Investigation on Turbo-matching of Trim 67 Turbo-charger for a TATA Commercial Vehicle

Badal Dev Roy, Dr.R.Saravanan

Abstract— **Commercial vehicles and heavy vehicles require boosting of charge specifically at higher load. The turbocharger is such charge booster for automobile engines. Selection and matching are needed more attention and care. Because the mismatch of turbo charger for the desired engine may lead to disadvantages like surge and choke at engine air flow. Test based matching is adopted in this research. The initial matching performance is identified by the simulation method. The data-logger type matching method is used for confirming or validating the performance of matching. The objective of this research is to find the appropriateness of matching of B60J67 Turbo Charger for the TATA 497 TCIC -BS III engine. The compressor map is used for evaluating the solutions yielded both methods. The appropriateness was evaluated at various route conditions and presented.**

Index Terms—**Trim 67, Data-logger, Turbo matching, surge, choke, Compressor.**

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].

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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 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 67 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 67 is used 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. 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.

Fig. 1 Experimental setup on Data-logger Method of turbo charger Matching

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 figure 1 depicts the setup for the data-logger testing in which the turbocharger is highlighted with a red circular mark.

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 and yield 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

D. 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 I. 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)

E. Turbocharger Specifications

The TATA Short Haulage Truck, HE221W-4045 series turbocharger (B60J67) is considered to examine the performance of matching for TATA 497 TCIC -BS III engine. Here B60 is the design code and J67 is the Trim Size of the turbocharger in percentage. The other Specification furnished in Table II.

Table II. Specification of Turbo Charger B60J67

S.No	Description	Specifications
1	Turbo maximum Speed	200000 rpm
2	Turbo Make	Holset
3	Turbo Type	WGT-IC (Waste gated Type with Intercooler
4	Trim Size	67
5	Inducer Diameter	46.1mm
6	Exducer Diameter	68.8 mm

III. EXPERIMENTAL OBSERVATION

The simulation and data-logger methods are adopted to analyze the turbo match of the Turbocharger B60J68 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 III. 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 tones of net weight. The grass weight of vehicle is 11 tones. The experimental setup for Data logger type matching is shown in Fig. I. 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 IV to Table VIII.

Table III. Simulated observations for Turbo matching

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec. sqrt K/Mpa)	Pressure Ratio
1	1000	10.67	1.783
2	1400	23.35	2.861
3	1800	30.81	3.401
4	2400	36.4	3.747

Table IV. Data-Logger observations at Rough Road

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	7.08	1.38
2	1400	15.11	1.98
3	1800	21.43	2.36
4	2400	27.09	2.58

Table V. Data-Logger observations at Highway

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	7.84	1.38
2	1400	15.62	1.98
3	1800	21.57	2.36
4	2400	27.46	2.59

Table VI. Data-Logger observations at City Drive

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	7.21	1.39
2	1400	15.32	1.98
3	1800	21.38	2.38
4	2400	26.97	2.61

Table VII. Data-Logger observations at slope up

Sl. No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	7.8	1.41
2	1400	15.51	2.04
3	1800	21.64	2.4
4	2400	27.77	2.64

Table VIII. Data-Logger observations at slope down

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec. sqrt K/Mpa)	Pressure Ratio
1	1000	7.67	1.36
2	1400	15.19	1.96
3	1800	21.46	2.34
4	2400	27.21	2.60

IV. RESULTS AND DISCUSSIONS

The turbo matching performance in both the methods is comparatively presented in route wise from figure 2 to figure 6 in the order of rough road, Highway, City Drive, Slope up and slope down. The simulated solution shows higher values compared to actual values in the routes. The pattern of variation of operating conditions for the desired engine with the turbocharger with Trim 67 is almost similar in all route conditions. The Surge occurs at the lower -speed that is, the mass flow rate limit below the compressor limit so the risk of flow reversal. This affects the engine.

