Experimental Investigation on Performance of Turbo-matching of Turbocharger A58N72 for TATA 497 TCIC -BS III Engine

Badal Dev Roy[1], Dr.R.Saravanan[2]

[1]Research Scholar, Department of Mechanical Engineering, School of Engineering, Vels Institute of Science, Technology &Advanced Studies (VISTAS), Vels University, Chennai, TN, India.
[2]Research Supervisor, Professor (Mechanical) & Principal, Ellenki Institute of Engineering and Technology, Jawaharlal Nehru Technological University, Hyderabad, TS, India.

---***---

Abstract – *The engines for commercial and heavy vehicles prefer charge boosting specifically at higher load to manage smoother operation, control emission etc. Turbocharger is employed for the same. Turbo-matching for desired engine is a critical task and needs intensive care. This can be done in many ways. This work deals with test based matching methods. The aim of this work is to evaluate the appropriateness of matching of A58N72 Turbo Charger for the TATA 497 TCIC -BS III engine. The simulator based matching is adapted to obtain the matching particulars. The results were validated with data-logger method by experimentally run the vehicle with different routes like Highway; slope-up, rough road, slope-down and city drive to discuss the appropriateness of the matching performance.*

Key Words: Data-logger, Simulation, Turbo-charger, Trim size, Turbo matching, Compressor mapping, , surge, choke.

1.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 simulation 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 72 to the TATA 497 TCIC -BS III Engine by simulator method. The validation of the same by Data Logger based Matching method.

2. 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 72 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.

Figure -1: Experimental setup of Data-logger Method

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.

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 with maximum efficiency of compressor. 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.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 11 | Nov -2017 www.irjet.net p-ISSN: 2395-0072

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 (A58N72) is considered to examine the performance of matching for TATA 497 TCIC -BS III engine. Here A58 is the design code and N72 is the Trim Size of the turbocharger in percentage. The other Specification furnished in Table 2.

Table -2: Specification of Turbo Charger A58N72

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(%)	72
5	Inducer Diameter	50.1 mm
6	Exducer Diameter	69.58 mm

3. EXPERIMENTAL OBSERVATION

The simulation and data-logger methods are adopted to analyze the turbo match of the Turbocharger A58N72 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 tonnes of net weight. The grass weight of vehicle is 11 tonnes.

Table -3: Observation from Simulation

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	13.265	1.284
2	1400	24.789	2.678
3	1800	32.265	3.224
4	2400	36.256	3.427

Table -4: Data-logger observation – Rough Road

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	9.32	0.97
2	1400	17.23	1.77
3	1800	25.73	2.25
4	2400	29.72	2.38

Table -5: Data-logger observation Highway Route

Sl.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)	Pressure Ratio
1	1000	9.39	0.97
2	1400	17.28	1.77
3	1800	25.79	2.25
4	2400	29.77	2.38

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	9.43	0.99
2	1400	17.32	1.83
3	1800	25.84	2.29
4	2400	29.86	2.41

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	9.51	0.96
2	1400	17.76	1.85
3	1800	25.95	2.30
4	2400	29.93	2.46

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	9.27	0.98
2	1400	17.12	1.73
3	1800	25.47	2.18
4	2400	29.59	2.34

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

RESULTS AND DISCUSSIONS

The turbo matching performance of both the methods are comparatively presented in route wise from Chart 1 to Chart 5 in the order of rough road, Highway, City Drive, Slope up and slope down respectively. The simulated solution shows higher values compared to data logger solution.

