



BACHELOR THESIS - ME1841038

# THE EFFECT OF PISTON CROWN MODIFICATION TO NOISE AND VIBRATION ON FOUR STROKE ONE CYLINDER DIESEL ENGINE USING FUEL BIODIESEL B30 BASED ON SIMULATION.

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Surabaya  
2020

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**PENGARUH TINGKAT KEBISINGAN DAN GETARAN  
TERHADAP MODIFIKASI MAHKOTA TORAK PADA ME-  
SIN DIESEL SATU SILINDER EMPAT LANGKAH  
MENGUNAKAN BAHAN BAKAR BIODIESEL B30  
MENGUNAKAN SIMULASI.**

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## APPROVAL FORM

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#### *BACHELOR THESIS*

Submitted in fulfilment of requirement for the degree of Bachelor Engineering

at

*Marine Power Plant* (MPP) Laboratory  
Bachelor Program of Marine Engineering Faculty of Marine Technology  
Sepuluh Nopember Institute of Technology

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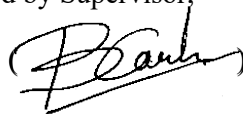
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## DECLARATION OF HONOR

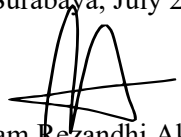
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Departement : Double Degree Marine Engineering

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Surabaya, July 2020



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## **ABSTRACT**

The piston is one of the important parts in the combustion process in a diesel engine, the piston part consists of two namely the piston head and connecting rod, where the piston head is divided again into three parts, namely the piston crown, piston rings, and piston pins. This thesis wants to prove which is more effective in modifying the TCC piston crown shape on a four-stroke one-cylinder diesel engine in terms of noise and vibration levels. To measure noise and vibration levels, several experiments were carried out. One way is to use an application that can help make measurement easier is to use the Simulation. The Simulation can measure the level of noise and vibration level by using the tools in that application the same as the original. The piston area is very influential on the combustion process, with the greater piston area, the resulting explosion is greater which results in and produces a high pressure also it is directly proportional to the level of noise and vibration in the diesel engine. After everything is measured, then we compare it with the engine's performance and give maximum results between the level of noise, vibration with engine performance. The result is using a piston case 4 (+1) which has a larger area experiencing the highest noise level using B30 Diesel Fuel or High Speed Diesel (HSD) Fuel. Under load conditions, with a 50% load the noise level on piston +1 (Case 4) experiences the highest noise level using B30 Diesel Fuel or High Speed Diesel (HSD) Fuel. In the diesel engine vibration analysis, the highest vibration level occurs at the RPM of 2200 using B30 Diesel Fuel or High Speed Diesel (HSD) Fuel, and the lowest vibration level occurs at RPM 1600 using B30 Diesel Fuel or High Speed Diesel (HSD) Fuel.

Keyword: Piston TCC, Noise, Vibration

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# **PENGARUH TINGKAT KEBISINGAN DAN GETARAN TERHADAP MODIFIKASI MAHKOTA TORAK PADA MESIN DIESEL SATU SILINDER EMPAT LANGKAH MENGGUNAKAN BAHAN BAKAR BI-ODIESEL B30 MENGGUNAKAN SIMULASI.**

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## **ABSTRAK**

Torak adalah salah satu bagian penting dalam proses pembakaran pada mesin diesel, bagian piston terdiri dari dua yaitu *Piston Head* dan *Connecting Rod*, dimana kepala torak dibagi lagi menjadi tiga bagian, yaitu mahkota torak, ring torak, dan pin torak. Tugas akhir ini ingin membuktikan mana yang lebih efektif dalam memodifikasi bentuk mahkota torak TCC pada mesin diesel satu silinder empat langkah dalam mengukur tingkat kebisingan dan getaran. Untuk mengukur tingkat kebisingan dan getaran, beberapa percobaan akan dilakukan. Salah satu caranya adalah dengan menggunakan *software* yang bisa mempermudah pengukuran dengan menggunakan simulasi. Dalam simulasi dapat mengukur tingkat kebisingan dan getaran dengan menggunakan alat-alat dalam aplikasi yang sama seperti aslinya. Luasan torak sangat berpengaruh terhadap proses pembakaran, dengan semakin besarnya luasan torak maka menghasilkan ledakan semakin besar yang mengakibatkan dan menghasilkan tekanan yang tinggi pula hal itu berbanding lurus dengan tingkat kebisingan dan getaran pada mesin diesel tersebut. Setelah semuanya diukur, maka penulis membandingkannya dengan performa mesin dan memberikan hasil maksimal antara tingkat kebisingan, getaran dengan kinerja mesin. Hasilnya dengan menggunakan torak *case 4(+1)* yang memiliki luasan lebih besar mengalami tingkat kebisingan paling tinggi menggunakan bahan bakar B30 ataupun HSD. Pada kondisi beban, dengan beban 50% tingkat kebisingan pada torak *case 4(+1)* mengalami tingkat kebisingan paling tinggi menggunakan bahan bakar B30 ataupun HSD. Pada Analisa getaran mesin diesel, tingkat getaran paling tinggi terjadi pada RPM yaitu 2200 menggunakan bahan bakar B30 ataupun HSD, dan tingkat getaran terendah terjadi pada RPM 1600 menggunakan bahan bakar B30 maupun *High Speed Diesel* (HSD).

Kata Kunci: Torak TCC, Kebisingan, Getaran

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# CHAPTER I

## INTRODUCTION

### 1.1. Background.

Technological developments in the maritime industry currently show significant graphs and continue to improve renewable methods. Many modifications on the inside of the diesel motor can increase new ideas for a diesel engine to go forward. One of the important things to look at is the piston set, which has a lot of variation. The shape of the piston is very affected in many aspects, such as the level of noise and vibration in the piston which will affect the performance of the diesel engine itself.

One of the main problems with diesel engines is the noise generated from the combustion process. Noise is an unwanted sound or sound that can interfere with the health and comfort of the environment expressed in decibels (dB). So that the noise from the combustion process that occurs should be in accordance with the specified limits namely existing international regulations from IMO, ILO, ISO 2923: 1996. (Annur, 2019)

Vibration in the engine can be caused by one of the compression pressure factors in the combustion chamber. Due to combustion in the combustion chamber, there will be a very high pressure increase in a very short time. If this happens naturally. As a result of the movement in the engine (piston, crankshaft, connecting rod and others) coupled with the presence of air pressure in the combustion chamber, it will cause excitation forces (Marviansyah, 1998).

Based on the high pass filtering technique, the noise and cylinder pressure signal is directly proportional to the noise itself. (Narayan, 2015). For the level of vibration, changing the crown will change the compression ratio which gives rise to combustion.

Diesel engines have a high compression ratio, because diesel engines have high pressure and temperature to burn diesel fuel completely. In addition, the quality of diesel fuel as seen from the cetane number affects the combustion process. By using a modified piston shape will be able to reduce and increase the level of noise and vibration in the diesel engine.

Therefore, this thesis research will examine the effect of standard piston crown shapes with modified on noise and vibration levels on Yanmar TF85 direct engine with biodiesel fuel B30.

### 1.2. Research Problem.

In conducting research, there are several problems statement, so that research can be conducted in a directed and appropriate manner in the background, namely:

1. How does the modification piston of the High Speed Diesel (HSD) fuel and Biodiesel B30 fuel affect the noise level of the diesel engine?

2. How does the modification piston of the High Speed Diesel (HSD) fuel and Biodiesel B30 fuel affect on the vibration of the diesel engine?

### **1.3. Problem Limitation.**

For ease of study, preliminary design and analysis, the limitation within this research stated as follows:

1. The fuel used is biodiesel B30.
2. Research was conducted using software.
3. Not analyze noise and vibrations due to knocking.
4. Does not calculate performance engine.
5. Using Yanmar TF85 standard Diesel Engine Specification.

### **1.4. Research Objective.**

With the above problem statement, the research objective of the research can be determined, namely:

1. To analyze piston modifications on HSD and Biodiesel B30 fuels affecting diesel engine noise levels.
2. To analyze piston modifications on HSD and B30 fuel impact on diesel engine vibrations.

### **1.5. Research Benefits.**

The benefit that can be obtained from this final research research is to find out the results of the comparison of noise level and vibration between the modification of the normal crown piston shape and concave piston crown, which later is expected to consider choosing the shape of the piston crown that has noise and vibration.

## CHAPTER II

### LITERATURE STUDY

#### 2.1. Definition of Diesel Engine.

Diesel motors are a type of internal combustion engines, where the combustion process is in the cylinder. In figure 2.1 is an example of a diesel engine. Diesel engines use liquid fuel that is injected into the combustion chamber of the motor cylinder by injecting using an injection pump. Fuel enters the cylinder or combustion chamber in a finer form by using a nozzle and entering it into the cylinder at the intake step is pure air. In the compression step, this pure air is compressed to produce enough heat to ignite the fuel injected into the combustion chamber of the motor. Diesel engines are often called compression ignition engines.

According to the Marine Engineering, Faculty of Marine, Sepuluh Nopember Institute of Technology Surabaya Team, diesel engine components consist of a cylinder head, combustion chamber, piston, crank pin, piston ring, connecting rod, crankshaft, Bearing journal, the successor wheel, the valve, Timing gear, Shaft nook (camshaft), Regulators (governor). Fuel is injected by the injection pump and atomized with a nozzle. Fuel is granted to facilitate the mixing of fuel and air.



