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Experimental evaluation of Turbo-Matching of B60j67, B60j68 and A58n75 Turbochargers by Data-logger Method

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Abstract*: Turbocharger is considered as Charge booster of IC Engine, especially at higher load. Negative compressor performance like Surge and Choke occurs by improper turbo-matching. Turbo-matching is a tedious task and requires extreme care. It is one time job for an engine kind and expensive. This research articles focuses on evaluation of appropriateness in turbo-matching of B60J67, B60J68 and A58N75 turbochargers for TATA 497 TCIC -BS III engine. The simulation and data-logger method used obtaining the operating conditions. The road conditions like rough, city drive, highway, slope and slope down were included for on road test (data Logger method). The appropriateness evaluated with use of compressor map.
Keywords*: Turbocharger, Turbo-Matching, Surge. Choke, Simulation, Data-Logger.

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 a centrifugal compressor, the turbocharger with 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 the a displacement charger with turbocharger [10],[11] facilitating the geometrical variation on the compressor and a 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 the system is not exact, match for petrol engines [15]. Even though many findings were reported in this case still the problem is exist. [12],[15]-[18]. Though the advancements in system design like the variable geometry turbine, common rail injection system, and multiple injections, the problem has still persisted due to the limiting parameter say the 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 tedious 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 affected as well as affects 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 the 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 appropriateness of matching of the turbocharger with B60J67, B60J68 and A58N75 for 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 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 67,68 and 75 are considered for investigation.

A. Turbo-matching by Simulaion

Various kinds of simulation software are being used for turbo matching. In this research the minimarts 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.

B. Turbo-matching by Data Logge

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 type 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.

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. 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 1,500 rpm. The other specifications can be found in Table1

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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.

E. Turbochargers Specification

The TATA Short Haulage Truck, turbochargers of B60J67, B60J68 and A58N75 are considered to examine the performance of matching for TATA 497 TCIC -BS III engine. For example, if specification A58N75 means in which the A58 is the design code and N75 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	B60J67	B60J68	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	68	75
5	Inducer Diameter	46.1mm	46.9mm	52.5 mm
6	Exducer Diameter	68.8 mm	68.9 mm	70 mm

III. EXPERIMENTAL OBSERVATION

The simulator and data-logger method is adopted to match the turbo Chargers B60J67, B60J68 and A58N75 for TATA 497 TCIC -BS III engine. The simulated matching performance obtained by use of manufacturer data. 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 for B60J67, B60J68 and A58N75 Turbo matching. 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 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 data logger observations were tabulated road condition wise from Table 4 to Table 8.

Fig.1 Experimental set up of Data-Logger method

TABLE 3 SIMULATED OBSERVATIONS FOR B60J67, B60J68 AND A58N75 TURBO MATCHING

S.N	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)			Pressure Ratio		
		B60J67	B60J68	A58N75	B60J67	B60J68	A58N75
1	1000	10.67	11.449	14.230	1.783	1.856	1.288
2	1400	23.35	22.560	25.936	2.861	3.051	2.696
3	1800	30.81	29.451	34.568	3.401	3.556	3.388
4	2400	36.40	36.872	38.456	3.747	3.817	3.625

TABLE 4 DATA-LOGGER-ROUGH ROAD OBSERVATION B60J67, B60J68 AND A58N75 TURBO MATCHING

S.N	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)			Pressure Ratio		
		B60J67	B60J68	A58N75	B60J67	B60J68	A58N75
1	1000	7.08	7.37	10.46	1.38	1.35	0.84
2	1400	15.11	15.41	18.45	1.98	1.95	1.70
3	1800	21.43	21.73	26.84	2.36	2.33	2.17
4	2400	27.09	27.43	30.82	2.58	2.55	2.32

TABLE 5 DATA-LOGGER – HIGHWAY OBSERVATIONS FOR B60J67, B60J68 AND A58N75 TURBO MATCHING

S.N	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)			Pressure Ratio		
		B60J67	B60J68	A58N75	B60J67	B60J68	A58N75
1	1000	7.84	8.12	10.52	1.38	1.35	0.84
2	1400	15.62	15.92	18.51	1.98	1.95	1.70
3	1800	21.57	21.87	26.89	2.36	2.33	2.17
4	2400	27.46	27.87	30.85	2.59	2.56	2.32

