To investigate the performance enhancement of engine by changing the Turbo Design Characteristic

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Abstract- The main objective of current work is to investigate the performance enhancement in EMD 710G3B engine by changing the design characteristics of turbo inlet screen and to further study its impact on failures of turbo superchargers due to debris ingression into the turbine inlet of turbo super charger. The changes in the performance of engine are reflected in the load test performance of the engine..

Index Terms- Turbo Super charger, EMD, Design

I. Introduction

Turbo Superchargers are centrifugal compressors driven by an exhaust gas turbine and employed in engines to boost engine horsepower and provide better fuel economy through the utilization of exhaust gases. It takes power from exhaust gases coming from an engine and use that power to suck fresh air from the atmosphere and supply it to the engine for combustion. Turbo Supercharger was invented by Swiss Engineer Alfred Buechi in 1905. It was not described as Turbo supercharger as it is known today but rather an axial flow turbine and compressor that shared a common shaft with the engine they were applied to. Turbo Supercharger is used in petrol powered cars, diesel powered cars, motorcycled, trucks, aircrafts, marine engines, locomotives etc.The basic idea is that the exhaust drives the turbine, which is directly connected to the compressor, which rams air into the engine. Here then, in summary, is how the whole thing works:Waste gas from the cylinder exits through the exhaust outlet.The hot exhaust gases blowing past the turbine fan make it rotate at high speed.The spinning turbine is mounted on the same shaft as the compressor (shown here as a pale orange line). So, as the turbine spins, the compressor spins too.The exhaust gas leaves the car, wasting less energy than it would otherwise.Cool air enters the engine's air intake and heads toward the compressor.The compressor fan helps to suck air in.The compressor squeezes and heats up the incoming air and blows it out again.Hot, compressed air from the compressor passes through the heat exchanger, which cools it down.Cooled, compressed air enters the cylinder's air intake. The extra oxygen helps to burn fuel in the cylinder at a faster rate.Since the cylinder burns more fuel, it produces energy more quickly and can send more power to the wheels via the piston, shafts, and gears.

