International Journal of Engineering Research & Management Technology
ISSN: 2348-4039
July-August 2023 Volume-10, Issue-4
Email: editor@ijermt.org www.ijermt.org

TURBO CHARGER SELECTION AND MATCHING CRITERIA IN A HEAVY DUTY DIESEL ENGINE USEFUL FOR SHIPPING

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Abstract

For the purpose of increasing the output power of petrol and/or diesel engines, one of the essential equipment that is being utilized is a turbocharger, which is of the utmost importance when used in heavy duty diesel engines. The purpose of this work is to improve the power output of a six-cylinder turbocharged, four-stroke, direct injection heavy duty diesel engine by exchanging the turbocharger that is now installed with one that has been carefully chosen and matched to the engine. Research is being done on the matching criteria as well as the influence of intercooler presence. In order to study how well a turbocharged engine matches its turbocharger, a performance prediction model for the engine has been developed. In order to remedy this issue, the software code that chooses the appropriate engine turbocharger has been improved and changed to use the FORTRAN PowerStation 5.0 programming language. The research also includes an experimental component, in which three distinct turbocharger designs—specifically, HX80, HB3, and HX40—are put to the test. The P- diagram, the engine performance metrics, as well as the exhaust and soot emissions, have been measured and compared for the instances of the original turbocharger and the best turbocharger (HX80). The newly created computer method seems to offer findings that are in good agreement, to within an accuracy of + 5%, with the measured data. This fact encourages designers to trustfully apply it in their selection and matching of a turbocharger to diesel engines.

keywords: *Turbo charger, diesel engine*

INTRODUCTION

When it comes to heavy-duty diesel engines that provide power to the marine sector, selecting the appropriate turbocharger is an important decision to make. Because of the never-ending demands of the shipping industry, propulsion systems need to not only be durable and dependable but also optimized for performance, fuel efficiency, and emissions management. The incorporation of a turbocharger into this equation brings with it the potential to significantly contribute to the accomplishment of the aforementioned goals. When it comes to heavy-duty diesel engines used in the marine industry, this introduction digs into the fundamental aspects and selection criteria that should be used when choosing and matching a turbocharger. Every aspect of turbocharger selection is thoroughly investigated, from the power demands of the engine to the strictness of the emissions standards, from the complexities of the compressor maps to the sturdiness of the materials, and from the integration into the engine system to the continuous maintenance. The marine environment is harsh, which puts engines in a position where they are subjected to a multitude of problems. These challenges include the necessity to fulfill high emission requirements, huge loads, and fluctuating ambient temperatures. As a result, choosing turbochargers becomes a procedure that requires fine-tuning and has the potential to have a significant influence not just on the vessel's performance but also on its environmental imprint and its running expenses. This debate will serve as a thorough reference for professionals working in the marine industry, engineers, and stakeholders engaged in the selection and integration of turbochargers for heavy-duty diesel engines used in ships. This guide will be provided below. It is our hope that by the time you reach the conclusion of this article, you will have a firm grasp of the most important considerations that go into selecting a turbocharger and an appreciation for how this decision contributes to the effective and ecologically conscientious running of marine engines.

Turbocharger Construction

An internal combustion engines intake air pressure may be increased with the help of a device called a turbocharger. This device is made up of a compressor wheel and an exhaust gas turbine wheel that are connected to one another by a solid shaft. Energy is extracted from the exhaust gas by the exhaust gas turbine, and this energy is then used to drive the compressor and overcome the effects of friction. Radial flow is utilized in the vast majority of applications that are related to automobiles, and this includes both the compressor and the turbine wheel. An axial flow turbine wheel can be utilized in some applications in place of a radial flow turbine. One example of this would be in medium- and low-speed diesel engines. Figure 1 [Schwitzer 1991] depicts the flow of gases as they travel through a standard turbocharger that consists of a radial flow compressor and turbine wheels.

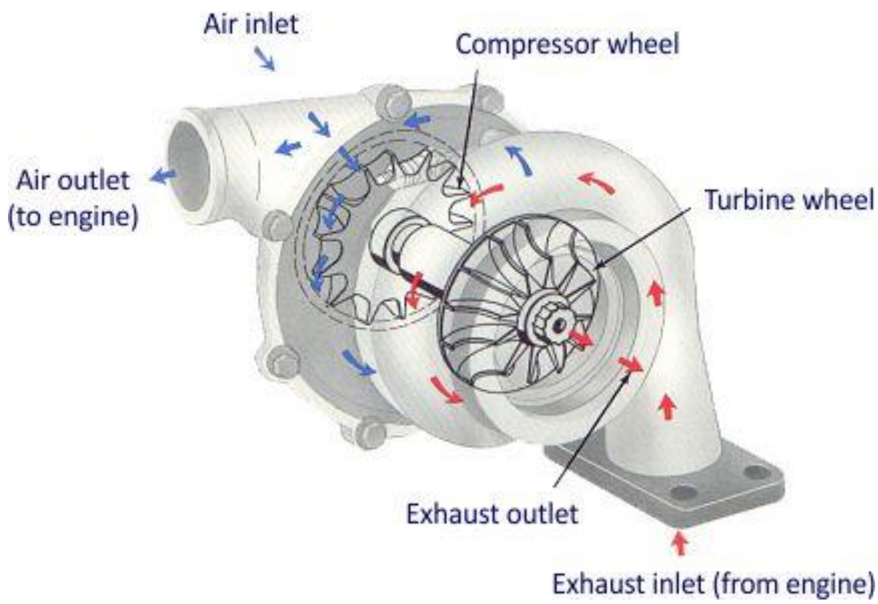


Figure 1. Turbocharger construction and flow of gases

(Source: Schwitzer)