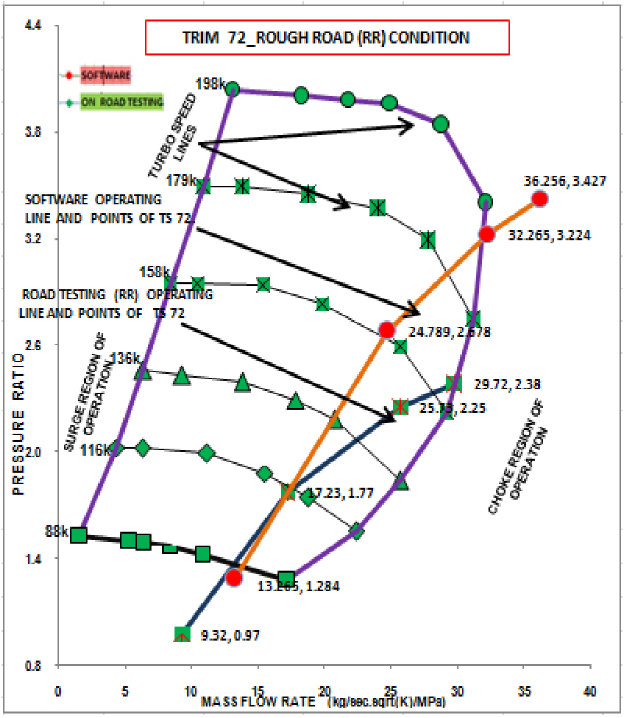

Chart -1: Turbo-match performance in simulation and Data-logger Methods (Rough Route)

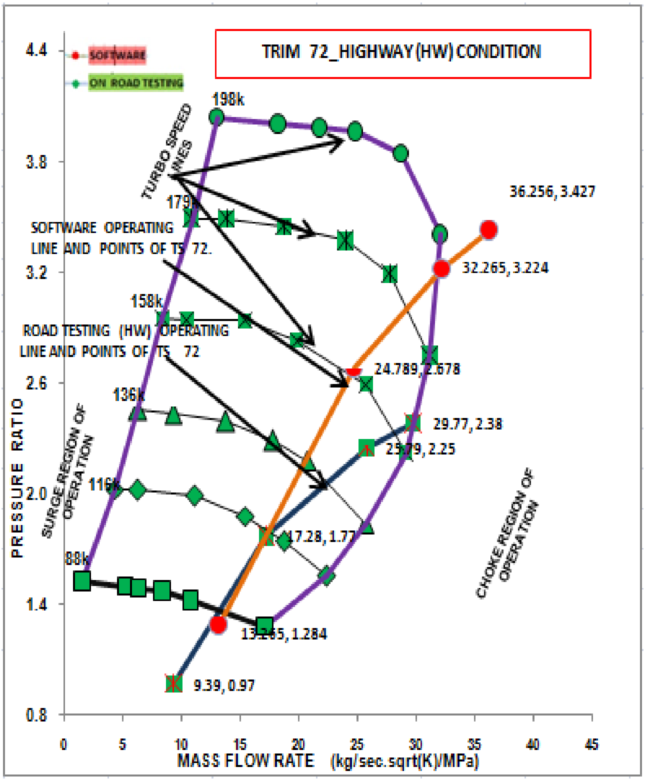

Chart -2: Turbo-match performance in simulation and Data-logger Methods (Highway Route)