TABLE 6 DATA-LOGGER – CITY DRIVE OBSERVATIONS FOR B60J67, B60J68 AND A58N75 TURBO MATCHING

S.N	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)			Pressure Ratio		
		B60J67	B60J68	A58N75	B60J67	B60J68	A58N75
1	1000	7.21	7.41	10.58	1.39	1.36	0.88
2	1400	15.32	15.52	18.54	1.98	1.95	1.76
3	1800	21.38	21.68	26.93	2.38	2.35	2.19
4	2400	26.97	27.39	30.91	2.61	2.59	2.36

TABLE 7 DATA-LOGGER – SLOPE UP ROUTE OBSERVATIONS FOR B60J67, B60J68 AND A58N75 TURBO MATCHING

S.N	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)			Pressure Ratio		
		B60J67	B60J68	A58N75	B60J67	B60J68	A58N75
1	1000	7.80	8.02	10.62	1.41	1.38	0.88
2	1400	15.51	15.81	18.60	2.04	2.00	1.79
3	1800	21.64	21.94	26.98	2.4	2.39	2.19
4	2400	27.77	27.97	30.95	2.64	2.62	2.39

TABLE 8 DATA-LOGGER – SLOPE DOWN ROUTE OBSERVATIONS FOR B60J67, B60J68 AND A58N75 TURBO MATCHING

S.N	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)			Pressure Ratio		
		B60J67	B60J68	A58N75	B60J67	B60J68	A58N75
1	1000	7.67	7.97	10.37	1.36	1.35	0.81
2	1400	15.19	15.79	18.42	1.96	1.95	1.68
3	1800	21.46	21.76	26.53	2.34	2.33	2.16
4	2400	27.21	27.41	30.67	2.6	2.60	2.30

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IV. RESULTS AND DISCUSSIONS

The operating conditions obtained for all three turbo-chargers matching with engine. The observation of both simulated and data-logger at various road conditions like rough, highway, city drive, slope-up and slope-down, were marked in the respective compressor map. In the each graph the simulated matching performance shown for easy comparison and understanding. The fig.2 illustrates the turbo match by simulation and data-logger (Rough Road Route) for turbo Chargers B60J67, B60J68 and A58N75 for TATA 497 TCIC -BS III engine. Similarly the Fig.3 to Fig. 6 illustrates the turbo-match of turbo chargers B60J67, B60J68 and A58N75 for TATA 497 TCIC -BS III engine by simulation and data-logger at highway, City Road, Slope up and Slope down respectively. This was observed that turbo-match of turbocharger B60J67 and B60J68 with the TATA 497 TCIC -BS III engine exhibits well in particularly in medium and higher speeds, but at lower speeds, the surge occurred. That is the risk of flow reversal at lower speed when adapting the turbo-chargers B60J67 and B60J68 with TATA 497 TCIC -BS III engine. But these turbo chargers can be matched if the situation permits to raise the minimum speeds i.e., more than 1200 rpm for turbo-charger B60J67 and little above 1000rpm for turbo-chrgers B60J68. On other hand match of A58N75 turbocharger exhibits well at low, medium but choke hazard found at high speeds and found in unsafe for application. The same was ensured in simulator test, data-logger with all the road conditions like Rough, City Drive, highway, slope up and slope down. The turbocharger can be matched if the situation permits to reduce the engine maximum speed less than 2200 rpm.