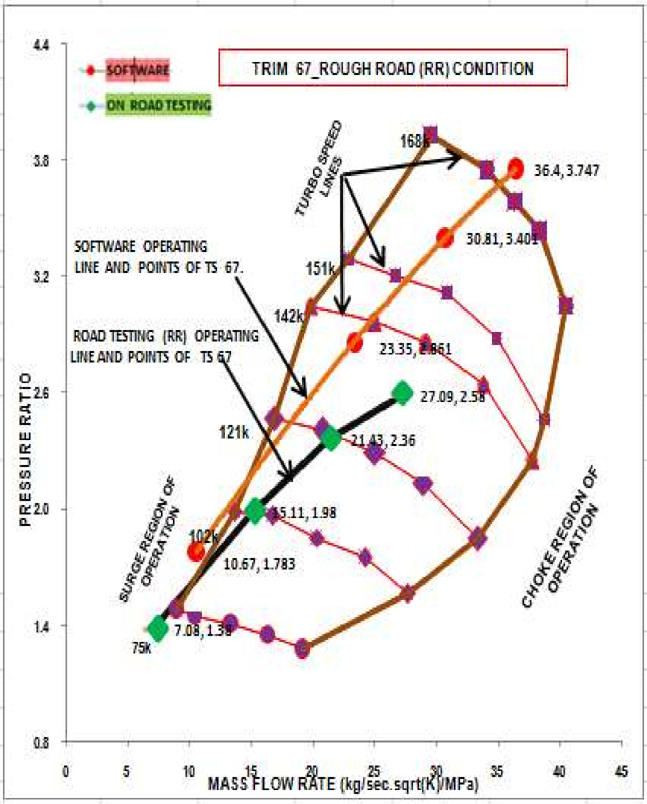

Fig. 2 Turbo-matching by simulation and at Rough Route

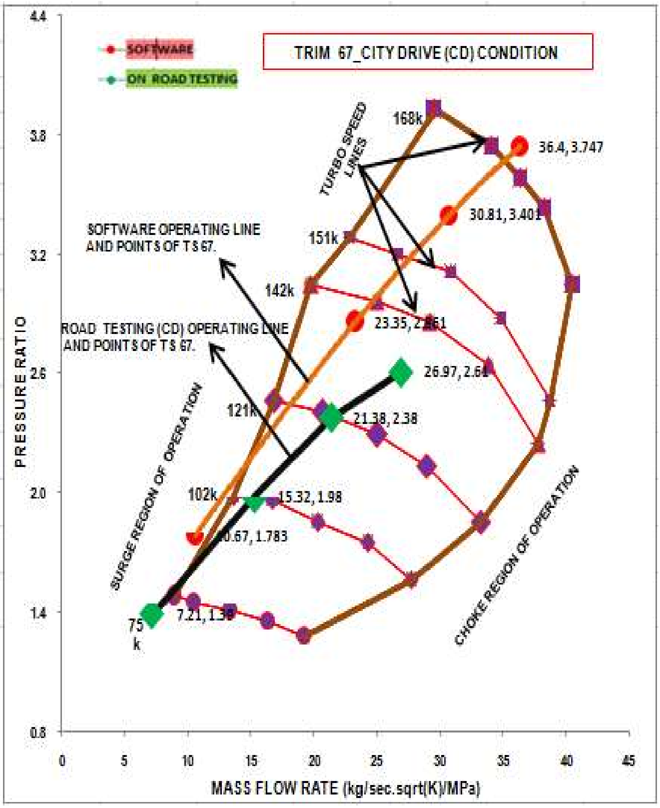

Fig. 4 Turbo-matching by simulation and at City Route

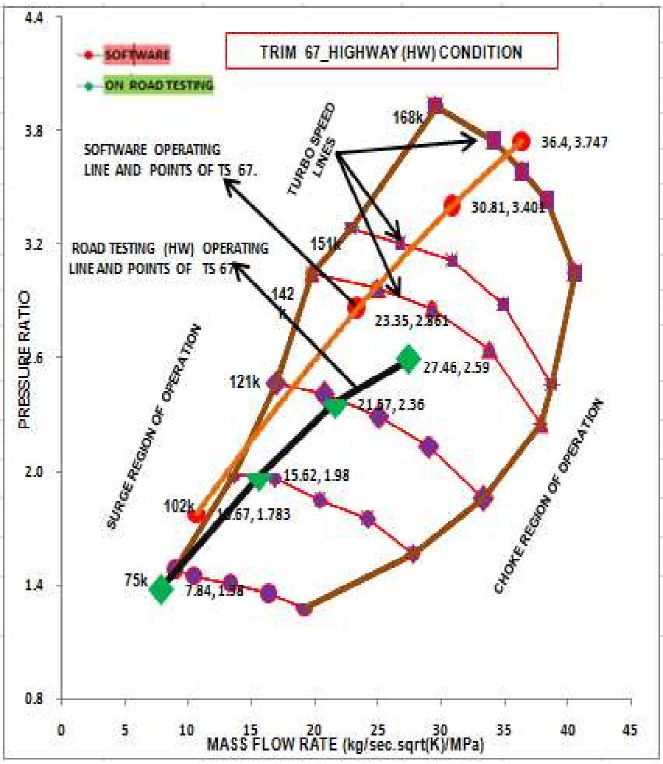

Fig. 3 Turbo-matching by simulation and at Highway Route

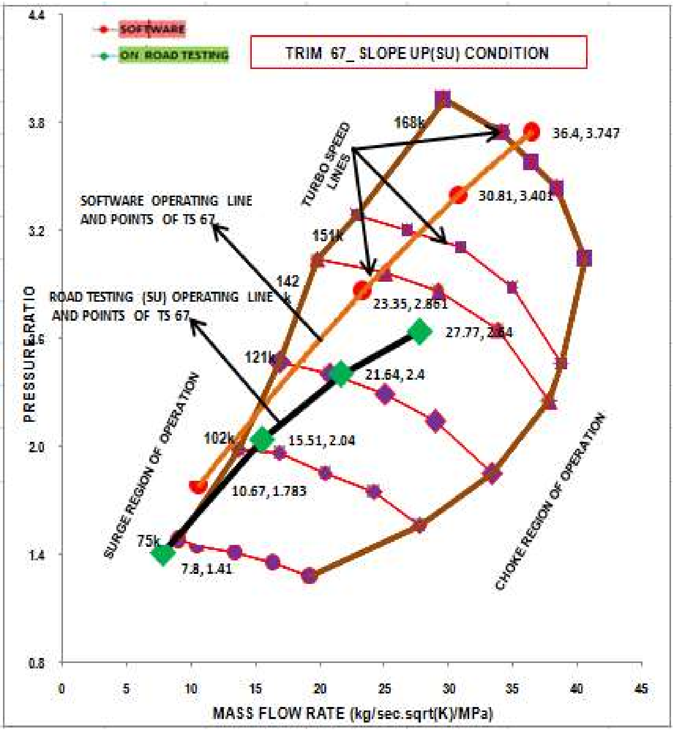

Fig. 5 Turbo-matching by simulation and at slope-up Route

performance. In other words the engine demands at higher operating speed than required speed, even the routes like city drive, rough road, slope up as well as down to avoid the surge. The average SFC will be increased.

V. Conclusion

The TATA 497 TCIC -BS III Engine is preferred for medium type commercial vehicle, In this paper, the matching performance of turbocharger HE 221W-4045 series with trim 