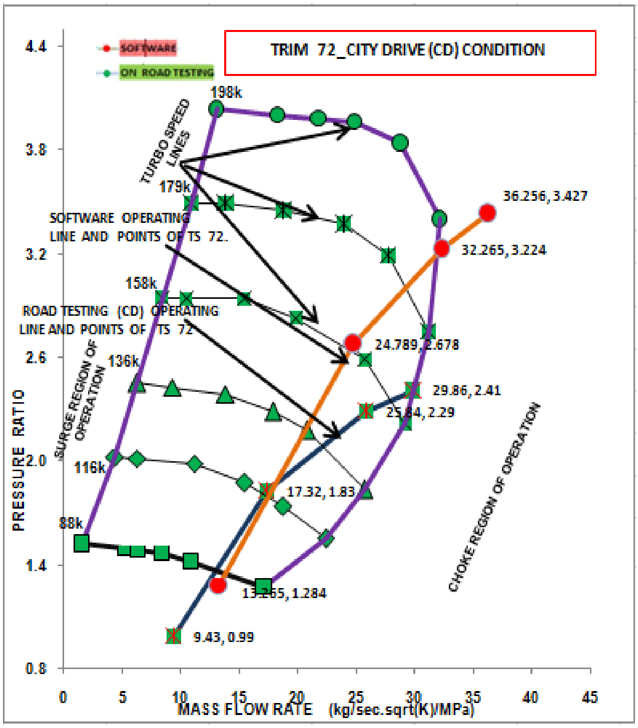

Chart -3: Turbo-match performance in simulation and Data-logger Methods (City Drive)

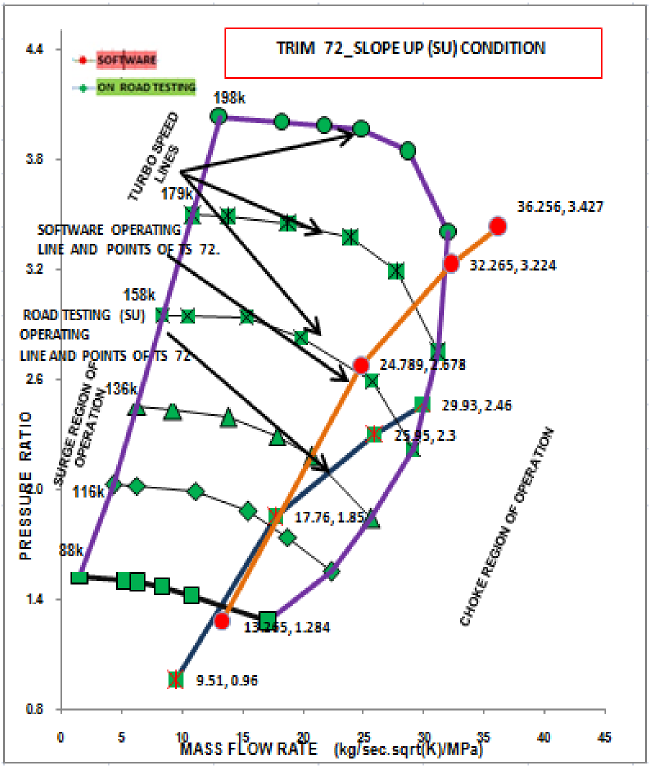

Chart -4: Turbo-match performance in simulation and Data-logger Methods (Slope –up Route)

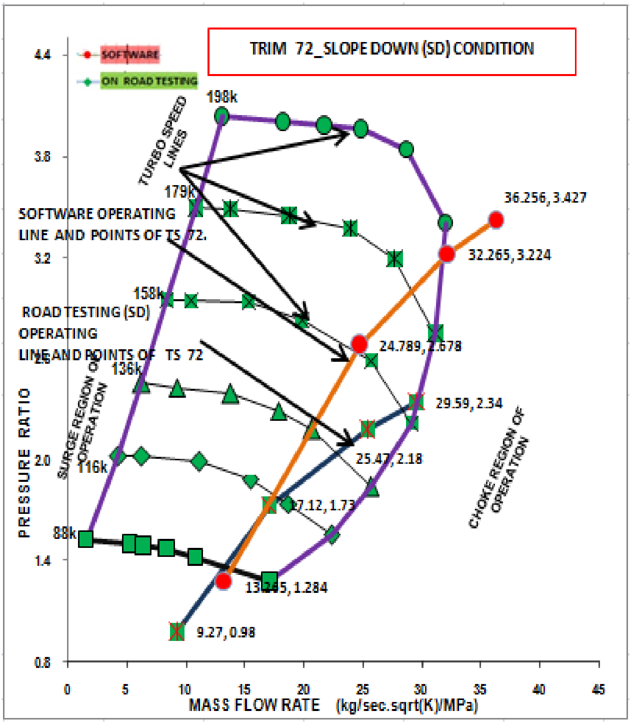

Chart -5: Turbo-match performance in simulation and Data-logger Methods (Slope –Down Route)