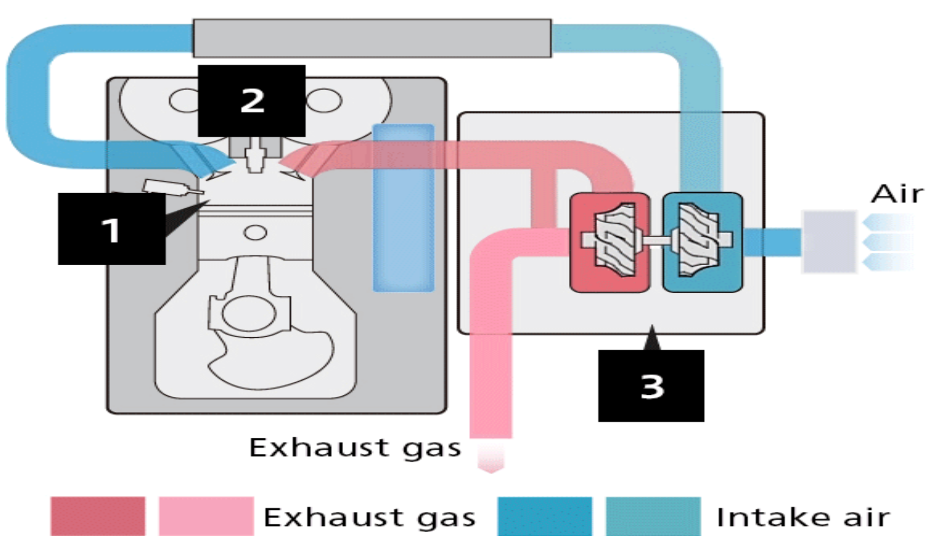

Figure.1 Simplified diagram of Turbo Supercharger

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A turbo compressor is an air compressor driven by exhaust fumes. Exhaust gases, going out from an engine through an exhaust manifold, are directed to a turbine chamber where a rotor is situated. By means of a shared shaft, it drives compressor`s rotor located on the other side of the device, which compresses the air supplying the engine. Since compressed air includes more oxygen in one volume unit, it is possible to create better conditions for the combustion process.
Increased oxygen amount with additional amount of fuel can be used to increase engine power, or as with diesel engines, it facilitates more complete combustion, reducing the amount of emitted contamination and boosting its efficiency.
Increasing air compression, that is the amount of gas included in the same volume, at the same time, its temperature is increased. Higher temperature relates to lower density, which means that cylinders receive the amount of oxygen smaller than if the air temperature were lower. Therefore, a charging air radiator (intercooler) is used.The turbocharger assembly is primarily used to increase engine horsepower and provide better fuel economy through the utilization of exhaust gases. As shown in cross-section, Figure 5., on slide 8 the turbocharger has a single stage turbine with a connecting gear train.
The connecting gear train is necessary for engine starting, light load operation, and rapid acceleration. Under these conditions there is insufficient exhaust heat energy to drive the turbine fast enough to supply the necessary air for combustion, and the engine is driving the turbocharger through the gear train assisted by exhaust gas energy.
When the engine approaches full load, the heat energy in the exhaust, which reaches temperatures approaching 538°C (1000°F) is sufficient to drive the turbocharger without any help from the engine. At this point, an overrunning clutch in the drive train disengages and the turbocharger drive is mechanically disconnected from the engine gear train.
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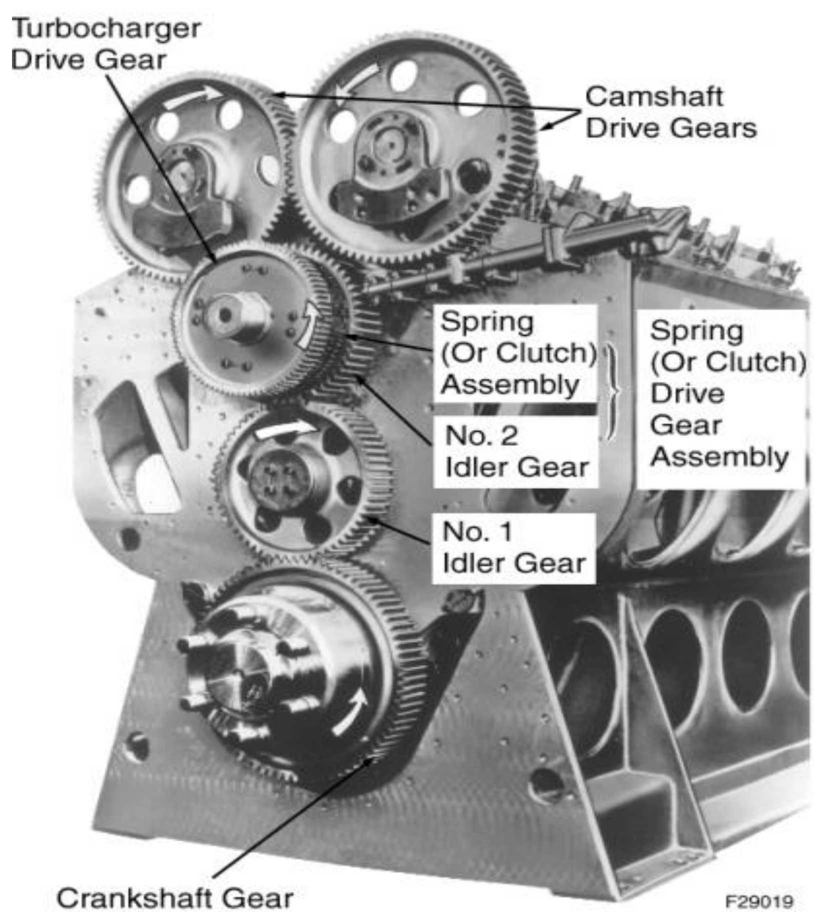

Figure.2 Turbo clutch drive gear arrangement

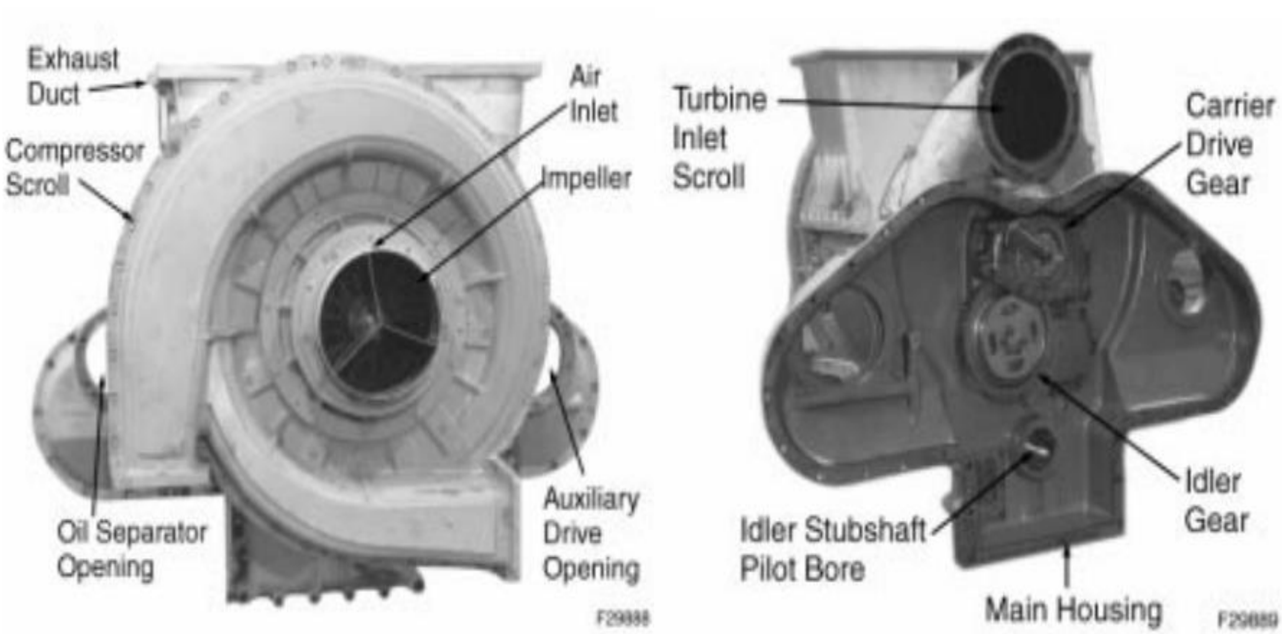

Figure.3 Turbo of EMD 710G3B Engine (Front and rear view)

