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Turbo-matching of A58N70 Turbo-charger for a Commercial Vehicle Engine

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Abstract
Turbocharger is a Charge booster, which helps the automobiles, especially at higher loads by providing best operating performance. The adaption of such turbocharger for the desired engine is a tedious job and requires intensive care. The mismatch may decrease the operating performance by occurrence of surge or choke in the flow of charge and may cause bearing oil leakage. As the turbochargers are now supplier supply, the simulation and data-logger matching methods are considered for evaluation. The matching performance is predicted by the simulation and the same was verified with data-logger method. This research aims to find the appropriateness of matching of A58N70 Turbo Charger for the TATA 497 TCIC -BS III engine. The data-logger matching was carried out with various routes like Rough Road, Highway, City Drive, slope up and slope down were considered in evaluating matching performance. The results compared with use of compressor map.
Keywords- ***TS70, Turbo matching, Data-logger, trim size, surge, choke***

1. 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 CO_2 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 manage this problem. They are: adopting the sequential system [8], incorporate the limiting fuel system, reducing the inertia, improvements in bearing, modification on 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 that system is not accurate match for petrol engines [15]. Even though many researches 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 monotonous 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 affecting the engine performance [5],[20],[21]. So it is a 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 this method the performance match can be evaluated with respect to various speed as well as various road conditions. The objective of the research is investigating the matching performance of the turbocharger with trim size 70 to the TATA 497 TCIC -BS III Engine by simulation method. The validation was carried out by Data Logger turbo matching method.

2. Materials And Methods

A logical science of combine 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 is used for investigation.

2.1 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 engine and turbocharger are enough to find the matching performance. 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 operating pressure, mass flow rate and SFC, required power, SFC etc at various speeds. These values are located in the compressor map that is the plot of pressure ratio vs. mass flow rate. Based on the position of points and curve join those points the performance of matching will be decided.

2.2 Data Logger based Matching

This type of data collection and matching is like on road test of 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. The inputs are gathered from sensors at various parts of engine and turbo charger. 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 plot of pressure ratio vs mass flow rate. The figure 1 depicts the experimental setup and the turbocharger is highlighted with a red circular mark.

Figure 1 Experimental setup on Data-logger Method

2.3 Decision Making

The decision making process is based on the position of the operating points in the turbo map. The Turbo map is plot of pressure ratio versus the mass flow rate plot. The plot has a curved region like hairpin bend road, in which the left extreme region is called as surge region. The operating points falls on the curve or its left side, is said to be occurrence of surge. That means the mass flow rate limit below the compressor limit. This may cause the 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 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 region holds good, i.e., heart region with maximum efficiency. It must be ensured at all level of operation of the engine holds good with the turbo charger. The manufacturer of Turbocharger provides the compressor map for each turbo charger based on its specifications.

2.4 Engine Specifications

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.

Table 1Specification of Engine

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

2.5 Turbocharger Specifications

The TATA Short Haulage Truck bearing HE 221W-4045 series turbocharger (A58N70) is considered for examine the performance of matching for TATA 497 TCIC -BS III engine. Here A58 is design code and N70 meant that the Trim Size of the turbo charger in percentage. The other Specification furnished in Table 2.

Table 2 Specification of Turbo Charger A58N70

Description	Specification
Turbo maximum Speed	200000 rpm
Turbo make	Holset
Trim Size	70
Inducer Diameter	48.6 mm
Exducer Diameter	69.4 mm
Intercooler	WGT-IC (Waste gated Type with Intercooler)

3. Experimental Observations

The simulation and data-logger methods are adopted to analyze the turbo match of the Turbocharger A58N70 to TATA 497 TCIC -BS III engine. The matching performance can be obtained by simulation by using the data from the manufacturer catalogue. The desired combination is simulated at various speeds (1000, 1400, 1800 and 2400 rpm) speeds to obtain the predicted operating conditions for this combination. The specific fuel consumption, pressure ratio and mass flow rates are important parameters to know the turbo matching performance. The simulated observations presented in the Table 3. 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 for Data logger type matching is shown in Fig. 1. The operating conditions collected while driving at a specific speed in the selected route. For the same set of engine speeds the operating conditions were observed while vehicle driving in the routes like Rough Road, Highway, City Drive, Slope up and Slope down. The observations were recorded in the data-logger automatically through sensors and other sophisticated equipments. Those observations were tabulated road condition wise from Table 4 to Table 8.

