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Research Article

EXPERIMENTAL INVESTIGATION ON APPROPREATENESS OF TURBO-MATCHING OF TURBOCHARGERS OF TRIM SIZES 68, 72 AND 75 FOR COMMERCIAL TRUCK ENGINE

Badal Dev Roy[1]* and Saravanan R[2]

[1]Department of Mechanical Engineering, Vels Institute of Science, Technology & Advanced Studies (VISTAS), Vels University, Chennai, Tamil Nadu, India
[2] Department of Mechanical Engineering, Ellenki Institute of Engineering and Technology, Jawaharlal Nehru Technological University, Hyderabad, TS, India

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ABSTRACT

The Turbocharger is most powerful equipment integrated with engine for boosting AND UPKEEPING performance of IC engines at all speeds ranges as well as higher load. The arbitrary selection of turbocharger for desired engine may cause negative effects sometimes like a surge or choke in the charge flow. The careful and tactful approach required. This research article focuses on matching of turbochargers with engine by simulation and on road testing. This work emphasis in finding matching appropriateness of turbochargers with trim 68 (B60J68), trim 72(A58N72) and trim 75 (A58N75) for the TATA 497 TCIC -BS III truck engine. The on-road testing like Data – Logger method is employed through the rough road routes, highway, city Drive, slope up and Slope down. The compressor map is employed to evaluate the appropriateness of turbo-matching.

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. (Guzzella *et al*, 2000; Cantore *et al*, 2001; Lecointe and Monnier, 2003; Saulnier and Guilain 2004; and Lake *et al*, 2004). Due to the character of a centrifugal compressor, the turbocharged engine yields lesser torque than naturally aspirated engine at lower speeds (Lefebvre and Guilain, 2005; and Attard *et al*, 2006). 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 (Tashima *et al*, 1994), incorporate the limiting fuel system, reducing the inertia, improvements on bearing, modification on aerodynamics (Watanabe *et al*, 1996), facilitating the geometrical variation on the compressor and turbine (Kattwinkel *et al*, 1999), adopting the twin turbo system (Cantemir, 2001), the usage of positive displacement charger i.e., secondary charging system and use of either electric compressor or positive displacement charger with turbocharger Ueda *et al*, 2001 and Kattwinkel *et al*, 2003), establishing electrically supported turbocharger (Kattwinkel *et al*, 2003), and dual stage system Choi *et al*, 2006). 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 (Andersen *et al*, 2006). Even though many researches were done on this case still the problem is exist (Kattwinkel *et al*, 1999; Brace *et al*, 1999; Filipi *et al*, 2001; Arnold *et al*, 2001 and Andersen *et al*, 2006). Though the advancements in system design like a variable geometry turbine, common rail injection system, and multiple injections, the problem has is still persist due to the limiting parameter say the supply of air. Qingning Zhang *et al*, 2013 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

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Corresponding author:* **Badal Dev Roy
Department of Mechanical Engineering, Vels Institute of Science, Technology & Advanced Studies (VISTAS), Vels University, Chennai, Tamil Nadu, India

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 effected as well as affects the engine performance (Watson and Janota, 1982; Lake *et al*, 2004 and Millo *et al*, 2005). 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 (Watson and Janota, 1982). 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 (Qingning Zhang *et al*, 2013). 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 (Qingning Zhang *et al*, 2013). The on road test type investigation is called Data Logger based Matching method is adopted in this research. Badal Dev *et al*, 2016 discussed that the data-logger turbo matching method in detail and compared with the result of test bed, turbo matching and simulator turbo-matching methods. The authors exhibited that the data logger method outputs are reliable but expensive. 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 B60J68, A58N72 and A58N75 for the TATA 497 TCIC -BS III Engine by simulator method. The validation of the same by Data Logger based turbo-matching method.

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 inlet to the exit in percentage. This parameter is closely related to the turbo matching. Various trim sizes are available, but in this study the trim size 68, 72 and 75 are considered for investigation.

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.

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 the engine and turbocharger 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.

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 a choke. In 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.

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 Table1.

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 speed	2400 rpm (Max power), 1400 rpm (Max Torque)
7	Engine Bore / Engine Stroke	97 mm/128mm.

Turbochargers Specifications

The TATA Short Haulage Truck, turbochargers of B60J68, A58N72 and A58N75 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 Size of the turbocharger in percentage. The other specifications furnished in Table 2.