EXPERIMENTAL SETUP

In the experimental investigation, an actual heavy duty diesel engine of the type OT-62, which has a serial number of MHYT02ZKC and a nominal power of 300 HP, is utilized. Figure 2 depicts the experimental setup, which contains the measuring apparatus that was utilized to acquire information regarding the performance of the engine as well as its emission behavior. This particular engine has six cylinders, is in line, is water cooled, has a diameter and stroke of 150 mm and 180 mm, respectively, a compression ratio of 15: 1, and its rated output is 300 horsepower at 1800 revolutions per minute. In Egypt's Helwan University's Faculty of Engineering, which is also the location of the testing facility, it is evaluated. The dynamometer was mounted to the vehicle in the precise alignment with the engine; this ensures that the vehicle runs smoothly and removes any vibrations. A Froude hydraulic dynamometer of the type D. P.Y. is used for the application of the external loading. In order to make the connection between the dynamometer and the engine, a cardan shaft that has two universal joints and is constructed in a way that avoids spinning was made available. At 3500 revolutions per minute, the water brake has the potential to provide a maximum braking power of 500 horsepower. The dynamometer is a device that utilizes a mechanical scale to measure the torque produced by the engine. According to the manufacturer, this dynamometer has an accuracy that is within 0.025% of the nominal value. K-type thermocouples are used to continuously monitor the temperatures of all engine fluids. The fuel injection time may be adjusted in a number of different ways thanks to the engine's adjustable features. During the course of the testing, a flowmeter from the FTB500 Series was utilized to determine the engine's fuel consumption. This flowmeter included high accuracy, high resolution, a high pressure range that reached up to 6000 psig, and a low-range. A calculation was made to determine the fuel usage per hour. The amount of air that is supplied to the engine is measured using a pressure drop in accordance with an orifice flow meter. This orifice plate is fixed in place before the entrance of the compressor at a great distance in order to guarantee a consistent flow of air. Toothed gear and a magnetic pick up combination were mounted on the engine output shaft in order to monitor revolutions per minute (rpm) of the engine. However, in order to take into account the rotation of the shaft, the turbocharger speed has to design a unique circuit that consists of a sender and a receiver. The temperature of the engine coolant was maintained via a heat exchanger tower system. This system was designed to thermostatically set and maintain a certain coolant output temperature. A test console has the controls for the dynamometer as well as traditional gages for indicating things like the engine speed, the engine oil pressure, the water pressure going into and coming out of the dynamometer, as well as the temperatures of the input and outlet water of the engine and the dynamometer, and the temperatures of the exhaust gases. In addition, the values of the pressure and temperature at the most important sites along the intake and exhaust system are identified, as well as the high frequency pressure data at those locations. In addition, the in cylinder high pressure sensor (ICP-Model 113B22-up to 350 Pa), which is responsible for measuring the pressure within the cylinder, is installed within the engine.

Fig. 2. The primary program window for the data gathering software

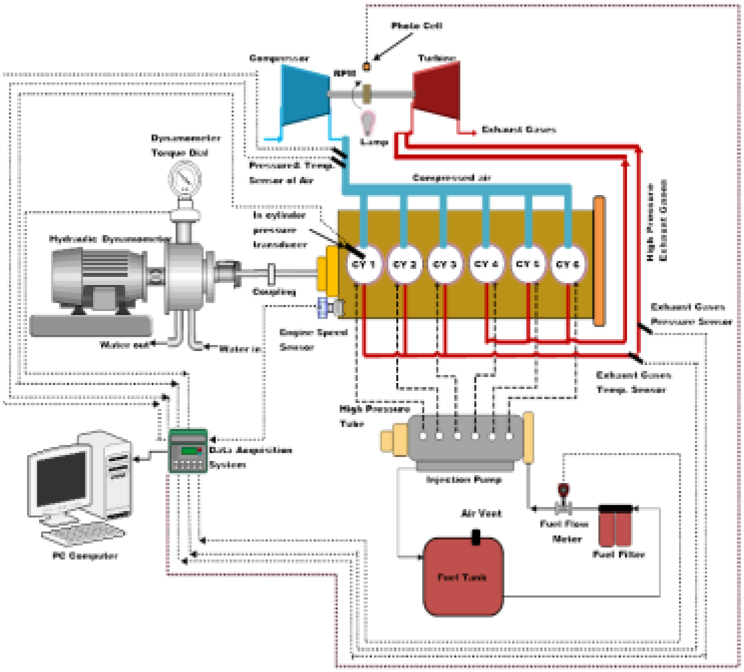


Fig. 3. Illustration of the blueprint for the computer-controlled engine test stand.