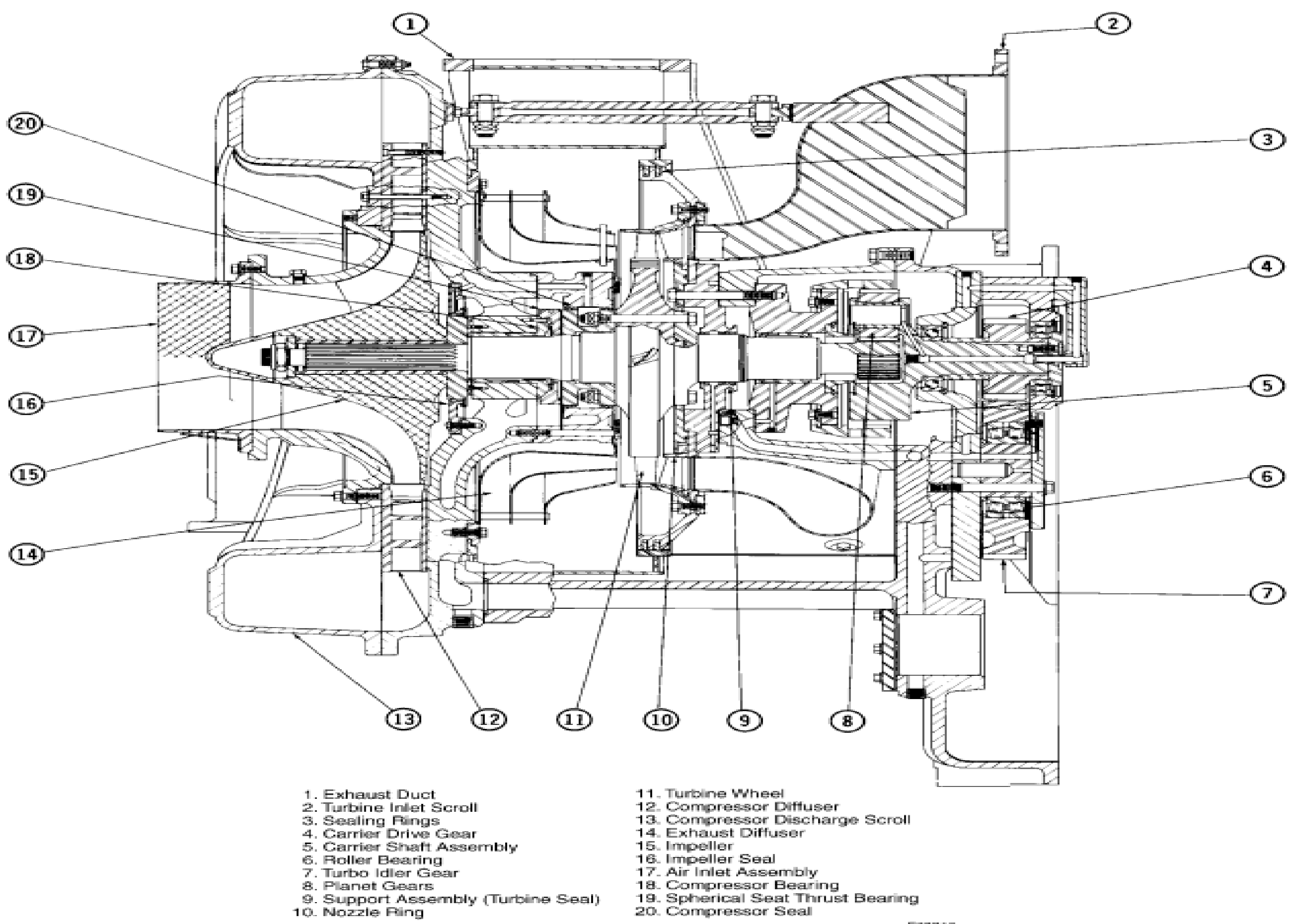

Figure.4 Turbo supercharger cross-sectional view

II. LITERATURE SURVEY

The world's first functional supercharged engine was made my Dugald Clerk, which was used in two-stroke engine in 1878. Diamler received a German patent for supercharging an IC engine in 1885. In a supercharger the loss can be up to 15% of engine output. To reduce the loss of power, later on the compressor was driven by a turbine using the exhaust gas energy. Then this technology became popular by the name as Turbocharging during early 1980's.