Table 2 Specification of Turbo Chargers

S.No	Description	B60J68	A58N72	A58N75
1	Turbo max. Speed	200000 rpm		
2	Turbo Make	HOLSET		
3	Turbo Type	WGT-IC (Waste gated Type with Intercooler)		
4	Trim Size (%)	68	72	75
5	Inducer Diameter	46.9mm	50.1 mm	52.5 mm
6	Exducer Diameter	68.9 mm	69.58 mm	70 mm

Experimental Observation

The simulation and data-logger method is adopted to match the turbo chargers B60J68, A58N72 and A58N75 for TATA 497 TCIC -BS III engine. The matching performance can be simulated by software with use of manufacturer specifications. The parameters like pressure ratio and mass flow rate at various speeds are used to find the matching performance. The simulated observations for matching of the turbochargers B60J68, A58N72 and A58N75 turbochargers were furnished 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 gross weight of vehicle is 11 tonnes. The experimental setup is shown in the Fig. I. The same operating speeds are1000, 1400, 1800 and 2400 rpm) were set for making observations. The on road test conducted and recorded data at different routes, namely rough route, highway, city drive, slope-up and slope-down and the same was-logger database. Those observations presented in the order of rough route, highway, city drive, slope-up and slope-down from Table 4 to Table 8 with respect to various engine speeds. The compressor map used for analysing the matching performance of turbochargers for the desired engine. The recorded observations were plotted on the compressor map in such a way that the simulator solution and data logger solution in combine in single compressor map for each route. The Fig.2 is for turbo-match of B60J68, A58N72 and A58N75 turbochargers (left to right) at rough route and simulated solution. Similarly Fig.3 to Fig 6 for highway, city drive, slope up, slope down routes respectively.

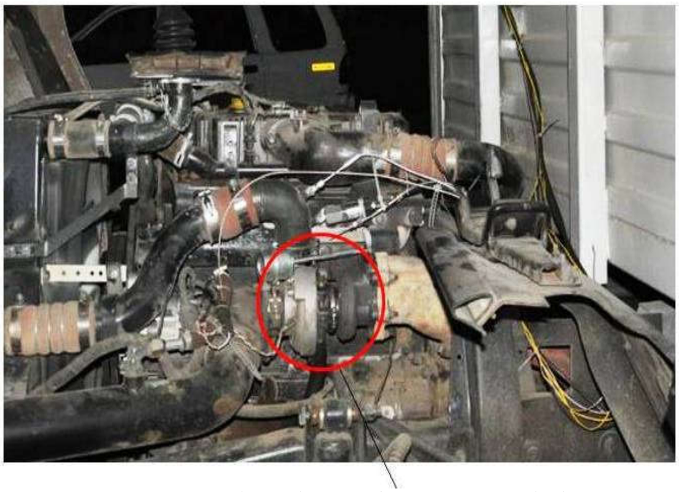

Figure 1 Experimental set up of Data-Logger method

Table 3 Simulated observations for B60J68, A58N72 and A58N75 Turbo matching

S.N	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)			Pressure Ratio		
		B60J68	A58N72	A58N75	B60J68	A58N72	A58N75
1	1000	11.449	13.265	14.23	1.856	1.284	1.288
2	1400	22.56	24.789	25.936	3.051	2.678	2.696
3	1800	29.451	32.265	34.568	3.556	3.224	3.388
4	2400	36.872	36.256	38.456	3.817	3.427	3.625

Table 4 Data-logger-Rough Road observation for B60J68, A58N72 and A58N75 Turbo matching

S.N	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)			Pressure Ratio		
		B60J68	A58N72	A58N75	B60J68	A58N72	A58N75
1	1000	7.37	9.32	10.46	1.35	0.97	0.84
2	1400	15.41	17.23	18.45	1.95	1.77	1.70
3	1800	21.73	25.73	26.84	2.33	2.25	2.17
4	2400	27.43	29.72	30.82	2.55	2.38	2.32

Table 5 Data-logger-Highway observations for for B60J68, A58N72 and A58N75 Turbo matching

S.N	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)			Pressure Ratio		
		B60J68	A58N72	A58N75	B60J68	A58N72	A58N75
1	1000	8.12	9.39	10.52	1.35	0.97	0.84
2	1400	15.92	17.28	18.51	1.95	1.77	1.70
3	1800	21.87	25.79	26.89	2.33	2.25	2.17
4	2400	27.87	29.77	30.85	2.56	2.38	2.32

Table 6 Data-logger-City Drive observations for B60J68, A58N72 and A58N75 Turbo matching

S.N	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)			Pressure Ratio		
		B60J68	A58N72	A58N75	B60J68	A58N72	A58N75
1	1000	7.41	9.43	10.58	1.36	0.99	0.88
2	1400	15.52	17.32	18.54	1.95	1.83	1.76
3	1800	21.68	25.84	26.93	2.35	2.29	2.19
4	2400	27.39	29.86	30.91	2.59	2.41	2.36

