Journal of Thermal and Fluid Science
Volume 3, Issue 2, December 2022, pp 59 - 76
https://doi.org/10.26706/jtfs.3.2.20221204

Experimental Evaluation on Super- Turbocharged HCCI Engine

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Abstract- The impacts of a Twin-charged (turbo + super) technology on a single-cylinder four-stroke diesel engine were explored in this experimental investigation under various operating situations. Because the supercharger burns output power and the turbocharger has turbo-lag, we conducted an experimental investigation on the twin-charged system in this research to solve the drawbacks of both the super and turbocharger. The experiments were carried out on a constant speed engine of 1500 rpm with varied load and compression ratio. The load varies from 0 to 12 kg in 2 kilogramme increments, with a compression ratio of 12-18. The results show that super, turbocharged boost air improves volumetric efficiency significantly, however super and turbocharger diminish thermal efficiency at low and part load for all compression ratios. Furthermore, the engine was updated with a twin-charged (turbo + super) boost to improve thermal efficiency. Tri-charging has a positive impact on engine emissions, lowering CO, HC, and NOX. However, managing the combustion phasing, expanding the operating range, and reducing unburned hydrocarbon and CO emissions remain difficult difficulties in the successful operation of HCCI engines. Massive global research has resulted in significant advances in the control of HCCI combustion.

Keywords: Turbocharging, HCCI Engine, engine emissions, thermal efficiency.

Article – Peer Reviewed
Received: 9 Dec 2022
Accepted: 20 Dec 2022
Published: 31 Dec 2022

Cite this article: Sanskar Sane, Smit Kore, Ojas Gatkal, Bhavik Tamore, “Experimental Evaluation on Super- Turbocharged HCCI Engine”, *Journal of Thermal and Fluid Science*, RAME Publishers, vol. 3, issue 2, pp. 59-76, 2022.
https://doi.org/10.26706/jtfs.3.2.20221204

1. Introduction

In the fiscal year 2018, India's yearly fuel demand is expected to increase by 5.86% over the previous year. According to statistics, if the current rate of depletion continues, fossil fuel reserves will be depleted in 30 to 40 years. According to World Health Organization data published in May 2016, 30 Indian cities are among the Top 100 Most Polluted Global Cities (in terms of particulate matter PM10). In India, air pollution is the fifth greatest cause of death. Off-road vehicles powered by internal combustion engines, like on-road vehicles, consume a lot of fossil fuels and emit a lot of pollutants into the atmosphere. Internal combustion engines emit carbon dioxide (CO2), nitrogen oxide (NOX), carbon monoxide (CO), particulate matter, and hydrocarbons, according to the US Environmental Protection Agency (EPA). Greenhouse gases CO2 and NOX contribute to global warming, whereas SO2 and NOx emissions contribute to acid rain. As a result, the usage of internal combustion engines is a significant environmental concern. Furthermore, these chemical substances are harmful to one's health. Many efforts have been made to alleviate these detrimental impacts, including evaluations of energy consumption and pollution released by agricultural tractors. Several research studies conducted in the early 2000s evaluated various approaches and determined the average absolute and specific emission values from agricultural tractors, finding that the usage of hydrocarbon fuels must be gradually replaced by cleaner fuels or electricity systems. Other research has advocated utilizing a fossil fuel model to simulate different agricultural production situations in order to improve future strategies. To address this issue, we must minimize emissions, notably in the vehicle industry, by reducing the usage of gasoline and diesel. To address the aforementioned issues, we must employ technologies such as turbochargers and superchargers.

After 30000 km, the engine has increased vibration, waste gate damage, more pollution, and is noisier, and the engine efficiency drops dramatically. There is also a timing fault that causes belt slip and engine breakdown. As a result, there is room for development in terms of brake power, volumetric efficiency, thermal efficiency, and capacity, with a desirable reduction in fuel consumption. NOx gases will be tested for emissions under all conditions. The greatest strategy to reduce pollution is to encourage the use of environmentally beneficial activities. Furthermore, the rate at which our traditional (non-renewable) fuel sources are decreasing is quite worrying and may lead to their demise. In order to meet the world's expanding energy need. This should concern not only automobile manufacturers, but the entire country, because India still requires diesel, but without the pollution. Mr. Chapavy claims that the batteries are currently double the price, costing around the same as a standard tractor. The second constraint is power and duration. It is more likely that smaller tractors will be electrified.

1.1 Supercharger

A supercharger is a type of air compressor that boosts the pressure or density of the air delivered to an internal combustion engine. This provides more oxygen to the engine during each intake cycle, allowing it to burn more fuel and do more work, resulting in increased power.

The supercharger collects energy from the crankshaft and generates power for the engine. It is either directly coupled to the crankshaft or connected to the engine through a belt. The ambient air is compressed, and boost air is introduced into the system. Because superchargers lack a waste gate, their emissions are higher than those of turbochargers.

Advantages of Supercharger :-

- Higher torque output across the entire speed range.
- Frictional and thermal losses are reduced in supercharged engines due to their decreased volumetric displacement.
- Increases horsepower; installing a supercharger to any engine is a quick way to increase power.
- Improved fuel-air mixture

1.2 Turbocharger

A turbocharger is a device that is installed in a vehicle engine to improve overall economy and performance. The shaft connects the compressor and turbine wheels in a turbocharger. On one side, hot exhaust gases spin a turbine, which is linked to another turbine, which draws in and compresses air for delivery to the engine. Because more air can enter the combustion chamber, more fuel can be added for greater power, which is what delivers the extra power and efficiency.

The exhaust stream is used by turbochargers to generate energy, which is then passed through a turbine, which spins the compressor. A turbocharged engine can be more efficient than a naturally aspirated engine because the turbine forces more air into the combustion chamber, resulting in proportionately more fuel. In turbocharging, the turbocharger is powered by a gas turbine that uses exhaust gases and has alternate equipment that lowers the pressure.

Advantages of Turbocharger :-

- Improved torque at low rpm in case diesel engine.
- The engine runs Smoother & quieter.
- Reduces diesel Knock.
- More efficient as it draws its power from exhaust gases
- Better mixing of fuel and air.

1.3 Homogenous Charge Compression Ignition (HCCI) Engine

- The Homogeneous Charge Compression Ignition (HCCI) engine combines Spark Ignition (SI-Engine or Otto-Engine) with Compression Ignition (Diesel Engine)
- Homogeneous Charge Compression Ignition (HCCI) is a type of internal combustion in which a well-mixed mixture of fuel and oxidizer (usually air) is compressed to the point of auto-ignition.
- It uses homogeneous fuel-air mixes, as does the SI-engine, and typically high compression ratios, allowing the mixture to auto-ignite, as does the diesel engine.
- Low NOx and soot emissions, as well as great volumetric efficiency, are advantages of HCCI engines.

1.4 Objective

i To Reduce the Turboloag
ii To reduce emissions of Carbon Dioxide ($CO2$) and Hydro Carbon (HC) to extent.
iii To improve engine capacitive and performance of the engine.

iv To get improvement in efficiency of engine to some extent.

1.5 Problem Statement

- The HCCI engine lacks air for combustion during the suction stroke, resulting in higher CO and CO2.
- Controlling fuel combustion is challenging, therefore the rich mixture in the HCCI engine tends to increase.
- When compared to conventional engines, HCCI engines emit higher hydrocarbons and monoxide.
- NOx emissions are reduced via super-turbo technology.
- Turbochargers and superchargers are used to increase power production.
- As a result, there is potential to use super-turbo technology on HCCI engines to boost performance and minimise emissions