Vidit Saxena et al [1] : There are many inventions aimed at increasing the performance of an Internal Combustion engines. When power increases, efficiency decreases. Presently, ethanol is prospective material for using in automobiles as an alternate fuels. The main reason for using ethanol is that it can be produced from natural products and waste materials, compared with gasoline, which is engendered from nonrenewable resources. Some methods and components are utilizable for incrementing performance of an IC engine. One such method is supercharging or turbo charging an IC engine. Anirudh H et al [2] : Over the years, raising man kind's standard of life has incremented the concentration of co2, one of the major contributors of green house effect, by 36% globally since the industrial revolution, which has emerged with wide usage of fossil fuel. The major contributors are automobiles. In this paper we will concentrate on reducing the number of cylinder and displacement what an engine uses, so as to lower the emission of co2. All these can be done by pressure boosting using a turbocharger or twin turbocharger. Jose Manuel Lujan et al [3] : In this paper the aim of improving the performance of IC engines working at low ambient temperatures. Pollution and fuel consumption are one of the important topic. In this, we use exhaust heat recovery system for a diesel engine during cold operation. We use the energy obtained from the exhaust to heat the intake air temperature. In this project the ordinary intercooler is replaced water/ air heat exchanger known as Water charge air cooler. During cold condition the Water charge air cooler comes into play, which uses the exhaust gas from engine. The exhaust gas enters the charger and heat exchange takes place with the ambient air so as to heat the cold ambient air and is fed into the engine.Jianqin Fu et al [4] : Now we are going to see various types of turbo charging , their principle, working and advantages. Due to the increasingly sever problems of energy and environment, especially the petrol shortage and air pollution ,more attention has to be paid on energy saving and environmental protection. Under this circumstances higher energy utilization efficiency and lower emission are the major development for an IC engine. There are several kind of approaches to improve the IC engine energy utilization they are turbo charging and super charging.Jenelle Pope [5] : The purpose of this is to analyze turbocharged diesel engine. In this project Chevrolet suburban was used, it comes with a stock turbo charger. In order to extract more power from the engine, a new larger turbo was used. The new turbo is coupled with air water inter cooling system to decrease the inlet air temperature. Thus the upgradation of turbo along with the intercooler produces better results than the stock turbo. Qijun Tang et al [6] : In this paper, various kinds of improved modes of exhaust gas turbocharging has been investigated on the performance, including steam assisted turbocharging, electronically controlled turbocharging. Steam assisted turbocharging A steam generating plant is coupled to the exhaust pipe so as to utilize the engine exhaust gas energy to generate high-temperature steam. The high temperature steam which has been produced is injected into the turbine. Thus it can be used as the working medium for turbine. By this means the turbocharger working performance can be improved under low-speed and low-load engine operating conditionP.Spring et al [7] : In this paper we are going to discuss about the exhaust gas recovery using pressure-wave supercharger. In pressure-wave supercharger energy is transferred between two gaseous fluid streams by bringing them together for a short time in a narrow channel. Pressure-wave mechanism uses the physical that if two fluids of different pressures are brought into contact, pressure equalization is faster than mixing. This device uses unsteady waves to produce a steady flow of gas to the engine.Wladyslaw et al [8] : In this paper we are going to discuss the main problem in the charged spark ignition engine was to control the air-fuel ratio near stoichiometric values at various boost pressure in order to extract more torque at the same level of specific fuel consumption and engine exhaust gas emission. Charging such engine was related with the problem of knock in the medium and high values of load at lower speeds. Higher boost pressure will lead to abnormal combustion and knocking. So we give a boost pressure control algorithm which prevents the knock, so the engine can work near the knock boundary. Toyota Yaris 1300cc SI engine was used for this experiment was equipped with variable turbine geometry turbocharger with the possibility to control mass flow rate in the turbine by using an additional waste gas system. Computer control programs in lab view environment was given in order to analyze knock signals produced and to regulate the opening signal was fed to the engine control unit, where it was transformed by fourier transforms. This gave a distribution of knock signals in the range of 2000- 8000 hertz. Control signal for the knock was obtained in the range of 0-0.1 Volts and was transferred to the engine control unit for regulating the mass flow rate of exhaust gases through the variable geometry turbine. When the value is greater than 0.01 Volts then the valve in waste gas was opened much more to reduce mass flow rate of the engine exhaust gas through the turbine which in turn decreases the rotational speed of the turbocharger and thus compressor pressure ratio falls.Muqeem [9] : The main objective of a turbocharger is to improve the efficiency of an engine by increasing the density of intake air. When the pressure of the intake air is increased, the temperature will also increase. The turbocharger unit makes use of intercooler to cool down the inlet air temperature near to the ambient temperature. The inter cooling of intake air was increased by installing a specially designed inter cooler in which the inlet air runs as a hot fluid and the refrigerant of the air conditioning system from cooling coil fitted in the dash board runs as a cold fluid. The intake air is cooled by the intake air flowing through the fins of the intercooler and the refrigerant coming from the

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evaporator. When an normal air is cooled by an intercooler the mass of the oxygen becomes 1.43 times but when refrigerated the mass of oxygen becomes 2.618 times. Increase in the oxygen leads to faster burning rates and can control the exhaust emission.

