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Turbo-Matching of B60J68 and A58N75Type Turbochargers for A Commertial Vehicle Engine

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Keywords:

TurboCharger;
Turbomatching;
Simulation;
Data-logger;
Compressor map.

Abstract

The Turbocharger is a charge booster for internal combustion engines to achieve the engine operating performance in safe range even at higher loads. Charge supplies must meet the engine requirements with respect to speed and load. The speed and load may differ based on the routes in which the vehicle operates. This study focuses the simulation based and test based matching of turbochargers with trim 68 (B60J68) and trim 75 (A58N75) for the TATA 497 TCIC -BS III engine. The routes like Rough road, highway and slope up are considered for evaluation. The turbomatch performances were obtained by simulation and data-logger method at various routes. The appropriateness of matching was evaluated in the range of minimum to maximum engine speeds. The appropriateness evaluation carried out with the help of compressor map.

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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 mange this problem. They are: adopting the sequential system [8], incorporate the limiting fuel system, reducing the inertia, improvements on bearing, modification on aerodynamics [9], establishing electrically supported turbocharger [10], the usage of positive displacement charger i.e., secondary charging

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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 the system is not exact match for petrol engines [15]. Even though many research 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 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 effects as well as affects the engine performance [5],[20],[21]. So it is 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]. [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 B60J68andA58N75 for the TATA 497 TCIC -BS III Engine by simulation. The validation of the same was carriedout by Data Logger 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 68 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 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. 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.

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 Details	DI Diesel Engine; bore97mm stroke 128 mm
6	Engine speed	2400 rpm (Max power), 1400 rpm (Max Torque)

2.5 Turbochargers Specifications

The TATA Short Haulage Truck, turbochargers of B60J68 and A58N75are 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	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 (%)	68	75
5	Inducer Diameter	46.9mm	52.5 mm
6	Exducer Diameter	68.9 mm	70.0 mm

Figure 1 Experimental set up of Data-Logger method

3. Experimental Observation

The simulation and data-logger method is adopted to match the Turbo Chargers B60J68 and A58N75 for TATA 497 TCIC -BS III engine. The matching performance is 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 3 for B60J68 and A58N75Turbo 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 gross weight of vehicle is 11 tonnes. The experimental setup for Data logger type matching is shown in figure 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. Those data logger observations were tabulated road condition wise from Table 4 to Table 8.

Table-3: Simulated observations for B60J68 and A58N75 Turbo matching

S.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)		Pressure Ratio	
		B60J68	A58N75	B60J68	A58N75
1	1000	11.449	14.23	1.856	1.288
2	1400	22.560	25.936	3.051	2.696
3	1800	29.451	34.568	3.556	3.388
4	2400	36.872	38.456	3.817	3.625

Table -4: Data-logger – Rough Road Route observations for B60J68 and A58N75 Turbo matching

S.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)		Pressure Ratio	
		B60J68	A58N75	B60J68	A58N75
1	1000	7.37	10.46	1.35	0.84
2	1400	15.41	18.45	1.95	1.7
3	1800	21.73	26.84	2.33	2.17
4	2400	27.43	30.82	2.55	2.32

Table- 5: Data-logger – Highway Route observations for B60J68 and A58N75 Turbo matching

S.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)		Pressure Ratio	
		B60J68	A58N75	B60J68	A58N75
1	1000	8.12	10.52	1.35	0.84
2	1400	15.92	18.51	1.95	1.70
3	1800	21.87	26.89	2.33	2.17
4	2400	27.87	30.85	2.56	2.32

Table- 6: Data-logger – City Drive observations for B60J68 and A58N75 Turbo matching

S.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)		Pressure Ratio	
		B60J68	A58N75	B60J68	A58N75
1	1000	7.41	10.58	1.36	0.88
2	1400	15.52	18.54	1.95	1.76
3	1800	21.68	26.93	2.35	2.19
4	2400	27.39	30.91	2.59	2.36

Table- 7 : Data-logger – Slope –Up observations for B60J68 and A58N75 Turbo matching

S.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)		Pressure Ratio	
		B60J68	A58N75	B60J68	A58N75
1	1000	8.02	10.62	1.38	0.88
2	1400	15.81	18.60	2.00	1.79
3	1800	21.94	26.98	2.39	2.19
4	2400	27.97	30.95	2.62	2.39