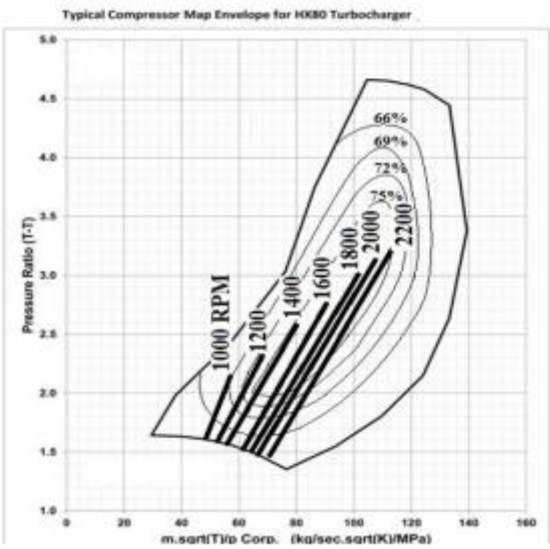
A data acquisition card NI model M series multifunction DAQ for USB -16 Bit, 250 KS/s, up to 80 analog input was used to digitize and record the signals coming from the pressure transducers, optical sensors, and thermocouples, as well as the engine speed and crank angle of rotation sensors. These signals were saved to the personal computer with the assistance of the LabView software and will be analyzed at a later time. This program was developed with the specific intention of integrating the data from all measuring devices and sensors and displaying it in a window on the computer. In order to streamline the processes of monitoring and reporting, the toolkit of software that is now being utilized was programmed in visual basic. The first and most significant purpose is to measure the crank angle trace of the pressure that is present within the engine cylinder. The application allows for simultaneous measurements of up to 8 differential signals to be taken at the same time. With the support of the measurement data, the software is also built to compute another parameter such as the temperature within the cylinder, the rate at which fuel is burned, and the rate at which heat is released (Fig. 2). In Figure 3, you can see a drawing of the engine architecture, which includes the locations of the various transducers and sensors that were utilized during the tests.

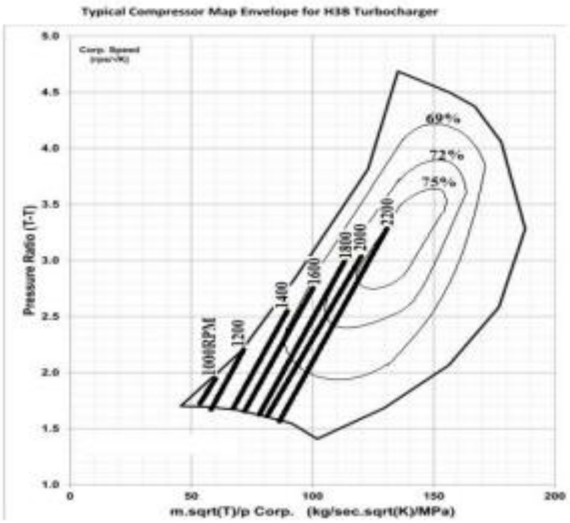
RESULTS AND DISCUSSION

Because it is obvious that a turbo machine is not perfectly suited to function in conjunction with a reciprocating machine, the combination of a diesel engine and turbocharger needs careful planning in order to be successful. It is of the utmost significance and absolutely necessary for the smooth running of a turbocharged diesel engine to ensure that the right turbocharger is paired with the diesel engine. All of the results are going to be presented and talked about in this part. First things first, you'll need to select the appropriate turbocharger based on how well it matches. Second, a discussion is had on the findings of the engine performance with the selected turbocharger under a variety of loads and speeds for the engine.

TURBOCHARGER MATCHING

The HX80, the HB3, and the HX40 are the names of the three distinct turbochargers that are compared in this article. Because heavy-duty diesel engines can work over a broad range of speed and load, the air flow needs may be spread throughout a greater portion of the compressor's map. Figure 4 illustrates a typical superimposition of engine air flow on a compressor map by displaying lines of constant engine speed (1000, 1200, 1400, 1600, 1800, 2000, and 2200 revolutions per minute) for all types of engines. The three maps make it abundantly evident that the HX80 type is a viable option since the operational area is located in a region of high efficiency and is located a significant distance from the surge line. On the other hand, when the load is changed while the speed remains the same, similar behavior is observed with a lower pressure ratio of up to 2.7 and a lower turbocharger efficiency; with operating conditions having a safe margin from the surge line and being close to the chock line, particularly at low part loads of up to 25%, as shown in figure 6. According to the figures 4 and 5, the HX80 type is the one that should be used since the operational region has clear margins from the surge and chock lines, and the majority of the engine speed lines fall within the area of high efficiency with a range operating pressure ratio of 2:4.5 and an average value of 3. It is not the purpose of the compressor to raise the air temperature; rather, the purpose of the compressor is to raise the pressure before the input manifold of the engine. Therefore, the effect of the presence of an intercooler will be researched to determine whether or not it may be overlooked in order to lower the size of the engine. The existence of an intercooler resulted in a 1.7% rise in the air mass flow rate; however, this increase is not rational and can be ignored; this will allow for a reduction in the size of the engine and its components. This will also lower the amount of maintenance required for the turbocharger and make it more suited for engines with size restrictions.