67 for TATA 497 TCIC -BS III Engine was evaluated by experimental and simulation methods. The vehicle operated at various routes in road test at various speeds with the

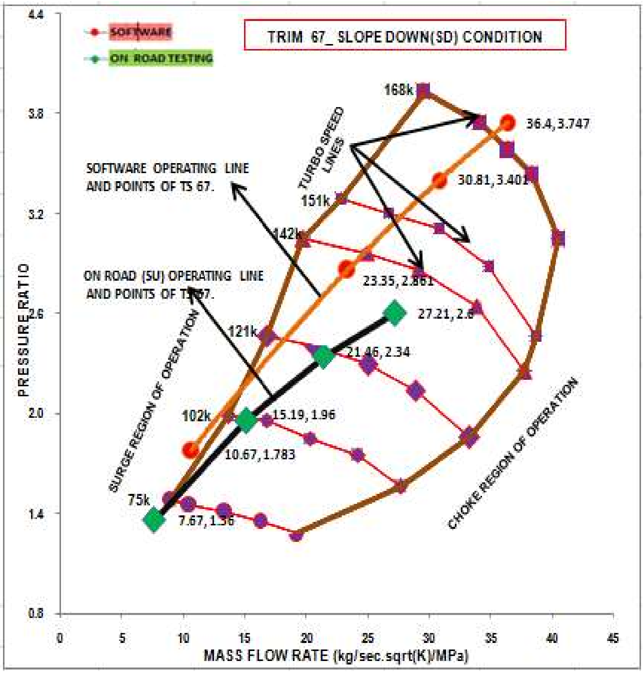

Fig. 6 Turbo-matching by simulation and at slope-down Route

operating range from 1000 rpm to 2400rpm. The operating performance at various speeds evaluated and found that the occurrence of surge at lower speeds and safe operations ensured at higher speeds. For avoiding such surge the engine to be operated at higher It is concluded that the turbocharger HE 221W-4045 series with trim 67 can be matched for TATA 497 TCIC -BS III Engine by increasing its minimum operating speed. 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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