Table- 8: Data-logger – Slope –Down observations for B60J68 and A58N75 Turbo matching

S.No	Engine Speed (rpm)	Mass Flow Rate (Kg/sec.sqrt K/Mpa)		Pressure Ratio	
		B60J68	A58N75	B60J68	A58N75

1	1000	7.97	10.37	1.35	0.81
2	1400	15.79	18.42	1.95	1.68
3	1800	21.76	26.53	2.33	2.16
4	2400	27.41	30.67	2.60	2.30

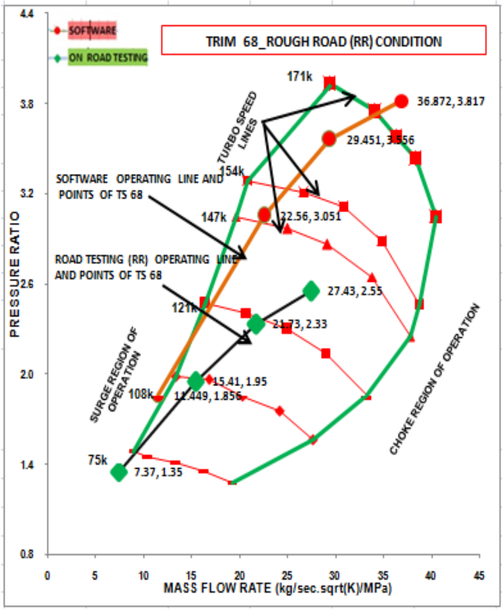

Figure: 2 B60J68 Turbo-match-Rough Road

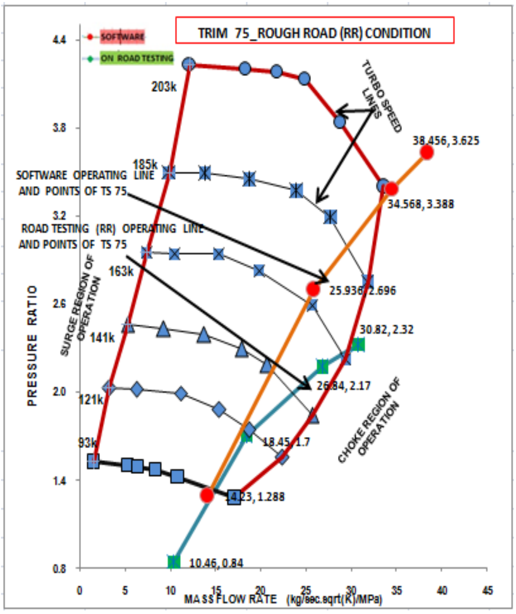

Figure: 3A58N75 Turbo-match- Rough Road

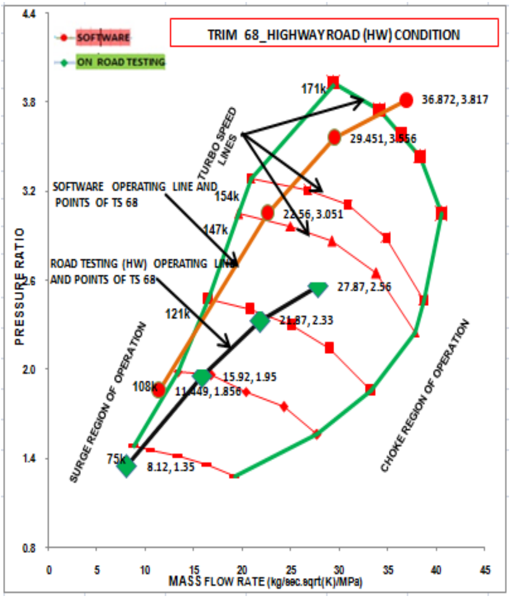

Figure: 4 B60J68 Turbo-match-Highway

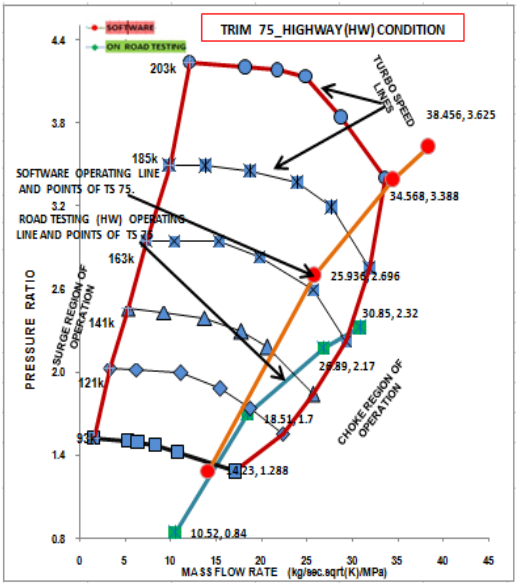

Figure:5A58N75 Turbo-match-Highway Road

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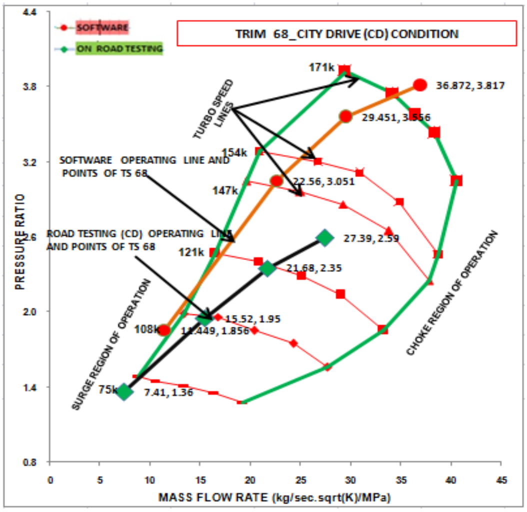

