



Automotive Mechanical Engineering

Powertrain Design & Efficiency

Turbo Charger Analysis

Lecturer: R Lewis

Module Code: M5X02200

By

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Abstract

All the world now looking for how increase the power without increasing the materials such as the fuel, that why the typical petrol engine now might loss 30% of the power contained in how to do supplying the fuel to the engine, optimum and correct timing and useful function under typical conditions, so it is important to look at the 70% of another wastage energy, to show that fact consist of ,16% heat energy to the coolant system in the engine, 7% heat energy to friction such as dynamic movement and pumping, 38% heat energy to let leaving exhaust gases, 9% heat energy to that purpose which is surrounding air.

Consequently, the huge energy is important for design reasons, it is permitted to escape to the ambient through the exhaust system.

the first priority of the turbocharger is using a part of the energy consists of exhaust gas, that happened while it is allowed by opening the exhaust valve until the final of a power stroke, probably 50 degrees before the bottom dead centre.

To guide turbine wheel which is at the same time pushing the centrifugal compressor wheel.

Diesel engine using turbo at the present time and soon will be used in the petrol engine as well.

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Acknowledgment

It is all my pleasure to express my special thanks of gratitude to Pro/ R Lewis, who help me and gave me guidance and orientation to complete the turbocharger analysis assignment, it is really interesting topic to take opportunity for exploring and learning new technique to increase the engine's power, I am really to thankful him.

Thanks

Introduction

Turbocharger

Basically it is sort of air pump delivering air atmospheric pressure and compressing to as possible high pressure and crossing the compressed air by the inlet valve to the engine. Also is a specific process which the turbine during spinning at significant speed before outputting any sort of usable boost in its function, this thing guide to a case called turbo lag, where while the beginning of the acceleration, the performance feels like nothing increases happened in appearance.

As normal increasing the speed of the turbine, the surge power line as sudden will show and introduced this position which named a boost.

How turbo charger increase engine power?

Most diesel engines using a turbocharger, but all the designers and manufacturers going now towards turbocharger in the petrol engines.

The turbocharger technique is dependent on the waste gases are ejected from the engine and directed or led to the hot wheel of the turbo or to the turbine,

Consequently completes the cycle with improving and increasing the power of the engine.

the turbo function by passage of exhaust gas emissions throughout the turbine blades, when it is going speed by the acceleration that making high gas performance supply it can be gained, so you can increase and decrease if the engine is accelerating or decelerating, as any sort of low rotation movement (torque) the turbo engine reaction or respond will be not satisfying for good performance.

some issues of acting an atmospheric block, the reason is the small turbine blade, when its start to work and compressing the air at the low revs will affect the engine be strangles particularly high engine ranges.

But the big turbine blades will make a lot of difference, which increases the torque double while the engine is accelerating.

(Digital, 2018)

Stripping down the turbocharger.



Figure (2) (Barsoum, 2018)
the beginning start with the total turbocharger stripped from diesel engine.



Figure (3) (Barsoum, 2018)
the figure show the cavity of the gas emissions flow came from the exhaust manifold

throughout the turbine cavity.



Figure (4) (Barsoum, 2018)
the four cylinders emission outlet into manifold exhaust gasket connected to the turbocharger.



Figure (5) (Barsoum, 2018)
here you can see waste gate, small emission gate to let the gas cycle go from turbine cavity move to another area.



Figure (6)

(Barsoum, 2018)

Start to remove the nut of the waste gate inside the body which it is job is letting the exhaust gas in and out of the turbine cavity while its circulation gas cycle, also this arms take orders to open and close it dependent on boost pressure the exhaust gas pressure is increased or decreased.

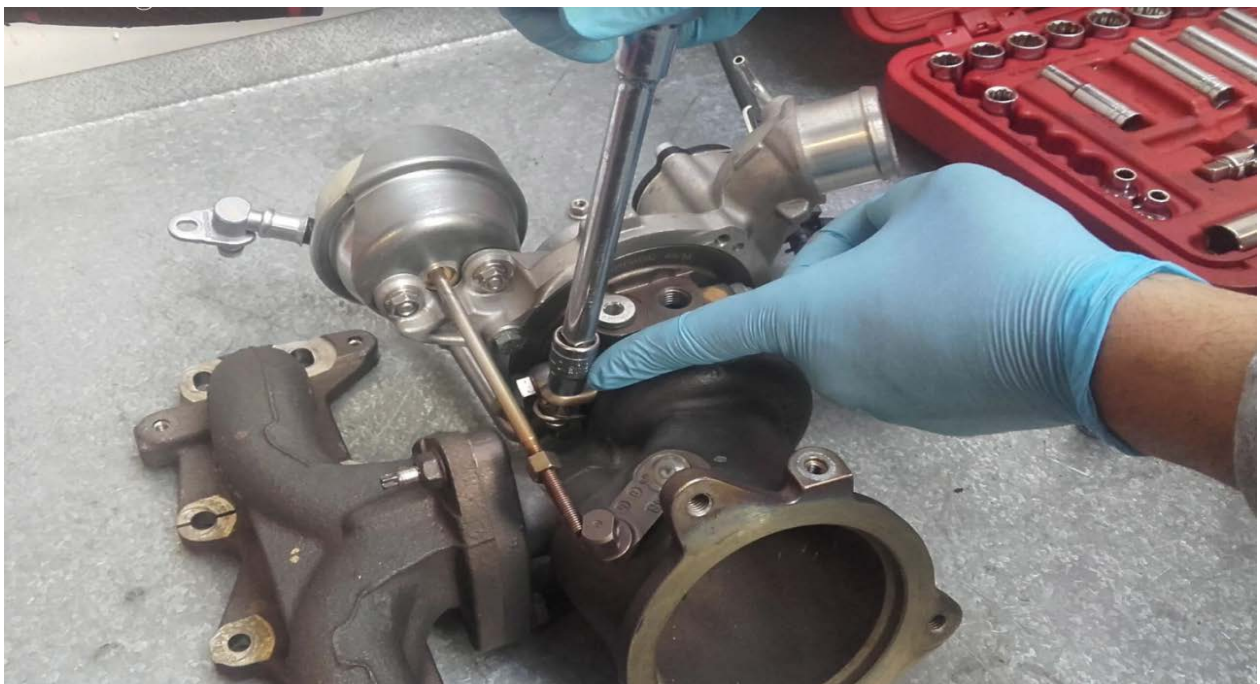


Figure (7)

(Barsoum, 2018)

take off the nut and Remove the clip of the turbine housing.



Figure (8) (Barsoum, 2018)
move the bolt and wisher kindly and keep the bolt, nut, and wisher aside of the turbocharger.



Figure (9) (Barsoum, 2018)
Keep the metal clip totally jointed with nut, wisher and bolt.



Figure (10)

(Barsoum, 2018)

Continue to strip other turbo component by take the four bolt which is are hold the other side of the ambient air inlet or intake air flow.



Figure (11)

(Barsoum, 2018)

make everything while your working is tidy and clean, use always the appropriate sockets for their correct purposes, also record all the important data during the stripping operation.



Figure (12)

(Barsoum, 2018)

remove all the oil pipes and hoses , check the turbine movement if there is any sort of wobble or trembling between each side for intake air flow from the ambient and exhaust gas housing came from the exhaust manifold.