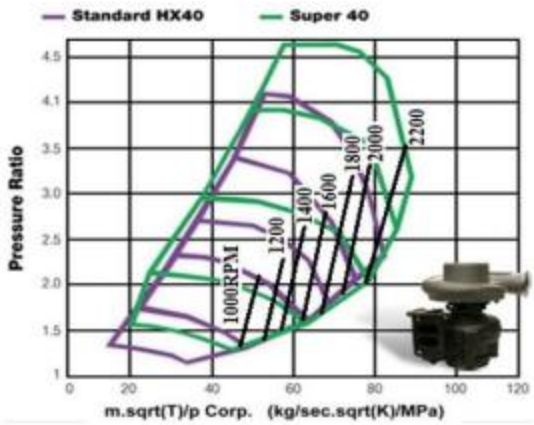
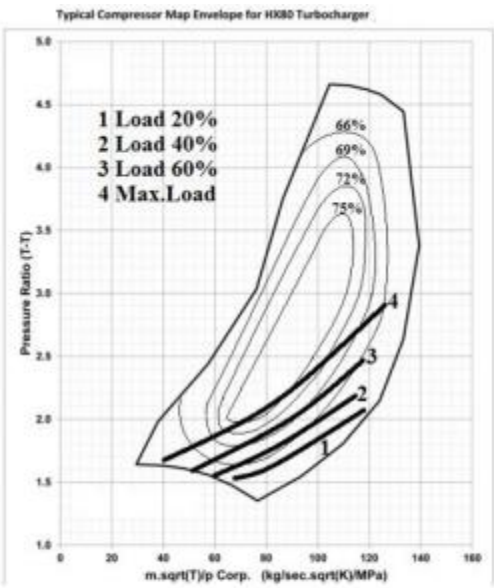


Fig. 4. Compressor map with the engine's operational area placed on it at varying engine speeds



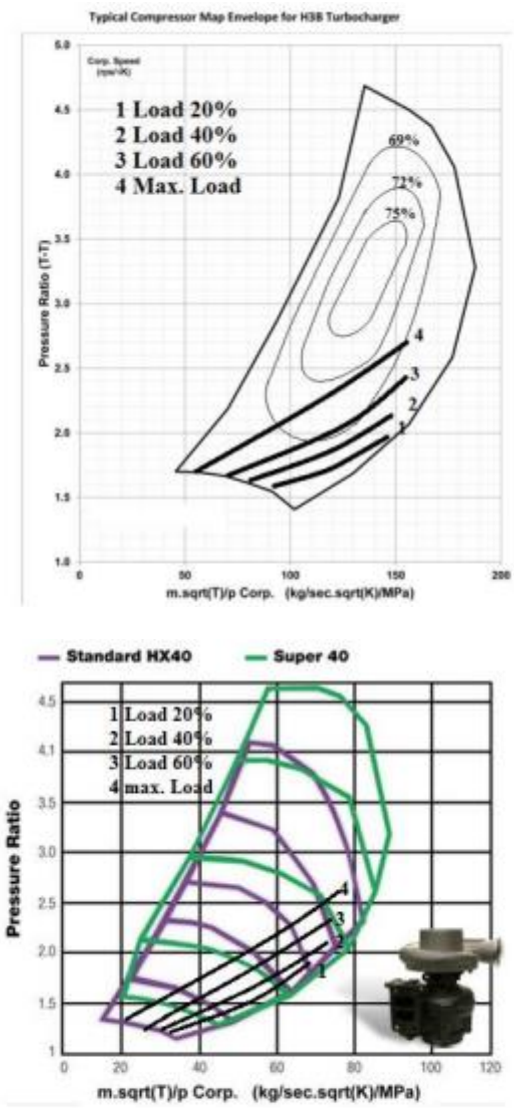


Fig. 5. The engine's operational area placed on the map of the compressor at varying engine loads

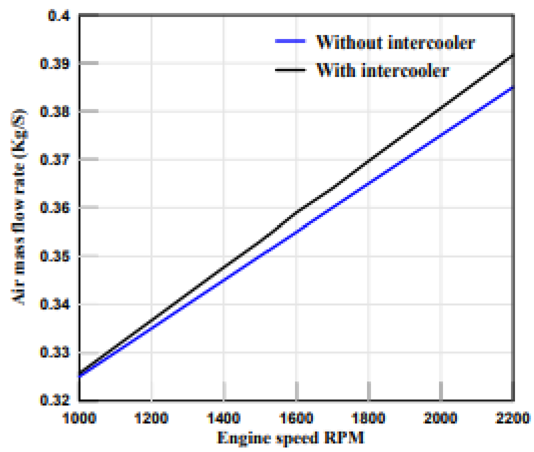


Fig. 6. Variations in the flow of air mass at various engine speeds with and without an intercooler.