Figure 2. 1 Diesel Engine  
Source: (Matheus M. Dwinanto1, 2019)

In a diesel engine, the air is compressed by a piston and fuel is injected into the room towards the end of the compression stroke. At this point, the temperature is high enough to cause the fuel to ignite spontaneously. Usually, the time interval between starting fuel injection and igniting the first part of the mixture is 1 ms, this represents 12 ° crankshaft rotation for engines running at 2,000 rpm. During this time the fuel must enter the cylinder, break down into smaller droplets, evaporate and join the air to form a mixture that is within the flammable boundary and is at a temperature

high enough for the ignition itself. Because of this, the process of mixing between air and fuel is very important for combustion this mixing depends on the characteristics of the fuel spray (Taufik, 2015).

## **2.2. Biodiesel.**

Biodiesel is an alternative liquid fuel that can substantially replace conventional diesel fuel and reduce exhaust gas pollution and motor maintenance costs. This renewable fuel can be produced from a variety of materials containing fatty acids such as animal fats, non-edible oils (castor oil, cotton seed oil, bintaro seed oil and rubber seed oil), cooking oil and cooking oil and algae (Ogunwole, 2012), Biodiesel is usually produced from vegetable oils or animal fats with short chain alcohols such as methanol or ethanol. Biodiesel has a higher oxygen content than diesel oil and its use in diesel engines has shown significant reductions in particulate matter, carbon monoxide, sulfur, polyaromatics, hydrocarbons, smoke and noise. In addition, the combustion of vegetable oil-based fuels does not cause CO<sub>2</sub> emissions because these fuels are made from agricultural materials produced through carbon fixation photosynthesis (Sukjit, 2013).

The biodiesel standard is not determined from the basic ingredients of oil used but is more emphasized on the characteristics of biodiesel produced. Some parameters used in determining the quality of biodiesel include density, viscosity, cetane number, flash point, fog point, carbon residue, water and sediment, content phosphorus, acid reflux, free glycerol levels, total glycerol levels, iodine numbers and others. The characteristics of biodiesel which are the reference standard in Indonesia are based on Standar Nasional Indonesia SNI 7182:2015 explained in the table.

Table 2. 1 Characteristic of Biodiesel According to SNI.

Source: (Anon., n.d.)

	Test Parameters	Unit, min/max	Requirements
1.	Density on 40 °c	kg/m <sup>3</sup>	850 - 890
2.	Kinetic Viscosity at 40 <sup>0</sup> C	mm <sup>2</sup> /s (CSO)	2.3-6.0
3	Equivalent Numbers	min	51
4.	Flash point	°c, min	100
5.	Pour point	°c, max	18
6.	Carbon residues in the original sample; or deep 1094 dregs destillation	%-mass, max	0,05
7.	Water and Sediment	%-volume, max	0,05
8.	Destillation temperature 90%	°c, max	360
9.	Sulfurized ash	%-mass, mass	0,02
10.	Sulfur	mg/kg, max	50
11.	Phosphor	mg/kg, max	4
12.	Acid number	mg-KOH/g, max	
13.	Glycerol free	%-mass, max	0,02
14	Glycerol total	%-mass, max	0,24
15.	Alkyl ester levels	%-mass, min	96,5
16.	Iodine number	%-g-12/100g, maks	115
17.	Oxidation stability, indicative period of the raciamat method or the petroxy method	Minute	480 36

### 2.3. Combustion Process.

Combustion is a process of rapid chemical reaction between fuel fluid and air. This process produces an explosion in the combustion chamber. In an internal combustion engine, there are several combustion periods or stages for different engines.

In the Compression Ignition Engine, in the compression step, only the air has been compressed at very high pressure and temperature. The compression ratio used is in the range of 12 to 120.

The temperature of the air becomes higher than the temperature of High Speed Diesel (HSD) Fuel in the CI (Compression Ignition) engine. Then High Speed Diesel (HSD) Fuel is injected in the combustion chamber under very high pressure around 120 to 210 bar. Fuel temperature is around 20 to 35 degrees before Top Dead Point (TDC).

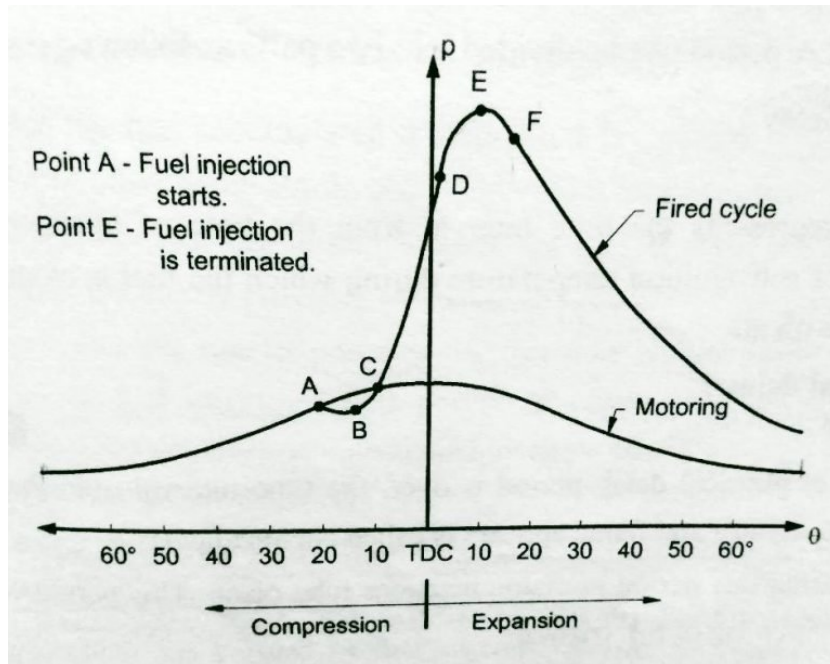


Figure 2. 2 Combustion Process Ignition Engine  
Source: (Anon., n.d.)

There are 4 different combustion stages as follows:

1. Ignition Delay Period

At this first stage of combustion in the CI engine, the fuel from the injection system sprayed in the combustion chamber in the form of a jet. Due to atomization and vaporization, this fuel disintegrates at the core which is surrounded by a spray of air and fuel particles.

In this vaporization process, the fuel gets heat from the compressed and hot surrounding air. It causes some pressure drop in the cylinder. It can see at pressure drop (curve A-B) in the above figure 2.2.

2. Period of Uncontrolled Combustion

This is the second stage of combustion in the CI engine. After the above-mentioned delay period is over, the air and fuel mixture will auto-ignite as they have achieved their self-ignition temperature.

The mixture of air and fuel in CI engines is heterogeneous unlike homogeneous in the SI engines. Due to this heterogeneous mixture, flames appear at more than one location where the concentration of the mixture is high.

During this stage, you can't control the amount of fuel burning, that's why this period is called a period of uncontrolled combustion. This period is represented by the curve C-D in the above figure 2.2.

3. Period of Controlled Combustion

When the accumulated fuel during the delay period completely burned in the period uncontrolled combustion, the temperature and pressure of the mixture in the cylinder are so high that new injected fuel from the nozzle will



burn rapidly due to the presence of sufficient oxygen in the combustion chamber.

That's the reason we can control the rise of pressure into the cylinder by controlling the fuel injection rate. Therefore, this period of combustion is called a period of controlled combustion.

#### 4. After Burning

This is the last stage out of the four stages of combustion in CI engine. Naturally, the combustion process is completed at the point when the maximum pressure is obtained in the combustion chamber at point E as shown in the figure 2.2.

Combustion of fuel in the combustion chamber continues during the expansion step. Although the fuel injection process has ended, the combustion process is still ongoing. If the continued combustion period is too long, it will cause the exhaust gas temperature to be high and will cause the heat efficiency to decrease.

### 2.3.1. Parameters that Affect on Combustion Process.

Diesel engine is a combustion engine using compression. The quality of the diesel fuel injected affects the combustion process occurring in the combustion chamber which will affect the pressure and temperature rise in the combustion chamber. Quality The diesel fuel used in diesel engines must have its own flammability or self-ignition when injected in compressed air. The lower the self-ignition point of a diesel fuel will result in an increase in the combustion performance of a diesel engine which means an increase in the performance of a diesel engine. The quality of fuel in a diesel engine can be seen from the cetane number. The cetane number shows the ignition quality in the combustion chamber. The higher the cetane number the faster the ignition delay will reduce the possibility of knocking that affects vibration and noise. The average diesel engine requires fuel with a cetane number between 40-45. When using numbers that do not match the engine design will cause the following problems:

1. If it is too high, the effect of excessive heat on the engine can damage the engine components.
2. If it is too low, knocking symptoms arise due to incomplete combustion. (Coppenberg, 2017).

To produce good combustion. HSD fuel has the following conditions:

1. Flammable.
2. Not easy to experience freezing.
3. Has anti-knocking properties and makes the engine work softly.
4. Has sufficient thickness to be sprayed into the engine by an injector.
5. Remain stable and do not experience changes in structure, shape and color in the storage process.
6. Has a low sulfur content so as not to adversely affect the engine and reduce pollution.

### 2.3.2. Combustion Process that Affect on Noise and Vibration.

Diesel engines or often called compression ignition engines. So the combustion process that occurs in the engine cylinder occurs due to a mixture of compressed air with high temperature and pressure with diesel fuel. This mixing process causes a strong explosion, as a result of the explosion produces high noise and vibration.

The combustion process creates a force due to the rapid pressure of the rate of heat arising from combustion. Due to the proficiency level, the vibration and noise caused by the structure due to the large force acting on the motor will cause a beat or friction that causes vibration and noise.

Increasing the speed of the engine will increase fuel requirements. This happens because with increasing speed requires greater energy. Increasing the amount of fuel that enters the cylinder will increase ignition delay. The combustion process which has a long ignition delay causes the pressure in the cylinder to increase.