The pattern followed by engine with the desired turbocharger almost similar irrespective of routes of operating the vehicle. At lower speed the turbo charger and engine operating performance safe and acceptable region. Especially higher speed choke occurs. Simulated solution state that vehicle can operate safe and satisfiable with less than the engine speed of 1800 rpm of speed. But data logger results show that only at maximum engine speed (2400 rpm) is reaches the choke region and the same was repeated in all routes.

CONCLUSION

Turbo charger matching is a complicated task. The simulation and data-logger methods are employed in this research to evaluate the matching performance of turbocharger A58N72 for TATA 497 TCIC -BS III Engine. The results show that the choke hazards found at higher speeds that is according to simulation method the choke occur the engine operating speed above 1800 rpm. Actually the data logger results reveal that only at maximum speed (2400 rpm) such choke occur. The engine can adopt A58N72 turbocharger if its maximum speed less than 2400 rpm. 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.

ACKNOWLEDGEMENT

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 research.

REFERENCES

[1] G.Cantore, E.Mattarelli, and S.Fontanesi, "A New Concept of Supercharging Applied to High Speed DI Diesel Engines," SAE Technical Paper 2001-01-2485, 2001, pp.1-17, doi:10.4271/2001-01-2485, 2001.

[2] L.Guzzella, U.Wenger, and R.Martin, "IC-Engine Downsizing and Pressure-Wave Supercharging for Fuel Economy," SAE Technical Paper 2000-01-1019, 2000, pp.1-7, doi:10.4271/2000-01-1019, 2000.

[3] B. Lecointe and G.Monnier, "Downsizing a Gasoline Engine Using Turbocharging with Direct Injection," SAE

Technical Paper 2003-01-0542, 2003, pp.1-12, doi:10.4271/2003-01-0542, 2003.

[4] S.Saulnier and S.Guilain, "Computational Study of Diesel Engine Downsizing Using Two-StageTurbocharging," SAE Technical Paper 2004-01-0929, 2004, pp.1-9, doi:10.4271/2004-01-0929, 2004.

[5] T.Lake, J.Stokes, R.Murphy and R.Osborne, "Turbocharging Concepts for Downsized DI Gasoline Engines," SAE Technical Paper 2004-01-0036, 2004, pp.1-13, doi:10.4271/2004-01-0036, 2004.

[6] W.Attard, H.Watson, S.Konidaris and M.Khan, "Comparing the Performance and Limitations of a Downsized Formula SAE Engine in Normally Aspirated, Supercharged and Turbocharged Modes," SAE Technical Paper 2006-32-0072, 2006, pp.1-22, doi:10.4271/2006-32-0072, 2006.

[7] A.Lefebvre and S.Guilain, "Modelling and Measurement of the Transient Response of a Turbocharged SI Engine," SAE Technical Paper 2005-01-0691, 2005, doi:10.4271/2005-01-0691, 2005, pp.1-15.

[8] S.Tashima, H.Okimoto, Y.Fujimoto, and M.Nakao, "Sequential Twin Turbocharged Rotary Engine of the Latest RX-7," SAE Technical Paper 941030, 1994, doi:10.4271/941030,1994, pp.1-10.

[9] T.Watanabe, T.Koike, H.Furukawa, N.Ikeya, "Development of Turbocharger for Improving Passenger Car Acceleration," SAE Technical Paper 960018, 1996, doi:10.4271/960018, 1996, pp.1-9.

[10] T.Kattwinkel, R.Weiss and J.Boeschlin, "Mechatronic Solution for Electronic Turbocharger," SAE Technical Paper 2003-01-0712, 2003, pp.1-8, doi:10.4271/2003-01-0712, 2003.