COMBUSTION CHARACTERISTICS AND ENGINE PERFORMANCE

It is necessary to produce a comparison between the new turbocharger (HX80) and the one that was previously used in order to examine the differences in the combustion characteristics and performance of the engine. We talk about combustion characteristics such as cylinder pressure, peak cylinder pressure, and the temperature of the combustion zone and the amount of heat that is released. With varying engine loads and speeds, performance characteristics like as braking power and brake specific fuel consumption are considered.

CYLINDER PRESSURE AND TEMPERATURE

During the phase of the combustion process known as "premixed burning," the rate at which fuel is consumed is directly related to the cylinder pressure. Improving the quality of the combustion and the pace at which heat is released is facilitated by raising the cylinder's pressure. Figure 7 depicts the typical recorded in-cylinder pressure change with respect to crank angle at the rated engine speed for both the previous turbocharger and the new HX80. Due to the superior qualities of the HX80 turbocharger over those of the original, it is possible to observe that the cylinder pressure of an engine equipped with the original turbocharger has a lower value than that of an engine equipped with the HX80.

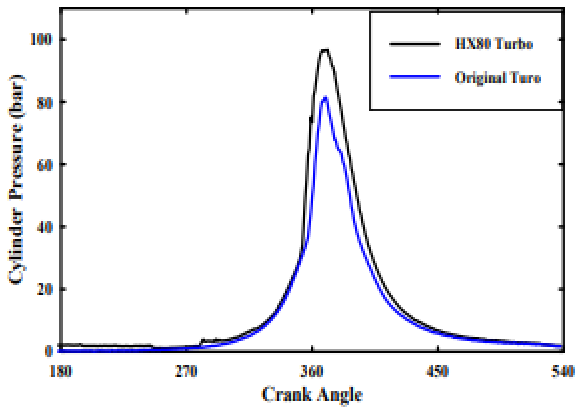


Fig. 7. The P-E diagram for the HX80 turbocharger as well as the original turbocharger

The highest pressure that can be acquired from the engine while it is at HX80 is 20% higher than the maximum pressure that can be achieved with the original turbocharger, while the maximum pressure that can be obtained in the other two circumstances is closer to TDC. The properties of the combustion are altered as a result of increasing the quantity of air, which results in the production of more carbon dioxide (CO2) and, as a consequence, the release of more heat from the exhaust gases. When the HX80 is combined with the engine, the peak temperature is therefore 20% greater than it is when the engine's original turbocharger is employed. At the rated speed of the engine, Figure 7 illustrates the fluctuations in in-cylinder temperature that occur with crank angle for both the original and HX80 turbochargers. The highest temperature that can be reached with HX80 is not any closer to TDC than the original. This is due to the fact that complete burning of fuel requires a greater quantity of air as well as more time.

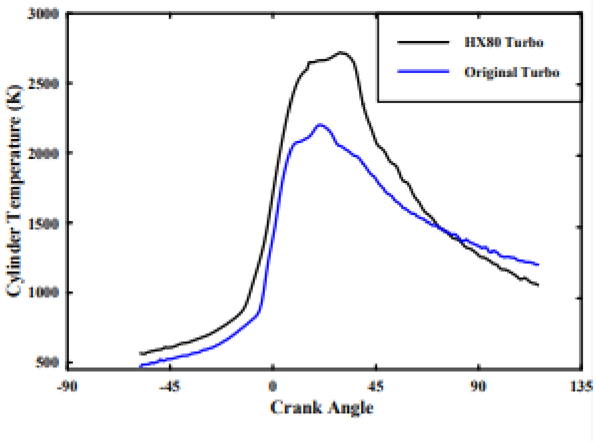


Fig. 8. Temperature changes inside the cylinders as a function of crank angle for both the original and the HX80 turbochargers

HEAT RELEASE RATE

In diesel engines, the gasoline is typically injected into the cylinder around the tail end of the compression stroke, just a few crank angle degrees before top dead center. In most cases, the liquid fuel is injected at a high velocity as one or more jets through a series of tiny orifices or nozzles located in the tip of the injector. It does this by penetrating the combustion chamber and atomizing the liquid fuel so that it becomes minute droplets. The atomized fuel draws heat from the heated compressed air that is all around it, vaporizes, and then combines with the heated high-pressure air that is all around it. The temperature of the mixture (which is largely air) reaches the ignition temperature of the fuel as the piston continues to travel closer and closer to its top dead center (TDC) position. After a certain amount of time has passed after the ignition delay period began, some pre-mixed fuel and air may spontaneously ignite. This immediate ignition is considered the beginning of combustion (it also marks the end of the ignition delay period), and it is denoted by a sudden rise in cylinder pressure as the fuel-air combination is burned off in the process of combustion. The unburned component of the charge is compressed, which warms it, and the increased pressure that results from the premixed combustion shortens the delay until the unburned portion of the charge ignites. In addition to this, the pace at which the fuel is lost to evaporation is sped up. The processes of atomization, vaporization, mixing of fuel vapor with air, and burning continue until all of the injected fuel has been completely consumed. Because an increase in the equivalent ratio enhances the heat capacity of the mixture, lowering the temperature in the cylinder and decreasing the efficiency of the fuel's low-temperature heat release mechanism, a sudden rise in the quick combustion stage occurs when the equivalence ratio is raised.