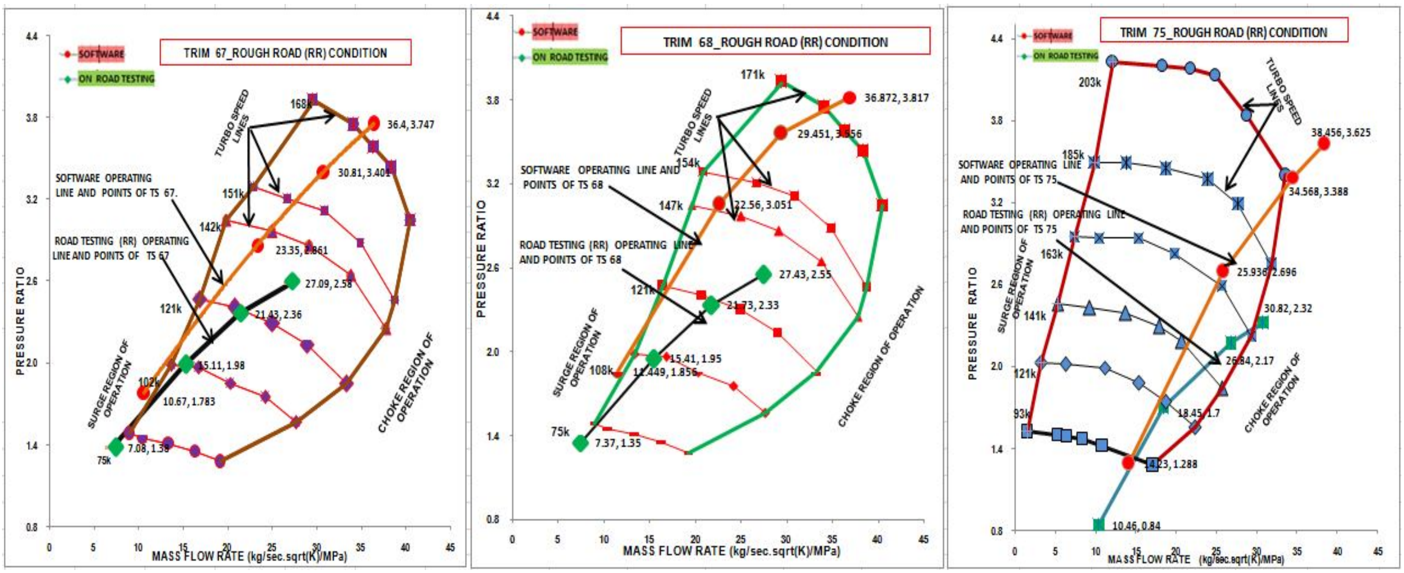

Fig. 2 B60J67, B60J68 and A58N75 Turbo-match- by Simulation & Data-logger – Rough Road

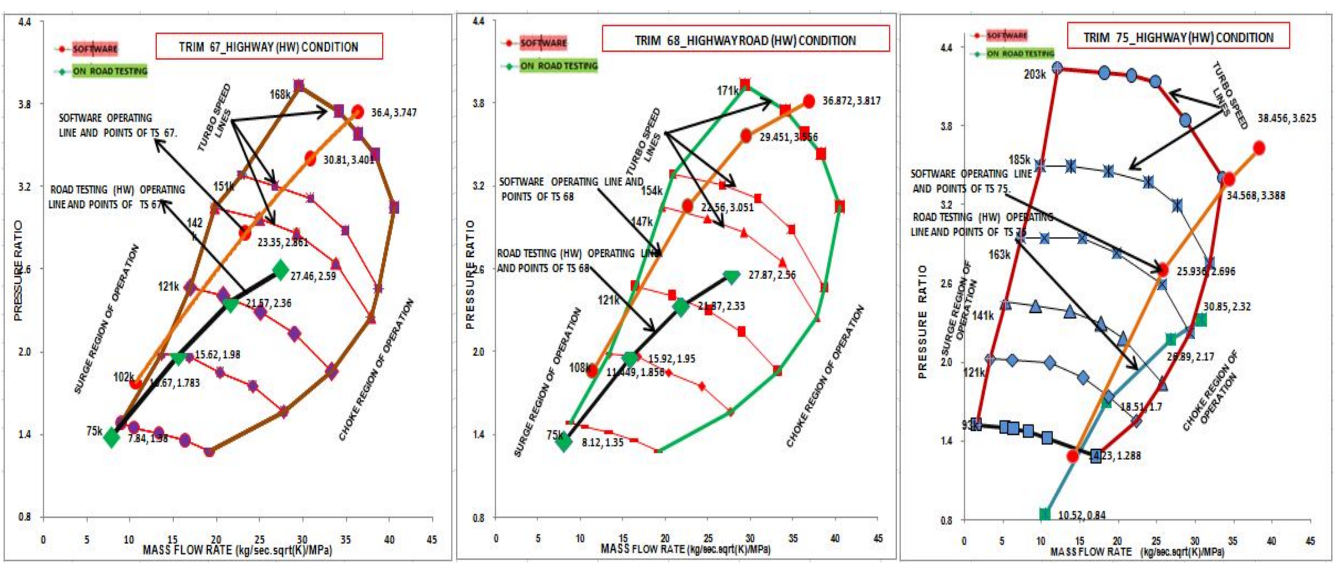

Fig. 3 B60J67, B60J68 and A58N75 Turbo-match- by Simulation & Data-logger – Highway Route