### 2.3.3. The Effect of Piston Modification on The Combustion Process.

Fuel in the engine serves to create combustion that can result in expansion of power in the combustion chamber. Expansion of power in the combustion chamber will result in the piston being pushed from the top dead center (TDC) to the bottom dead center (BDC) In choosing fuel, it must be adjusted to the characteristics of the engine. Here are some things to consider when choosing fuel (Harrington, 1992).

1. Viscosity.

Viscosity is the level of viscosity of a fluid. Viscosity on the fuel will affect the ease of injection of the fuel. The smaller the viscosity value the fuel has, the easier it is for fuel to flow.

2. Density.

Density or can be called specific gravity is defined by a comparison between weight and volume so that it has units of kg / m. Temperature change and he pressure experienced by the fuel can affect its specific gravity. The density value will increase if the temperature of the fuel decreases.

3. Heating Value.

Heating value will affect fuel consumption. Where the higher the heating value, the less fuel is needed to get the same power.

4. Ignition Quality.

The quality of the ignition can be done by modifying the injection time of the fuel, the temperature in the combustion chamber, the temperature of the fuel, and the opening and closing time of the valve mechanism. Ignition quality will affect the engine performance and emission levels that will be generated.

5. Carbon residue.

Fuels with high carbon content can have an impact on the amount of deposition resulting from combustion.

6. Sediment and Ash Content.

Solid particles such as ash can cause wear on some engine components, for example in fuel injection pumps, injectors, cylinder liners, piston rings, valve

- systems, and even can accelerate component wear on turbocharger systems. To reduce sediment and ash content, one of them is by purrifying fuel.
7. Sulfur Content.  
Sulfur content is one of the dangerous ingredients in fuel. That is because sulfur is acidic which can cause corrosion to engine components.
  8. Flash Point.  
The flash point is the lowest temperature when it can evaporate to form a liquid that can ignite fire in the air. the flash point on diesel fuel is influenced by the value of cethane contained.
  9. Pour Point.  
Pour point is the temperature of the fuel can be poured after experiencing freezing.

## 2.4. Definition of Piston.

The piston in Indonesian also known as “*Torak*”. “*Torak*” is a component of an internal combustion engine that functions as an inlet air suppressor and combustion receptor in the cylinder liner combustion chamber. This engine component is held by the piston handlebars which get the up and down motion of the crankshaft rotating motion. The shape of the piston parts can be seen as follows (Abdillah, 2010):

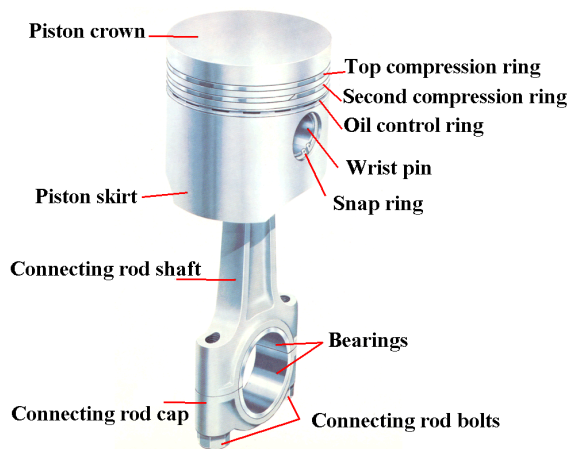


Figure 2. 3 The Part of Piston  
Source: (Anon., n.d.)

## 2.5. Type of Piston.

Piston has some form, especially for the concave shape has three forms, namely: (PRABHAKARA RAO GANJI, 2018).

### 2.5.1. HCC (Hemispherical Combustion Chamber).

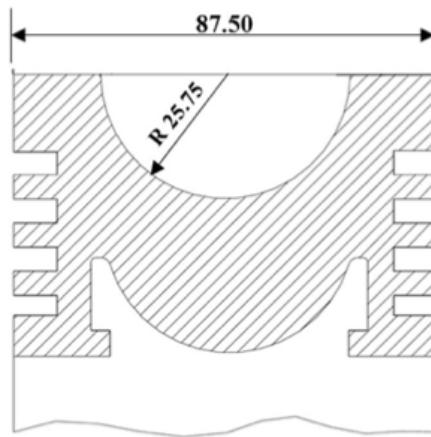


Figure 2. 4 HCC Piston Crown  
Source: (PRABHAKARA RAO GANJI\*, 2018)

On this piston, the surface also gives a small squish. But squish can be expected to be done by giving some variation in the ratio of depth to surface diameter (Gosh, 2016).

### 2.5.2. TCC (Toroidal Combustion Chamber).

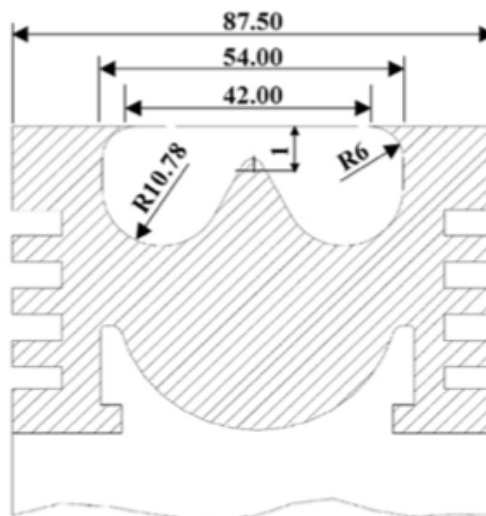


Figure 2. 5 TCC Piston Crown  
Source: (PRABHAKARA RAO GANJI\*, 2018)

In this piston, the resulting combustion chamber can increase its specific fuel consumption up to 35% and can reduce the resulting pollutant gases such as NO<sub>x</sub>, CO, and HC due to the geometry of the resulting combustion chamber giving the opportunity for fuel injection to be fully atomized and combusted (Soeharto, 2012).

### 2.5.3. SCC (Shallow-depth Combustion Chamber).

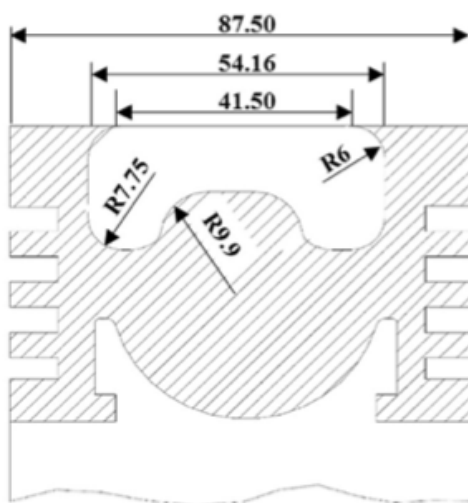


Figure 2. 6 SCC Piston Crown  
Source: (PRABHAKARA RAO GANJI\*, 2018)

The piston has a shallow surface and is generally used on large, low-speed engines. But because it has a very large cavity, then squish can be ignored. Squish is a movement that occurs when a piston approaches TDC (Gosh, 2016)

## 2.6. Definition of Noise.

### 2.6.1. Basic Concept of Noise.

Noise is an unwanted sound from a business or activity at a certain level and time that can cause human health problems and environmental comfort. The biggest source of noise on the ship is in the engine room. Noise with a high level of intensity that is not realized causing serious impacts for the crew and discomfort for each passenger. That way there is a need for noise reduction to obtain a healthy environment.

The mechanism of sound energy propagation and propagation is as follows:

#### 1. Structure Borne Noise

Is the noise produced by the propagation of the structural vibration of the components of a system. The vibrating structure or part will radiate or propagate acoustic energy or sound in the form of longitudinal waves. The energy source is

obtained from the damage or imbalance of parts and the back and forth movement of a system.

## 2. Liquid Borne Noise

Noise caused by fluctuations in fluid pressure propagation, resulting in fluid column vibrations, vortex flow, sound flow, and cavitation.

## 3. Airborne Noise

The noise that propagates through pressure fluctuations that arise in the air. Noise propagation through two media like this will be interrelated. Where if something happens, sound propagation originating from the structure, then the vibration of the structure will be able to vibrate the air around it. At the same time, the vibrating air will vibrate the structure again. So, the noise that occurs can be changed from one form to another sustainable form (Odio Setyawan, 2015).

Noise is an unwanted sound or sound that can interfere with the health and comfort of the environment expressed in disables (dB). Disability is the smallest unit of noise level that can be felt by humans. This noise is always avoided by humans because it can cause work disorders and can reduce concentration at work. Noise in addition to having a bad impact on humans, noise can also have a negative impact on the surrounding environment. Noise level values are: (30 dB: weak whispering sound); (85 dB: safe limit, you should use ear protectors); (90 dB: can damage hearing within 8 hours, for example: the sound of lawn mowers, the sound of trucks on traffic jams); (100 dB: damage to hearing within 2 hours, for example: the sound of chainsaws, sound over the telephone); (105 dB: damage hearing within 1 hour, for example: the sound of a helicopter, the sound of a stone crusher); (115 dB: damage to hearing within 15 minutes, for example: baby crying, boisterous in a soccer stadium); (120 dB: damage hearing within 7.5 minutes, for example: rock concert music); (125 dB: pain threshold in the inner ear, for example: sound of firecrackers and sirens); (140 dB: danger of hearing in a short time, for example: gunfire and jet engines) (Annur, 2019).

### 2.6.2. Type of Noise.

The type of noise that is often found according to (P.K, 1996, 58), namely:

1. continuous noise with a wide frequency spectrum (steady-state wideband noise).
2. continuous noise with a narrow frequency spectrum (steady-state narrow band noise).
3. Intermittent Noise.
4. Impact or Impulsive Noise.
5. Repeated Impulsive Noise.