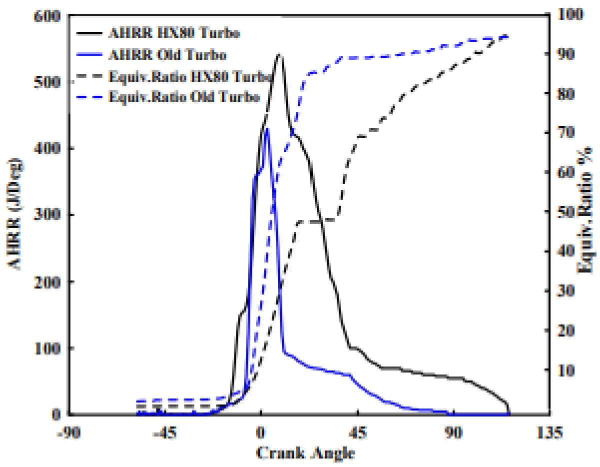


Fig. 9. Changes in the apparent heat release rate and the equivalency ratio as a function of crank angle for the stock and the HX80 turbochargers

Because an increase in fuel concentration makes it easier for the mixture to react, the second stage of mixing controlled combustion may be completed in a shorter amount of time when the equivalency ratio is raised. Figure 9 makes it abundantly evident that the use of HX80 led to an increase in both the heat release rate and the heat transfer rate, which, in turn, led to an increase in both the engine pressure and the engine power at the rated engine speed.

MAXIMUM IN-CYLINDER PRESSURE

The highest possible cylinder pressure is a leading indicator of an increase in the amount of power that is produced by the engine. This is what was discovered when the maximum pressure of both turbochargers was measured under a variety of loads. When compared to the stock turbocharger, the HX80 produces a greater maximum cylinder pressure under all loads, with values coming in at over 10 bar regardless of the engine speed (Fig.9).

BRAKE POWER (BP) AND BRAKE SPECIFIC FUEL CONSUMPTION (BSFC)

The change in braking power and torque with the HX80 compared to the original turbocharger is displayed in figures 11 and 12, respectively. Because of the improvement in combustion that occurs when more air is introduced, the power output of the engine increases, and the BSFC value drops as a direct result. In addition to this, the ratio of power to weight will improve as a direct result of the power upgrade. In order to attain maximum power, the rated maximum engine speed location has been increased from 1800 to 2000 RPM (figure 10). However, this adjustment does not appear to have any discernible impact on the performance of the engine. Because of their higher compression ratio, diesel engines are capable of producing a greater amount of torque. Because of the increased pressure in the cylinder and the increased pressures acting on the connecting rods and crankshaft, the components need to be stronger and heavier. Diesel engines can't accelerate for a given displacement because their rotating components are heavier than those of gasoline engines. When comparing engines, it is just as helpful to compare them based on their maximum torque as it is to compare them based on their maximum RPM. Figure 12 shows that by employing the HX80 turbocharger, it is possible to get a significant increase in engine torque of 17.2%. This is an excellent result for a diesel engine.

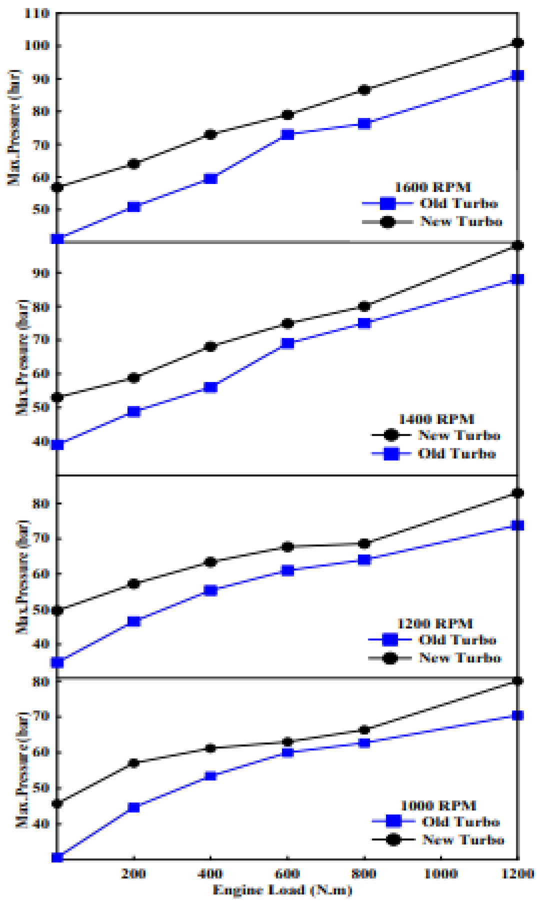


Fig. 10. Variations in maximum in-cylinder temperature change brought on by a variety of loads and operating at a variety of engine speeds