Figure 6B60J68 Turbo-match- City Drive

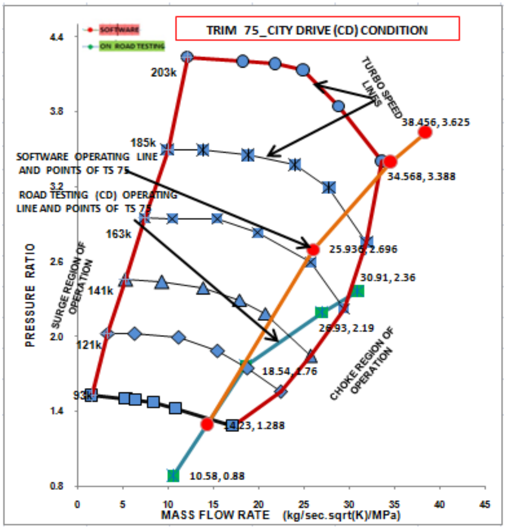

Figure 7A58N75 Turbo-match-City Drive

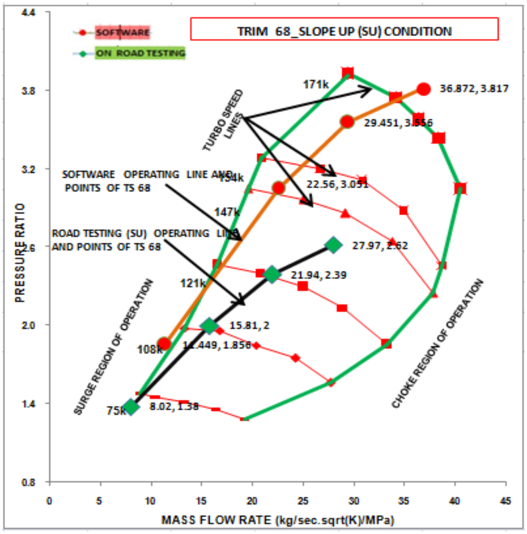

Figure 8B60J68 Turbo-match – Slope Up

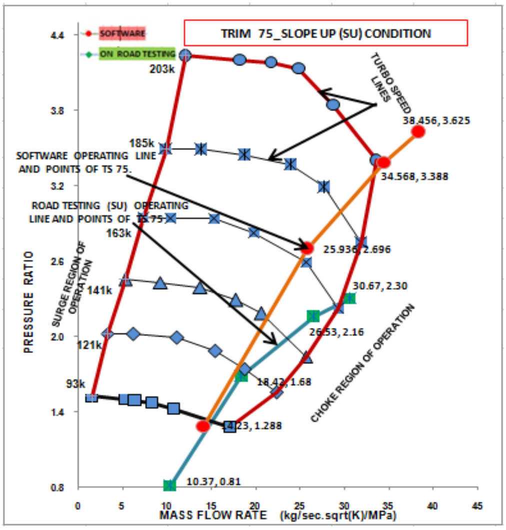

Figure 9 A58N75 Turbo-match- Slope-Up

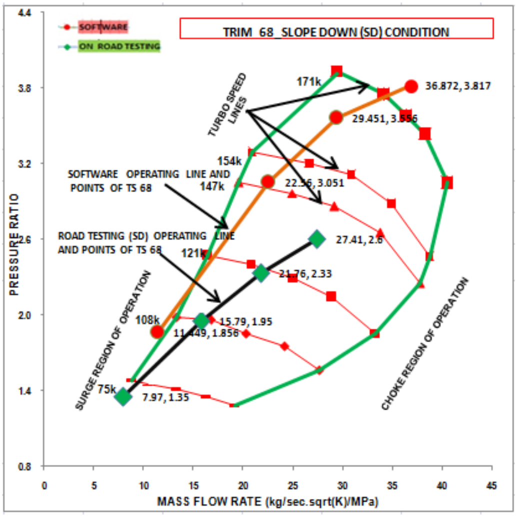

Figure 10B60J68 Turbo-match- Slope-Down

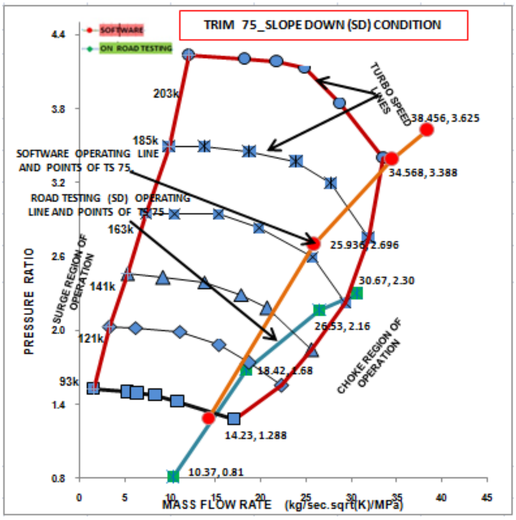

Figure 11A58N75 Turbo-match -Slope Down

4. Results and Discussions

The operating conditions obtained in both cases of turbochargers with engine for both simulation and data-logger method in road routes like the rough road, Highway, city drive, slope-up and slope-down, were obtained. These operating conditions were marked on the respective compressor map. That is, The Fig.2 and Fig.3 are illustrating the turbomatch of B60J68 turbocharger and A58N70 Turbochargers for TATA 497 TCIC -BS III Engine respectively, for matching methods of simulation and data-logger at rough routes. Similarly Fig.4 and Fig.5 turbomatch in simulation and data-logger in Highway route, Fig.6 and Fig.7 for City Drive route, Fig.8 and Fig.9 for Slope up and Fig.10 and Fig.11 for Slope down routes. It was observed from the compressor maps (Fig.2 to Fig.11) that match of turbocharger B60J68 exhibit well operating performance in the medium and higher speeds, but at lower speed (1000rpm), the surge occurred. That is the risk of flow reversal at lower speeds by using the B60J68 turbocharger. Suppose theB60J68 Turbocharger adopted for the TATA 497 TCIC -BS III engine, the minimum speed of the engine to be raised from 1000 rpm. On other hand match of A58N75 turbo-charger exhibits well operating performance at lower and medium speeds but at higher speeds (approximately above 2200 rpm) the choke occurred.That is there was a chance for compressor end oil leakage and/or insufficient air supply. The avoiding such risks the engine maximum speed to be reduced.

5. Conclusion

The evaluation of the appropriateness of turbo-matching of B60J68 turbocharger andA58N75 turbochargers for TATA 497 TCIC -BS III engine is discussed in this article. The simulation and data-logger methods were used for such evaluation. From the observation, it was found that the simulated values higher than the data-logger values. The data-logger values obtained through on road experimentation. The data-logger method adopted in this research may feel as expensive but it is one time job of finding the best turbomatch for an engine category. The appropriateness of turbomatching is evaluated. The results reveal that the choke hazard occurs especially at higher speeds with A58N75 turbocharger. The reduction operating speed certain extent can be compromised. So for adapting A58N75 turbocharger requires the lowering of the maximum speed. The turbomatch of B60J68 turbocharger has a surge hazard at lower speed (1000 rpm). The minimum engine speed to be increased slightly to match this turocharger for the TATA 497 TCIC -BS III engine.

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