Table 3. Simulated observations

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	9.534	1.856
2	1400	20.186	3.042
3	1800	27.958	3.548
4	2400	35.488	3.764

Table 4. Data-Logger observations at Rough Road

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	8.43	1.29
2	1400	16.27	1.90
3	1800	23.87	2.29
4	2400	28.49	2.51

Table 5. Data-Logger observations at at Highway

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	8.52	1.31
2	1400	16.39	1.87
3	1800	23.94	2.3
4	2400	28.91	2.51

Table 6 Data-Logger observations at City Drive (CD)

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	8.49	1.32
2	1400	16.31	1.95
3	1800	23.78	2.33
4	2400	28.37	2.56

Table 7 Data-Logger observations at Slope up (SU)

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	8.58	1.31
2	1400	16.34	2.00
3	1800	23.98	2.37
4	2400	28.98	2.58

Table 8 Data-Logger observations at Slope down (SD)

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	8.47	1.3
2	1400	16.32	1.95
3	1800	23.89	2.31
4	2400	28.42	2.5

4. Results And Discussions

The observations collected as discussed above, but the appropriateness of matching can be found by plotting that observation in the compressor map. The compressor map is a mapped plot of the pressure ratio vs. mass flow rate for various speeds. The simulated observation is compared with each route observation of data-logger. The Figure 2 illustrates the turbo-matching of A58N70 Turbocharger for the TATA 497 TCIC -BS III engine in data-logger-Rough Road route and simulation methods. Similarly the Figure 3 illustrates simulation and data-logger - Highway (HW) route, the Figure 4 for simulation and data-logger - City Drive (CD) route, the Figure 5, for simulation and data-logger at slope up (SU) route in Figure 5 and for the Figure 6 for simulation and data-logger- slope down (SD) route. It is noticed that the pattern of variation of the observed data with respect to speed is almost similar in all considered cases. According to simulated solution, the matching performance is at lower speeds are nearby surge region but safe and very safe at higher speeds. But as per data-logger method solution all the observed operating conditions are found at safe region (refer Figure 2 to Figure 6). Hence this turbo-matching can be recommended.