II.PRESENT PROBLEM WITH THE TURBO SCREEN

There has been a considerable increase of failures of Turbo superchargers due to debris ingress and also the booster air pressure to the Engine is affected because of the screen design. The main objective of current work are as follows:To investigate the failures of Turbo super charger due to design flaw in TSC screen.Provide a modified design of TSC screen and implement it in the EMD turbo as a simulation. Study the changes in engine performance changes due to changes in the TSC screen design.

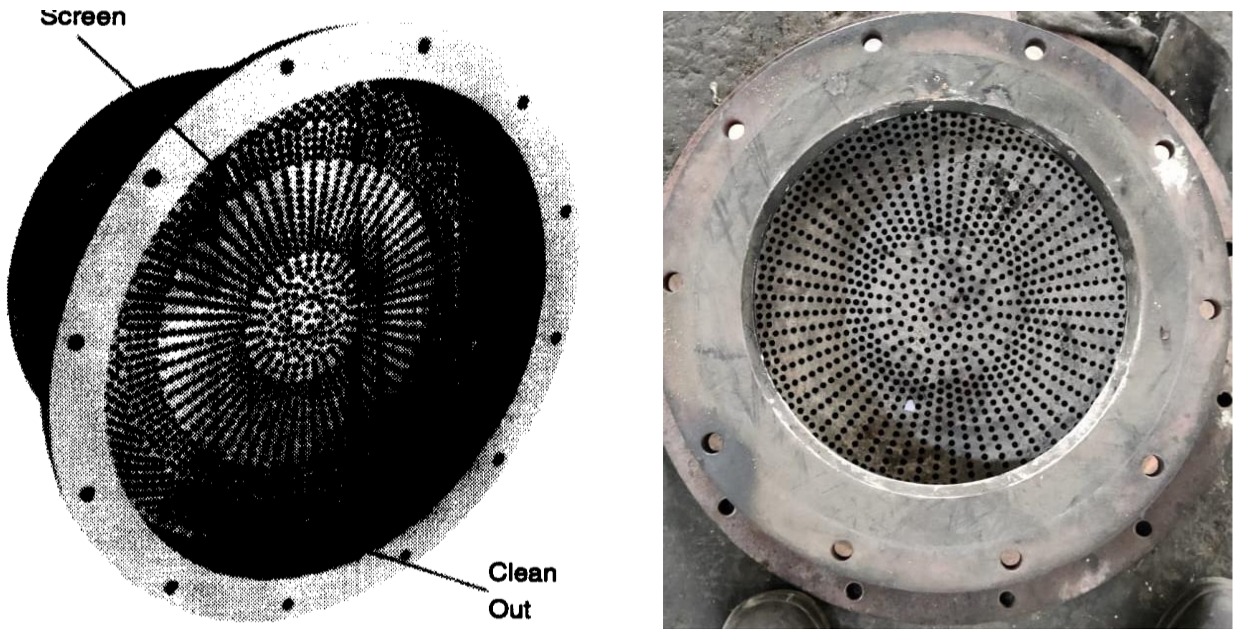

Figure.5 Turbo supercharger Screen existing design

In Present design of the Turbo super charger screen Assembly is located between turbocharger and rear manifold and is manufactured with numerous small diameter openings designed to prevent passage of foreign material. This protects the turbocharger from broken power assembly components such as ring or valve fragments. Such material can destroy the turbocharger if it strikes the blades of critically balanced turbine wheel. The Screen is susceptible to plugging from carbon (souping), water treatment residue(cracked head or liner), etc. Plugged screen lowers the turbo efficiency and ultimately causes “burping” due to gas flow restriction. The screen plate attached to metal support strips within housing to allow thermal expansion without tendency to fracture. The size of the holes in the TSC screen is still susceptible to allow metal debris to pass through the screen and damage the turbo.

The air passage area of holes in the screen is 32.2% of the total area which creates greater restriction of air flow in the turbine and thus leads to problems like unregulated load and surging in the turbo super charger.