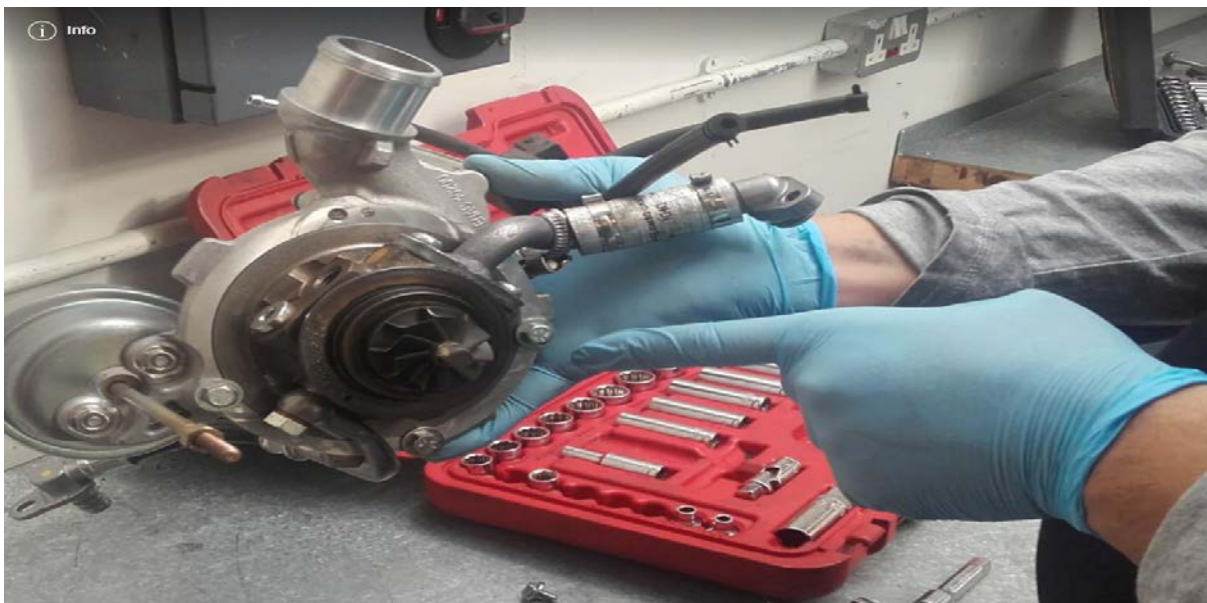


Figure (13)

(Barsoum, 2018)

Take off the four bolt start front each one to another.



Figure (14)

(Barsoum, 2018)

take off the turbine case and check if there is any sort of cracks on the seals areas.



Figure (15)

(Barsoum, 2018)

set thr turbine housing and start to split both side which is fitted on the same axis.



Figure (16) (Barsoum, 2018)
the axis thread is French thread to prevent the axis lose both sides, keep them tight all the time.



Figure (17) (Barsoum, 2018)
compressor wheel ,spindle and turbine wheel ,the axis holding both sides of the flow circulation from the ambient inlet and exhaust turbine which guide increase the air flow into the engine when its rotation in the same axis.



Figure (18) (Barsoum, 2018)
 the most important during stripping the turbocharger is gain a lot of experiences and techniques, that will help you to rely on yourself.

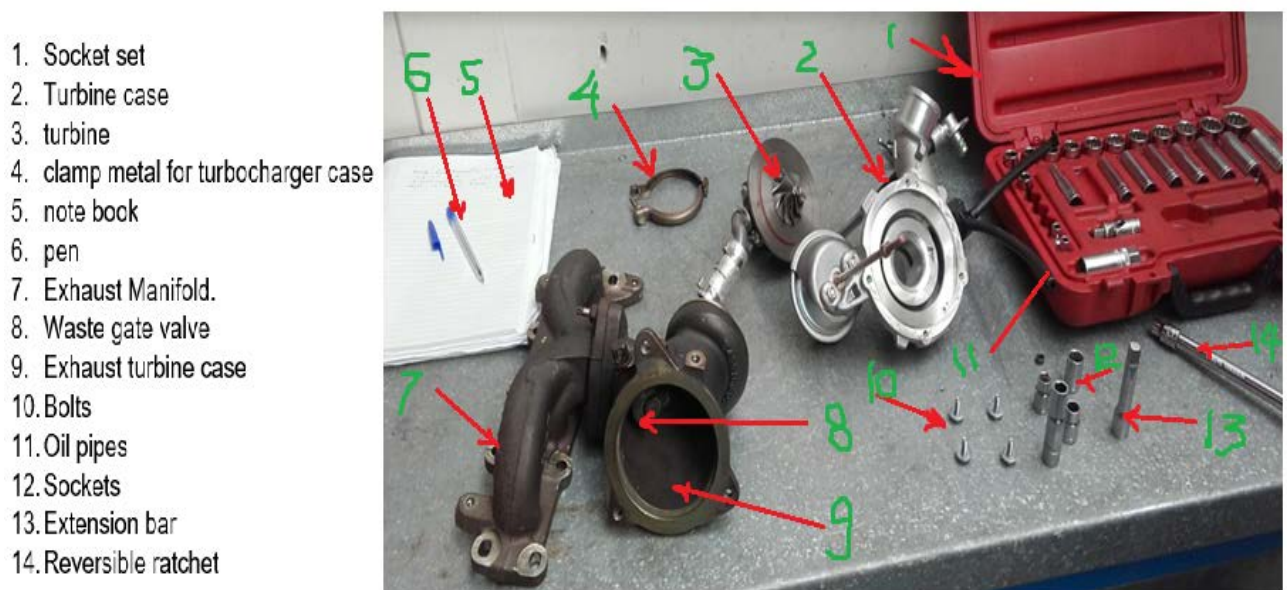


Figure (19) Haynes manual (Barsoum, 2018)

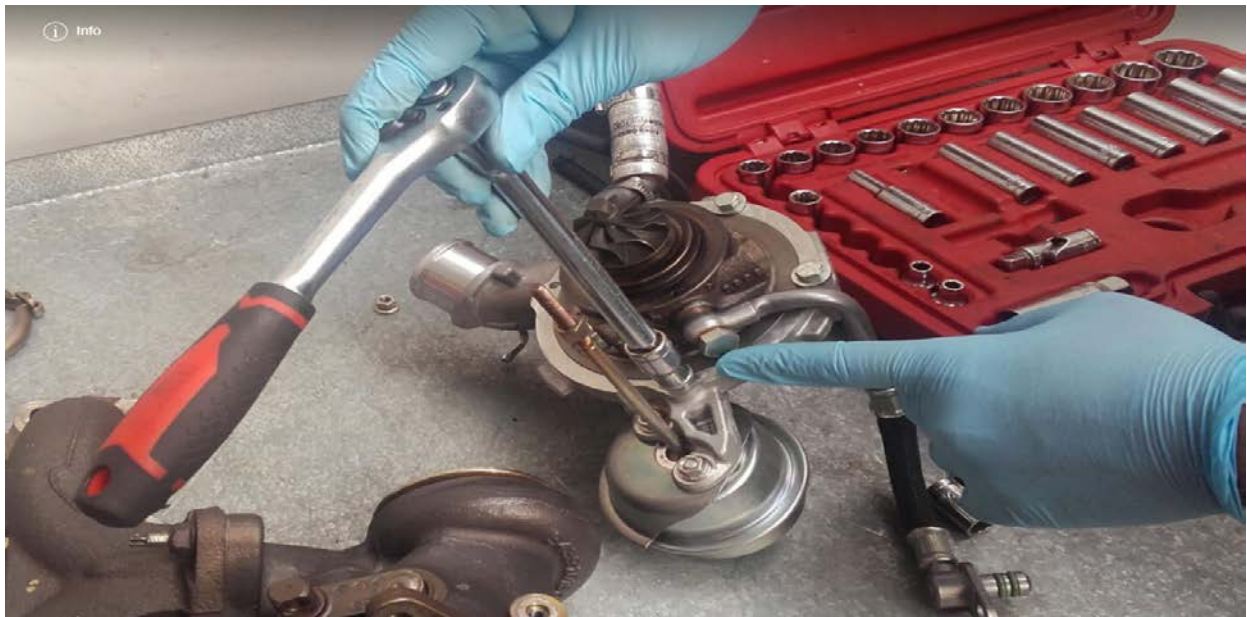


Figure (20) (Barsoum, 2018)
 start to refit all the turbocharger component again, look at the distance between the oil pipe and the bolt rotation area to avoid any sort of damage.



Figure (21) (Barsoum, 2018)
 tightly check all the bolt at the same torque to avoid any sort of air or exhaust gas leak while the turbocharger functioning.



Figure (22) (Barsoum, 2018)
always use the ratchet in the correct position which is 90 degrees for get good functioning.



Figure (23) (Barsoum, 2018)
check at the turbocharger case there no any sort of corrosion or rust and any cracks.



Figure (24) (Barsoum, 2018)
after you fit the waste gate case fit the clamp metal to connect the body of the turbocharger.