[11] N.Ueda, N.Matsuda, M.Kamata, H.Sakai, "Proposal of New Supercharging System for Heavy Duty Vehicular Diesel and Simulation Results of Transient Characteristics,"

[12] SAE Technical Paper 2001-01-0277, 2001, pp.1-9, doi:10.4271/2001-01-0277, 2001.

[13] J.Kawaguchi, K.Adachi, S.Kono and T.Kawakami, "Development of VFT (Variable Flow Turbocharger)," SAE Technical Paper 1999-01-1242, 1999, doi:10.4271/1999-01-1242, 1999, pp.1-8.

[14] C.Cantemir, "Twin Turbo Strategy Operation," SAE Technical Paper 2001-01-0666, 2001, doi:10.4271/2001-01-0666, 2001, pp.1-11.

[15] C.Choi, S.Kwon and S.Cho, "Development of Fuel Consumption of Passenger Diesel Engine with 2 Stage Turbocharger," SAE Technical Paper 2006-01-0021, 2006, doi:10.4271/2006-01-0021, 2006, pp.1-9.

[16] J.Andersen, E.Karlsson and A.Gawell, "Variable Turbine Geometry on SI Engines," SAE Technical Paper 2006-01-0020, 2006, doi:10.4271/2006-01-0020, 2006, pp.1-15.

[17] Z.Filipi, Y.Wang and D.Assanis, "Effect of Variable Geometry Turbine (VGT) on Diesel Engine and Vehicle System Transient Response," SAE Technical Paper 2001-01-1247, 2001, pp.1-21, doi:10.4271/2001-01-1247, 2001.

[18] C.Brace, A.Cox, J.Hawley and N.Vaughan, et al., "Transient Investigation of Two Variable Geometry Turbochargers for Passenger Vehicle Diesel Engines," SAE Technical Paper 1999-01-1241, 1999, doi:10.4271/1999-01-1241, 1999, pp.1-17.

[19] S.Arnold, M.Groskreutz, S.Shahed and K.Slupski, "Advanced Variable Geometry Turbocharger for Diesel Engine Applications," SAE Technical Paper 2002-01-0161, 2002, pp. 1-12, doi:10.4271/2002-01-0161, 2002.

[20] Qingning Zhang, Andrew Pennycott, Chris J Brace, 'A review of parallel and series turbocharging for the diesel engine' Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering.Volume: 227 issue: 12, Sep. 2013, pp. 1723-1733. https://doi.org/10.1177/0954407013492108.

[21] F.Millo, ,F.Mallamo and G.Mego, , "The Potential of Dual Stage Turbocharging and Miller Cycle for HD Diesel Engines," SAE Technical Paper 2005-01-0221, 2005, pp. 1-12, doi:10.4271/2005-01-0221, 2005.

[22] N.Watson and M.S.Janota, Wiley-Interscience Ed. "Turbocharging the internal combustion engine,", Diesel motor – 1982, 608 pages. https://doi.org/10.1007/978-1-349-04024-7

[23] Badal Dev Roy, R.Saravanan, R.Pugazhenthi and M.Chandrasekaran, "Experimental Investigation of Turbocharger Mapped by Data-logger in I.C. Engine" ARPN Journal of Engineering and Applied Sciences, 11 (7), April 2016, pp. 4587 – 4595.

BIOGRAPHIES

"Er.Badal Dev Roy post graduated in Automotive Engineering. He served in R&D cell of an automobile sector and has hands on experience on Engine testing and development. He also worked at Cummins Turbo Technologies. At present he pursues his research degree at VISTAS, Vels University, Chennai, India".

"Dr.R.SARAVANAN acquires all his degrees at nationally ranked institutions in India. He possesses mammoth experience in Teaching, Research and Industries. His area of research includes Composite Materials, Material processing, Manufacturing, Design, Automobile and Manufacturing Management".