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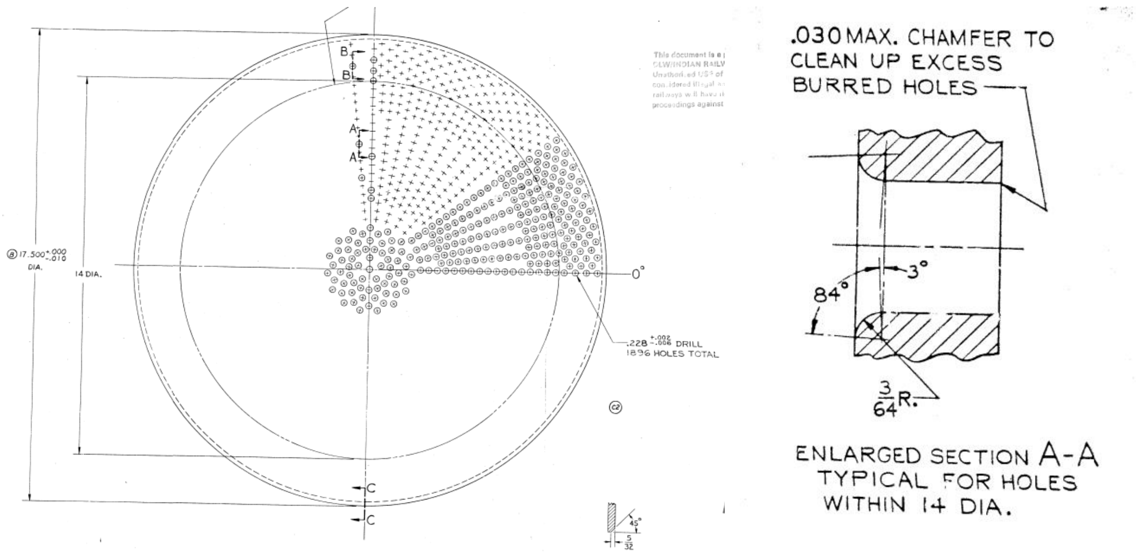

Figure.6 Turbo supercharger Screen existing design

Features of existing design: There are 1896 Number of holes of .228” diameter in present design and are arranged throughout the screen as shown in the previous slide. The covered area of these holes is about 32.2% of the circular area of the screen. The diameter of the screen is 17.5” and the thickness of the screen is about .31”. The existing design contains the holes in which only the inlet of the hole rounded as shown in the previous figure.

III.PROPOSED DESIGN CHANGES TO THE TSC SCREEN

In order to improve the engine performance and to avoid the failures related to debie ingress into the Turbo following changes have been implemented. The No. of holes are increased from 1896 to 3367 and diameter hole is decreased from 0.228” to .1875”.The covered area of these holes is increased from 32.2% to 36.6% of the circular area of the screen.The holes are arranged in more symmetric manner throughout the screen as shown in the slide below.The diameter of the screen is kept same as 17.5” and the thickness of the screen is increased to.375”.The existing design contains two types of holes, the proposed design contains single type of hole which have both sides of the holes rounded with 3/8” radius.

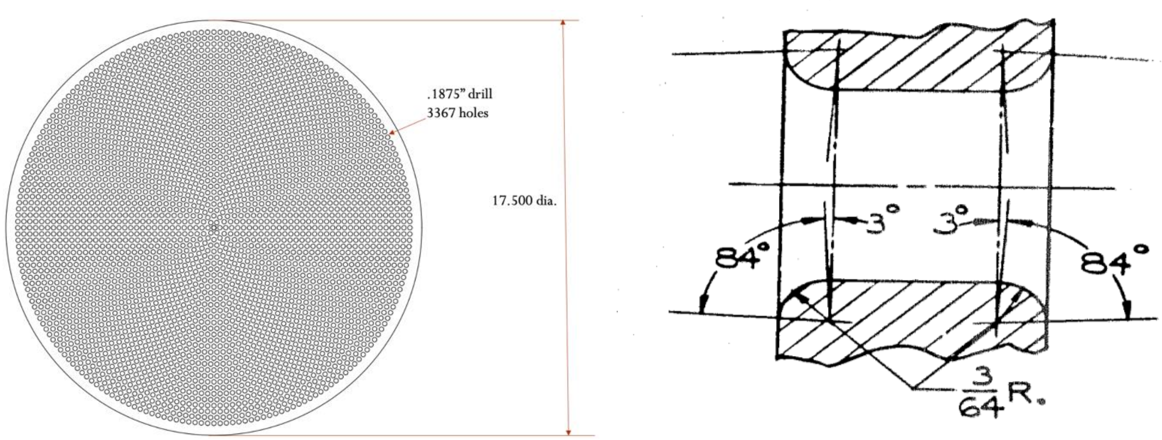

Figure.7 Turbo supercharger Screen Modifieddesign

A(Basic Dia.)	B(Basic Angle)	C(No. Of holes)	A(Basic Dia.)	B(Basic Angle)	C(No. Of holes)
0	0	1	8.5	0	102
0.5	0	6	9	0	108
1	0	12	9.5	0	114
1.5	0	18	10	0	120
2	0	24	10.5	0	126
2.5	0	30	11	0	132
3	0	36	11.5	0	138
3.5	0	42	12	0	144
4	0	48	12.5	0	150
4.5	0	54	13	0	156
5	0	60	13.5	0	162
5.5	0	66	14	0	168
6	0	72	14.5	0	174
6.5	0	78	15	0	180
7	0	84	15.5	0	186
7.5	0	90	16	0	192
8	0	96	16.5	0	198

