An Approach for Turbo-matching of B60J67 and A58N75 Turbochargers for a Haulage Truck Engine

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Abstract - Boosting of high density charged air for commercial and heavy vehicles especially at higher load is basic need. Turbocharger is such integrated equipment that gives charge booster for automotive engines. Great care requires in proper selection of turbocharger for particular engine as its leads to disadvantages of choke, surge and end bearing oil leakage. Test based matching is adopted for this research. The basic initial matching performance is identified by the simulation method. Validation of matching performance is done through Data-Logger type Matching Method. The prime objective of this research is to find the matching performance of B60J67 and A58N75 turbocharger for the TATA 497 TCIC -BS III engine. The compressor map is used for evaluating the solutions of both methods. Various route conditions are used and both methods are compared and presented.

Keywords— *Turbocharger, turbo-matching, Surge, Choke, Compressor, Data-logger, Simulation.*

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 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 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 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 B60J67 and A58N75 for the TATA 497 TCIC -BS III Engine by simulator method. The validation of the same by Data Logger based Matching method.

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II. 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 67 and 75 are considered 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 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.

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 a red circle.

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. 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 Specification

Table -1: Specification 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 Bore / Engine Stroke	97 mm/128mm.
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.

2.5 Turbochargers Specifications

The TATA Short Haulage Truck, turbochargers of B60J67 and A58N75 are considered to examine the performance of matching for TATA 497 TCIC -BS III engine. For example, if specification A58N72 means in which the A58 is the design code and N75 is the Trim Percentage in Percentage. The other specification is furnished in the Table 2.

Table - 2: Specification of Turbo Chargers

S.No	Description	B60J67	A58N75
1	Turbo maximum Speed	200000 rpm	
2	Turbo Make	HOLSET	
3	Turbo Type	WGT-IC (Waste gated Type with Intercooler)	
4	Trim Size (%)	67	75
5	Inducer Diameter	46.1mm	52.5 mm
6	Exducer Diameter	68.8 mm	70.00 mm

III. Experimental Observation

The simulator and data-logger method is adopted to match the turbo Chargers B60J67 and A58N75 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 pressure ratio and mass flow rate at various speeds as measure of performances for identifying the matching performance of the turbo-charger for desired engine. 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 is shown in the Fig. I. The range of operating speeds for both methods, including the maximum and minimum speeds are 1000, 1400, 1800 and 2400 rpm. The road conditions preferred are: the rough road, Highway, city drive, slope up and slope down. The road condition wise observation presented from Table 4 to Table 8. The turbo match can be identified by mark the observed operating conditions in the compressor map. The maps presented here as self explanatory for simulated observation and data-logger observations at different routes preferred. The Fig. 2 and Fig. 3 are for Rough for turbo Chargers B60J67 and A58N75 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

S.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)		Pressure Ratio	
		B60J67	A58N75	B60J67	A58N75
1	1000	10.67	14.230	1.783	1.288
2	1400	23.35	25.936	2.861	2.696
3	1800	30.81	34.568	3.401	3.388
4	2400	36.40	38.456	3.747	3.625

Table 4 Data-logger – Rough Road observations

S.N	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)		Pressure Ratio	
		B60J67	A58N75	B60J67	A58N75
1	1000	7.08	10.46	1.38	0.84
2	1400	15.11	18.45	1.98	1.7
3	1800	21.43	26.84	2.36	2.17
4	2400	27.09	30.82	2.58	2.32

Table- 5 Data-logger – Highway observations

S.N	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)		Pressure Ratio	
		B60J67	A58N75	B60J67	A58N75
1	1000	7.84	10.52	1.38	0.84
2	1400	15.62	18.51	1.98	1.7
3	1800	21.57	26.89	2.36	2.17
4	2400	27.46	30.85	2.59	2.32

Table- 6: Data-logger – City Drive observations

S.N	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)		Pressure Ratio	
		B60J67	A58N75	B60J67	A58N75
1	1000	7.21	10.58	1.39	0.88
2	1400	15.32	18.54	1.98	1.76
3	1800	21.38	26.93	2.38	2.19
4	2400	26.97	30.91	2.61	2.36