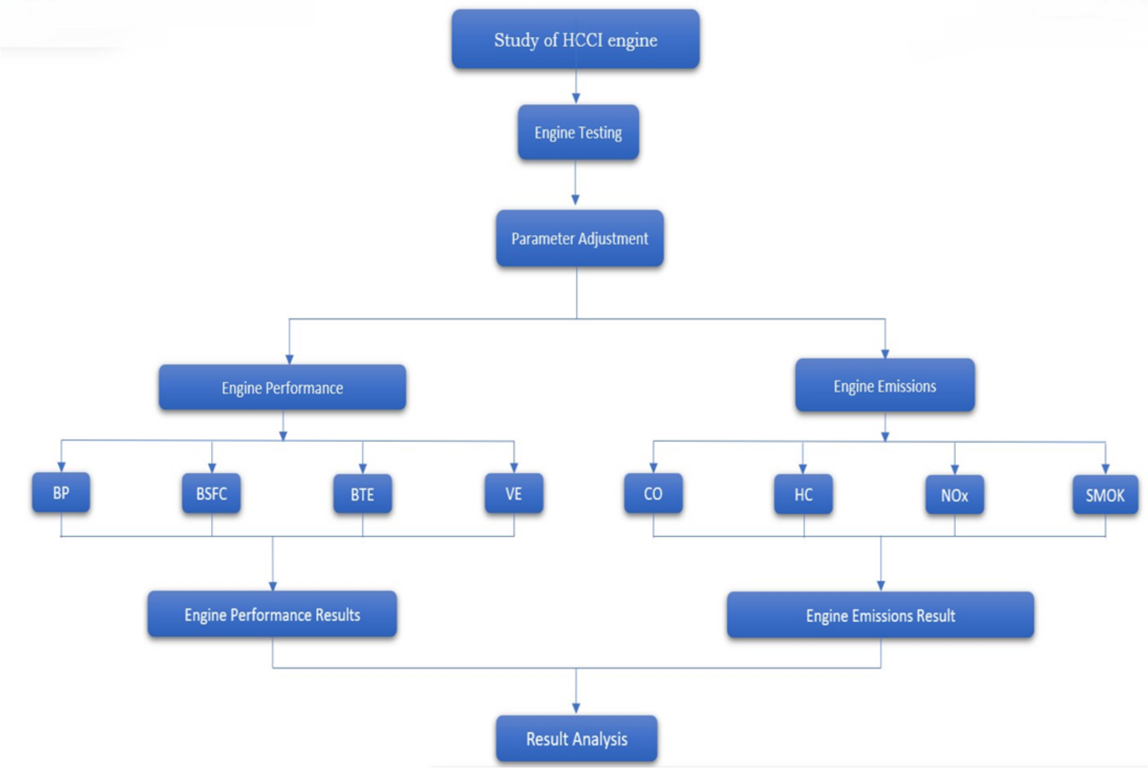


Figure 1. Flow Chart of Methodology

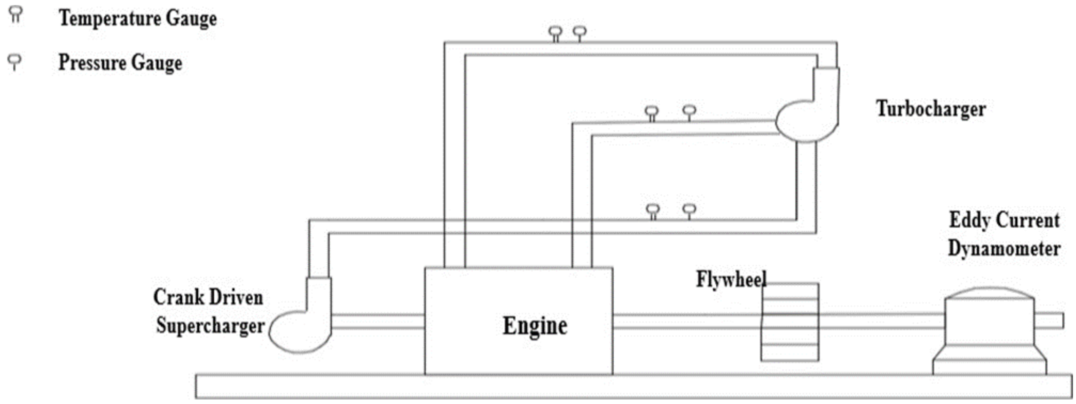


Figure 2. CAD Layout of Model

Methodology is the methodical, theoretical examination of the procedures used in a particular field of study. It consists of a theoretical examination of the corpus of methods and principles linked with a particular field of knowledge.
This project includes the following steps:

1. Problem identification: As the vehicle industry grows in demand, so does the need for more efficient systems. Turbochargers are used to improve engine efficiency. As a result, our effort is focused on boosting turbocharger performance.
2. Experiment on a simple HCCI engine without a supercharger or turbocharger.
3. Experiment with a supercharged HCCI engine to see if it can be made more powerful.
4. Experimentation on a turbocharged HCCI engine to boost efficiency.
5. Experiment with a hybrid charged (Super-Turbo charged) HCCI engine to reduce emissions.

2. Literature Survey

In December 2006, Mr. Owen Ryder, Herbert Sutter, and Laurentius Jaeger did an experiment on "The Design And Testing Of An Electrically Assisted Turbocharger For Heavy Duty Diesel Engines" and proposed a paper for it. According to the report, The use of a turbocharger with an integrated electric motor/generator is said to result in better fuel usage, faster transient response, and lower emissions. This article discusses the mechanical design of different turbocharger and electric motor choices, as well as the design chosen for this EU-funded research. The study also discusses turbocharger testing on a gas stand, where the performance capabilities of the motor and turbocharger were determined in both powered and generator modes. The effects of a heavier and longer rotor assembly on dynamic shaft motion are also studied. Finally, the report summarises the results of testing on a heavy duty truck diesel engine, highlighting the advantages and disadvantages of such a system.

Mr Muruga Ganesan, James Gunasekaran, Ramesh, and Loganathan did an experiment titled "Investigation of Combustion and Emission Characteristics of a Single Cylinder DI Diesel Engine Used in Farm Transportation Vehicles" and proposed a report on the results. This research describes the efforts made to improve the combustion characteristics of a DI diesel engine used in farm transportation vehicles. Because fuel injection pressure is important in combustion, four different fuel injection pressures are investigated: 200, 400, 600, and 800 bar. 3-dimensional computational fluid dynamic modelling has also been used to better comprehend minute subphysical processes. Theoretical and practical data show that increasing pressure results in higher brake thermal efficiency, higher NOx emissions, and reduced soot emissions. Fuel injection pressures above 800 bar have no effect on brake thermal efficiency. While the simulation reasonably forecasts the pressure heat release pattern, it over predicts NOX emission at greater injection pressure, necessitating more analysis. It can be concluded that increasing injection pressure will enhance transportation vehicle economy.

In 2002, Mr. Devesh Upadhyay, V.I. Utkin1, and Giorgio Rizzoni performed an experiment on "Multivariable control scheme for intake flow management of a diesel engine using sliding mode" and proposed a paper on it. This experiment demonstrates that stringent CAFÉ rules, as well as technological breakthroughs in materials, high-pressure fuel injection, and complicated turbocharging systems, have reignited interest in diesel engines for passenger vehicle applications. A modern Diesel engine is not only clean and quiet, but it also has comparable drivability to gasoline engines while providing significant fuel economy advantages. The current generation diesel engine, on the other hand, is a complex system. Variable Geometry Turbo Charging (VGT), Exhaust Gas Recirculation (EGR), and High Pressure Common Rail (HPCR) fuel injection are all common features. The design of a multivariable controller for the VGT-EGR system for intake flow regulation is discussed in this work. The sliding mode framework is used for control design.

In December 2021, Mr. Xiaoyang Yu, Wanhua Su, and Binyang Wu did an experiment titled "Experimental investigation on the technique for increased brake thermal efficiency on a two-stage turbocharged heavy-duty diesel engine" and proposed a paper for it. The strategy to improving brake thermal efficiency (BTE) for a heavy-duty diesel engine was examined through experiment analysis in this experiment. The engine was built around a two-stage turbocharger system (high-pressure (HP) turbine with variable geometry turbine) and a variable effective compression ratio achieved by delayed intake valve closing timing. To optimise the BTE, coordinated management of minimum charge density, compressor efficiency, and compressor pressure ratio distribution was proposed. The principle of interaction was then clarified. Because of the promotion of the mixing rate, the results showed that the gross indicated thermal efficiency (ITEg) rose significantly with charge density. However, the increasing charge density had a threshold above which the pumping loss (PL) rapidly rose, stifling the ITEg growth rate. As a result, a minimum charge density should match to the required mixing rate. Furthermore, when the charge density was held constant, the PL fell as the turbocharger driving power decreased. As a result, when the minimum charge density meets the mixing rate, the minimum turbocharger driving power should be controlled to minimise PL by enhancing compressor efficiency and optimising compressor pressure ratio distribution. The simultaneous optimization of the mixing and gas exchange processes was therefore recognised as the heart of the cooperative management of minimum charge density, compressor efficiency, and compressor pressure ratio distribution. This type of adjustment helped to maximise the BTE.

Mr. Giuseppe Genchi and Emiliano Pipitonein did a preliminary experimental study on double fuel HCCI combustion in 2014 and offered a paper for it. This work describes an experimental investigation into a specific internal combustion engine technology that blends Double Fuel combustion with Homogeneous Charge Compression Ignition (HCCI) using natural gas (NG) and gasoline mixes. The CFR engine tests show that HCCI combustion may be achieved with NG-gasoline mixes without knocking for low to medium engine loads by changing the amount of the two fuels. The key advantage of this new combustion technique is the significantly improved engine efficiency attained as compared to normal spark ignition operation, as well as the significant reduction in NOX emissions.

Mr. Jinsha Rajeevana, Hans M Hb, Antonio Josephb, and Kiran T Sc 2006 did a study on "Hybrid Turbocharged SI Engine with Cooled Exhaust Gas Recirculation for Improved Performance" and proposed a paper on it. According to this study, turbocharging in its most modern variants has enough space for improvement while working at lower engine speeds. Because of the low mass flow rate of exhaust gases, the effects have been more obvious with petrol engines. The SI engine's mathematical model is created in MATLAB utilising a two-zone combustion model and thermodynamic relations constructed using the unsteady flow energy equation. The developed model is used to analyse engine performance when it is naturally aspirated, turbocharged, or hybrid turbocharged. The incidence of knock, which dictates the extent of turbocharging, is addressed with sufficient care by applying wavelet analysis of the engine's acoustic emissions. The proposed solution takes into account technologies such as supercapacitor batteries for hybrid turbocharging and cooled EGR for regulating knocking and dissociation. The results show a 40% improvement in low end torques, paving the possibility for future downsizing of petrol engines.