Table 7 Data-logger-Slope up observations for B60J68, A58N72 and A58N75 Turbo matching

S.N	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)			Pressure Ratio		
		B60J68	A58N72	A58N75	B60J68	A58N72	A58N75
1	1000	8.02	9.51	10.62	1.38	0.96	0.88
2	1400	15.81	17.76	18.60	2.00	1.85	1.79
3	1800	21.94	25.95	26.98	2.39	2.30	2.19
4	2400	27.97	29.93	30.95	2.62	2.46	2.39

Table 8 Data-logger – Slope down observations for B60J68, A58N72 and A58N75 Turbo matching

S.N	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)			Pressure Ratio		
		B60J68	A58N72	A58N75	B60J68	A58N72	A58N75
1	1000	7.97	9.27	10.37	1.35	0.98	0.81
2	1400	15.79	17.12	18.42	1.95	1.73	1.68
3	1800	21.76	25.47	26.53	2.33	2.18	2.16
4	2400	27.41	29.59	30.67	2.60	2.34	2.30

RESULTS AND DISCUSSIONS

It is observed that the operating conditions obtained in three cases of turbochargers with engine for both simulated and data-logger method with the rough road route, highway route, City Drive, Slope Up and the slope-Down route were obtained. These operating conditions were marked on the compressor map. The details of mappings already discussed above. This was observed that turbo-match of turbocharger B60J68 with the TATA 497 TCIC -BS III engine exhibits well in particularly in medium and higher speeds, but at lower speed (1000), the surge occurred.

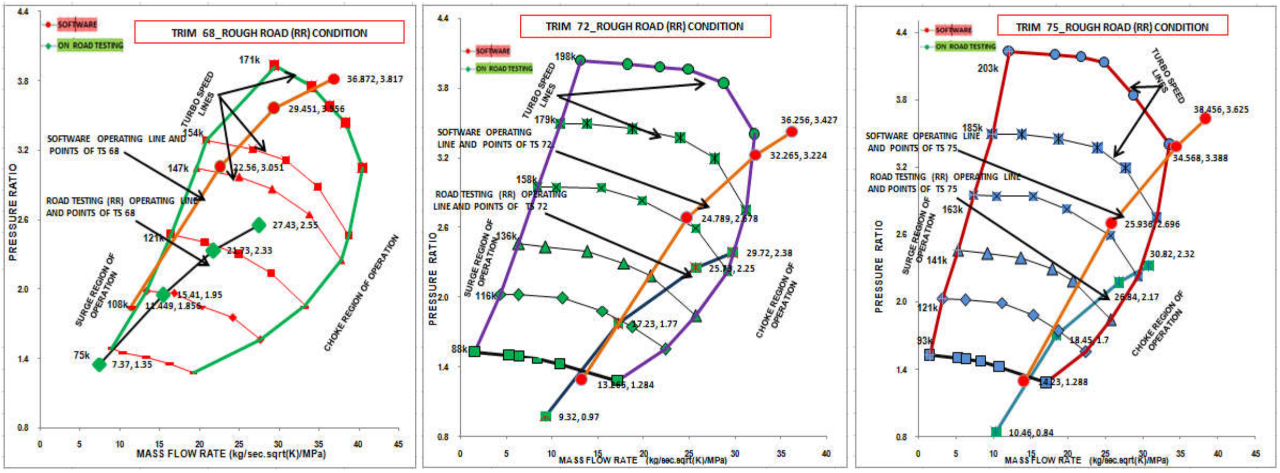

Figure 2 B60J68, A58N72 and A58N75 Turbo-match- by Simulation & Data-logger-Rough Road