Figure (25) (Barsoum, 2018)
make sure all the procedures going correctly and all the bolts are tightly correct.



Figure (27) (Barsoum, 2018)
put all the sockets in the sockets set ,all the sockets in correct number place.



Figure (28) (Barsoum, 2018)
Finally and important procedure leaves your area is clean and tidy, to let the other colleague get the same chance to enjoy to strip the turbocharger.

Turbocharger Description

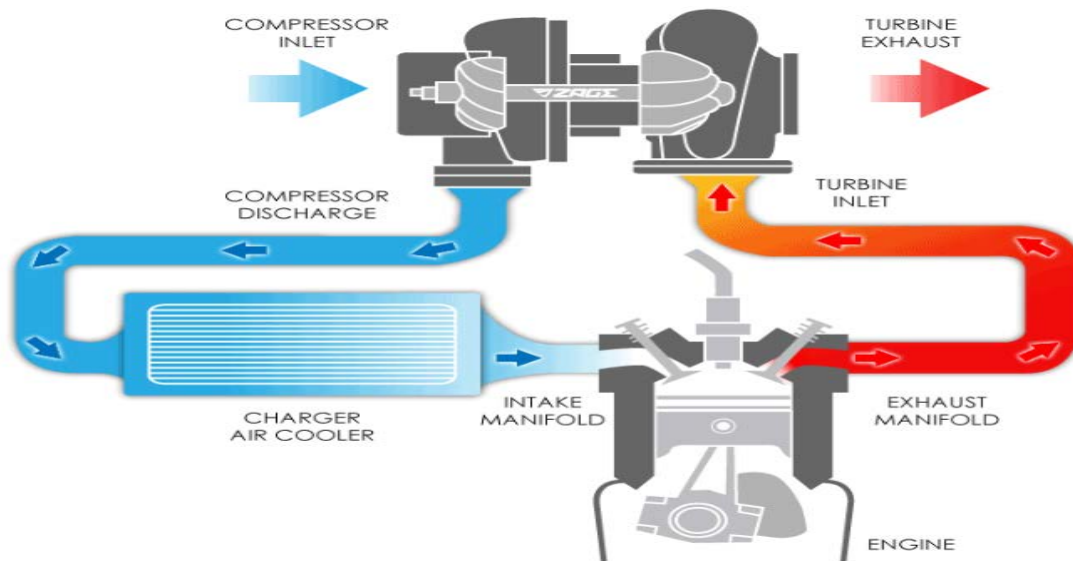


Figure (29)

(steamcommunity.com, 2018)

A turbocharger is consist of three main components, middle compressor wheel ,an interconnecting support spindle fixed on complete double plain floating bearings, housing, also the main component is an exhaust gas driven turbine.

(Heisler, 2001)

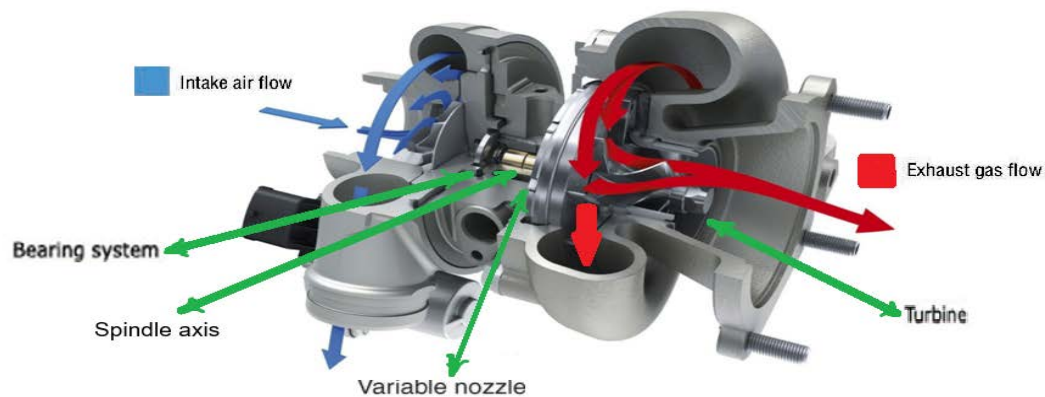


Figure (1)

(Barsoum, 2018)

The turbo anatomy show the air direction flow from intake air flow, the bearing system helps to increase the rotation movement which the torque to compress fresh air to the engine cylinder.

The air and Exhaust gases direction.

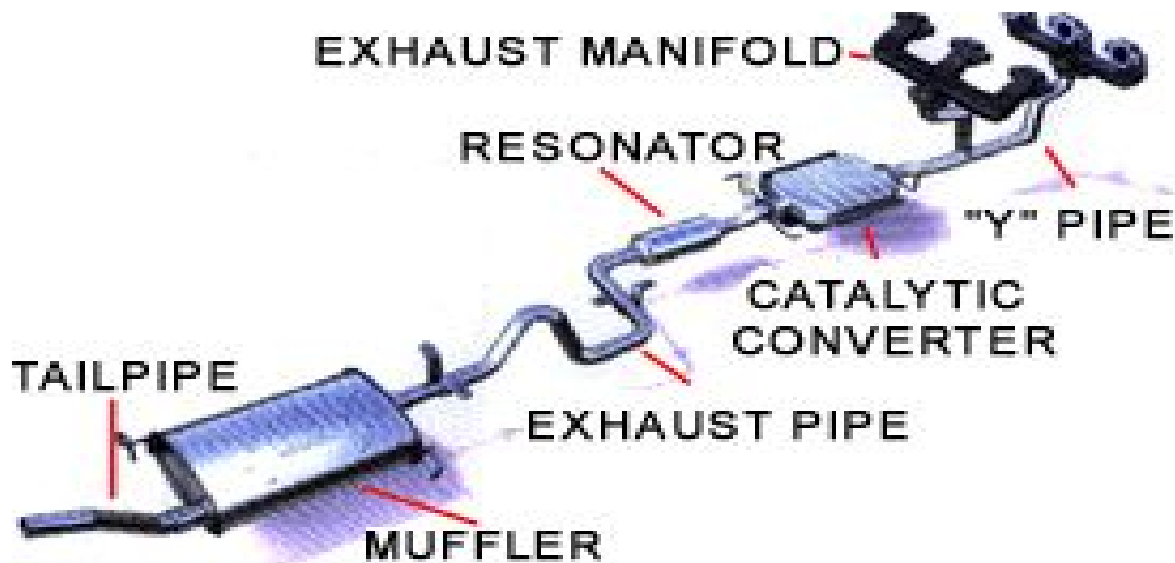


Figure (31)

(pinterest.co.uk, 2018)

As the figure shows, from the beginning air goes through intake air flow when the compressor wheel rotates by the turbine wheel it moves as well, which results in accelerating the engine revs, the turbocharger takes the benefits of the exhaust gases pressure to increase the engine power, the waste gases will go automatically to the Exhaust pipe and go to its way, the O₂ sensor will check the percentages of NO_x which the emission consists of, then will go to catalytic converter, which its job is to convert the exhaust gases to carbon dioxide and water, after that there is another lambda sensor to check the catalytic converter working properly, will go to resonator, which its purpose is to resonate and calm down and stop any loud sound coming from the muffler to silence it, and then the flow of emission goes to the muffler which is the last stage before the tailpipe and then will go to the ambient.

(Heisler, 2001)

Literature review

James D. Haladerman and Jim Linders in their book titled about Automotive fuel and emissions control systems, mention about the turbocharger which explain clearly. "the turbocharger is main advantage over mechanically driven supercharger is that turbocharger does not drain power from the engine, in naturally aspirated engine, about half of the heat energy contained in the fuel goes out the exhaust system."