In July 2006, Mr. Xiaolu Li, Chen Hongyan, Zhu Zhiyong, and Huang Zhen conducted an experiment titled "Study of combustion and emission characteristics of a diesel engine operated with dimethyl carbonate" and proposed a paper for it. According to the study, dimethyl carbonate (DMC) is typically combined with diesel fuel as an oxygenated addition to promote combustion and minimise emissions from diesel engines. However, because to its low cetane number and high latent heat of vaporisation, DMC is difficult to directly fuel diesel engines. This work presents a method for studying DMC combustion in diesel engines that combines internal exhaust gas recirculation (EGR) with a modest infusion of diesel fuel to ignite the DMC. A two-stroke, single-cylinder diesel engine was constructed using this approach. Preliminary research has shown that this engine can run on DMC with almost no smoke and a low exhaust gas temperature. This DMC-powered engine emits fewer nitrogen oxides (NOx) and produces less heat

In moderate and heavy load zones, the engine has a 2-3% higher effective thermal efficiency than a diesel engine. To analyse the DMC spray, additional tests were performed on a series of advanced digital particle imaging velocimetry (DPIV) measurement systems.

Mr. Woongkul Lee, Erik Schubert, Yingjie Li, and Silong Li carried out an experiment on "Electric turbocharger and supercharger for downsizing internal combustion engine" in March 2017 and proposed a paper on it. Forced induction is used in this experiment to improve the volumetric efficiency of an engine, allowing for improved thermodynamic efficiency. As worldwide fuel economy and greenhouse gas emission rules become more demanding, the usage of forced induction engines in passenger vehicles and light duty trucks has emerged as a new trend in the automotive industry. An exhaust driven turbocharger's aerodynamic matching is a trade-off between transient response at low exhaust energy levels and power targets at high levels. The move toward highly boosted smaller engines results in larger aerodynamic matches, which compromise low-end responsiveness, termed as turbo lag. The electrification of forced induction systems (electric forced induction systems (EFIS)) has emerged as a viable alternative, with different advantages depending on their topologies. This paper investigates system level topologies, performance, various types of highspeed machines, power electronics, and control techniques to provide a comprehensive study on EFIS. The benefits and drawbacks of the existing electric forced induction system are summarised, and new challenges and opportunities are introduced.

Mr. N. R. Karthik and B. Gautam did an experiment on the " Review on turbo charger and supercharger " in September 2016 and proposed a report on it. According to this report, as the demand for new efficient and environmentally friendly engines grows, new technologies emerge. Because of the rich air fuel mixture, combustion emissions will increase; therefore, turbocharging the engine will provide more power while emitting less pollution. This paper provides a review of numerous applications of turbo charging and supercharging technology. The behaviour of an IC engine with a turbo/super charger and the need for a turbo/super charger installation are investigated.

2.1 Summary of Literature Survey

- The use of a turbocharger with an integrated electric motor/generator is said to result in better fuel usage, faster transient response, and lower emissions.
- Fuel injection pressure is important in combustion; higher pressure results in higher brake thermal efficiency, higher NOx emissions, and lower soot emissions.
- Fuel injection pressures of 200, 400, 600, and 800 bar are explored. The peak heat release rate is raised by 66% between 200 and 400 bar, from 150 kJ/m3 -deg to 250 kJ/m3 -deg.
- Similarly, between 400 and 600 bar, peak heat values increase by 28%, from 250 kJ/m3 -deg to 320 kJ/m3 -deg.
- Fuel injection pressures above 800 bar have no effect on brake thermal efficiency.
- Tringent CAFÉ laws, along with technological breakthroughs in materials, high-pressure fuel injection, and complicated turbo charging systems, provide not only clean and quiet operation, but also comparable drivability to gasoline engines with significant fuel economy improvements.

- The BTE is optimised through the coordinated regulation of minimum charge density, compressor efficiency, and compressor pressure ratio distribution.
- Because of the promotion of the mixing rate, gross indicated thermal efficiency (ITEg) increased rapidly with charge density. However, the increasing charge density had a threshold beyond which the pumping loss (PL) increased rapidly, stifling the ITEg growth rate.
- The CFR engine tests show that HCCI combustion may be achieved with NG-gasoline mixes without knocking for low to medium engine loads by changing the amount of the two fuels.
- The advantage of the HCCI novel combustion process is based on the significantly improved engine efficiency attained as compared to conventional spark ignition operation, as well as the significant reduction in NOX emissions.
- Dimethyl carbonate (DMC), an oxygenated additive, is typically combined with diesel fuel to improve combustion and minimise emissions from diesel engines. However, because to its low cetane number and high latent heat of vaporisation, DMC is difficult to directly fuel diesel engines.
- Force induction is used to improve volumetric efficiency, which reduces turbolag and increases thermodynamic efficiency.
- When a turbocharger and a supercharger work together, the exhaust gas is recirculated, lowering NOx emissions.
- With 30% COME, smoke concentration is reduced by 30% at full load.
- Because rich air fuel mixture combustion emissions increase, turbocharging the engine can provide greater power while emitting less pollution.
- EGR increases soot and NOx emissions.
- For lower emissions, we can utilise high reactive diesel in RCCI.

3. Experimental Analysis

An experimentation has been carried out on the engine with the set of input parameters and find out the output parameters as per the requirement. The observation table and their results are available in the following tables for total 4 runs.

Figure 3. Experimental Setup

3.1 Run 1 with Conventional or Naturally Aspirated

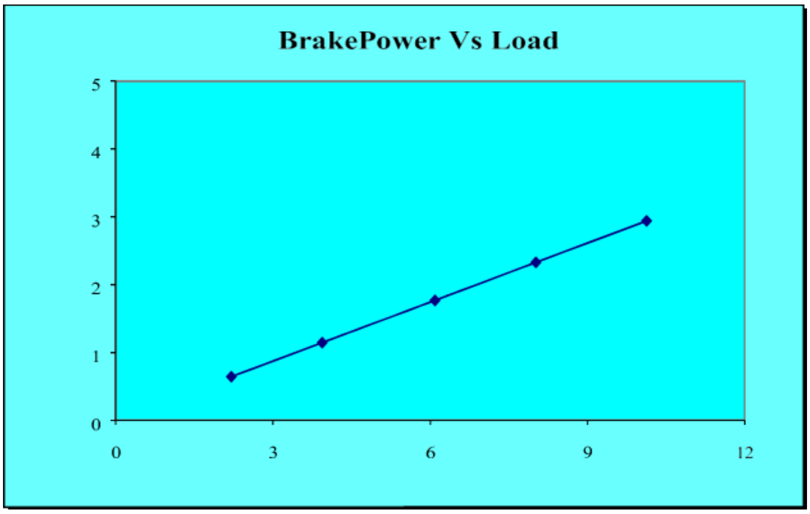
Table 1: Observations for Conventional or Naturally Aspirated

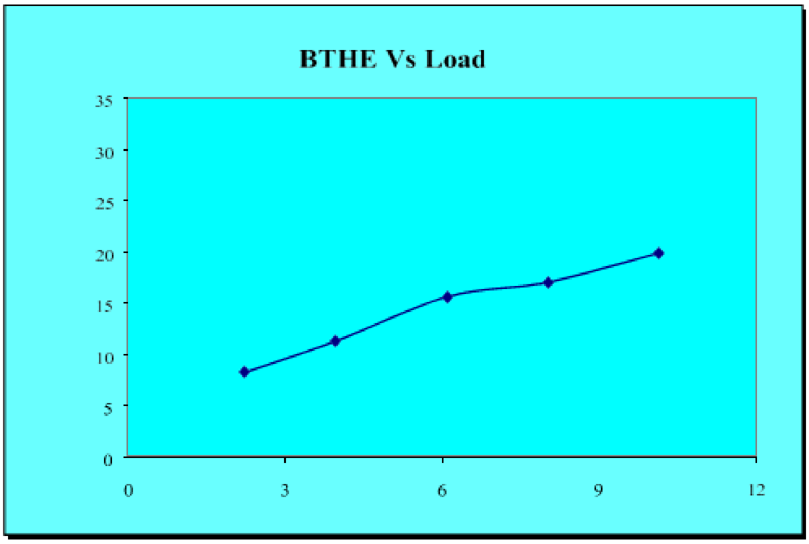
Engine Speed (Rpm)	Load (Kg)	Mano. defle. (mm)	Fuel flow (cc/min)	Engine cooling water (Lph)	Calo. water (Lph)	T1/T3 (Engine water in) DegC	T2 (Engine water out) DegC	T4 (Calo. water out) DegC	T5 (Exhaust in) DegC	T6 (Exhaust out) DegC	Second Fuel mass flow rate (ms)	Second Fuel Mass Flow rate (kg/hr)
1522	2.219	69	9	200	100	33.04	39.307	37.1	143.9	94.352	3	0.2
1522	3.951	69	13	200	100	33.08	42.122	37.11	190.14	129.168	3	0.2
1524	6.102	69	15	200	100	33.12	43.792	37.09	221.94	148.887	3	0.2