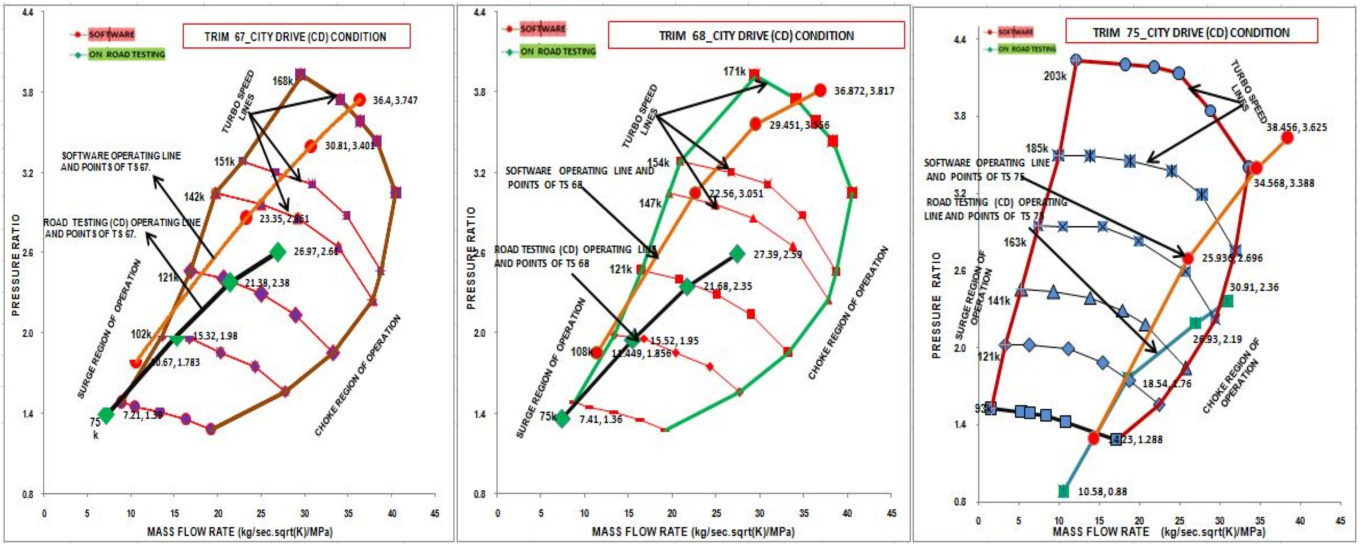

Fig. 4 B60J67, B60J68 and A58N75 Turbo-match- by Simulation & Data-logger – City Route