(Linder, 2009)

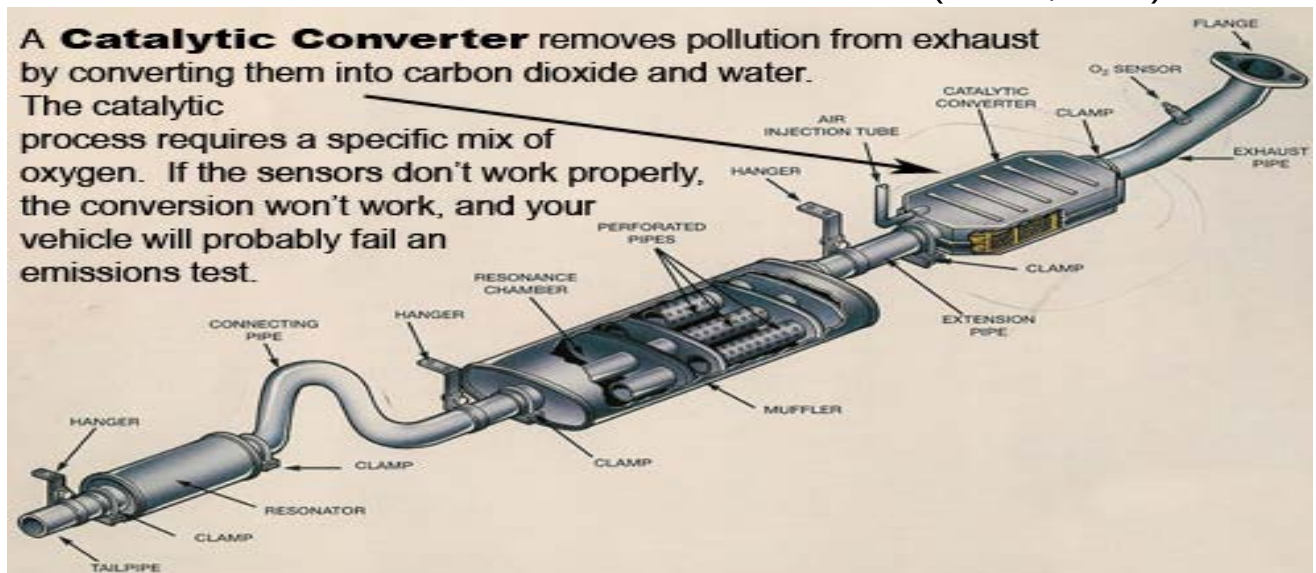


Figure (36)

(Integrity Auto Care, 2018)

The exhaust is an important part of the car which is all the manufacturers they improving and enhance it is performed every time

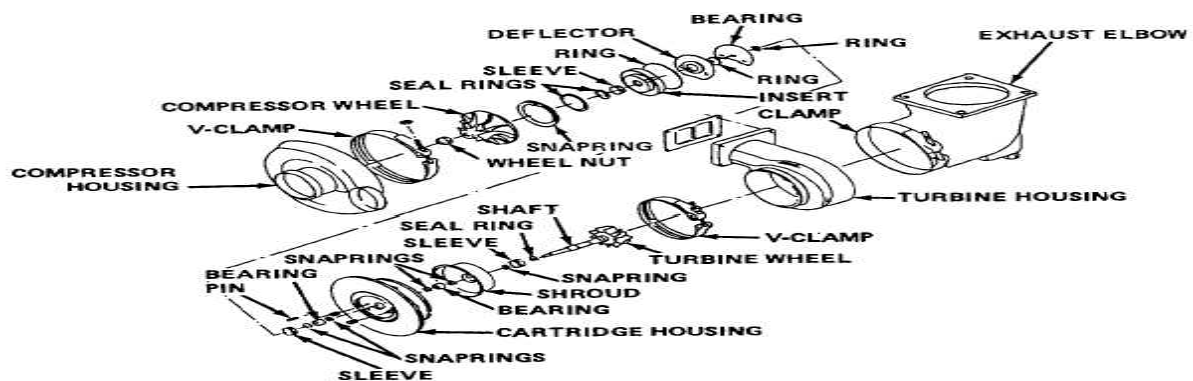


Figure (33)

(keywordlister.com, 2018)

the figure for disassembling turbocharger, very precis components, that must fitted tightly and proper.

Turbocharger

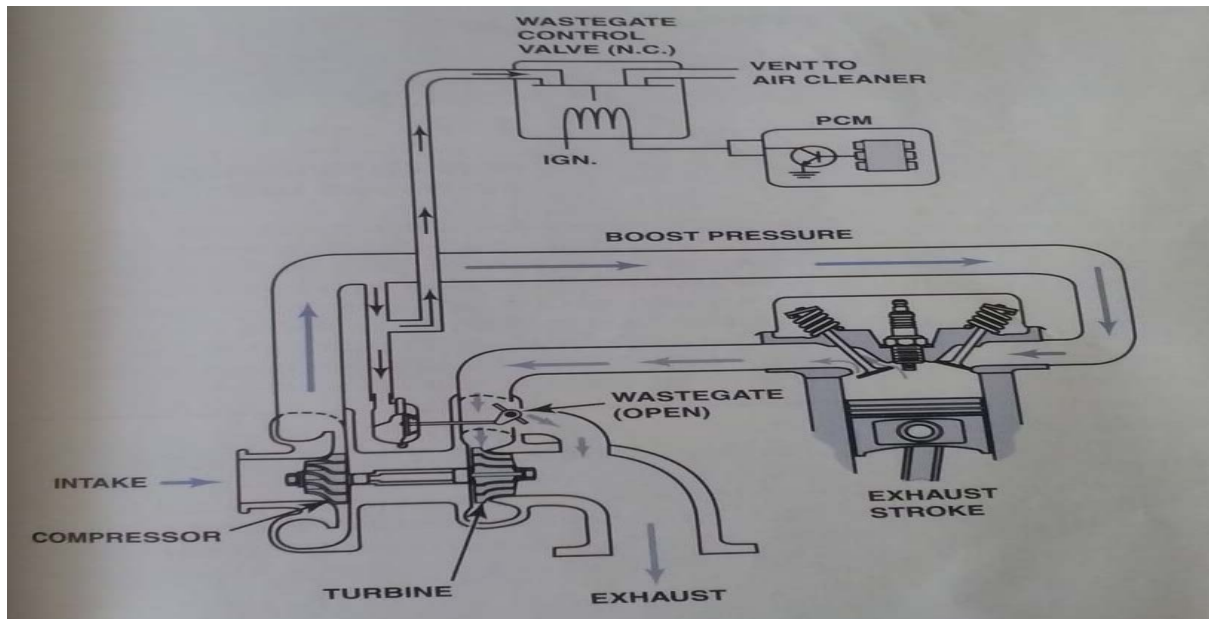


Figure (37)

(Heisler, 2001)

really it is very advanced to take the exhaust gases as waste power to generate new power to increase the amount of air fresh to combustion operation.

Turbocharger Anatomy

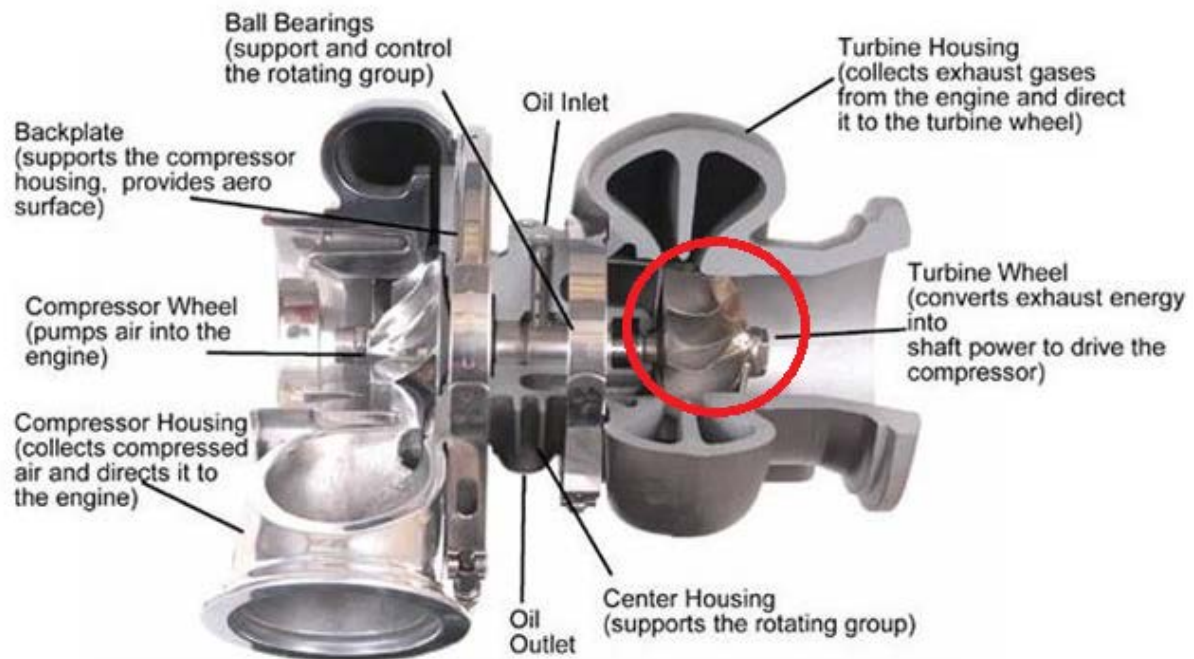


figure (33)

