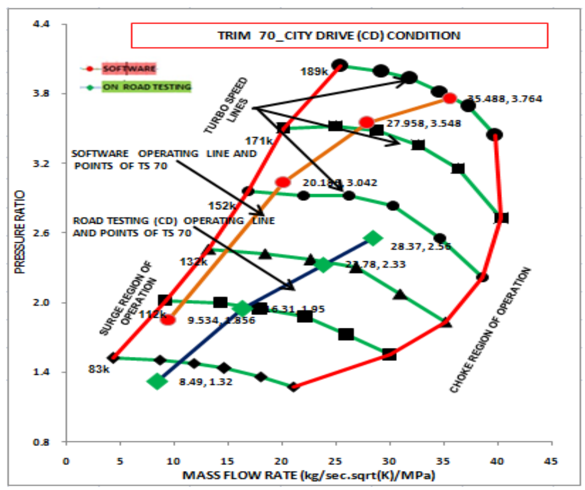


Figure 6: A58N70 Turbo-match- City Drive

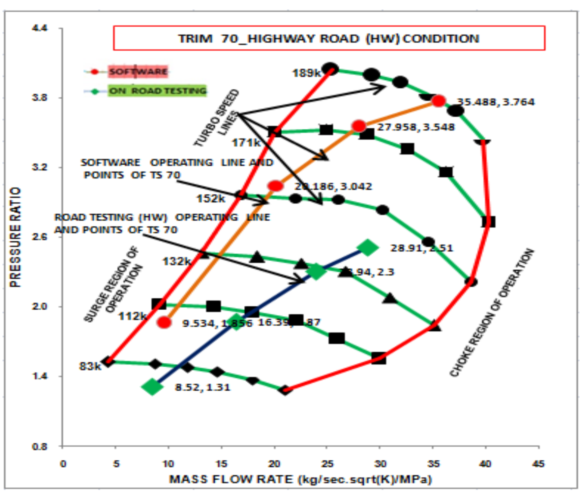


Figure 4: A58N70 Turbo-match-Highway

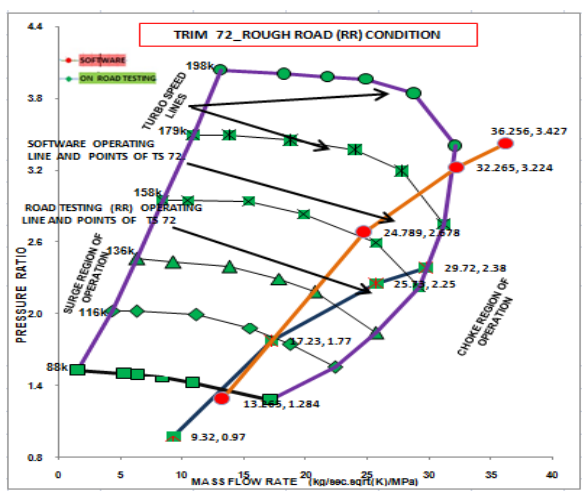


Figure 3: A58N72 Turbo-match – Rough Road

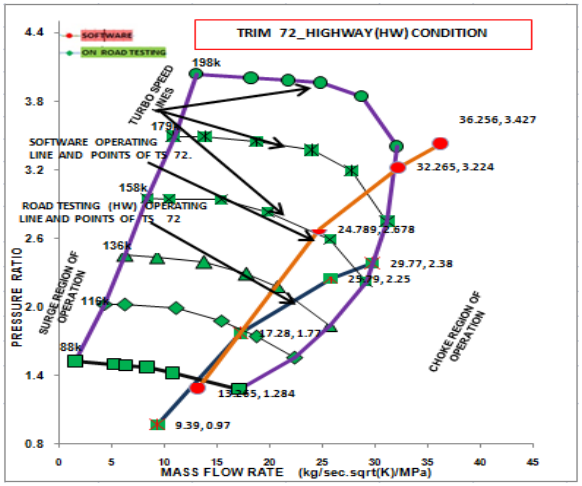


Figure 5: A58N72Turbo-match- Highway

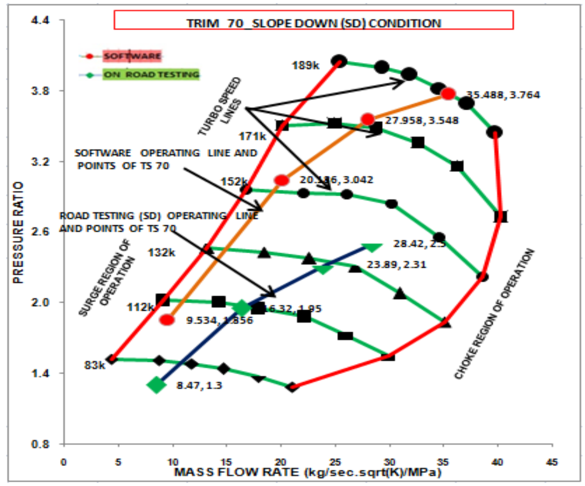


Figure 10: A58N70 Turbo-match - Slope-Down

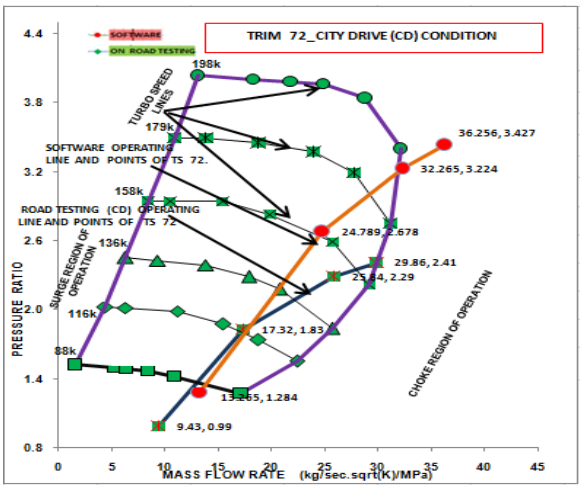


Figure 7: A58N72 Turbo-match – City Drive

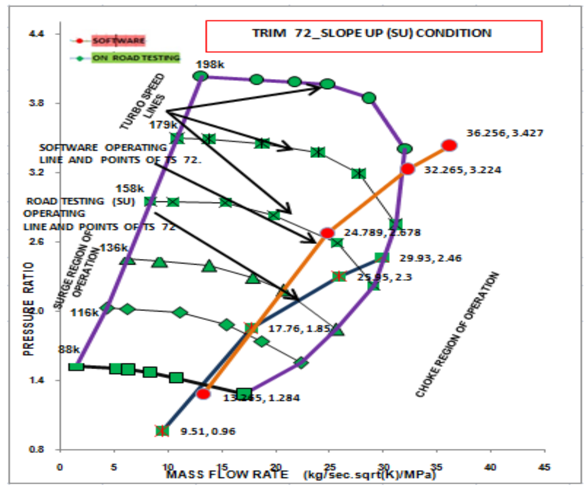


Figure 9: A58N72 Turbo-match- Slope-Up

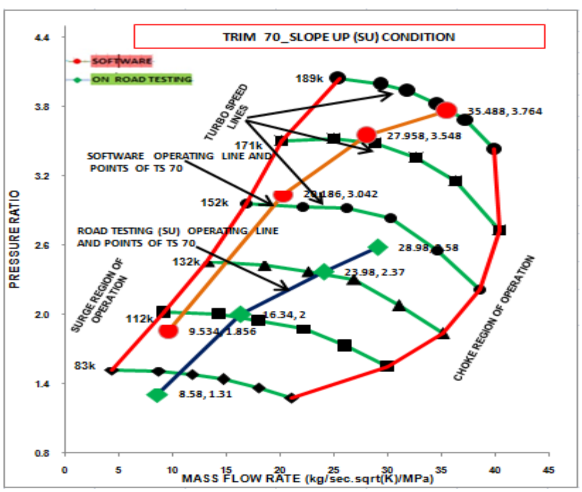


Figure 8: A58N70 Turbo-match- Slope-up

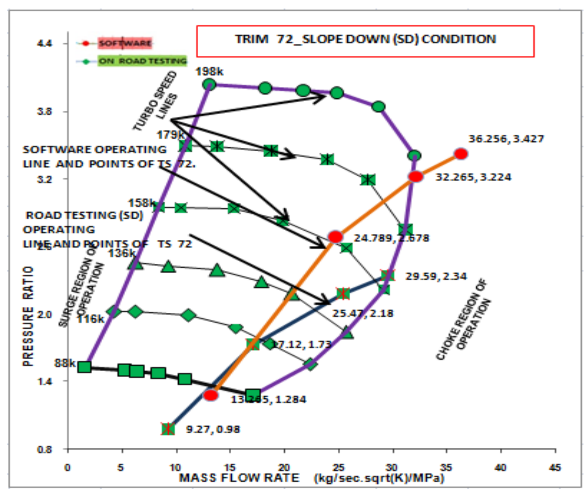


Figure 11: A58N72 Turbo-match – Slope Down

## 3. RESULTS AND DISCUSSIONS

The operating conditions obtained for both case of turbo-chargers with engine for both simulator and data-logger method with rough road route, highway route and slope-up route, City Drive and Slope down were obtained. These operating conditions were marked on the compressor map. The details of mappings already discussed above. This can be noted that the turbo-match A58N72 at higher load moves towards choke region of operation which decreases the compressor performance but at lower speed the matching performance is safe. But the A58N70 turbo match it was found in both methods that operating conditions are satisfied at all the range of speeds away from surge and choke irrespective of routes the vehicle operated. The data-logger method adapted in this research may feel as expensive but it is one time job of finding the best turbo-match for an engine category.

## 4. CONCLUSION

The turbo-matching of A58N70 turbocharger and A58N72 turbocharger for TATA 497 TCIC -BS III engine is considered. The simulator method is employed to found match of turbochargers individually with the engine. The same was verified by experimental method called Data-logger at different routes. The simulator gives more values than the actual values obtained by experimentation that is data-logger method. The results were deployed and presented with compressor map. The turbo-charger A58N72 performs well at all operating fields except higher speed. Because, the operations of vehicle at higher speed, the choke occurs at flow. The same operating performance was observed in simulated solution as well as data-logger method with irrespective of routes. The turbocharger A58N70 operating performance shows that the turbo-match is good at lower ,medium as well as at higher speed, much away from surge and choke region of operation. As the occurrences of choke at higher speed with turbocharger A58N72 was observed and such speeds are unavoidable and there is no compromise. Hence it is concluded that the adaption of A58N70 will meet the requirement completely with the TATA 497 TCIC -BS III engine. So A58N70 turbocharger is found match for TATA 497 TCIC -BS III engine.

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