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Turbo-Matching Of A58N75 Turbocharger For TATA 497 TCIC -BS III Engine – An Experimental Investigation

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ABSTRACT: *In automobile, particularly heavy vehicles necessitate charge boosting at higher load by turbocharger. Choice of turbocharger should be made with utmost care. Because, the mismatching leads to either surge and choke at engine air flow. Even though many methods of turbo charging reported in the literature, this research work focuses on test based matching. Primarily the matching of turbocharger to desired engine obtained by the simulation method. The data-logger matching method was used for validating the same. The objective of this research is to find the accuracy of matching of A58N75 Turbo Charger for the TATA 497 TCIC -BS III engine. The compressor map is used for comparing the solutions. The appropriateness was experimentally evaluated at various vehicle routes and discussed.*

Keywords: *Data-logger, Simulation, Turbo-charger, Trim size, Turbo matching, Compressor mapping,*

I. 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 bed 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 matching performance of the turbocharger with trim 75 to the TATA 497 TCIC -BS III Engine by simulator method. The validation of the same by Data Logger based Matching method.

II. MATERIALS 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 75 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 the 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 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.

2.2 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 circular mark.

2.3 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 having maximum compressor efficiency. 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.

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 -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)

2.5 Turbocharger Specifications

The TATA Short Haulage Truck, HE221W-4045 series turbocharger (A58N75) is considered to examine the performance of matching for TATA 497 TCIC -BS III engine. Here A58 is the design code and N75 is the Trim Size of the turbocharger in percentage. The other Specification furnished in Table 2.

Table -2: Specification of Turbo Charger A58N75

S.No	Description	Description
1	Turbo maximum Speed	200000 rpm
2	Turbo Make	Holset
3	Turbo Type	WGT-IC (Waste gated Type with Intercooler)
4	Trim Size(%)	75
5	Inducer Diameter	52.5 mm
6	Exducer Diameter	70 mm

III. EXPERIMENTAL OBSERVATION

The simulation and data-logger methods are adopted to analyze the turbo-matching of the Turbocharger A58N75 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) to obtain the predicted operating conditions for this combination. The 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-

Table -3: Observation from Simulation

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	14.230	1.288
2	1400	25.936	2.696
3	1800	34.568	3.388
4	2400	38.456	3.625

logger automatically through sensors and other sophisticated equipments. Those observations were tabulated road condition wise from Table 4 to Table 8.

Table -4: Data-logger observation – Rough Road

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	10.46	0.84
2	1400	18.45	1.70
3	1800	26.84	2.17
4	2400	30.82	2.32

Table -5: Data-logger observation Highway Route

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	10.52	0.84

2	1400	18.51	1.70
3	1800	26.89	2.17
4	2400	30.85	2.32

Table -6: Data-logger observation City Drive Route

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	10.58	0.88
2	1400	18.54	1.76
3	1800	26.93	2.19
4	2400	30.91	2.36

Table -7: Data-logger observation - Slope-up Route

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	10.62	0.88
2	1400	18.60	1.79
3	1800	26.98	2.19
4	2400	30.95	2.39

Table -8: Data-logger observation – Slope-down Route

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	10.37	0.81
2	1400	18.42	1.68
3	1800	26.53	2.16
4	2400	30.67	2.30

IV. RESULTS AND DISCUSSIONS

The appropriateness of turbo matching can be found by plotting the observations in the compressor map. So the data logger and simulated observations plotted on common compressor map for easy comparison for each selected route. The Fig. 2 illustrates the comparison of data logger matching at Rough Road route and simulated matching performance of A58N75 turbocharger for TATA 497 TCIC -BS III engine. Similarly for the Fig. 3 for Highway (HW) route, Fig. 4 for the City Drive (CD) route, Fig. 5 for the slope up (SU) route and Fig. 6 for the slope down (SD) route. The plots show that the pattern of variation of operating performance with respect to speed is almost similar irrespective of routes. The simulated solution results implied that this combination provides surge occurs at lower speed (1000 rpm). But the operating performance higher speeds found satisfactory. But the safe operating performance was observed at all routes through data logger method (Refer Fig. 2 to Fig. 6). The compressor map presented from figure 2 to figure 6 are self explanatory. It is noted that the Choke occurs at higher speed.