(Buy Auto Parts, 2018)

Turbocharger CAD

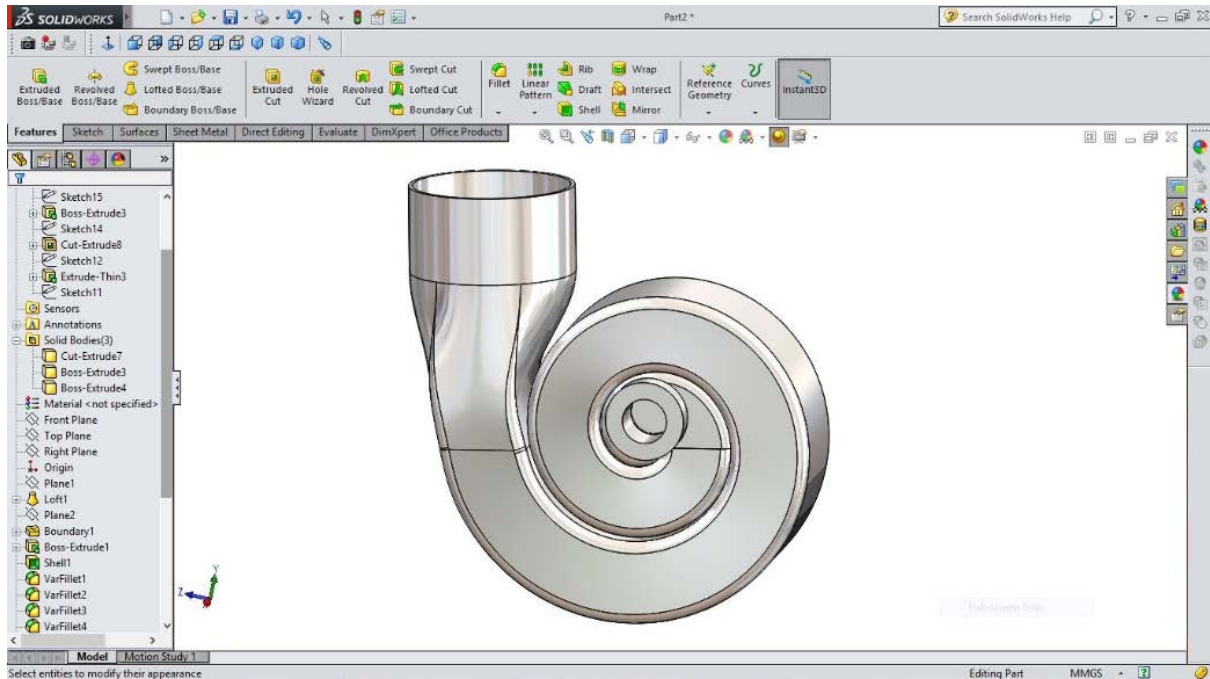


Figure (34)

(Youtube. CAD CAM TUTORIAL, 2018)

Turbocharger CAD

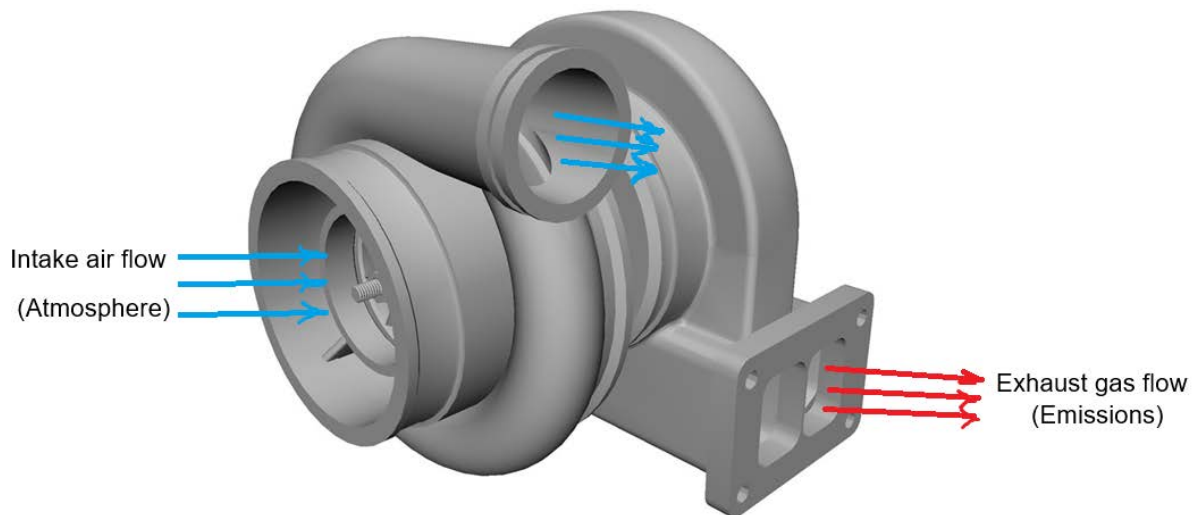


Figure (35)

(3dcadbrowser.com, 2018)

(Barsoum, 2018)

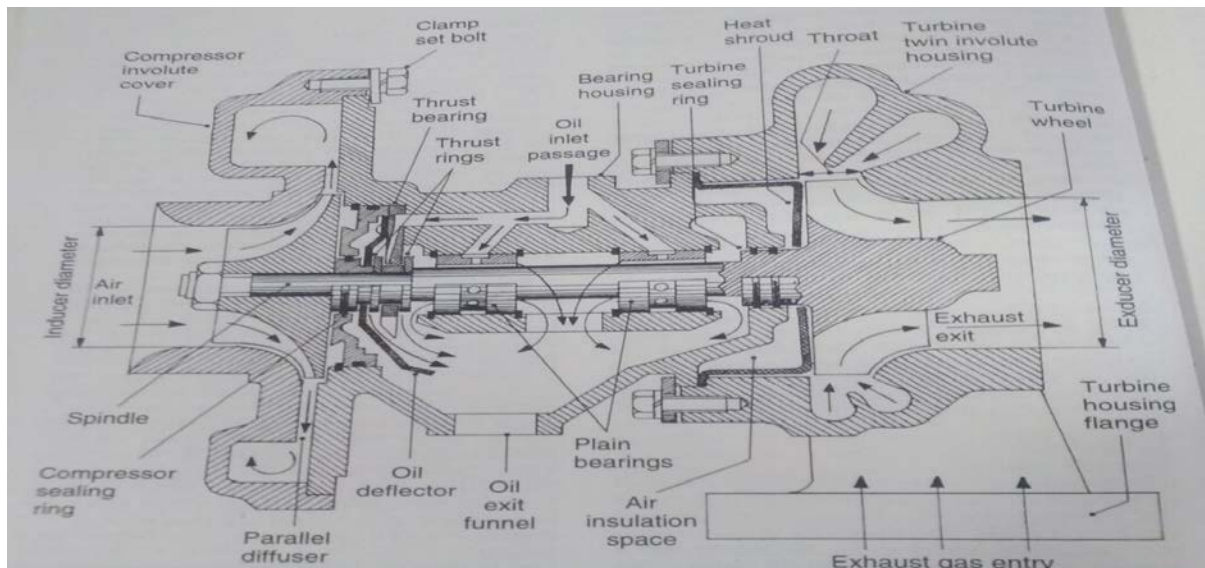


Figure (36)

(Heisler, 2001)

The turbocharger consist of very precise component, as the figure displaying air inlet, spindle which carried compressor wheel and turbine wheel, compressor sealing ring, oil deflector, oil exit funnel, plain bearings for more flexibility while the turbine wheel and compressor wheel turning quickly and smoothly, exhaust gas entry and exit throughout turbine wheel, the turbine is most beneficial component in the cars in this generation.