A comparison of the performance curves is shown in figure 11, and it illustrates how the brake specific fuel consumption varies as a function of the engine speed. In most cases, the BSFC will gradually reduce as the engine speed increases, reach a minimal value (best economic) owing to the efficient burning of fuel, and then begin to gradually increase after the engine speed has reached a high value. In conclusion, the BSFC of the engine when operating at any speed and utilizing HX80 is superior to that of the original engine by 5.8%. Controlling emissions is one component of complying with the regulatory standards that regulate the discharge of air pollutants into the atmosphere. Diesel exhaust consists of the gaseous exhaust generated by a diesel engine as well as any particles that may have been present. It is possible for its composition to change depending on the type of fuel used, the pace of consumption, or the amount of air. During the testing of the HX80 turbocharger, the amount of carbon monoxide is reduced as a result of the complete combustion of the fuel. In the event that HX80 is used, a rise in the cylinder temperature leads to an increase in the likelihood of NO production. On the other hand, this rise has neither a major nor a discernible impact (see figure 13). The soot number is an indication of the amount of unburned fuel that results from their being inadequate air. When an older turbocharger is used in a vehicle's engine, the presence of unburned carbon particles in the vehicle's exhaust gases contributes to a rise in the BSFC level. Figure 12 demonstrates that the modified engine has lower values of soot number as a result of the improvement in the combustion process, which limits the creation of soot. This is demonstrated by the fact that the modified engine has lower values.

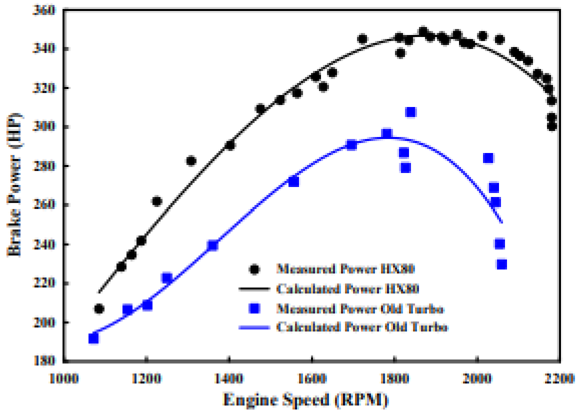


Fig.11 A comparison of the braking power that was measured and that which was estimated for the old turbocharger and the HX80 turbocharger at various engine speeds.

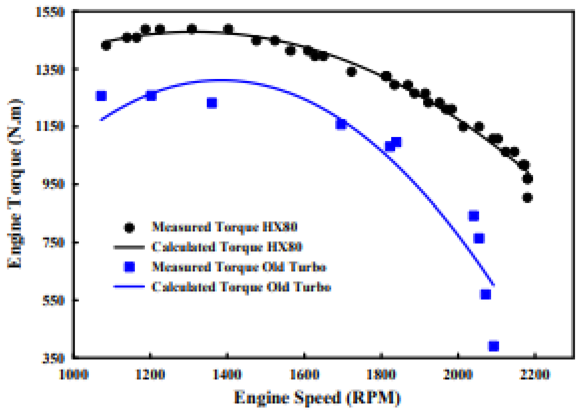


Fig. 12 A comparison of the engine torque obtained through measurement and that which was estimated for the original and HX80 turbochargers at various engine speeds.

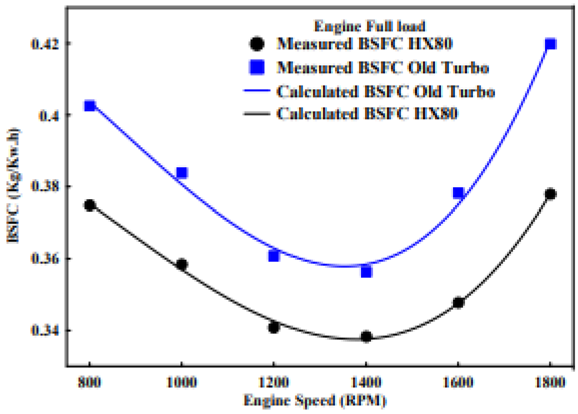


Fig. 12 A comparison of the BSFC that was measured and that which was predicted for the original and HX80 turbochargers while operating at varying engine speeds

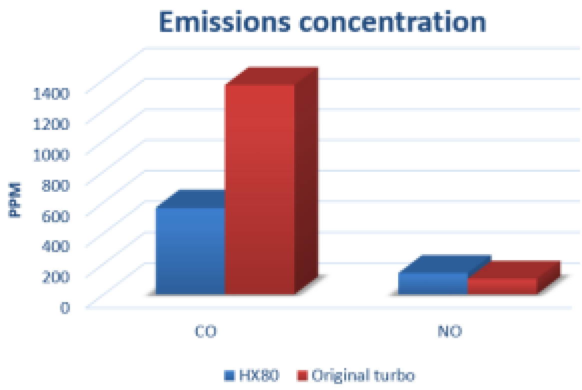


Fig. 13. Comparison of the concentrations of CO and NO emissions produced by the original and the HX80 turbochargers