Figure 1 Data-Logger Method

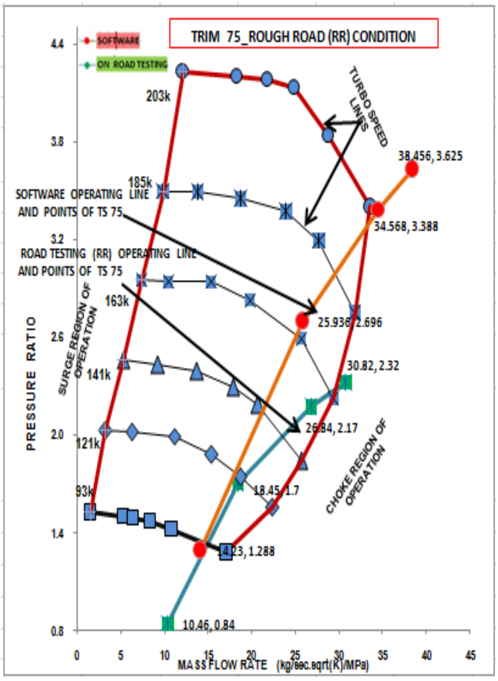

Figure 2 Turbo-match - simulation & Rough Route

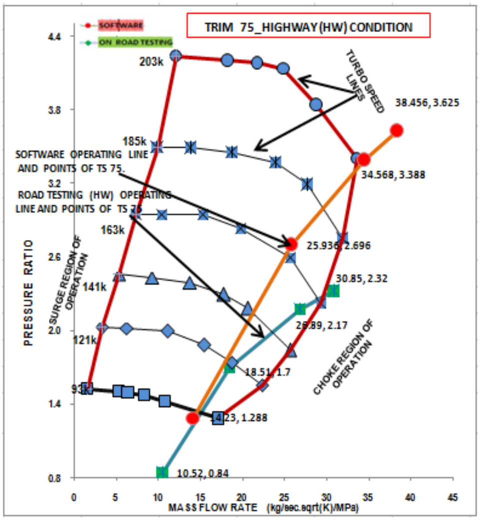

Figure 3 Turbo-match - simulation & Highway

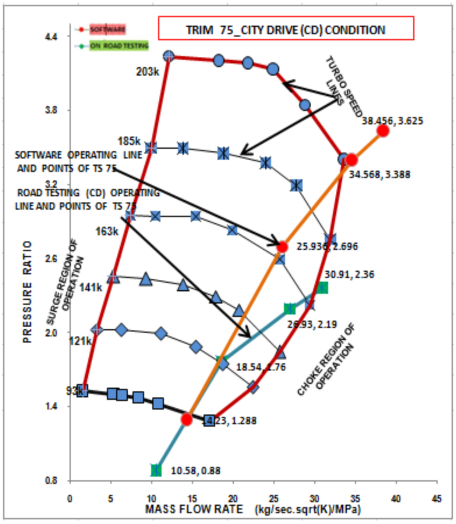

Figure 4 Turbo-match - simulation & City Drive

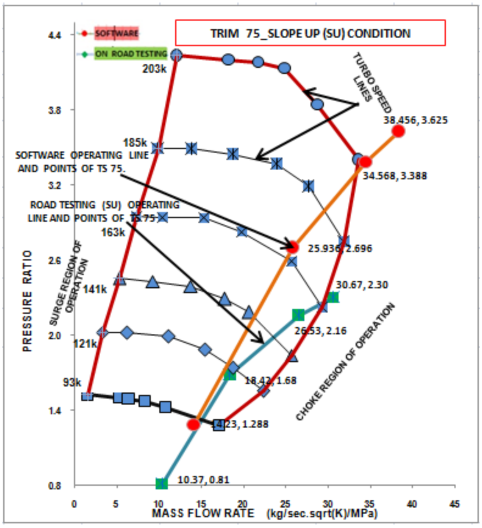

Figure 5 Turbo-match - simulation & slope-up

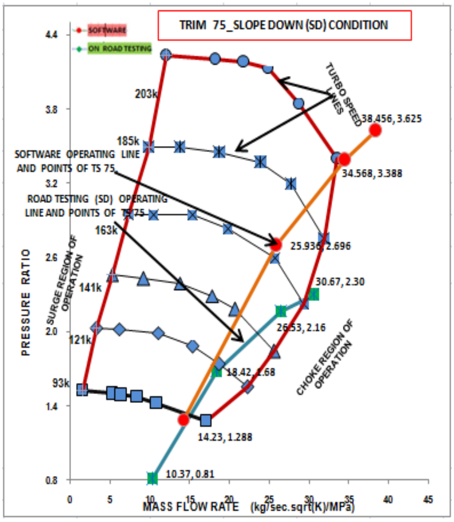

Figure 6 Turbo-match - simulation & slope-down

V. CONCLUSION

The turbo matching A58N75 Turbo Charger for the TATA 497 TCIC -BS III engine is discussed in detail. The simulated solution is validated with data-logger method. The appropriateness presented in the graphical form in compressor map. The results reveal that the choke hazard occurs especially at higher speeds. During the choke, 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 reduction operating speed certain extent can be compromised. But this case, the maximum engine speed to be less than 2200 rpm to ensure safe operation. Hence this turbo-matching is suitable if the maximum speed can be altered. 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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