Meanwhile, according to Sihar Tigor Benjamin Tambunan (2005: 7) at work, noise is classified into two types: 1) Steady Noise, which is divided into two, namely: (1) Discrete Frequency Noise, in the form of pure "tones" at various frequencies, (2) Broadband noise, noise that occurs at interrupted frequencies that are more variable (not pure "tone"). 2) Unsteady Noise, which is divided into three: (1) Fluctuating noise, noise that is always changing during a certain period, (2) Intermittent noise, noise that is cut off and its magnitude can vary, for example, traffic noise, (3)

Impulsive noise, produced by sounds of high intensity (deafening) in a relatively short time, the sound of a gun explosion (Hanifa, 2005).

### **2.6.3. The Effect of Noise.**

The influence of noise on the workforce is their perturbations, such as below (RI, 2003):

#### **1. Physiological Disorders**

The physiological disorder is a disorder that initially generated as a result of noise. Discussion or instruction in the work can not be heard clearly, the speaker was forced to shout also need the extra power adds to the noise. Examples of physiological disorders: rising blood pressure, the pulse becomes fast, emotions increase, vascular blood pressure, muscles become tense or the body's metabolism increases. All of these things are a mechanism of the human body's resistance to the dangerous situation spontaneously (Utomo, 2002). Noise can also reduce muscle performance, namely the reduced ability of muscles to contract and relax, the reduced ability of these muscles to indicate muscle fatigue.

#### **2. Psychological Disorder**

The influence of noise on employment is to reduce comfort in the work, disrupt communications, reducing the concentration (Budiono, 2003) can interfere with work and cause errors because even small noise levels can interfere with concentration so that several complaints arise in the form of feelings of slowness and unwillingness to do activities.

When sound waves come from outside will be captured by the auricle then these sound waves pass through the ear canal, where the ear canal will harden the sound with a frequency of around 3000 Hz using resonance. This sound is then received by the eardrum, partly reflected and partly transmitted to the hearing bones and finally moving the stapes that cause waves to occur in the perilymph.

#### **3. Organic Pathological Disorders**

The influence of noise on hearing aids is the most prominent cause of temporary deafness to permanent hearing noise can lower power and deafness due to noise. The main effect of noise on health is damage to the sense of the listener which causes progressive deafness.

In the workplace, the noise level generated by the engine can damage hearing and can also cause health problems (noise level is 80 s / d 90 dBA, or more may harm hearing. Someone who is exposed to noise continuously can cause him to suffer deafness, hearing loss due to noise which is caused by continuous exposure is divided into two namely temporary deafness, namely temporary hearing loss, permanent deafness dam, which is permanent hearing loss or called neuralgia (RI, 2003).

### **2.6.4. Noise Threshold Value.**

Making noise standards and criteria is an attempt to reduce disturbances, such as disturbance during sleep, communication disorders, hearing damage. Some criteria and legal noise standards already apply equally well today, while the other standard is only used as a guide for evaluating the noise on the equipment and the

environment. Noise standards usually consider sound levels. Ordinate limit noise equation is usually considered the measured noise levels of noise limits in residential areas, where the level of noise in the morning low. In residential areas, the noise level limit usually occurs is 55 dB(A) in the morning until the afternoon, while 50 dB at night. The determination of noise standards is based on the duration, noise level, and hearing standard limits. In America and Europe, the criteria for a dangerous noise level while working are 90 dB(A) for 8 working hours.

The following are guidelines for exposure to noise (NAB of Noise) Based on the decision of Menteri Tenaga Kerja Indonesia (Kerja, 1999) about the Threshold Limit Factor Value at Work.

Table 2. 2 Threshold Limit Factor.  
Source: (Kerja, 1999)

Exposure Time per day	Time	Noise intensity in dB(A)
8	Hours	85
4		88
2		91
1		94
30	Minute	97
15		100
7,5		103
3,75		106
0,94		112
28,12	Seconds	115
14,06		118
1,88		109
7,03		121
3,52		124
1,76		127
0,88		130
0,44		133
0,22		136
0,11		139
Should not		140



Table 2. 3 Noise Limits according to ISO- R 1996 Assesment of Noise with Respect to Community Response.

Source: (SOLAS, 2012).

Area / Location	Noise Criteria (dBA)
Residential area (outside the house)	35-45
Rural, Hospital	40-45
Countryside, Rural area	45-55
City area with several industries	50-60
Workshop	55-65
Regional Trade	60-70
Industrial area	35
Nonresidential area (inside the room), large office, seminar room	45
Store, silent restaurant, large restaurant, secretariat room	45-75

According to SOLAS, it is stated that when humans enter a room with a nominal noise level of more than 85 dB (A), they are required to wear hearing protection while in the room with a limit of 110 dB (A).

Table 2. 4 SOLAS Chapter 4 Maximum Acceptable Sound Pressure Level.

Source: (SOLAS, 2012).

Designation of rooms and spaces	Ship Size	
	1.600 up to 10.000 GT	≥ 10.000 GT
Workspace:		
a. Enginery space	110	110
b. Enginery Control room	75	75
c. Workshop other than those forming part of enginery spaces	85	85
d. Non-specified workspaces (other work areas)	85	85

The noise level limit has been made so that personnel is not exposed to Lex which exceeds 85 dB(A). For new ships, compliance with this criterion must be verified based on sea level trials measuring noise levels by calculating expected noise exposure from each category of crew members by predetermined methods.

Because the piston under study is in the ship engine room, the maximum limit for noise levels in the engine room is 110 dB A) with a safe noise level of 85 dB(A) (SOLAS, 2012).

### 2.6.5. Noise Measurement.

In making measurements depends on the location or point to be measured. A good measurement is if the Sound Level Meter is placed in a place where the display can be done directly and the ease of holding the Sound Level Meter. The measurement technique used is the Sound Level Meter and the microphone is close to the object (SOLAS, 2012).

Measurements should be considered carefully so that the results can be maximized and reflect the level of noise that occurs. The things that must be considered in noise measurement are as follows:

1. The purpose of the measurement, namely compliance with the regulations on noise, noise control, how big an impact the user.
2. Sources of noise and time of operation come from the noise source.
3. The type of noise that occurs.
4. The location of the noise that happens.

In addition to consideration of the noise to be measured, another thing to consider is the condition of the engine during the measurement. The engine conditions that must be done are as follows:

1. The engine is in a stationary state, the rpm is increased by half the maximum rotation, the maximum rpm.
2. Measurements were taken in the night (Utami, 2012).

## 2.7. Definition of Vibration.

### 2.7.1. Basic Concept of Vibration.

Vibration is a movement back and forth in a certain time interval. Vibration associated with the oscillation motion of objects and forces associated with the motion. All objects that have mass and elasticity are able to vibrate, so most engineering engines and structures experience vibrations to some degree and their design usually requires consideration of the nature of the oscillation.

Vibration is the movement back and forth or oscillatory motion of an object that has mass and elasticity as a mass-spring system (Royan Hidayat, 2017).

Based on its motion:

- a. *Vibration Rectilinear*, the mass moves up and down or back and forth.
- b. *Vibration Rotational*, the mass moves rotating.

Indonesia of Menteri Negara Lingkungan Hidup about standard vibration rate, which meant vibration is a movement back and forth a mass with through a

balanced state a point of reference, mechanical vibration is the vibration caused by the facilities and equipment of human activities, Vibration seismic are ground vibrations caused by natural events and human activities, Vibration shock is a vibration that takes place suddenly and for a moment.

The standard level of mechanical vibration and shock vibration is the maximum limit of the level of mechanical vibration that is allowed from businesses or activities on solid media so that it does not cause interference with the comfort and health and integrity of the building (Hidup, 1996).

### **2.7.2. Type of Vibration.**

Based on Oscillation Motion a type of vibration are known to exist 2, divided by type are:

#### **1. *Free Vibration***

All systems that have mass and elasticity can experience free vibrations or vibrations that occur without external stimulation. The first thing that is interesting for such a system is the natural frequency of its vibration. Our goal here is to learn to write the equation of motion and calculate its natural frequency which is primarily a function of the mass and stiffness of the system. Free vibrations occur if the system oscillates due to the operation of the forces in the system itself and when no external forces work.

#### **2. *Forces Vibration***

Forced vibrations are vibrations that occur due to external force stimulation or excitation and if the excitation oscillates, the system is forced to vibrate at the excitation frequency. If the excitation frequency is equal to one of the system's natural frequencies, a dangerous resonance, and large oscillation state will be obtained. Damage to large structures such as bridges, buildings or aircraft wings is a frightening event caused by resonance. Calculation of natural frequency is one of the main things (Priatmoko, 2012).

If forced harmonic excitation affects the system, the system will vibrate according to the frequency of the excitation. The source of excitation on rotating engines can result from an imbalance in the system, the forces produced by the engine, or other influences that depend on the operating conditions of the engine. This excitation may not be desirable if the resulting impact can interfere with the safety of the structure, such as an excessive amplitude value of the vibration (Wahyu, 2015).

### 2.7.3. Vibration Testing.

Based on decision Menteri Negara Lingkungan Hidup No: KEP-49/MENLIH/11/1996 about The Standard Vibration Level is explained as follows:

Table 2. 5 Standard level of vibration comfort for comfort and health.

Source: (Hidup, 1996).