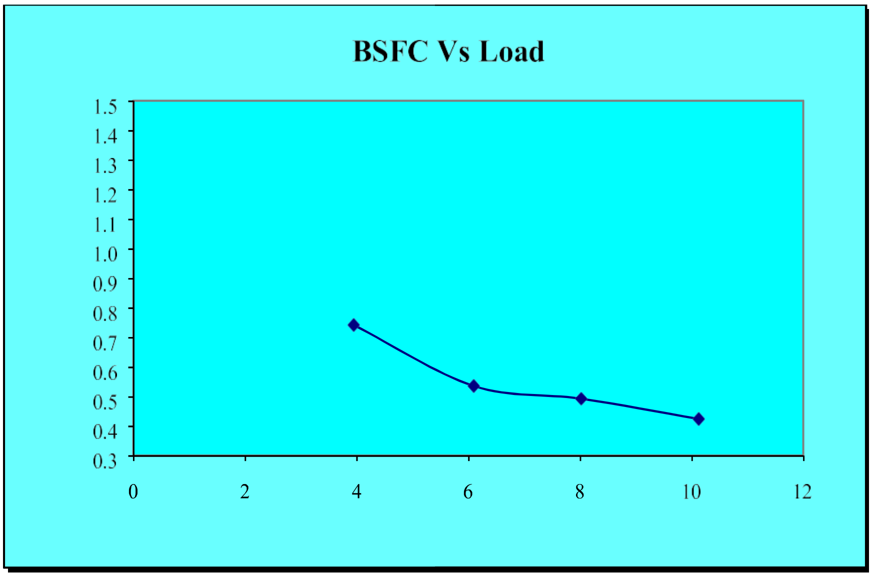
1525	8.026	69	19	200	100	33.18	45.733	37.11	264.6	176.959	3	0.2
1527	10.13	69	21	200	100	33.3	48.167	37.11	320.51	215.669	3	0.2
1528	11.98	69	25	200	100	33.42	49.509	37.12	352.25	234.538	3	0.2

Table 2: Result for Conventional or Naturally Aspirated

Brake power (Kw)	BMEP (Bar)	Torque (N.m)	BSFC kg/kwH	BTh.eff. (%)	Air flow (kg/hr)	Fuel flow (kg/hr)	Voleff (%)	A/F Ratio	Heat Equi.of work (%)	Heat by cool water(%)	Heat by exhaust (%)	Radiation (%)
0.6	0.77	4.0	1.0	8.19	26.9	0.45	76.7	41.5	0.6	18.6	6.0	74.7
1.1	1.36	7.2	0.7	11.25	26.9	0.65	76.7	31.8	1.1	20.7	6.6	71.6
1.8	2.10	11.1	0.5	15.61	26.9	0.75	76.6	28.4	1.8	21.9	7.1	69.2
2.3	2.77	14.6	0.5	17.04	26.9	0.95	76.5	23.5	2.3	21.4	7.3	69.0
2.9	3.49	18.4	0.4	19.86	26.9	1.05	76.4	21.6	2.9	23.3	8.3	65.4
3.5	4.13	21.7	0.4	20.30	26.9	1.25	76.4	18.6	3.5	21.8	8.0	66.7







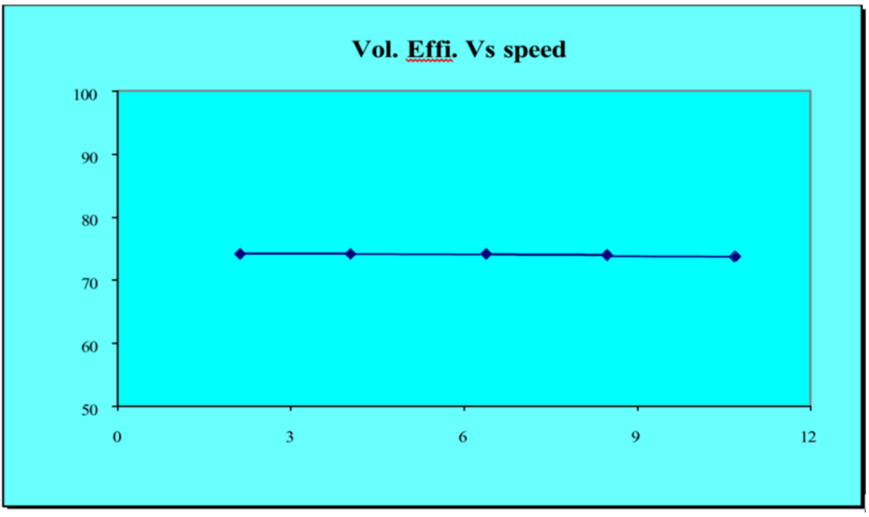


Figure 4. Graphical representation of brake power, BTHE, BSFC vs Load and Volumetric efficiency vs speed for Conventional or Naturally Aspirated

Table 3. Emission Data of Conventional or Naturally Aspirated

Load	**CO**	**HC**	**CO_2**	**O_2**	**NO**
2	0.04	6	1.40	19.81	239
4	0.04	10	2	19	427
6	0.04	13	2.20	18.75	488
8	0.05	17	2.40	18.50	498
10	0.10	25	2.80	18.18	490
12	0.58	48	0.80	14.55	870

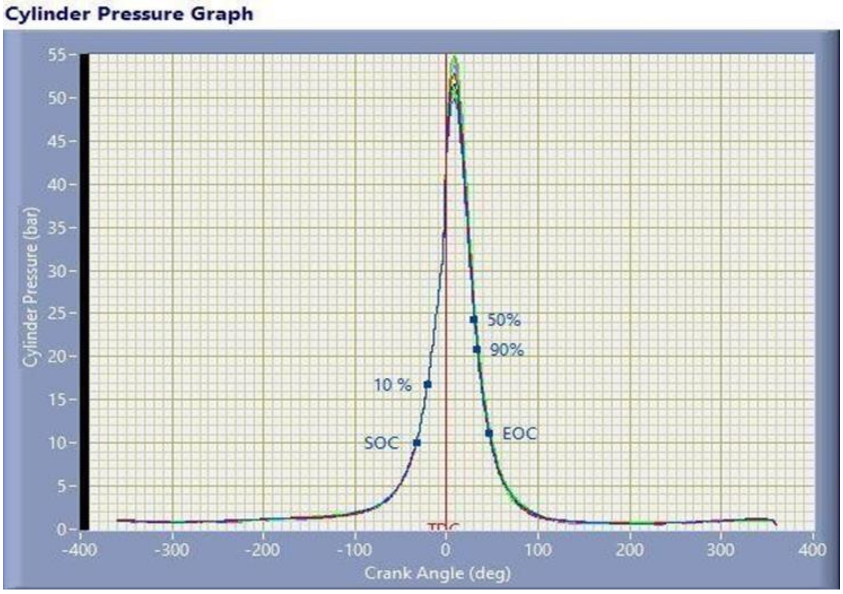


Figure 5. Graphical representation of crank angle vs cylinder pressure for Conventional or Naturally Aspirated

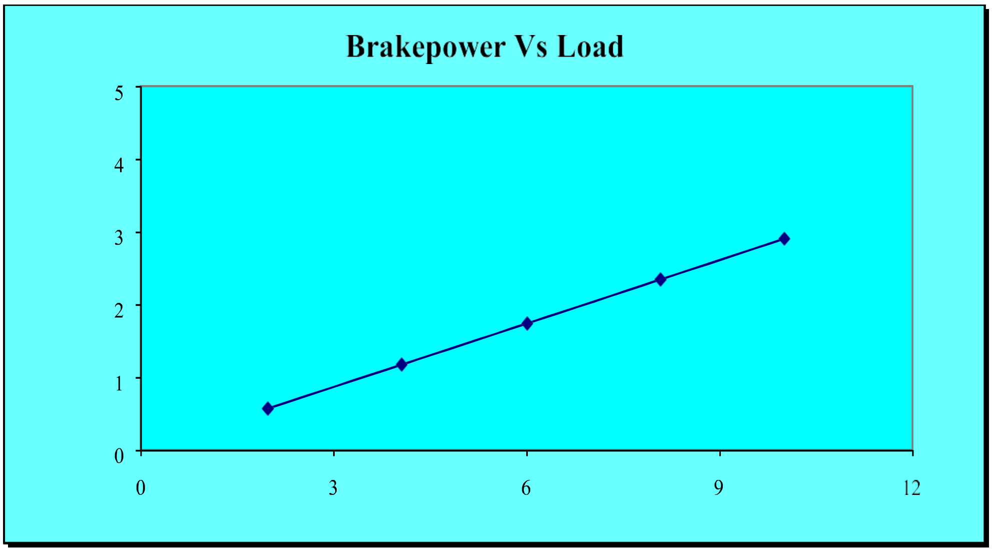
3.2 Run 2 with Supercharger

Table 4. Observations Table for supercharger

Engine Speed (Rpm)	Load (Kg)	Mano. defle. (mm)	Fuel flow (cc/min)	Engine cooling water (Lph)	Calo. water (Lph)	T1/T3 (Engine water in) DegC	T2 (Engine water out) DegC	T4 (Calo. water out) DegC	T5 (Exhaust in) DegC	T6 (Exhaust out) DegC	Second Fuel mass flow rate (ms)	Second Fuel Mass Flow rate (kg/hr)
1546	2.38	82	12	200	100	33.3	39.1	32.6	86.99	82.653	3	0.25
1536	4.27	82	14	200	100	33.3	44.37	34.14	133. 1	125.271	3	0.2
1521	6.25	82	16	200	100	33.3	46.97	35.05	157	147.109	3	0.2
1555	8.17	82	19	200	100	33.4	48.91	36.12	183.3	170.878	3	0.2
1503	9.68	82	19	200	100	33.4	50.34	37.33	209	192.442	3	0.2
1486	12.3	82	24	200	100	33.5	52.77	38.23	239.8	217.861	3	0.2