Table- 7 : Data-logger – Slope –Up observations

S.N	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)		Pressure Ratio	
		B60J67	A58N75	B60J67	A58N75
1	1000	7.8	10.62	1.41	0.88
2	1400	15.51	18.6	2.04	1.79
3	1800	21.64	26.98	2.4	2.19
4	2400	27.77	30.95	2.64	2.39

Table- 8: Data-logger – Slope –Down observations

S.N	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)		Pressure Ratio	
		B60J67	A58N75	B60J67	A58N75
1	1000	7.67	10.37	1.36	0.81
2	1400	15.19	18.42	1.96	1.68
3	1800	21.46	26.53	2.34	2.16
4	2400	27.21	30.67	2.6	2.30

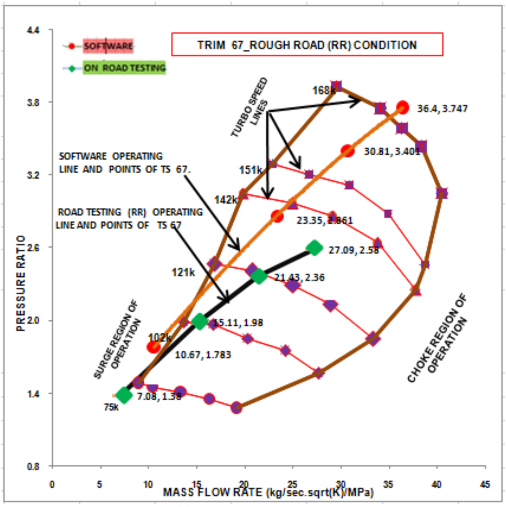

Fig. 2 B60J67 Turbo-match-Rough Road

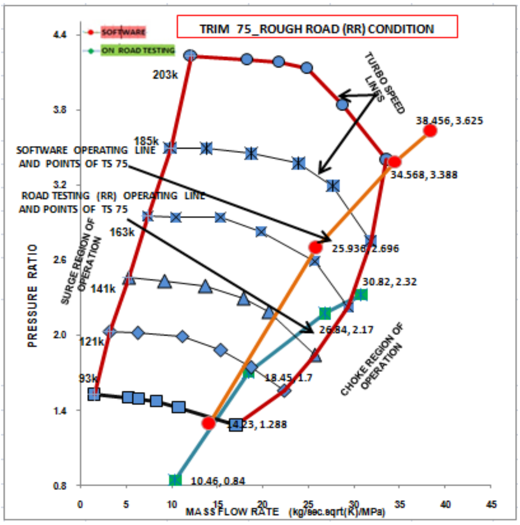

Fig. 3 A58N75 Turbo-match-Rough Road

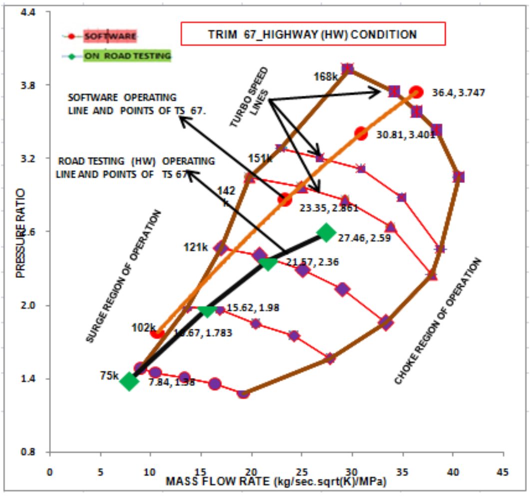

Fig. 4 B60J67 Turbo-match- Highway

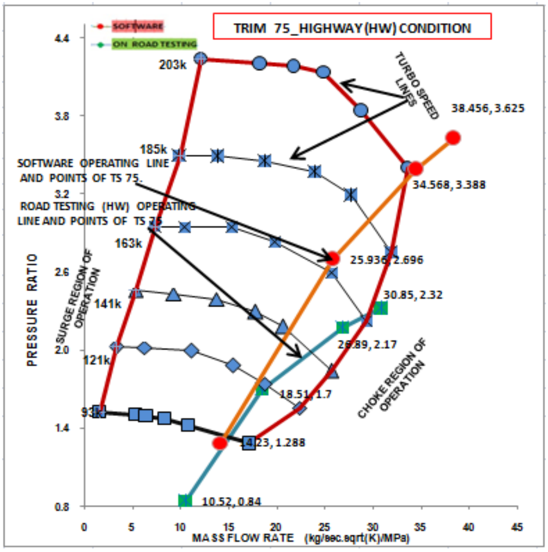

Fig. 5 A58N75 Turbo-match – Highway

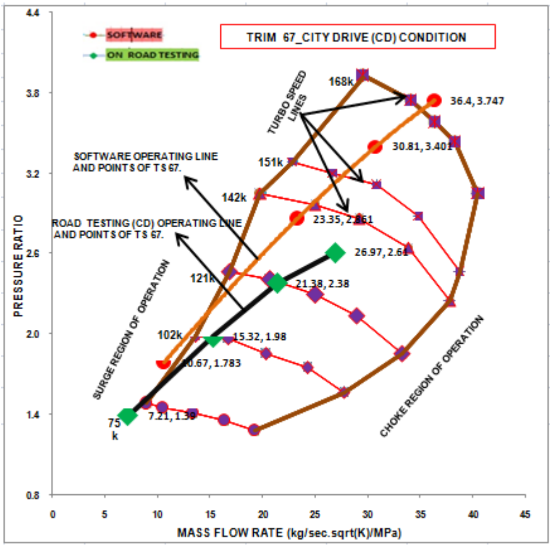

Fig. 6 B60J67 Turbo-match- City Drive

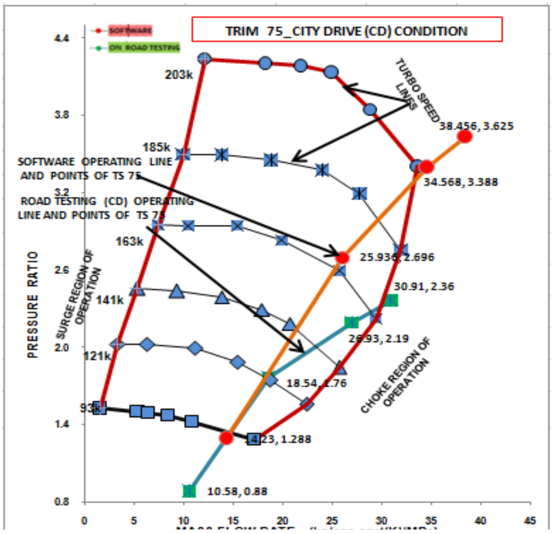

Fig. 7 A58N75 Turbo-match – City Drive

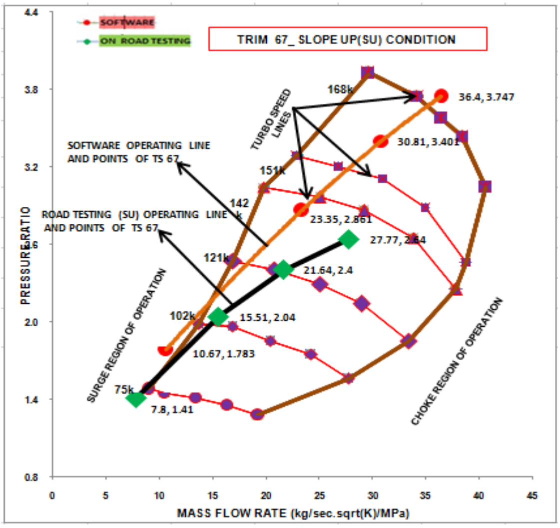

Fig. 8 B60J67 Turbo-match- Slope-up

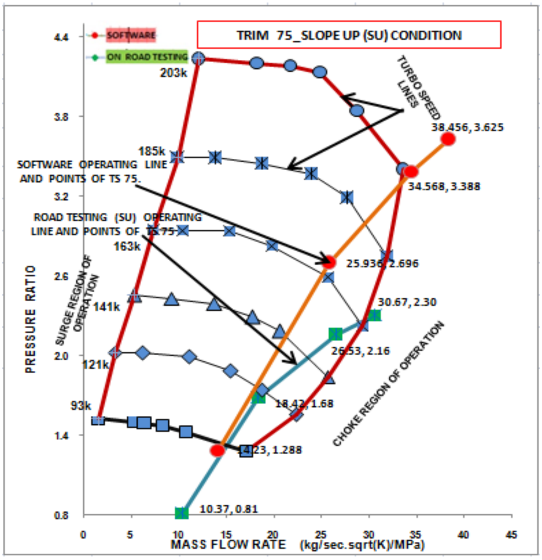

Fig. 9 A58N75 Turbo-match - Slope-up

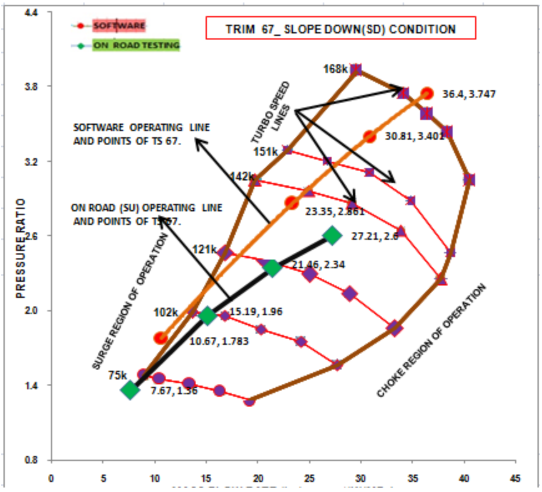