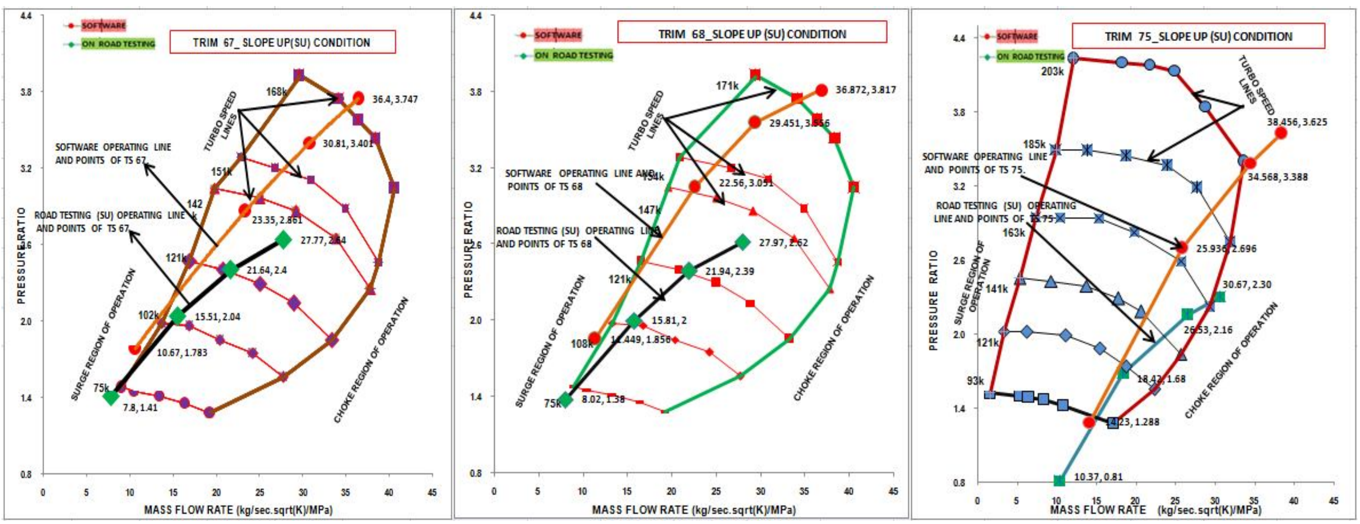

Fig. 5 B60J67, B60J68 and A58N75 Turbo-match- by Simulation & Data-logger – Slope-up Route

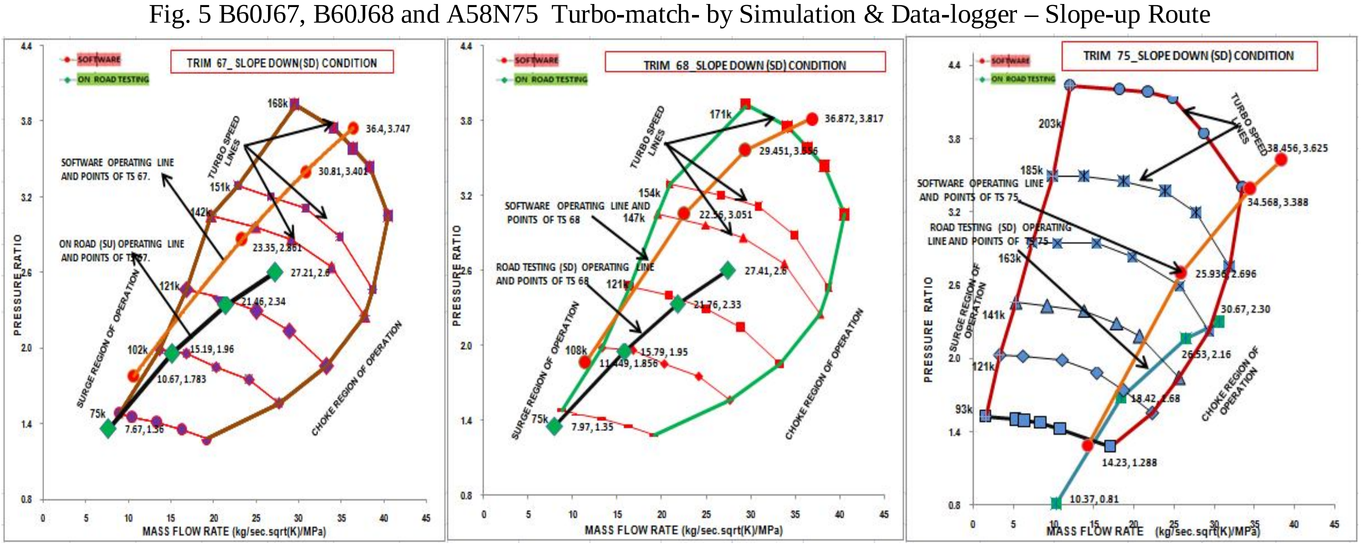

Fig. 6 B60J67, B60J68 and A58N75 Turbo-match- by Simulation & Data-logger – Slope-Down Route

V. CONCLUSION

The turbo-matching of B60J67, B60J68 and A58N75 turbochargers for TATA 497 TCIC - BS III engine is discussed in this paper. The simulation and the data-logger methods used for obtaining operating conditions. The turbo-match of turbo-chargers obtained individually for each turbo- charger. 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. The simulated values deviated (by higher values) from actual values (data-logger). The turbo-match for B60J67 and B60J68 turbochargers require rising of minimum speeds and turbo charger A58N75 requires reducing the maximum speed. Among these three turbo chargers, the B60J68 turbocharger requires minimum raise of engine speed from 1000 rpm. Hence the B60J68 turbocharger can be easily matched for the TATA 497 TCIC -BS III engine than other two turbochargers.