Table 5. Results for supercharger

Brake power (Kw)	BMEP (Bar)	Torque (N.m)	BSFC kg/kwH	BTh.eff. (%)	Air flow (kg/hr)	Fuel flow (kg/hr)	Voleff (%)	A/F Ratio	Heat Equi.of work (%)	Heat by cool water(%)	Heat by exhaust (%)	Radiation (%)
0.7	0.82	4.3	1.2	6.84	29.3	0.60	82.3	34.6	0.7	13.2	15.0	71.1
1.2	1.47	7.7	0.8	10.93	29.3	0.70	82.8	31.0	1.2	22.6	24.5	51.7
1.8	2.15	11.3	0.6	14.38	29.3	0.780	83.6	28.0	1.8	25.2	27.4	45.5
2.4	2.82	14.8	0.5	16.45	29.3	0.95	84.0	24.5	2.4	25.2	29.2	43.2
2.8	3.32	17.6	0.4	19.33	29.3	0.95	84.6	24.5	2.8	27.5	34.1	35.6
3.5	4.25	22.4	0.4	20.24	29.3	1.20	85.6	20.3	3.5	26.1	33.5	36.9


Brakepower Vs Load
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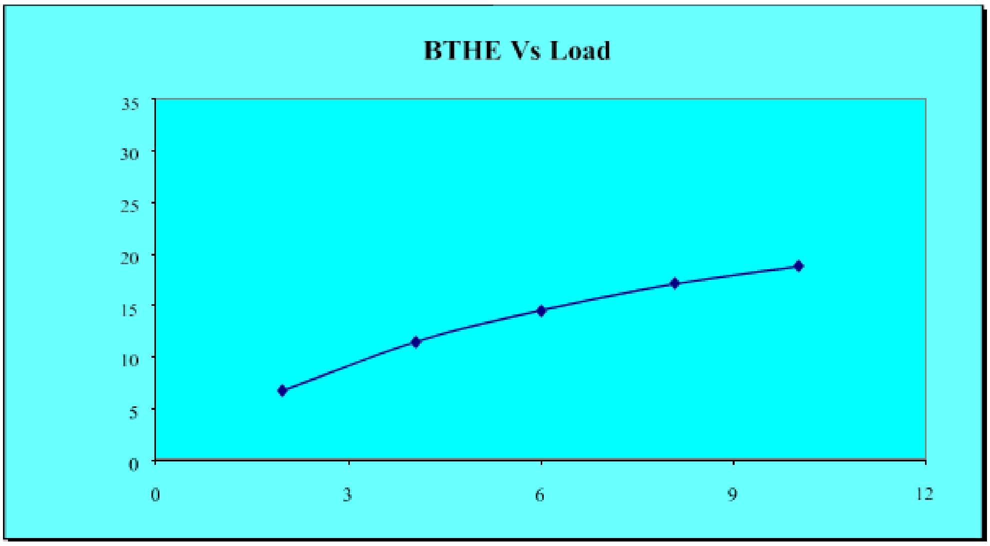
BTHE Vs Load
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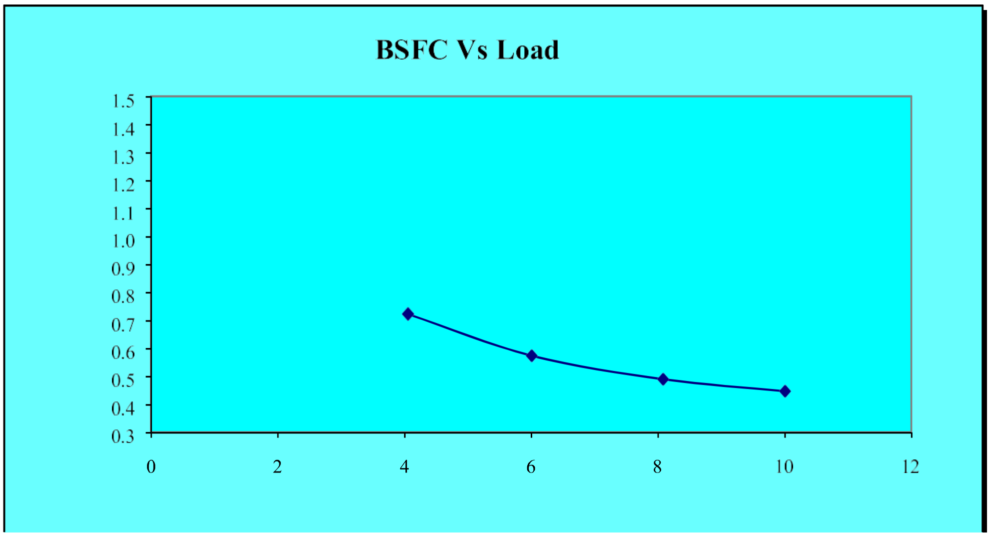
BSFC Vs Load
0.3
0.4
0.5
0.6
0.7
0.8
0.9
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1.2
1.3
1.4
1.5
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12

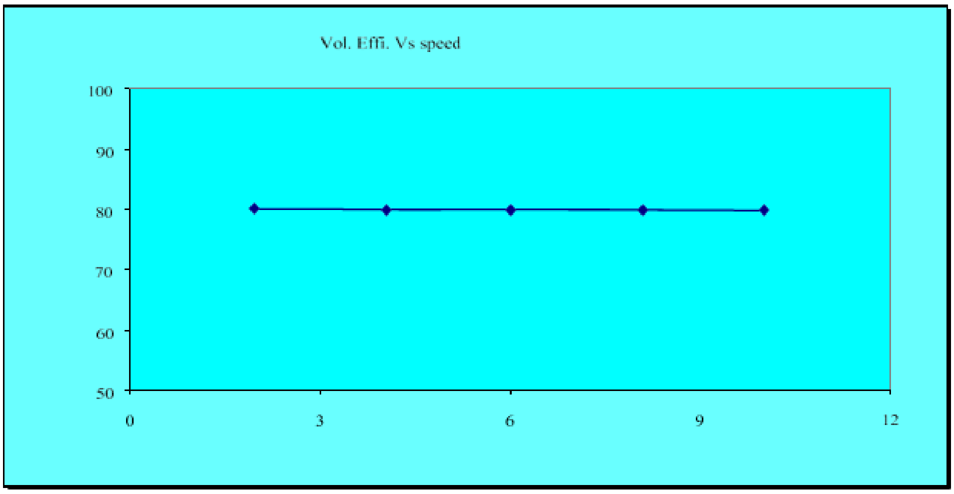


Figure 6. Graphical representation of brake power, BTHE, BSFC vs Load and Volumetric efficiency vs speed for supercharger

Table 6. Emission Data of Supercharger

Load	CO	HC	CO_2	O_2	NO
2	0.1	23	3.30	17.60	625
4	0.09	21	3.80	17.27	817
6	0.08	30	4.90	16.27	1075
8	0.09	27	4.6	16.60	909
10	0.18	43	5.90	15.40	1053
12	0.48	47	5.10	15.91	714

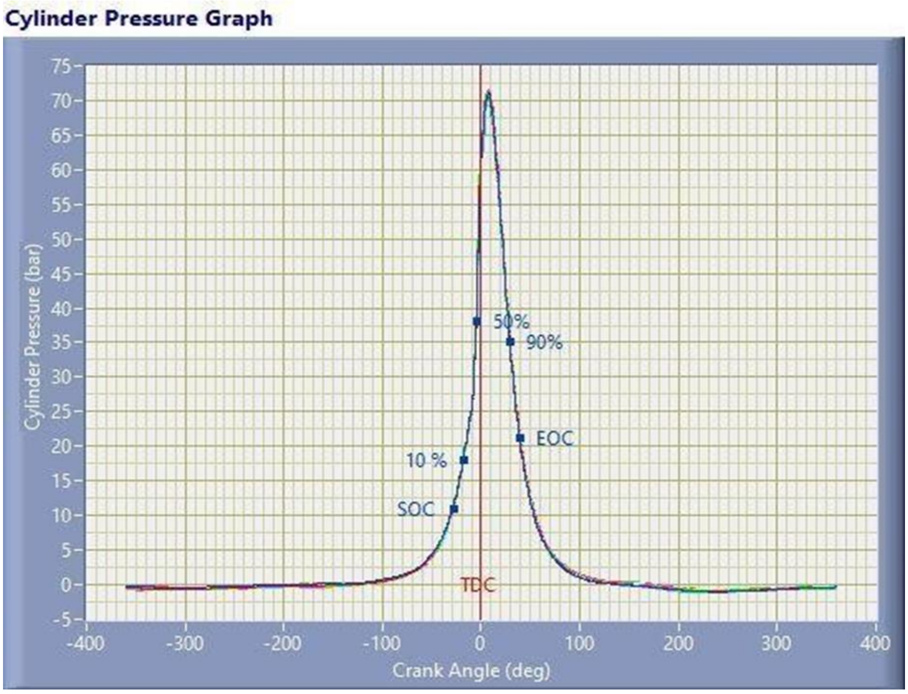


Figure 7. Graphical representation of crank angle vs cylinder pressure for Supercharger