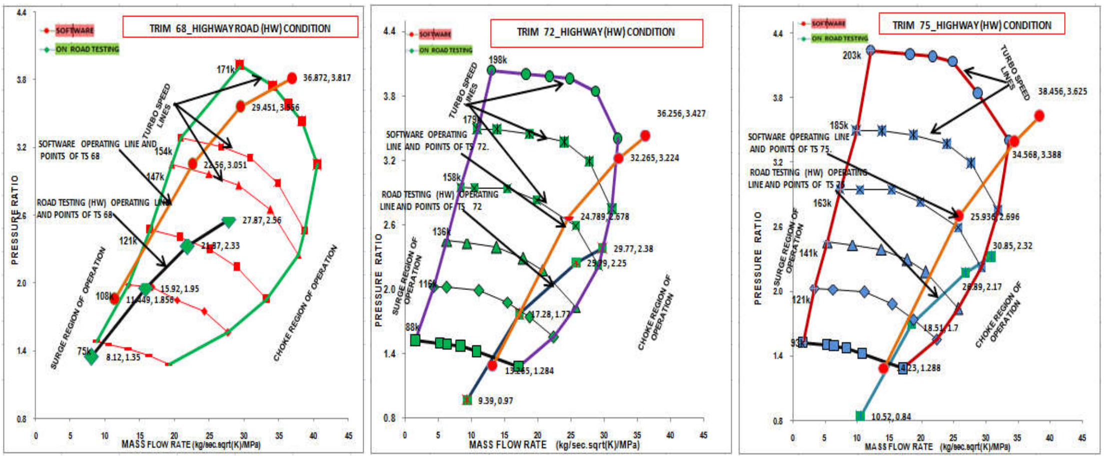

Figure 3 B60J68, A58N72 and A58N75 Turbo-match- by Simulation & Data-logger – Highway Route

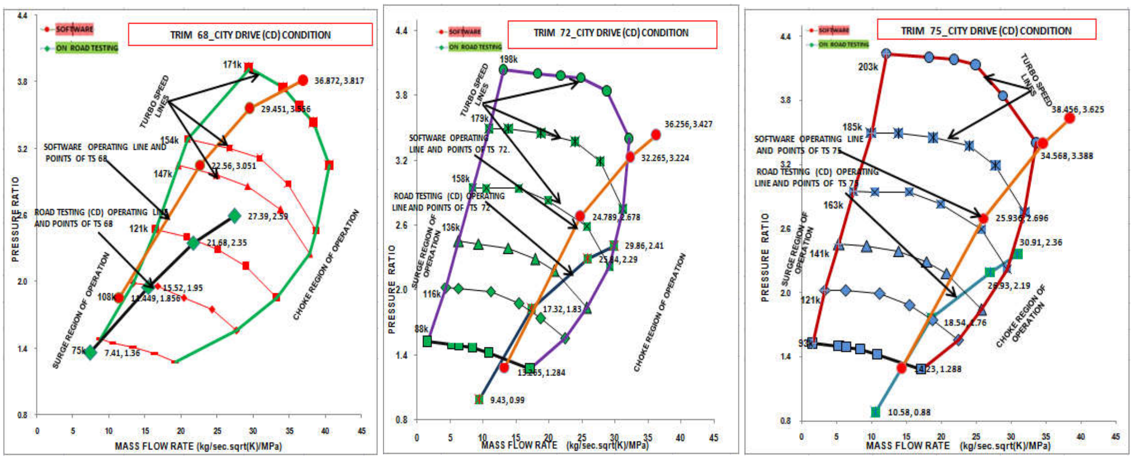

Figure 4 B60J68, A58N72 and A58N75 Turbo-match- by Simulation & Data-logger – City Route