(Heisler, 2001)

Turbocharger flow

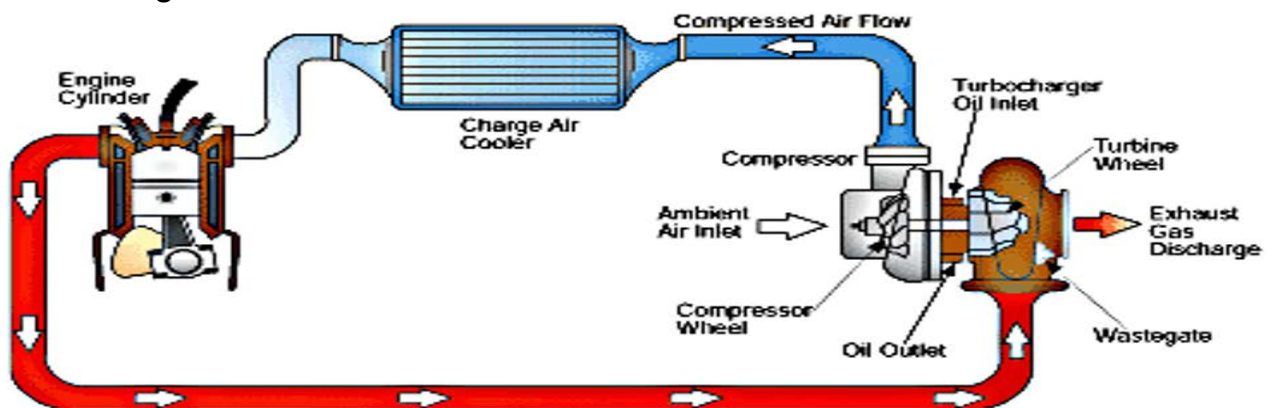


Figure (37)

as the figure shows the kick-off the exhaust gases from the engine cylinder going through the exhaust manifold and directed to waste gate to deal with turbine wheel which with its pressure will move the turbine wheel, when the turbine wheel respond to the exhaust pressure by rotation movement, the turbine wheel is in the spindle with compressor wheel which suck the air comes from the ambient air inlet, the benefit is using the exhaust gases pressure to generate extra power or torque which is rotation movement , and send fresh air to compressor air flow to the engine cylinder for new cycle of internal combustion engine.

(cherrypicker.tripod.com, 2018)

3/ Analysis &1 Calculations

Engine Type=V8

N cylinders = 8

Bore = 95 mm converted to Meter by divided by 1000 = 0,095 m

Stroke 80mm converted to Meter by divided by 1000 = 0,08 m

Rev Limit N = 9500 rpm

Volumetric efficiency = 85%

RUS =12 Psi

Ambient temperature = 27°C converting to Kelvin by +273.15

$$T_{in} = 27 + 273.15 = 300.15 \text{ Kelvin}$$

η_i = efficient Intercooler = 60%

How should the Intercooler be Large?

=Engine speed = 9500(rpm)

η_v =Volumetric Efficiency =85%

v = Total engine displacement (m^3)

V =Volumetric Flow rate (m^3/s)

$$V = \frac{v \times \eta_v \times N}{2 \times 60}$$

$$\text{Bore } r = \frac{d}{2} \quad r = \frac{0.095}{2} = 0.0475 \text{ m} \quad L = \text{Stroke Length} = 0.08 \text{ m}$$

v =Total engine displacement is equal = volume of each cylinder x the number of engine cylinders.

$$\text{Cylinder Volume} = \pi \times r^2 \times L = \pi \times (0.0475)^2 \times 0.08 = 0.000567 m^3$$

$$\text{Total Engine displacement } v = 0.000567 \times 8 = 0.0045 m^3$$

$$V = \frac{0.0045 \times 0.85 \times 9500}{2 \times 60} = 0.303 m^3/s$$

to convert from m^3/s to lb/Min you have to go through this steps

$$1 m^3/s = 2119 \text{ CFM and then use } 1 \text{ CFM} = 0.07 \text{ lb/min}$$

$$\text{So } V = 0.303 \times 2119 = 642.1 \text{ Cfm}$$

$$\text{convert Cfm to lb/min by multiply } 642.1 \times 0.07 = 44.95 \text{ lb/min SO } V = 45 \text{ lb/min}$$

Volumetric flow rate V =45 lb/min

so the volume is going to the turbo is greater.

The calculation of the PR

PR= Pressure Ratio

Atmospheric pressure =14. 7 Psi

$$PR = \frac{\text{Total absolute pressure} + \text{Atmospheric Pressure}}{\text{Atmospheric Pressure}}$$

$$PR = \frac{12 + 14,7}{14,7} = 1.82 \text{ Ratio}$$

$$V = 0,303 \text{ m}^3/\text{s} = 45 \text{ lb/min}$$

$$\text{in } m^3/s \quad V_t = \frac{PR \times v \times \eta_v \times N}{2 \times 60} = \frac{1,82 \times 0,0045 \times 0,85 \times 9500}{2 \times 60} = 0,55 \text{ m}^3/s$$

$$V_t = 0,55 \times 2119 \text{ cfm} = 1165.45 \text{ cfm}$$

$$V_t = 1165,45 \times 0.07 = 81.58 \text{ lb/min}$$

$$\text{Second way in } (m^3/s) \quad V_t = 1,82 \times 0,303 = 0.55 \text{ m}^3/s$$

V From m^3/s into lb/min

$$V = 45 \text{ lb/min}$$

$$V_t = PR \times V = 1.82 \times 45 = 81.9 \text{ lb/min}$$

to find the curve of which compressor is can be suitable you have to calculate the percentage of V_t

$$100\% \text{ of } V_t = 81,9 \text{ lb/min}$$

$$50\% \text{ of } V_t = 81.9 \div 100 \times 50 = 40.95 \text{ lb/min}$$

$$20\% \text{ of } V_t = 81.9 \div 100 \times 20 = 16.38 \text{ lb/min}$$

$$T_{out} = PR^{0,28} \times T_{in}$$

$$T_{out} = 1,82^{0,28} \times 300.15$$

$$T_{out} = 354.94 \text{ Kelvin} = 81.79 \text{ }^\circ\text{C}$$

$$\eta_i = \frac{T_{co} - T_{io}}{T_{co} - T_a}$$

T_{io} = Temperature out of intercooler or outlet temperature intercooler (k)

T_{co} = Temperature out of turbo compressor or original compressor outlet temp (k)

T_a = Ambient Inlet Temperature

η_i = efficient intercooler 60%

$T_{io} = ?$

$T_{co} = 354.94$ Kelvin

$T_a = 27^\circ\text{C}$ converting to Kelvin by adding +273.15 to 27°C

So $T_a = 27 + 273.15 = 300.15$ Kelvin

T_{co} and $T_{out} = 354.94$ Kelvin

$$\eta_i = \frac{T_{co} - T_{io}}{T_{co} - T_a}$$

T_{io} is the subject so we will rearrange the formula.

$$T_{co} - T_{io} = \eta_i (T_{co} - T_a)$$

$$T_{co} - T_{io} = 0.6 (354.94 - 300.15)$$

$$T_{co} - T_{io} = 32.87$$

$$354.94 - T_{io} = 32.87$$

$$T_{io} = 354.94 - 32.87 = 322.07 \text{ Kelvin} - 273.15 = \text{equal } 48.92^\circ\text{C}$$

So the Temperature out of intercooler is 48,92 °C

$$\eta_c = \frac{(PR^{0.28} \times T_{in}) - T_{in}}{\text{Actual Temp Rise}} \quad T_{in} = 300,15 \text{ Kelvin}$$

$$\eta_c = 60\%$$

PR= 1.82 ratio

$$\text{Actual Temp Rise} = \frac{(PR^{0.28} \times T_{in}) - T_{in}}{\eta_c}$$

$$\text{Actual temp rise} = \frac{(1.82^{0.28} \times 300,15) - 300,15}{0.6} = 91,32 \text{ kelvin}$$

$$\text{equal to} = 91.32 - 273.15 = -181.83 \text{ °C}$$

(B) Compressor

The third compressor is better selection drawing and is chosen as the suitable compressor.