Frequency (Hz)	Vibration Rate Value, in microns ( $10^{-6}$ Meter)			
	Not disturb	Disturb	Uncomfortable	Painful
4	<100	100-500	>500-1000	>1000
5	<80	80-350	>350-1000	>1000
6,3	<70	70-275	>275-1000	>1000
8	<50	50-160	>160-500	>500
10	<37	37-120	>120-300	>300
12,5	<32	32-90	>90-220	>220
16	<25	25-60	>60-120	>120
20	<20	20-40	>40-85	>85
25	<17	17-30	>30-50	>50
31,5	<12	12-20	>20-30	>30
40	<9	9-15	>15-20	>20
50	<8	8-12	>12-15	>15
63	<6	6-9	>9-12	>12

By using the Vibration Analyzer measuring instrument, the vibration measurement method is carried out as follows:

- The vibration device is placed on a vibrating floor or surface and connected to a vibration measuring device equipped with a filter.
- Measuring devices installed at the amount of the deviation. If the tool is not equipped with the facility, a quantity conversion can be used.
- Readings and records are carried out every 4-63 Hz frequency or by sweeping by a vibrator.

### CHAPTER III

#### RESEARCH METHODOLOGY

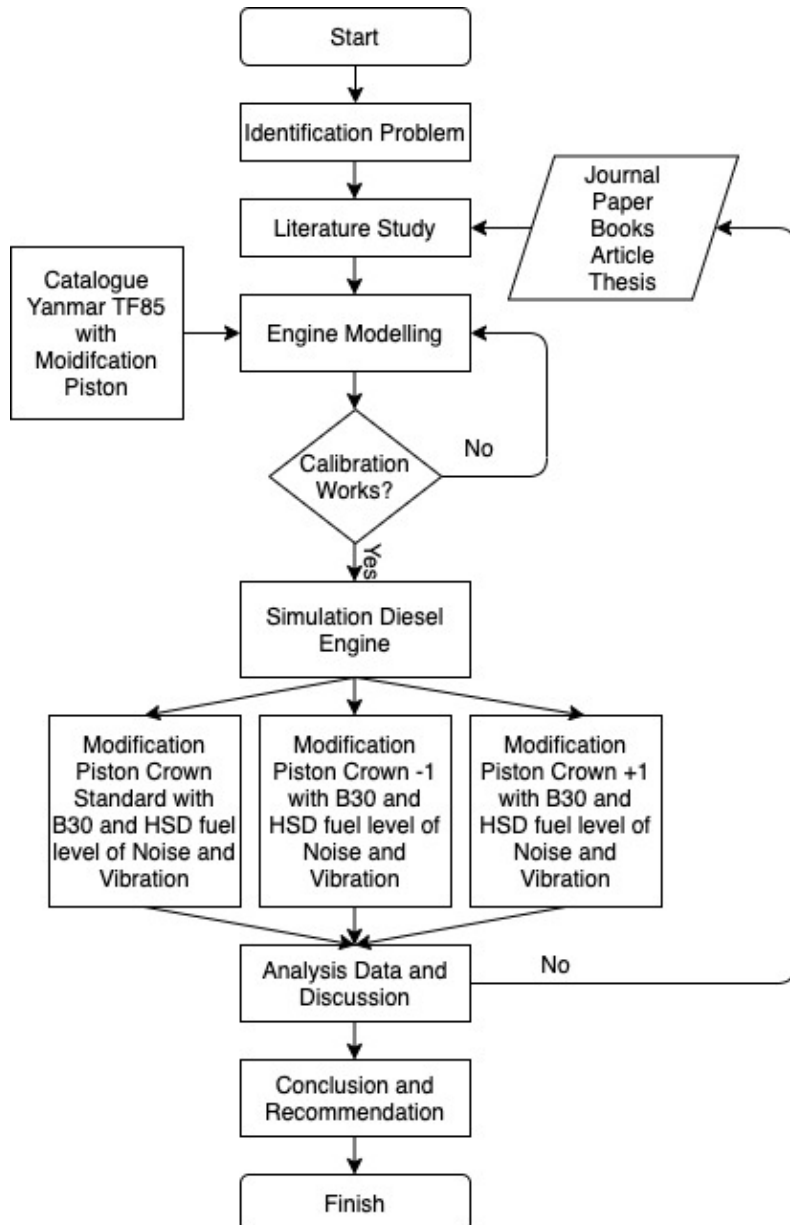


Figure 3. 1 Flow Diagram

In completing this thesis, the stages of the method of conducting research are used, the stages of the research can be seen as follows:

### 3.1. Identification Problem .

Identification of the problem of this research was to measure the levels of noise and vibration piston modification to the diesel engine One-cylinder Four-Stroke using B30 biodiesel fuel.

### 3.2. Literature Study.

From this hypothesis, a literature study was held to try to understand the problems that exist above so that by looking for the possibilities that occur then the initial allegation will be known why the problem could occur so that we can formulate and make a theoretical basis that supports research.

This stage will be completed on existing literature studies regarding the basic concepts of noise, noise threshold values, noise measurement methods, the effect of noise on humans, and methods of noise reduction. The study of literature itself is obtained from reference books, a collection of articles both from print and electronic media (internet).

### 3.3. Calibration with Engine Simulation.

At this stage, before we modify the piston and check the noise and vibration levels of the engine, we first calibrate the Yanmar TF85 engine, which is needed before performing the calibration as follows:

- a) Properties Fuel Diesel Engine.
- b) Catalog Yanmar TF85 Diesel Engine.
- c) Modified Piston Yanmar TF85.
- d) Level of Noise and Vibration placement simulation.

Determination of the variables used are as follows:

- a) RPM 1600, 1700, 1800, 1900, 2000, 2100, 2200.
- b) Palm Oil Diesel Fuel Engine.
- c) Level of Noise 1 meters in front of engine with Load 50%, 60%, 70%, 75%, 80%, 90%, and 100%.
- d) Level of Vibration
- e) Comparison of piston standard and modified piston.

The calibration process is carried out to get results that are close to that of the original Yanmar TF85 Diesel Engine in the field with those simulated in the software. Before starting the calibration process, it is necessary to know the characteristics of Yanmar TF85 Diesel Engine as follows:

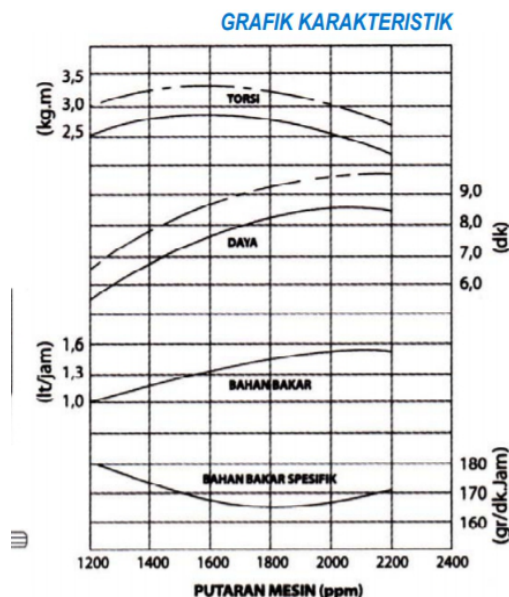


Figure 3. 2 Catalogue Yanmar TF 85

Source: (Anon., n.d.)

Make a series of components listed on the Yanmar TF 85 Diesel Engine engine catalog, the circuit is a reference in order to get results that are close to the software. The calibration process includes changes in TDC clearance, engine injection, Wrist Pin to Crank Offset, Engine Effective Rotating Inertia, and Cam Timing Angle.

To calibrate, the author determines the point or RPM that will be used as a benchmark. For power compared to 2200 RPM and for torque compared to 1600 RPM according to engine catalog instructions. For Calibration using diesel fuel 2 combust (HSD) refers to the specifications in the engine catalog. After the simulation, the following data are obtained:

Table 3. 1 Result of Simulation RPM 2200.

	Calibration	Manual book
Powe (HP)	8.59	8.5
Power (kW)	6.41	6.33
Torque (kgf-m)	-	-
SFOC (g/HP-h)	171.38	171

From the table, the simulation results show power 8.59 HP and SFOC 171.38 g / HP-h. When compared with the engine catalog in the picture where the

power is 8.5 HP and SFOC is 171 g / HP-h, an error difference of 1% for power and 1% for SFOC is obtained.

The next step to calibrate the torque value is done at 1600 RPM with the same steps. And the simulation data obtained as follows:

Table 3. 2 Result of Simulation RPM 1600.

	Calibration	Manual book
Power (HP)	-	-
Power (kW)	-	-
Torque (kgf-m)	3.21	3.4
SFOC (g/HP-h)	-	-

From the table, the simulation results show a torque of 3.21 kgf-m. When compared to the engine catalog in the picture where the torque is 3.4 kgf-m, an error difference of 0.9% is obtained.

### 3.4. Simulation Diesel Engine.

Data collection is carried out repeatedly with several variations of RPM, piston modification, variation loads, with two types of diesel fuel as a support to analyze the results level of noise and vibration. The Data is done by running software.