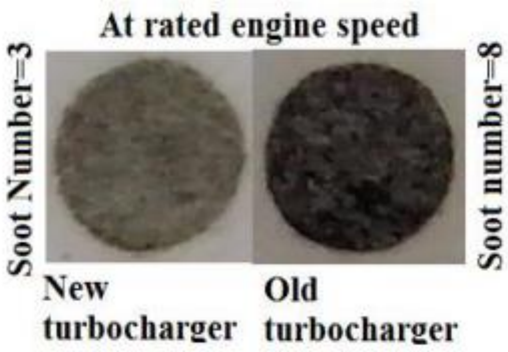


Fig. 14. Comparison of the amounts of CO and NO emissions produced by the original turbocharger and the HX80 version

CONCLUSION

Increasing the engine's specific power with the help of a turbocharger has always been an efficient method. The selection of the turbocharger and/or its matching is highly significant for increasing the power to weight ratio, as well as reducing the cost and the amount of time spent evaluating the vehicle. The following is a brief summary of the most significant technical contributions made by this study: (a) An rise in the maximum pressure inside the cylinder of up to 20% regardless of the load being applied. (b) An increase in the rate at which heat is released, which indicates an improvement in the mixing of fuel and air and reaction rates. (c) An increase in maximum engine power from 300 horsepower (with the stock turbocharger) to 350 horsepower; this is a very small gain of around 16.7 percent. (d) An increase in maximum engine torque from 1200 Nm (with the original turbocharger) to 1450 Nm; this is a marginal gain of about 17.2% and results in improved traction. (e) A reduction of 5.8% in the engine's BSFC thanks to the use of HX80. (f) When HX80 is used, a lower figure for the amount of soot is produced.

REFERENCES

[1] M. Muqeem and M. Ahmad, ‖Turbocharging of diesel engine for improving performance and exhaust emissions: a review‖, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 278-1684, p-ISSN: 2320-334X, Volume 12, Issue 4 Ver. III, PP22-29 ,Jul. -Aug. 2015.

[2] B. Dev, R. Saravanan, R. Pugazhenthi and M. Chandrasekaran‖, Experimental investigation of turbocharger mapped by datalogger in i.c. engine‖, ARPN Journal of Engineering and Applied Sciences, vol. 11, no. 7, april 2016

[3] K. Emara, A. Emara and E. A. Razek,‖ Turbocharging of a heavy duty diesel engine for a specific power and performance enhancement‖, Proceedings of the ASME, International Mechanical Engineering Congress and Exposition, November 13-19, 2015, Houston, Texas, USA.

[4] M. Yuan, B. Chen and J. Zhang,‖ Analysis of the combustion efficiencies and heat release rates of pool fires in ceiling vented compartments‖, Rocedia Engineering, 6 2-2 7 5 – 2 8 2, 2 0 1 3.

[5] M. Tancrez, J. Galindo, C. Guardiola, P. Fajardo and O. Varnier,‖ Turbine adapted maps for turbocharger engine matching‖, Experimental Thermal and Fluid Science 35 -146–153, 2011.

[6] K. Emara, A. H. El -Askary, S. A .Wilson and A. R .Syam, "Theoretical investigation into a pressure wave supercharger", Engineering Research Journal, Vol.35, No.2, and PP: 109-121, 2012.

[7] A. Alberto and B. Oretti,‖ Numerical evaluation of the performance of a compression ignition cng engine for heavy duty trucks with an optimum speed power turbine‖, International Journal of Engineering and Technology Innovation, vol. 1, no. 1, pp. 12-26, 2011.

[8] . S. Sandhu, M. K. G. Babu and L. M. Das, ―Performance and combustion characteristics of a typical motor bike engine operated on blends of cng and hydrogen using electronically controlled solenoid actuated injection system,‖ ARPN Journal of Engineering and Applied Sciences, vol. 6, no. 2, february 2011.

[9] R.Senthilkumar,M.Prabu and M.Sukumar, " Performance, Emission and Combustion Characteristics of a CI engine Using Karanja oil Methyl Ester as a biodiesel with Tyre Pyrolysis Blends," International Journal of Engineering Science and Innovative Technology (IJESIT) Volume 3, Issue 4, July 2014.

[10] M. Shahabuddin, A.M. Liaquat, H.H. Masjuki, M.A. Kalam, M. Mofijur, ―Ignition delay, combustion and emission characteristics of diesel engine fueled with biodiesel,‖ Renewable and Sustainable Energy Reviews- 21 (2013) 623–632.

[11] U. Kesgin,‖ Study on the design of inlet and exhaust system of a stationary internal combustion engine", Energy Conversion and Management 46 (2005) 2258–2287.

[12] Z. Liu, X. Jun and C. Wang,‖ Numerical simulation for exhaust manifold based on the serial coupling of STAR-CCM+ and ABAQUS ―, Research Journal of Applied Sciences, Engineering and Technology 6(20): 3903-3909(2013), ISSN: 2040-7459; e-ISSN: 2040-7467.

[13] M.Varma and L Suresh,‖ Exhaust manifold design – FEA approach‖, International Journal of Engineering Trends and Technology (IJETT) 2014– Volume17 Number 10–Nov.