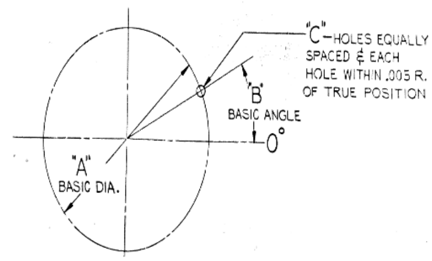

Table. 1 Turbo supercharger new hole configuration

The changes made to the Existing design are based on the failure analysis of the past which indicated that even with 0.228” hole foreign debris were finding ways to enter the turbine wheel inlet and damage the turbo.The decrease in the size of the hole is compensated by increasing the No. of holes in the screen from 1896 to 3367 which resulted in open area in the screen from 32.2% to 36.6%.The size of the holes is decreased but the inlet area for exhaust air has increased which will result in higher amount of air into the turbine with less restrictions.The thickness of the exhaust screen is increased to 0.375” to compensate for the decrease in strength due to increase in No. of holes and increase in open area of screen.

The inlet and outlet of all the holes have been rounded for smooth inlet and outlet transition of air.

IV.EXPERIMENTAL RESULTS OF MODIFIED INLET SCREEN

The experimental analysis for the current design have been carried out to find out the performance enhancement which can be achieved with the modified design. The load test have been carried out on 710G3B engines to find out their performance comparison for alternate screen design. For the test set up same engine is tested at different notches for both modified and unmodified turbo screen. The performance enhancement in the engine is achieved with the present test setup. Parameters that are being measured are as follows: Engine RPM, Engine Horse Power, LR%, Engine HP, TPU RPM, Engine Temp., Rack position, Lube oil pressure, Air Box pressure, Exhaust temperature and Crank case vacuum. These tests are conducted in the static conditions of the locomotive. The effect of dynamics of movement and Motor load is not considered in these results.

Table. 2 Engine performance with original design of Turbo Screen

S.No	Performance parameters	Idle	1^{st} Notch	2^{nd} Notch	3^{rd} Notch	4^{th} Notch	5^{th} Notch	6^{Th} Notch	7^{th} Notch	8^{th} Notch
1	Engine RPM	263	270	358	480	568	674	759	852	945
2	LR%	100	100	100	100	100	100	95	95	97
3	Engine HP	15	267	614	1048	1447	1898	2499	3231	4368
4	TPU RPM	4.3	4.5	5.9	8.0	9.5	11.2	14	17	19.4
5	Engine Temp. (C	51	55	60	63	67	69	75	77	79
6	Lube oil pressure (Kg/cm2)	1.4	1.4	1.8	2.4	3.1	3.6	4	5.2	5.7
7	Air box pressure (Kg/cm2)	0.1	0.2	0.3	0.5	0.7	0.9	1.2	1.4	1.7
8	Crank case vacuum(cm)	1	1	2	3	4	7	11	14	18
9	Exhaust Temperature	170	190	225	257	270	305	337	371	405

Table. 3Engine performance with Modified design of Turbo Screen

S.No	Performance parameters	Idle	1^{st} Notch	2^{nd} Notch	3^{rd} Notch	4^{th} Notch	5^{th} Notch	6^{Th} Notch	7^{th} Notch	8^{th} Notch
1	Engine RPM	265	271	356	475	572	683	761	853	949
2	LR%	100	100	100	100	100	100	100	100	100
3	Engine HP	13	268	603	1054	1503	1953	2560	3400	4489
4	TPU RPM	4.4	4.5	5.9	7.9	9.5	11.4	15.0	18.0	20.2
5	Engine Temp. (C	53	54	63	68	71	73	76	79	81
6	Lube oil pressure (Kg/cm2)	1.3	1.4	1.7	2.3	3.3	3.5	3.9	5.1	5.6
7	Air box pressure (Kg/cm2)	0.1	0.2	0.3	0.5	0.7	1.1	1.4	1.7	1.9
8	Crank case vacuum(cm)	1	1	2	3	4	7	11	14	18
9	Exhaust Temperature	180	192	236	264	279	318	359	389	426