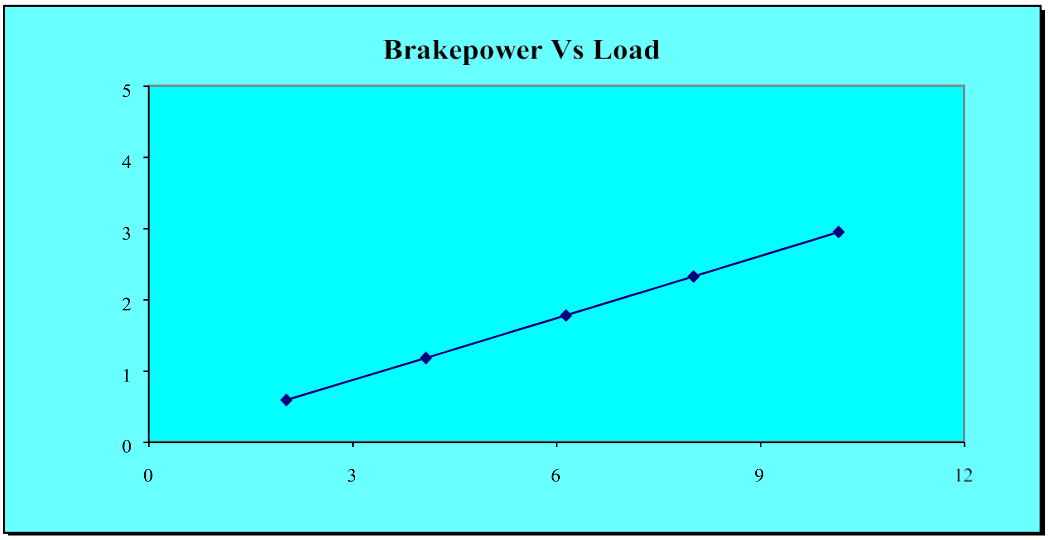
3.3 Run 3 with Turbocharger

Table 7. Observations for turbocharger

Engine Speed (Rpm)	Load (Kg)	Mano. defle. (mm)	Fuel flow (cc/min)	Engine cooling water (Lph)	Calo. water (Lph)	T1/T3 (Engine water in) DegC	T2 (Engine water out) DegC	T4 (Calo. water out) DegC	T5 (Exhaust in) DegC	T6 (Exhaust out) DegC	Second Fuel mass flow rate (ms)	Second Fuel Mass Flow rate (kg/hr)
1543	2.41	82	13	200	100	33.388	44.994	34.599	136.587	127.786	1.5	0.25
1531	4.21	82	14	200	100	33.407	46.026	35.05	150.088	140.445	1.5	0.2
1520	6.41	82	19	200	100	33.432	47.392	35.449	166.027	155.184	1.5	0.2
1509	8.26	82	19	200	100	33.462	49.587	36.324	190.158	176.523	1.5	0.2
1498	10.07	82	23	200	100	33.526	51.752	37.451	222.897	205.495	1.5	0.2
1482	12.31	82	24	200	100	33.563	51.632	38.204	235.635	216.937	1.5	0.2

Table 8. Result for turbocharger

Brake power (Kw)	BMEP (Bar)	Torque (N.m)	BSFC kg/kwH	BTh.eff. (%)	Air flow (kg/hr)	Fuel flow (kg/hr)	Vol eff (%)	A/F Ratio	Heat Equi.of work (%)	Heat by cool water(%)	Heat by exhaust (%)	Radiation (%)
0.7	0.83	4.4	1.2	6.96	29.3	0.65	82.5	34.6	0.7	26.6	27.1	45.6
1.2	1.45	7.6	0.7	11.40	29.3	0.70	83.1	32.7	1.2	27.3	29.0	42.5
1.9	2.21	11.6	0.6	13.58	29.3	0.95	83.7	25.6	1.9	23.8	26.1	48.3
2.4	2.85	15	0.5	17.35	29.3	0.95	84.3	25.6	2.4	27.5	30.7	39.5
2.9	3.47	18.3	0.5	17.94	29.3	1.15	84.9	21.8	2.9	26.5	31.8	38.8
3.5	4.24	22.3	0.4	20.95	29.3	1.20	85.8	21.0	3.5	25.4	32.7	38.4



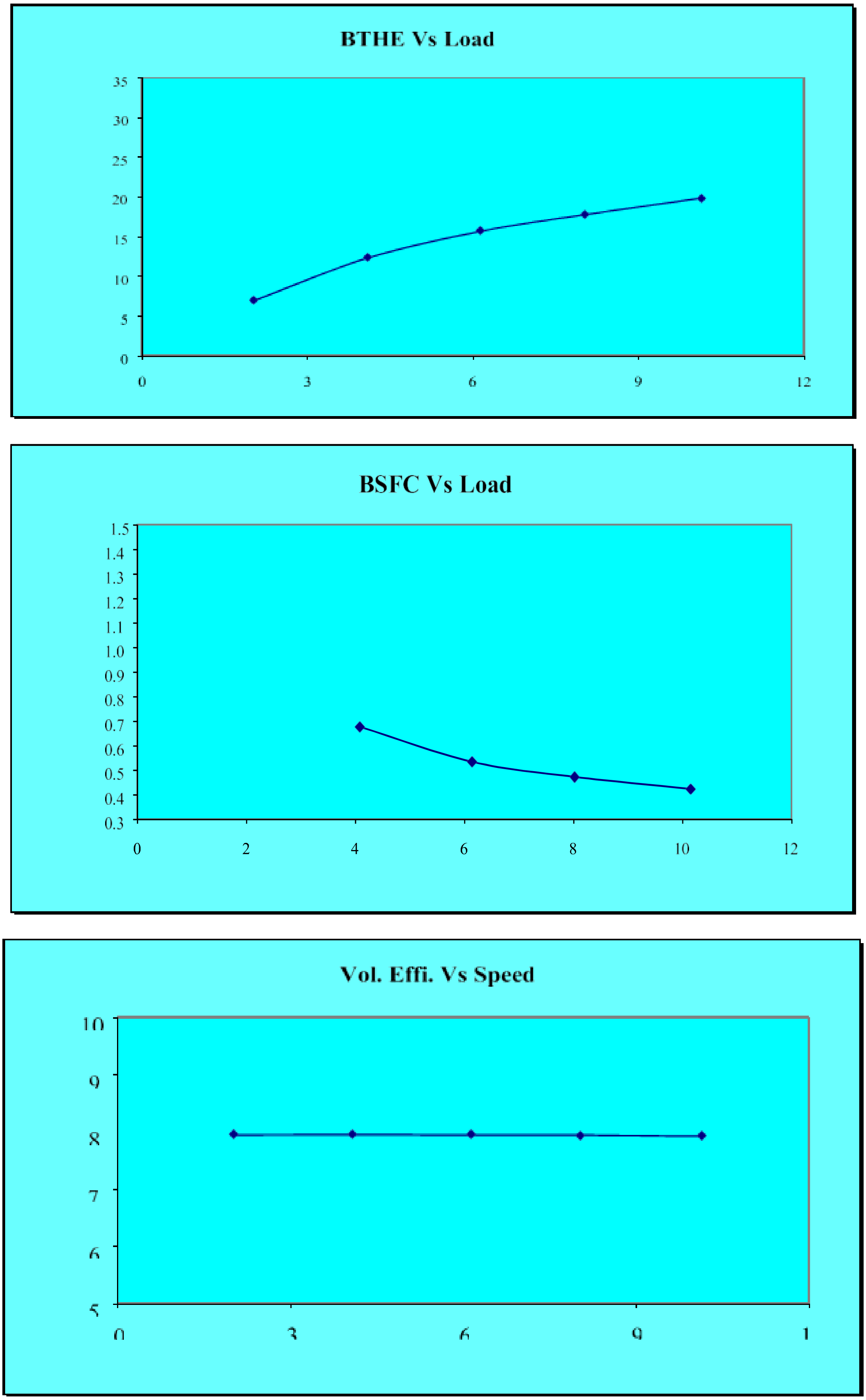


Figure 8. Graphical representation of brake power, BTHE, BSFC vs Load and Volumetric efficiency vs speed for turbocharger