After everything is calibrated, the next process is to install the parts on the software with the following picture:

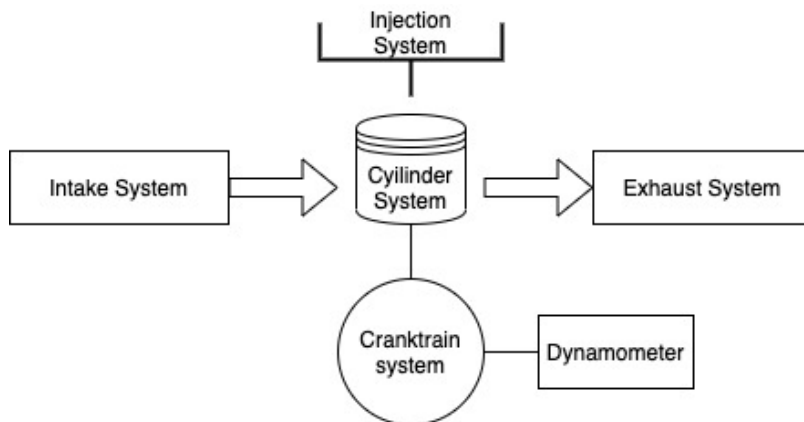


Figure 3. 3 Engine Yanmar TF85 Software

After connecting each component in sequence, adjust the case settings and plot settings according to the research in this simulation result. In the case setup can set the variations of RPM, variations of piston, injected mass, air fuel ratio, and the desired fuel to be tested in the simulation.







### 3.5. Properties B30 Diesel Fuel and High Speed Diesel (HSD) Fuel.

Table 3. 9 Properties B30 Diesel Fuel and High Speed Diesel (HSD) Fuel

No	Parameter	Unit	Analysis Data		Analysis Method
			HSD	B30	
1	Density 15°C	kg/L	815	844.4	Piknometri
2	Viscosity 40°C	mm <sup>2</sup> /s	2	2.2	Viskometri
3	LHV	kal/g	10330.09	10533.9	Bomb calorimetri
4	Flash point	°C	52	91	ASTM D-93
5	Cetana number	-	48	73.2	Octane-cetane Analyzer

### 3.5. Modified Piston.

The modified piston used in this simulation is a TCC (Toroidal Combustion Chamber) piston with several variations of modifications on the piston crown.

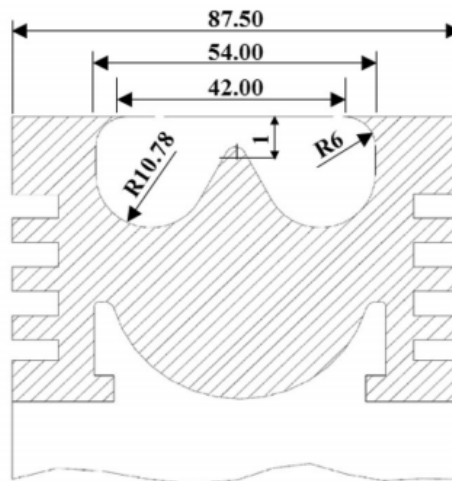


Figure 3. 4 Piston TCC Side View  
Source: (PRABHAKARA RAO GANJI\*, 2018)

For the shape of the piston crown to be modified, it is necessary to assume a table of changes in the shape of the TCC (Toroidal Combustion Chamber) piston crown, as follows:

Table 3. 10 Piston Size

Type Piston	Bowl Depth (mm)	Bowl Diameter (mm)	TDC Clearance (mm)	CR	Connecting Rod
Standard	15,5	45	0,8	18	118.1
Modified -1(Case 3)	14,5	45	1,08	18,01	117.82
Modified +1(Case 4)	16,5	43,4	0,7	17,97	118.2

Ratio Compression formula:

$$\frac{\text{Total Volume BDC}}{\text{Total Volume TDC}} = \frac{\text{vol. bowl} + \text{vol. silinder} + \text{vol. TDC}}{\text{vol. bowl} + \text{vol. TDC}}$$

Connecting Rod formula for modified piston:

$$\begin{aligned} \text{TDC Clearance (modifikasi)} - \text{TDC Clearance (standard)} &= \text{Distance} \\ \text{Connecting Rod (modifikasi)} &= \text{Connecting Rod (standard)} - \text{Distance} \end{aligned}$$

This is 2D picture design type of piston standard, piston -1, and piston +1:

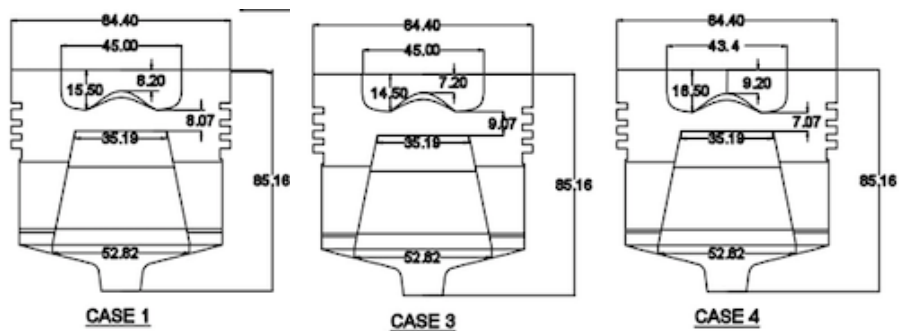


Figure 3. 5 Piston Standard, Piston -1, and Piston +1

### 3.6. Noise Point Measurement.

Basically, it is a weighted average of time over a certain time interval, usually less than 30 seconds (Shipping, 2017).

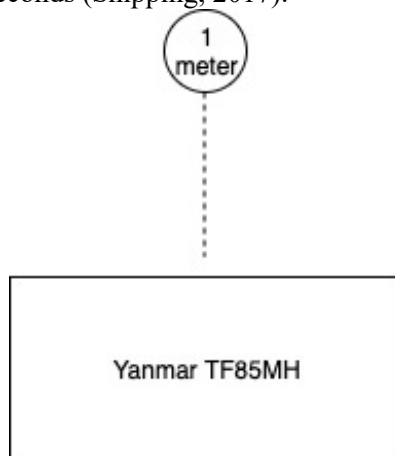


Figure 3. 6 Diagram Block Noise Point Measurement.

The 'source' noise level must be measured at a predetermined distance from the unit [usually 1 m (3.3 ft)] and is used to characterize the air source needed for acoustic modeling. It is generally best to determine these levels in the octave band so that they can be used as input data for detailed noise analysis (Shipping, 2017).

By using the software, glue the parts to the noise by giving the components that are attached to the engine that is the microphone with the placement as shown below:

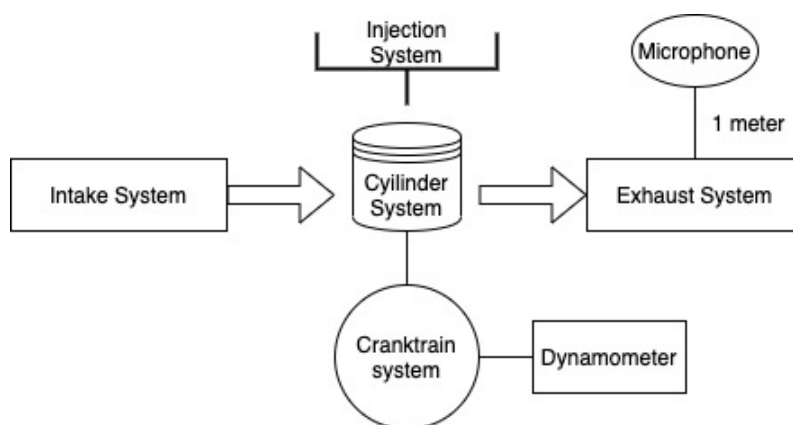


Figure 3. 7 Location Noise Level is in the software

After that, measurements are made per meter according to the existing rules of 1 meter in front of the engine itself with RPM 1600, 1700, 1800, 1900, 2000, 2100, and 2200 with load 50%, 60%, 70%, 75%, 80%, 90%, 100%, and Full Load.

### 3.7. Vibration Level Measurement.

Measurements of vibration is using FFT by installing a vibration sensor on the engine block of the engine to be measured, namely in the conditions of RPM 1600, 1700, 1800, 1900, 2000, 2100, and 2200.

With RPM, doing simulation on software to provide additional components on the scheme has been created, these components are:

1. Piston
2. Connecting Rod
3. Crank Pin
4. Crank Web
5. Engine Crank Train
6. FlyWheel
7. Bearing
8. Dynamometer
9. FFT

The definition of FFT is to convert the input signal into a wave graph, one of them is a vibration wave After the components are determined, the next step is to unite the components to become a schema in a clear and correct order, then the schema is generated as follows:

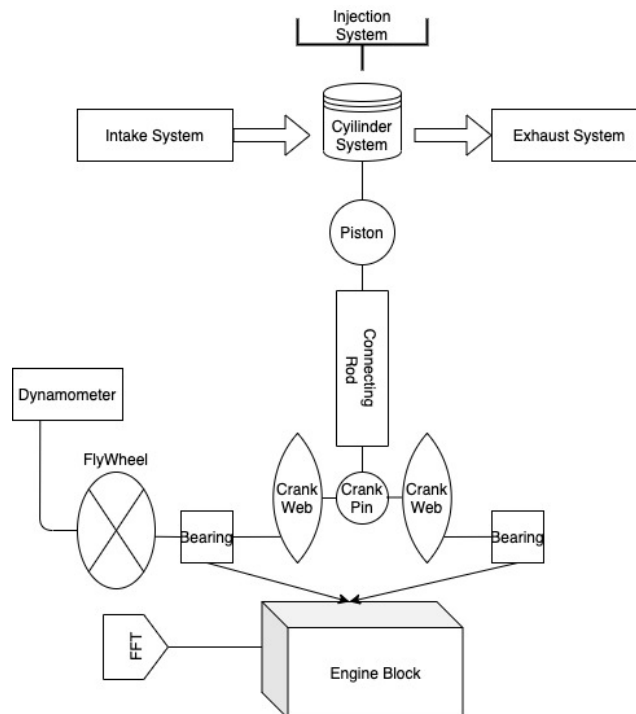


Figure 3. 8 Full Scheme of Vibration Level

### **3.8 Analysis Data and Discussion.**

Analysis performed is comparing the level of noise and vibration simulation results obtained from testing with a few variations of RPM, different variations of the piston crown, variation of loads, with two types of diesel fuel engine.