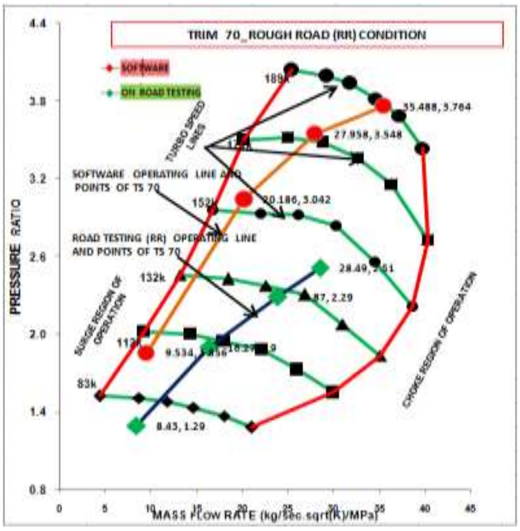

Figure 2 Turbo-matching by simulation and at Rough Route

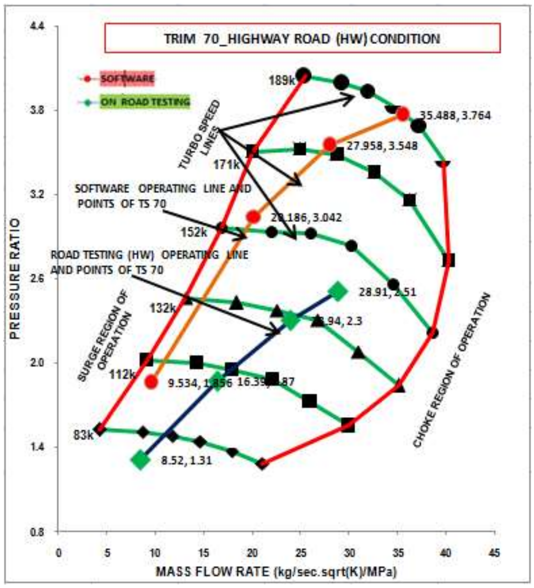

Figure 3 Turbo-matching by simulation and at Highway Route

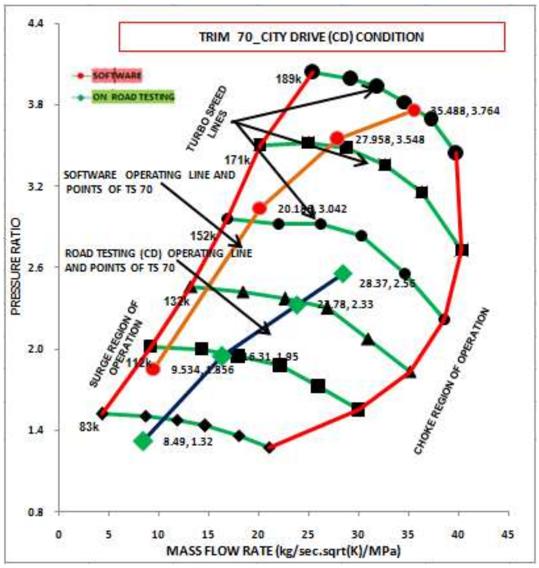

Figure 4 Turbo-matching by simulation and at City Route

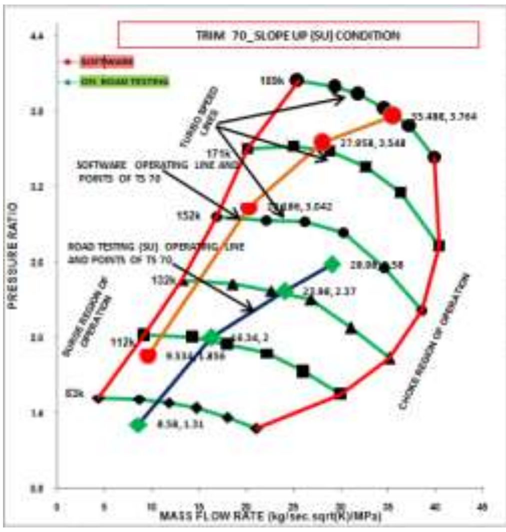

Figure 5 Turbo-matching by simulation and at slope-up Route

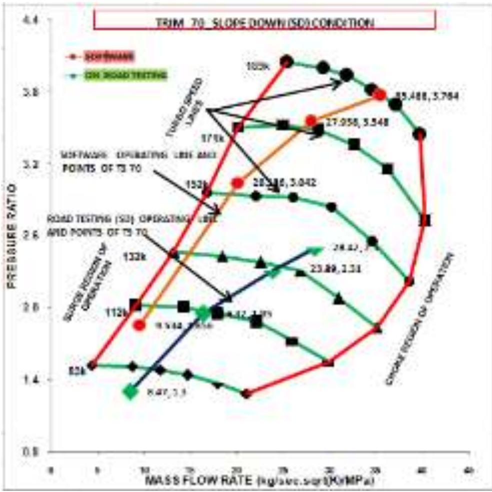

Figure 6 Turbo-matching by simulation and at slope-down Route

5. Conclusion

Investigation of matching performance of A58N70 Turbo Charger for the TATA 497 TCIC -BS III engine was investigated by Simulator method and Data logger method. The actual testing solution by data logger method is satisfiable than the initial solution which yielded in simulator method. In other words the operating conditions of PR, Mass flow rate, SFC found were found in safe region at all speeds as well as all routes during the data-logger testing. Hence it is concluded that the A58N70 Turbo Charger is perfect matched for the TATA 497 TCIC -BS III engine. 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.

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