Table 9. Emission Data of turbocharger

Load	CO	HC	CO_2	O_2	NO
2	0.07	12	1.70	19.17	294
4	0.05	13	2.10	18.87	502
6	0.04	12	2	18.96	494
8	0.05	17	2.80	18.27	606
10	0.06	20	2.80	18.13	576
12	0.14	27	3.10	17.87	510

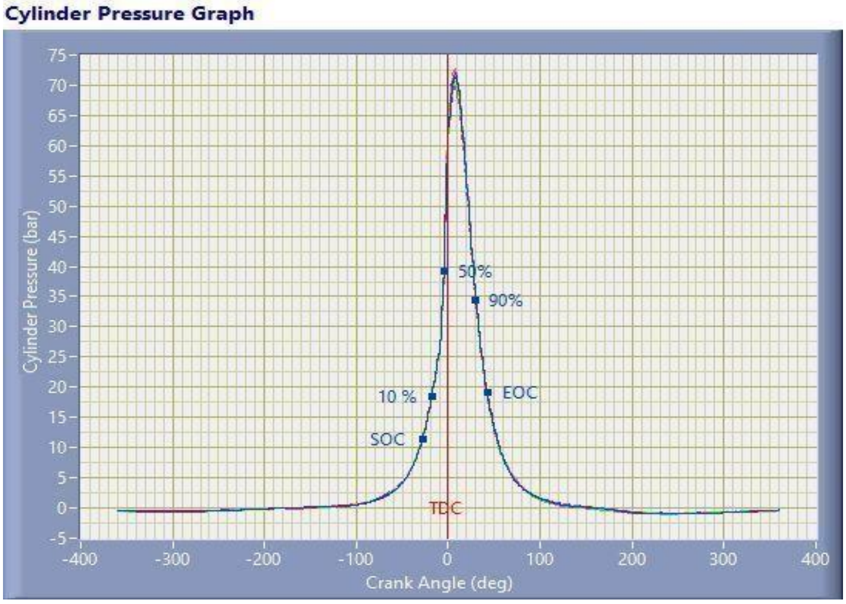


Figure 9. Graphical representation of crank angle vs cylinder pressure for turbocharger

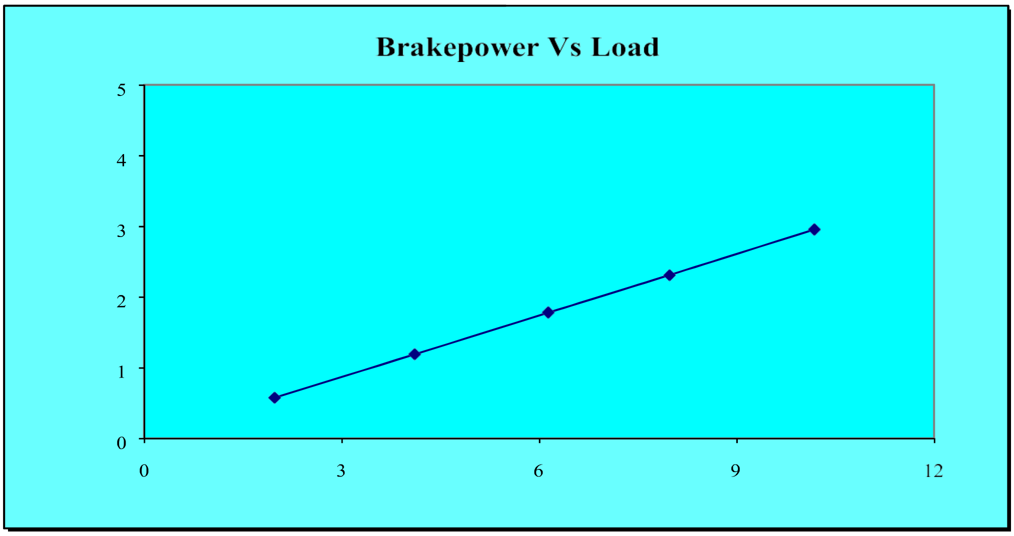
3.4 Run 4 with Super -Turbocharger

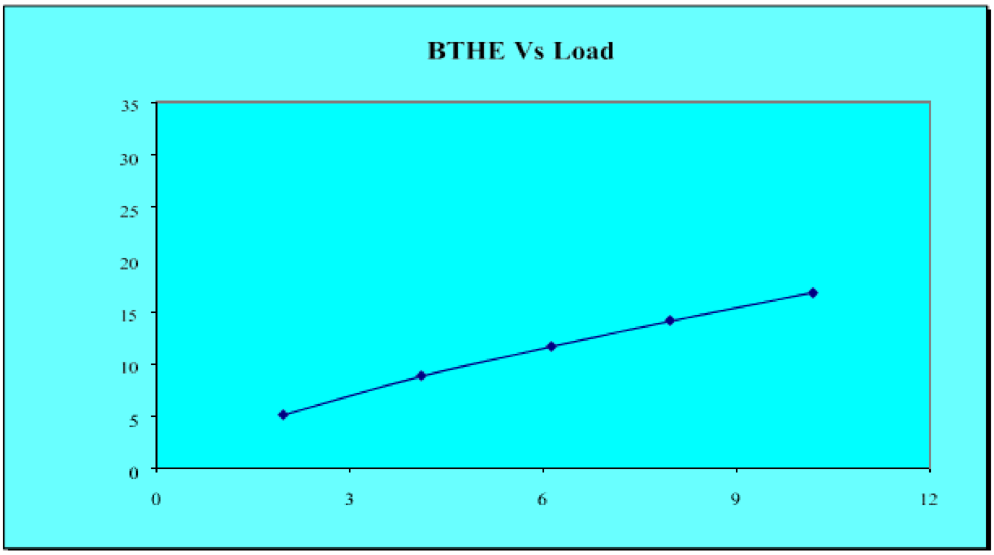
Table 10. Observations for super-turbocharger

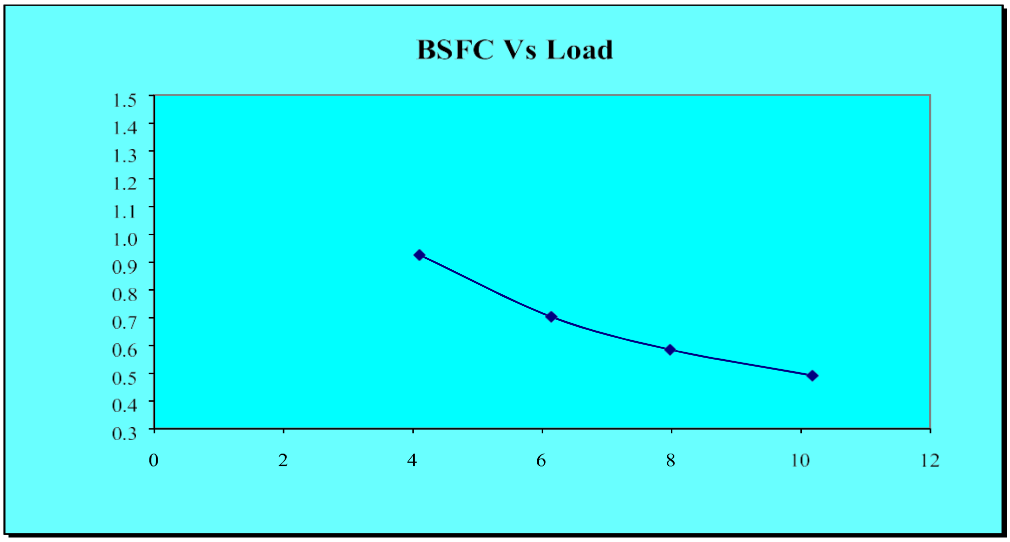
Engine Speed (Rpm)	Load (Kg)	Mano. defle. (mm)	Fuel flow (cc/min)	Engine cooling water (Lph)	Calo. water (Lph)	T1/T3 (Engine water in) DegC	T2 (Engine water out) DegC	T4 (Calo. water out) DegC	T5 (Exhaust in) DegC	T6 (Exhaust out) DegC	Second Fuel mass flow rate (ms)	Second Fuel Mass Flow rate (kg/hr)
1556	2.093	82	13	200	100	33.064	44.359	34.707	147.474	141.04	0	0
1553	4.112	82	15	200	100	33.169	46.453	35.712	175.189	166.391	0	0
1521	6.091	82	17	200	100	33.109	43.774	33.734	156.371	147.481	0	0
s1511	8.209	82	21	200	100	33.412	37.554	32.176	98.463	92.032	0	0
1504	10.03	82	22	200	100	33.478	46.363	34.387	170.368	160.277	0	0
1488	12.015	82	23	200	100	33.552	50.58	36.326	219.674	201.562	0	0

Table 11. Results for super-turbocharger

Brake power (Kw)	BMEP (Bar)	Torque (N.m)	BSFC kg/kwH	BTh.eff. (%)	Air flow (kg/hr)	Fuel flow (kg/hr)	Vol eff (%)	A/F Ratio	Heat Equi.of work (%)	Heat by cool water(%)	Heat by exhaust (%)	Radiation (%)
0.6	0.72	3.8	1.0	8.20	29.3	0.65	81.8	45.3	0.6	34.8	16.1	48.5
1.2	1.42	7.5	0.6	13.75	29.3	0.75	83.0	39.3	1.2	35.4	17.3	46.0
1.8	2.10	11.1	0.5	17.83	29.3	0.85	83.6	34.7	1.8	25.1	13.3	59.8
2.4	2.83	14.9	0.4	19.32	29.3	1.05	84.2	28.1	2.4	7.9	5.9	83.9
2.9	3.46	18.2	0.4	22.43	29.3	1.10	84.6	26.8	2.9	23.4	11.5	62.1
3.4	4.14	21.8	0.3	25.43	29.3	1.15	86.5	25.6	3.4	29.6	14.9	52.0