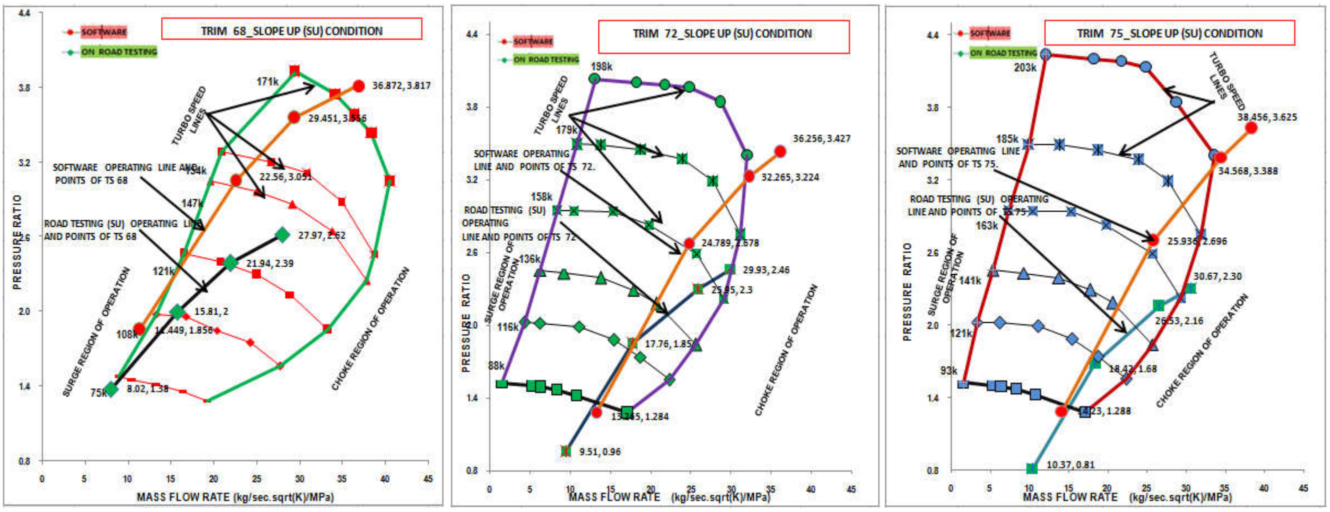

Figure 5 B60J68, A58N72 and A58N75 Turbo-match- by Simulation & Data-logger – Slope-up Route

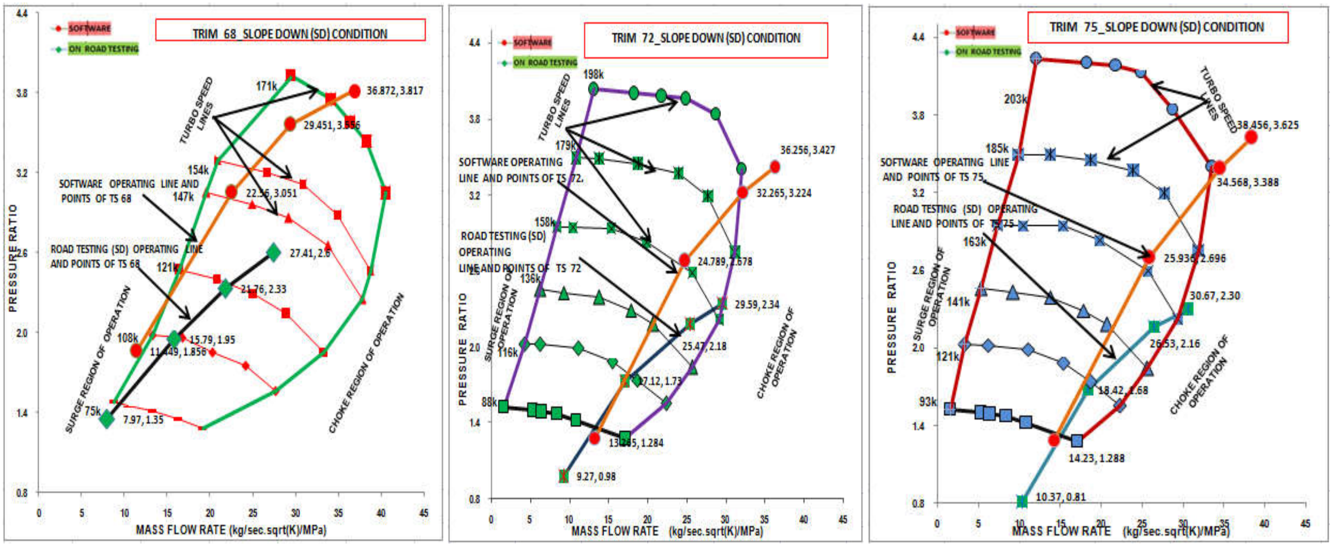

Figure 6 B60J68, A58N72 and A58N75 Turbo-match- by Simulation & Data-logger – Slope-Down

That is the risk of flow reversal. The rasing of the minimum speeds little bit above the turbocharger B60J68 will perform well with the TATA 497 TCIC -BS III engine. The turbo-match of Turbocharger A58N72 and A58N75 shows almost good performance at low engine speed but at higher speed, a choke occurred and operating at this speed decreases the overall efficiency. For matching A58N75 turbocharger the maximum speed must be lesser than 2200rpm but the turbo-matching of A58N72 turbocharger little bit reduction of maximum speed from 2400 rpm. The data-logger method adopted in this research may feel as expensive but it is one time job of finding the best turbo-match for an engine category.

CONCLUSION

The turbo-matching of B60J68, A58N72 and A58N75 turbochargers for TATA 497 TCIC - BS III engine by simulation and data-logger methods discussed. The simulated values found higher than the data-logger values, but the pattern of variation of operating performance with respect to engine speed is similar to data logger values. Hence the data-logger matching considered in decision making. From the evaluation of appropriateness of matching the little raise of minimum engine speed requires to satisfy the matching for B60J68 turbocharger. On the other hand the little reduction of the maximum engine speed requires satisfying the matching for A58N72 turbo-charger. The alteration of certain extent of speed may give neglected deviation on other performance. If so the turbocharger B60J68 and A58N72 can be matched for the TATA 497 TCIC -BS III engine.

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