Fig. 10 B60J67 Turbo-match- Slope-Down

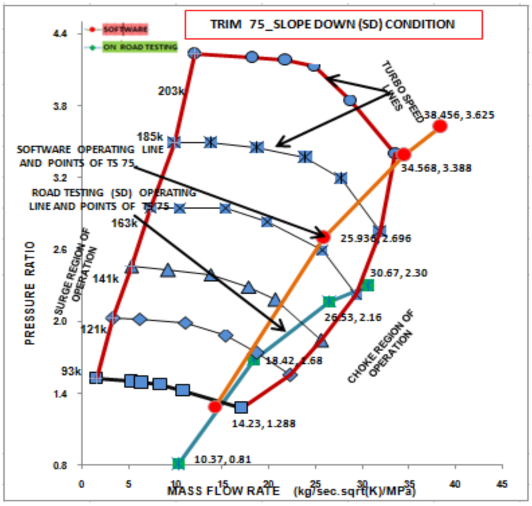

Fig. 11 A58N75 Turbo-match – Slope Down

IV. 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 City Drive and slope-up route were obtained. These operating conditions were marked on the respective compressor map. The details of mappings already discussed above. This can be noted that the turbo-match B60J67 except at lower speed the matching performance is safe and acceptable. Especially at higher speed the turbo-match is very perfect. But at the lower speed the surge occurs. In case of A58N75 Turbo-charger, match it was observed that performance of operating conditions are safe and acceptable at lower and medium speeds, but at higher speeds choke occurs. B60J67 turbocharger and B60J75 turbocharger can be adopted for the TATA 497 TCIC -BS III engine by altering the engine speed limits (minimum or maximum engine speed suitably).

V. CONCLUSION

This paper discussed the turbo-matching of B60J67 turbocharger and A58N75 turbocharger for TATA 497 TCIC -BS III engine. the appropriateness of turbo match was evaluated. The simulation gives more values than the data-logger observations, but the pattern of variation found similar with respect to speed variation. The turbo- match with B60J67 turbo charger performs worst al lower speed (1000 rpm). The turbo- match with A58N75 turbo charger performs worst at higher speed (2400 rpm). But both turbocharger can be match for TATA 497 TCIC -BS III engine by fixing the engine speed limits (maximum or minimum) appropriately. The data-logger method adapted in this research may feel as expensive but it is one time job for finding the best turbo-match for an engine category.

ACKNOWLEDGEMENTS

The authors acknowledge M/s the Cummins Turbo Technology and ARAI, India for their support and contribution for this research work. The authors also acknowledge to the Dr.M.Chandrasekaran, Joint Supervisor, Professor & Director / Mechanical Engineering, Dr.C.Dhanasekaran, Professor & Head / Mechanical Engineering, Co-ordinator for School of Engineering, Vels University. Chennai., Dr.V.Muthukumar, Professor, Saveetha Engineering College, Chennai. And Dr.S.Santhanam, Professor, Rajalaskmi Engineering College, Chennai. TN. India., for their valuable suggestion to carried out this piece of research.

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