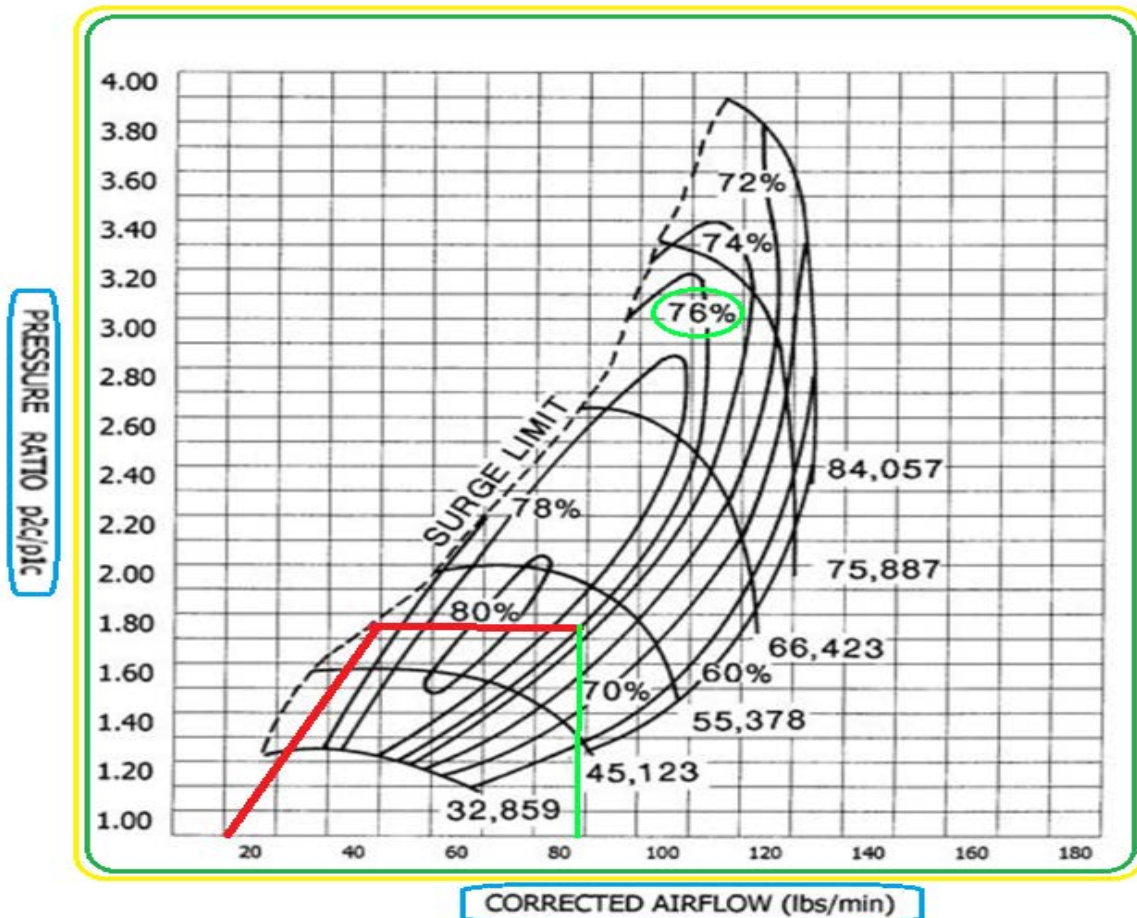


Figure (38)

(Barsoum, 2018)

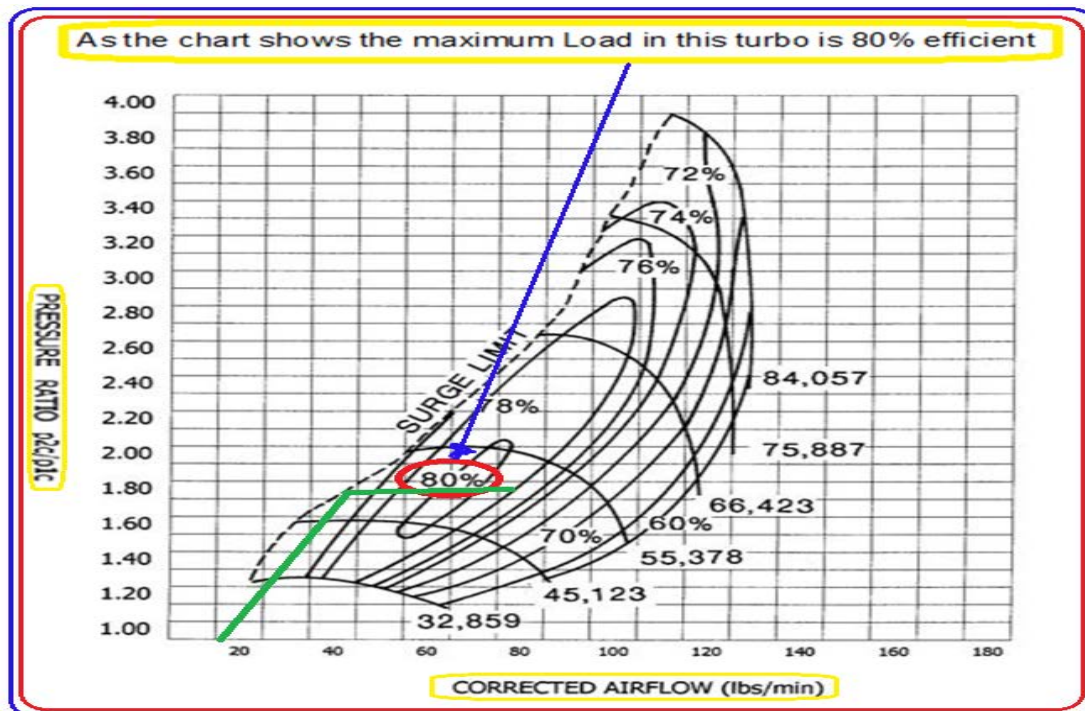


Figure (39)

(Barsoum, 2018)

(3.2) Sizing intercooler

there is a real relationship between the air flow rate and internal flow area requirements.

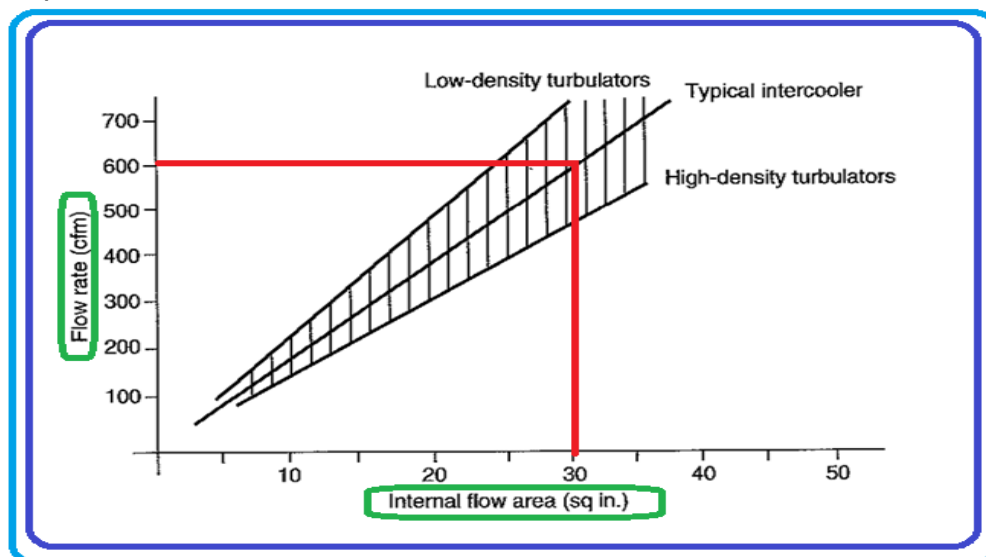


Figure (40)

(Barsoum, 2018)

Here the relationship between the flow rate& internal flow area match on typical intercooler line.