The analysis is carried out to observe the results obtained from the experimental results of piston modification testing and to use the conditions of RPM 1800, 1900, 2000, 2100, and 2200 with load 50%, 60%, 70%, 75%, 80%, 90%, 100%, and Full Load with examine the level of noise and vibration. The analysis will be used as a comparison graph that will be discussed in this study.

### **3.9. Conclusions and Recommendations.**

Conclusions are made based on the results of a whole series of studies, it is hoped that the conclusions will answer the entire formulation of the problem of research objectives that have been written.

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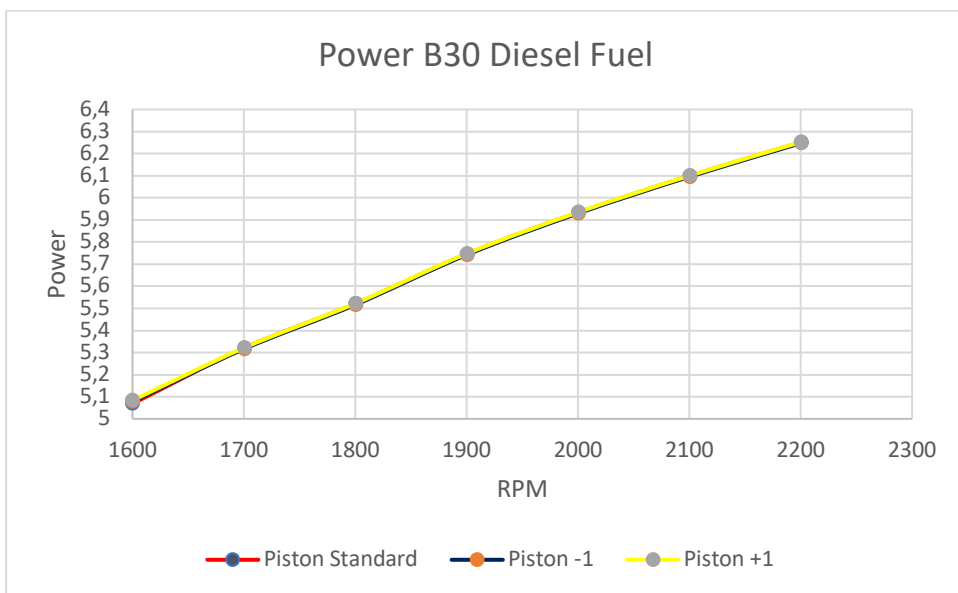


## CHAPTER IV

### RESULT AND DISCUSSION

In this chapter we will discuss the results of noise and vibration analysis of four stroke one cylinder diesel engines with piston and loading variations and rpm variations with simulation methods. The results of the data obtained from the simulation and then converted into a graph of noise and vibration so that it is easy to read and understand.

#### 4.1. Graph Power Full Load Condition with B30 Diesel Fuel.

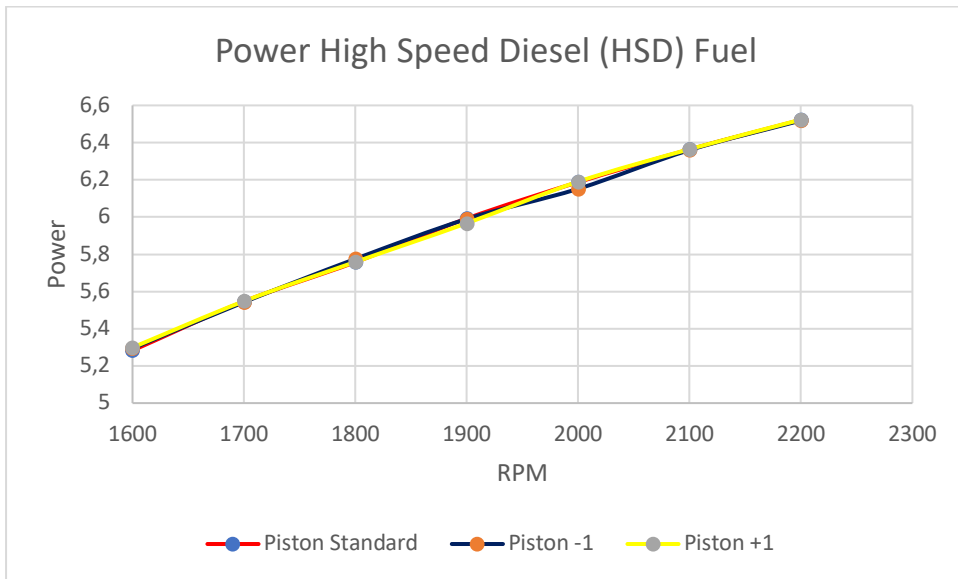


Graph 4. 1 Variartion RPM with Power B30 diesel Fuel.

In the Graph 4.1 can see the comparison of the power generated from 3 different types of pistons, namely Standard Piston, Piston -1, and Piston +1. Power produced from 3 types of pistons shows the difference in power produced by the engine. Where the highest RPM is RPM 2200, Piston +1 has a power of 6,251 kW, a Standard Piston has a power of 6,250 kW, and a Piston -1 has a power of 6,247 kW. When the engine RPM rises, the engine power output also increases.

This is proportional to the pressure and explosion of combustion in the combustion chamber is increasingly high. The conclusion is that Piston +1 has a higher power in each engine RPM, followed by a Standard Piston, then finally Piston -1 has the lowest power in each RPM.

#### 4.2. Graph Power Full Load Condition with High Speed Diesel (HSD) Fuel.



Graph 4. 2 Variation RPM with Power High Speed Diesel (HSD) Fuel.

From Graph 4.2 we can see the comparison of the power produced from 3 different pistons, namely Standard Piston, and Piston -1, and Piston +1. Power produced from 3 types of pistons shows the difference in power produced by the engine. Where the highest RPM is RPM 2200, Piston +1 has a power of 6,523 kW, Piston Standard has a power of 6,522 kW, and Piston -1 has a power of 6,528 kW. When the engine RPM rises, the engine power output also increases.

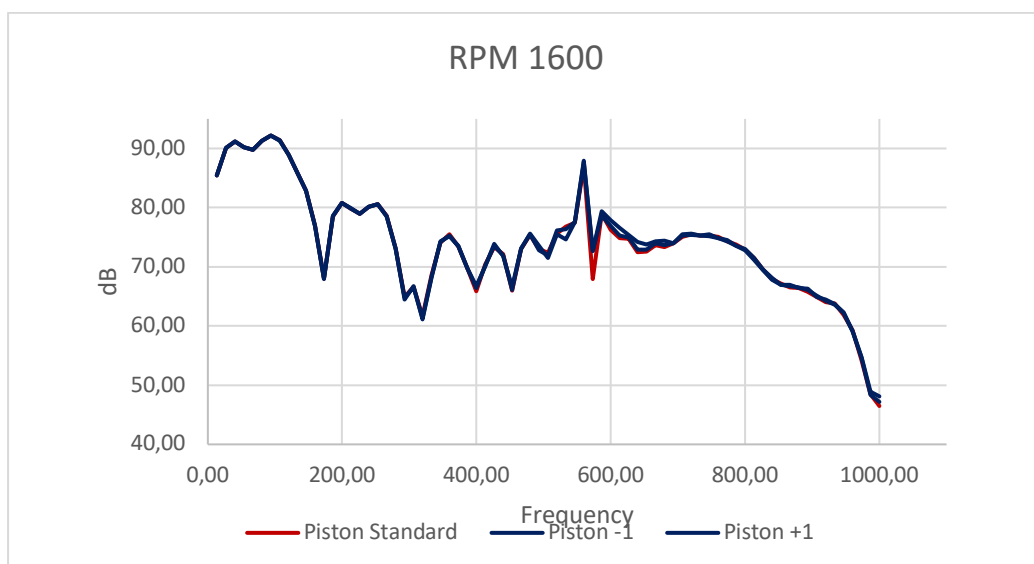
This is proportional to the pressure and explosion of combustion in the combustion chamber is increasingly high. The conclusion is that Piston +1 has a higher power in each engine RPM, followed by a Standard Piston, then finally Piston -1 has the lowest power in each RPM.

### 4.3. Noise Analysis Data Results for B30 Diesel Fuel.

In this simulation the level of noise testing of diesel engines is done using a variation of the piston with B30 Diesel Fuel. Obtained data in the form of Sound Pressure Level (SPL).

The variables used are RPM 1600, 1700, 1800, 1900, 2000, 2100 and 2200 by showing the SPL graph on each piston and fuel form being tested.