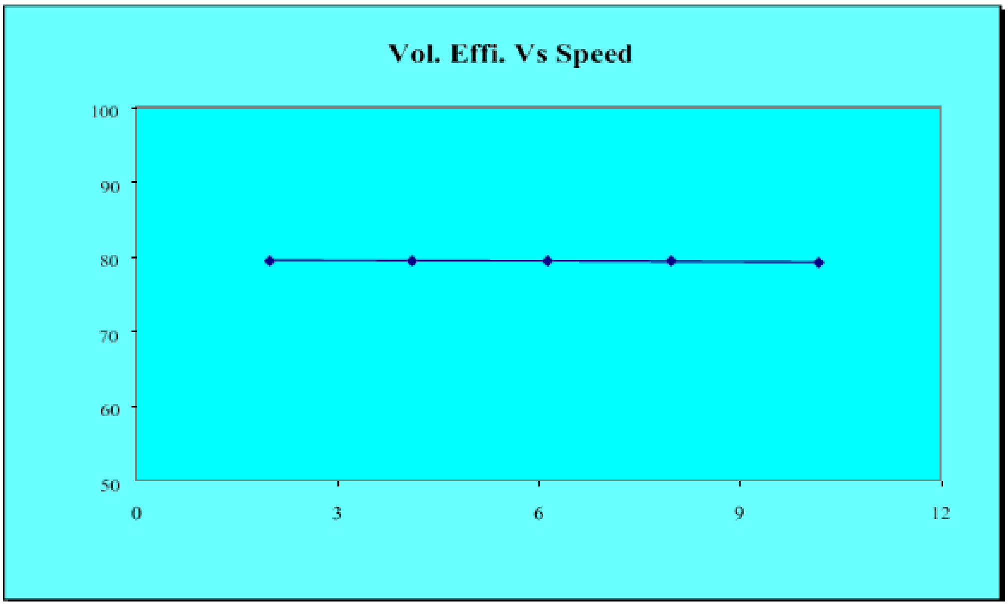


Figure 10. Graphical representation of brake power, BTHE, BSFC vs Load and Volumetric efficiency vs speed for super-turbocharger

Table 12. Emission Data of super-turbocharger

Load	CO	HC	CO_2	O_2	NO
2	0.1	23	3.30	17.60	625
4	0.09	21	3.80	17.27	817
6	0.08	30	4.90	16.27	1075
8	0.09	27	4.6	16.60	909
10	0.18	43	5.90	15.40	1053
12	0.48	47	5.10	15.91	714

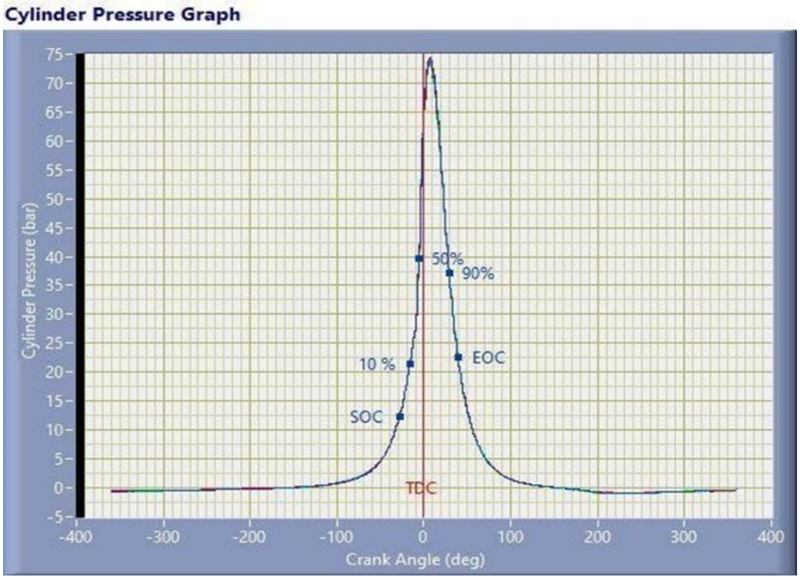


Figure 11. Graphical representation of crank angle vs cylinder pressure for turbocharger

4. Comparative Analysis

Based on the experimental analysis carried out in the engine with conventionally aspirated, supercharger, turbocharger and super-turbocharger, the comparative results for brake power, BTHE, and volumetric efficiency is plotted and shown in figure 12, figure 13 and figure 14.

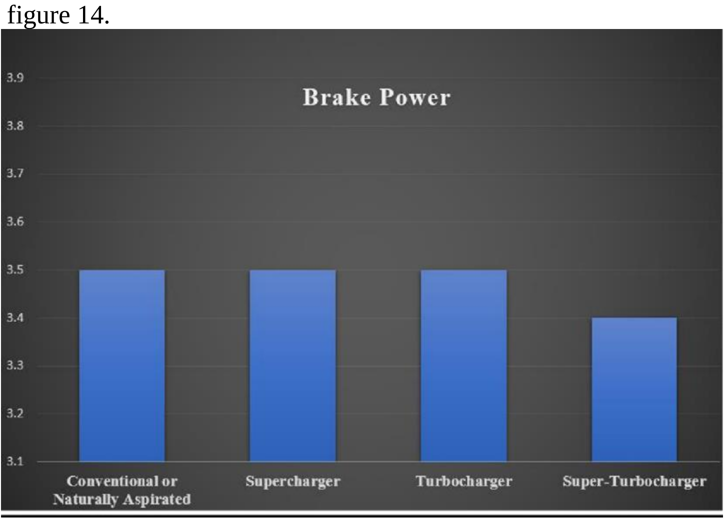


Figure 12. Comparative analysis for brake power

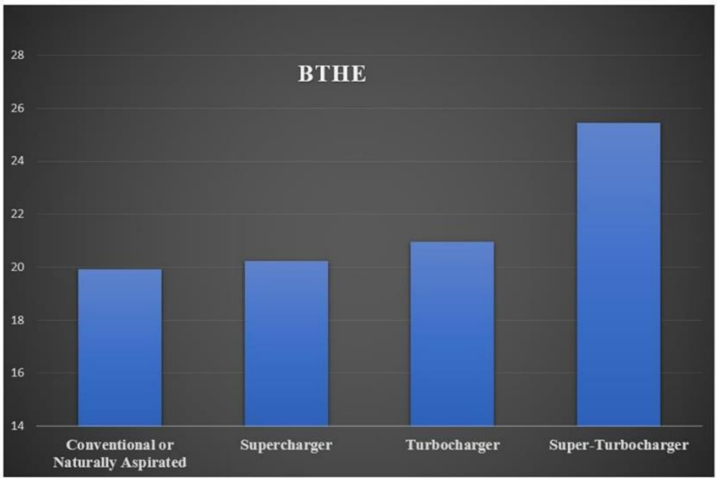


Figure 13. Comparative analysis for BTHE

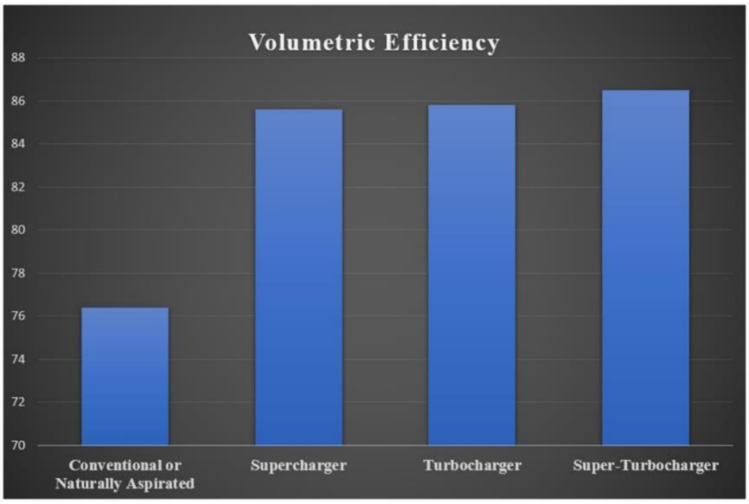


Figure 14. Comparative analysis for volumetric efficiency

5. Conclusion

Following conclusion can be drawn from observation of results: -

- With the usage of super-turbocharged technology, turbolag has been eliminated.
- According to the results and evaluation, the volumetric efficiency of the engine has increased after employing the turbocharger and supercharger.
- Engine performance and power output have grown as volumetric efficiency has increased.
- When we used a turbocharger in the system, we saw a reduction in NOx, CO2, HC, and CO emissions.
- The introduction of a supercharger improved performance while lowering emissions due to lean combustion.

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