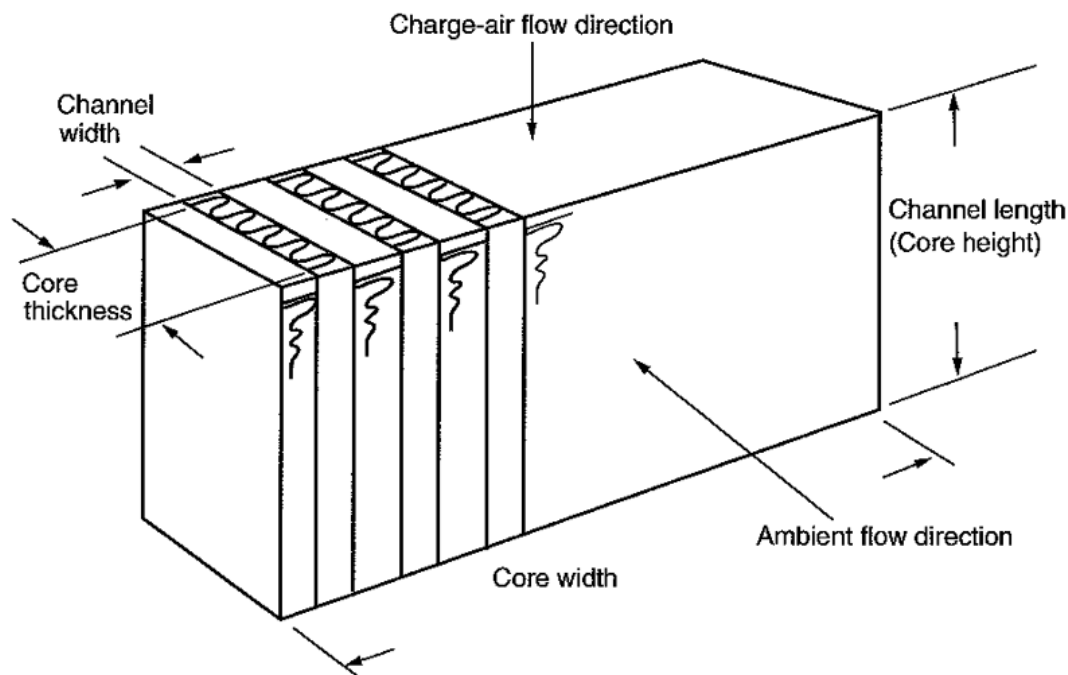
To calculate the typical intercooler roughly must be up 45% easy to go to tubes, the required area it should be up 45% factor.

so the internal area is 30 sq/inch is required.

The cross section area of charge air face = $\frac{1}{0.45} \times 30 = 66.6 \text{ sq/inch}$

Examples of the cross section area of charge air face

Internal flow area is the channel length x channel width x number of channels



GrimmSpeed Subaru TMIC Specifications			
Core Dimensions	19inx7inx3.75in	Measured Pressure Drop	.16psi @ 19psi
Core Flow Area	29.76in ² (120% increase)	Thermal Mass	19lbs
Internal Core Volume	208.32in ³ (140% increase)	Supported HP	550whp
Total Heat Transfer Area	17,827in ²	Inlet	M8x1.25 stainless inserts
Core Flow Rate	1580 CFM	Outlet	2.75" machined lip

Stock Dimensions	
Core Size (in mm)	710 x 64 x 11
Inlet ID	42mm
Rows	7
Core Volume	315in ³
Tube Height	8mm
Fin Height	7mm

Figure (36)

(mishimoto.com, 2018)

Basic principles of turbocharging.

the turbocharger is the very suitable technique for internal combustion engine instructions of operation, this generation of manufacturers preferring using turbocharging on commercial diesel engines which is work with four-stroke cycle pistons engines which is managed by intake and exhaust valves, as known contains four strokes while two complete rotation movement of a crankshaft.

The basic principles produce different possibilities of how to increase the power of the engine outlet.

Maximise swept volume

when the swept volume is enlargement that increasing the engine outlet power, so extra air is available in big area of combustion chamber that burns a lot of fuel, so you can approach this enlargement by increasing the volume of each single cylinder or increase the number of cylinders, actually, this appears in heavy and large engines capacity, intent as far as emissions and fuel consumption are considered, you can't predict a lot of advantages.

RPM increased

this another chance to increase the outlet power of the engine by acceleration or it is speed, that will be happened by increasing the timing of the firing of the strokes at each time of unit, the reason is the limit of mechanical stability,

Moreover when the speed it is increased makes pumping losses exponentially, frictional and the efficiency of the engine will be at the lowest level.

(turbos.bwauto.com/, 2018)

Discussion

In vehicles, aircraft, and motorcycles, the turbocharger will increase the power in the engine performance, this results of increasing the air pressure coming into the engine, the design and work principles will play the good role to increase the accomplishment of power.

As technology is developing everything nowadays, the turbocharger is an air pump to increase the burning fuel performance, increasing the outlet of engine power, the supercharger is connected with the crankshaft pulley, is something from nothing to increase the engine power outlet, day by day will see various technique to do so.

(www.brighthubengineering.com, 2018)

Conclusion

the great results after all this analysis you will gain a lot of acknowledgment around turbocharger and supercharger, which they are close to each other for some point, for example, supercharger is basically engine driven air pump which it is job to feed more than normal of air amount into the intake airport manifold and increase and boost power and engine torque.

the same turbocharger by the exhaust gases pressure guide the intake air manifold to boost the torque and power of the engine, but sometimes there is sort of delay or lag will happen is dependent on the engine is accelerating or decelerating.

supercharging is gives an instantaneous boost of an engine is powerful and torque without any sort of lag or delay, most of the time is connected with turbochargers, anyway, the supercharger is not efficient like turbocharger because it is driven by the engine crankshaft not needs the same horsepower to functioning like the turbocharger.

the essential concept here the supercharger is just air pump driven by the engine by itself, means using specific facility to transmit the rotation power from the engine to supercharger chain, or belt, gears, shafts from the crankshaft to turn the supercharger pump, that mean the turbocharger or super turbocharger they are in relationship to the engine during speed up the revs and fast.

(Heisler, 2001)

Bibliography

- Buy Auto Parts, 2018. *The Ultimate Turbocharger Diagram*, UK: .buyautoparts.com.
- 3dcadbrowser.com, 2018. *Turbocharger cad*, UK: 3dcadbrowser.com.
- Barsoum, E., 2018. *Turbocharger*, Swansea: E/ Barsoum.
- cherrypicker.tripod.com, 2018. <http://cherrypicker.tripod.com>, UK: cherrypicker.tripod.com.
- Digital, P. b. J., 2018. *Variable geometry turbo*, UK: Kelley Blue Book Co.
- Heisler, H., 2001. *Advanced Engine Technology*. UK: Butterworth-Heinemann.
- Integrity Auto Care, 2018. *Air and Exhaust gases*, USA: Integrity Auto Care.
- keywordlister.com, 2018. *Disassembling A Turbo*, uk: keywordlister.com.
- Linder, J. D. /., 2009. *Automotive fuel and Emissions Control Systems*. Second Edition ed. USA: PEARSON Education.
- mishimoto.com, 2018. *intercooler design* , UK: mishimoto.com.
- pinterest.co.uk, 2018. *Air & exhaust gases flow*, UK: pinterest.co.uk.
- steamcommunity.com, 2018. *Turbocharger work*, USA: Valve Corporation.
- turbos.bwauto.com/, 2018. *TURBOS*, UK: turbos.bwauto.com/.
- www.brighthubengineering.com, 2018. *Turbocharger principles*, UK: www.brighthubengineering.com.
- Youtube. CAD CAM TUTORIAL, 2018. *SolidWorks Tutorial Engine Air Turbo Housing. CAD CAM TUTORIAL*, UK: CAD CAM TUTORIAL.