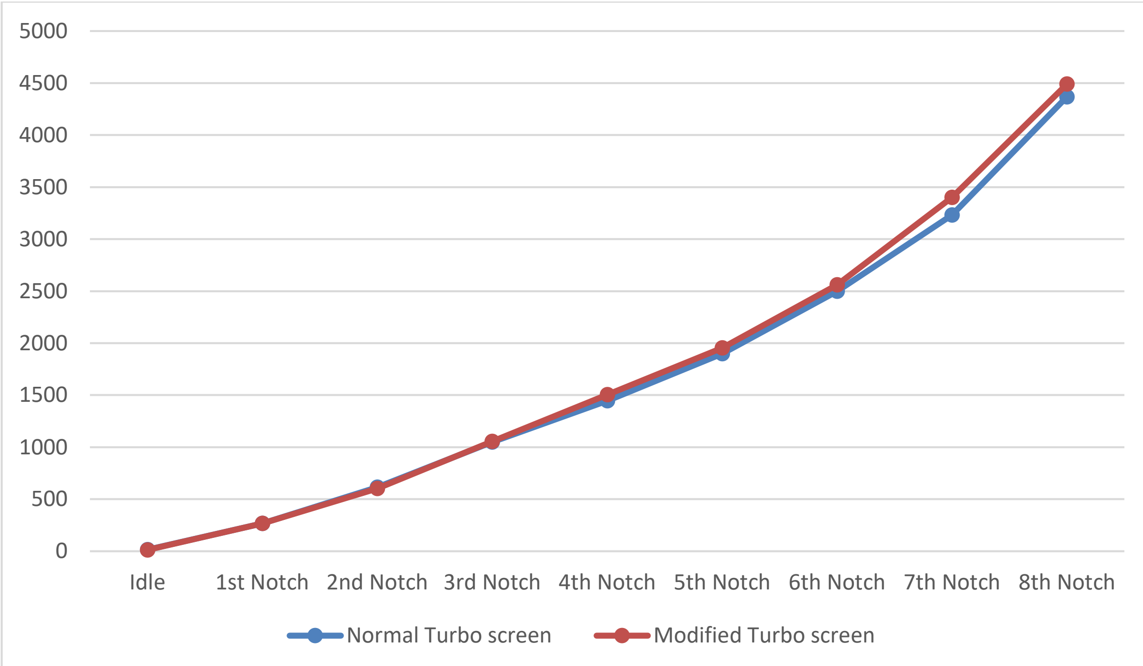

Figure.8Performance improvement in HP with respect to Notch position with modified turbo screen.

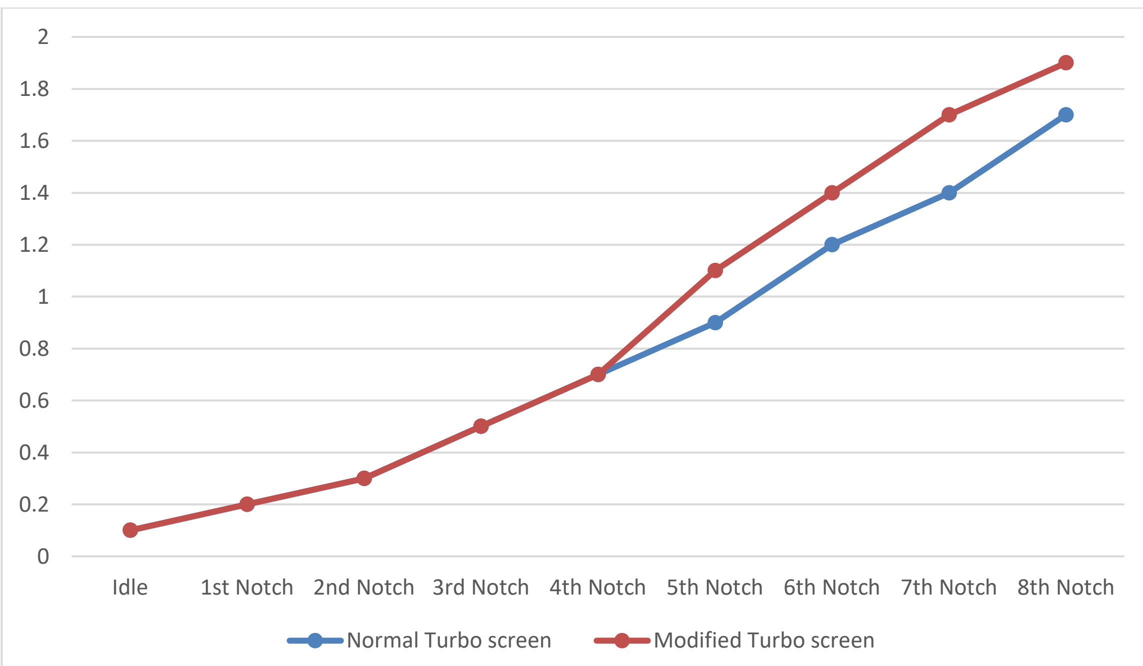

Figure.8Performance improvement in Booster pressure with respect to Notch position with modified turbo screen.

It can be seen from the notch wise performance parameters that the engine performance is enhanced by using modified design turbo screen. The increase in the horsepower of the 710G3B engine is due to the extra Booster pressure available for combustion of fuel. This results in better utilization of inlet boosted air due to easier flow of exhaust through the turbine of the Turbo super charger. No change in the Blade design of the Turbocharger is done in the present configuration. Only the exhaust screen design and hole configuration is changed. The notch wise performance improvement is given in the graph below.

V.CONCLUSION

From the performance data it can be inferred that there is an increase in 2.5% of horse power with modified turbo screen design and an improvement in booster air pressure is about 11.75% which results in increased horse power. Further, Load regulation at 7th and 8th notch also goes up to 100%. On the down side of the analysis it can seen that there is increase in engine exhaust temperature which requires detail study to find out the long term effect of this design on metallurgy of the engine and its components. The effect on the gas emission from the exhaust can also be done as future scope of research.

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