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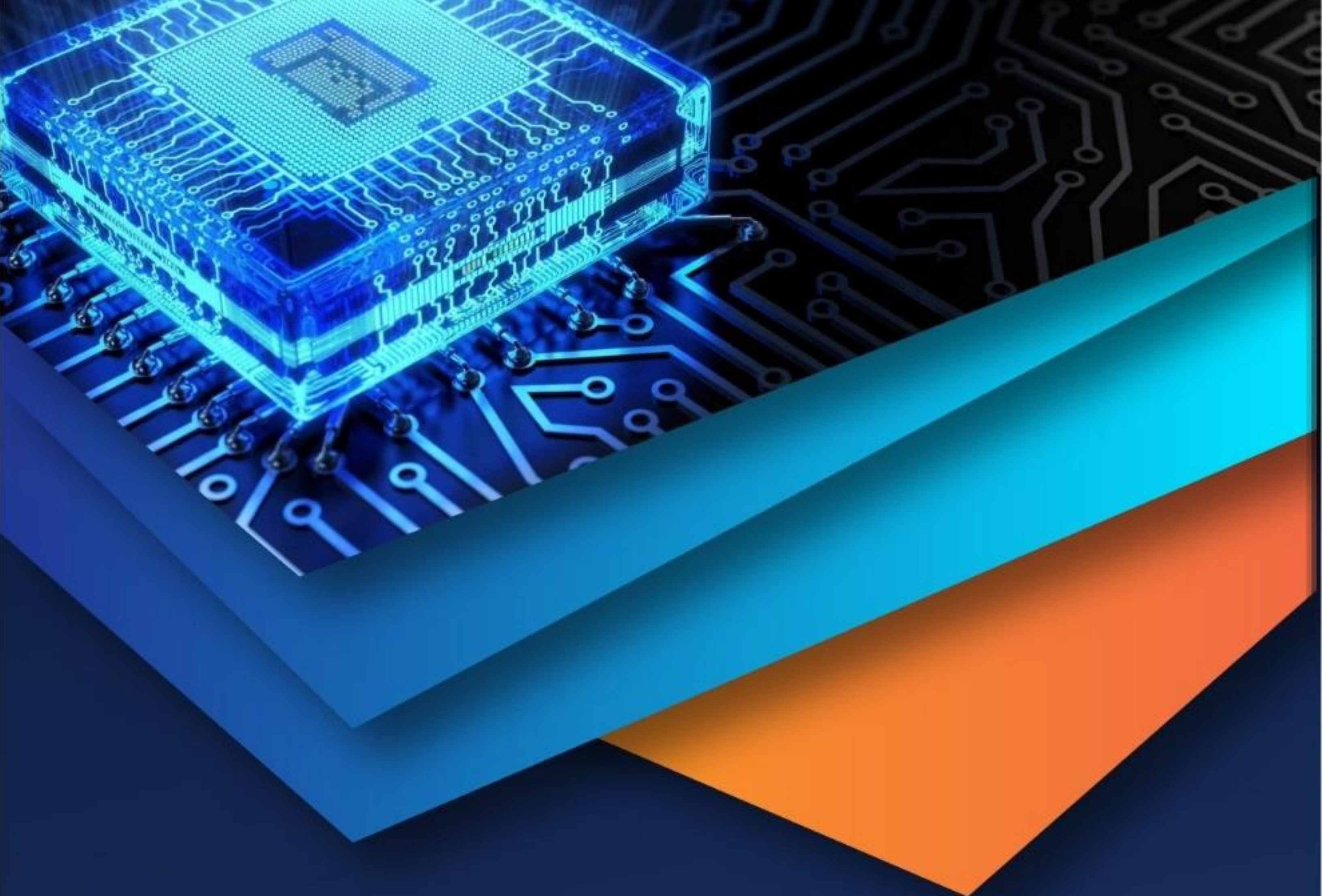

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