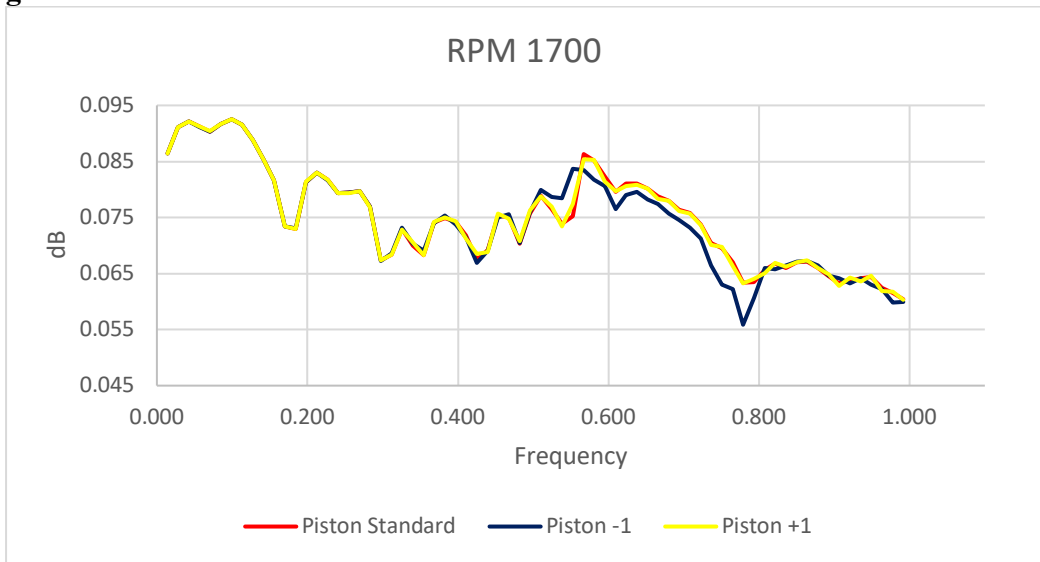
#### 4.3.1. Full Load Graph Analysis 1 Meter Distance with B30 Fuel Diesel Engine RPM 1600.



Graph 4. 3 Graph of Sound Pressure B30 Diesel Fuel RPM 1600 Full Load with All Variant Piston

In the graph 4.3 Graph of Sound Pressure B30 Diesel Fuel RPM 1600 Full Load with All Variant Piston, it can be seen the comparison of the noise level at 1600 RPM Full Load conditions with 3 variations piston of the B30 diesel fuel. The highest noise levels occurred at a frequency of 93.33 Hz with Piston +1 dB at 92.2, followed by Piston Standard of 92.18 dB, and the last at -1 Piston amounted to 92.17 dB. Piston +1 has the highest noise level because it has a higher power compared to the standard piston and -1.

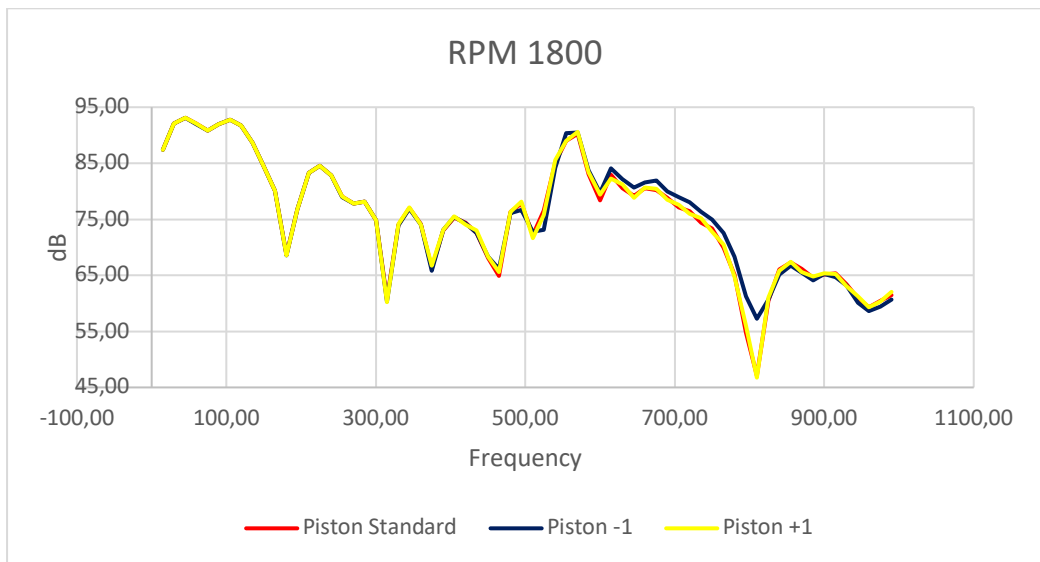
#### 4.3.2. Full Load Graph Analysis 1 Meter Distance with B30 Fuel Diesel Engine RPM 1700.



Graph 4. 4 Graph of Sound Pressure B30 Diesel Fuel RPM 1700 Full Load with All Variant Piston

In the graph 4.4 Graph of Sound Pressure B30 Diesel Fuel RPM 1700 Full Load with All Variant Piston, it can be seen the comparison of the noise level at 1700 RPM Full Load conditions with 3 variations piston of the B30 diesel fuel. The highest noise level occurs at a frequency of 99.16 Hz with +1 Piston of 92.55 dB, followed by a Standard Piston of 92.53 dB, and finally at Piston -1 of 92.53 dB. Piston +1 has the highest noise level because it has a higher power compared to the standard piston and -1.

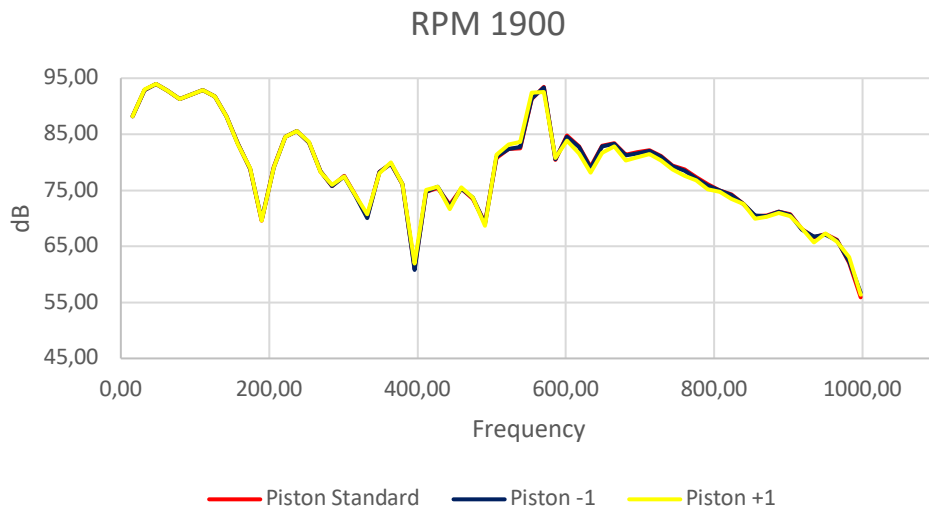
#### 4.3.3. Full Load Graph Analysis 1 Meter Distance with B30 Fuel Diesel Engine RPM 1800.



Graph 4. 5 Graph of Sound Pressure B30 Diesel Fuel RPM 1800 Full Load with All Variant Piston

In the graph 4.5 Graph of Sound Pressure B30 Diesel Fuel RPM 1800 Full Load with All Variant Piston, it can be seen the comparison of the noise level at 1800 RPM Full Load conditions with 3 variations piston of the B30 diesel fuel. The highest noise level occurs at a frequency of 105 Hz with +1 Piston of 92.79 dB, followed by a Standard Piston of 92.79 dB, and finally at Piston -1 of 92.79 dB. Piston +1 has the highest noise level because it has a higher power compared to the standard piston and -1.

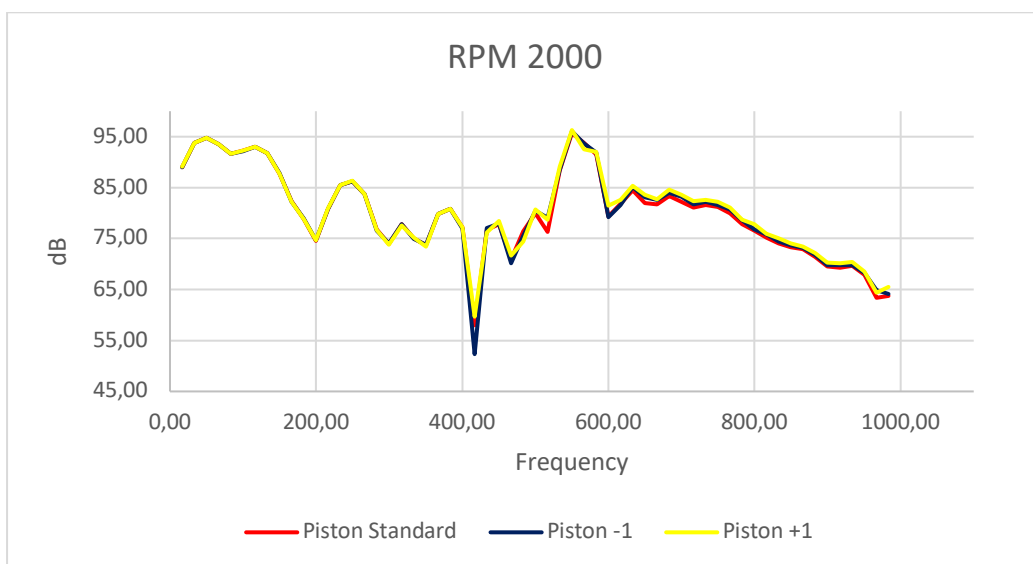
#### 4.3.4. Full Load Graph Analysis 1 Meter Distance with B30 Fuel Diesel Engine RPM 1900.



Graph 4. 6 Graph of Sound Pressure B30 Diesel Fuel RPM 1900 Full Load with All Variant Piston

In the graph 4.6 Graph of Sound Pressure B30 Diesel Fuel RPM 1900 Full Load with All Variant Piston, it can be seen the comparison of the noise level at 1900 RPM Full Load conditions with 3 variations piston of the B30 diesel fuel. The highest noise level occurs at a frequency of 47.5 Hz with +1 Piston of 93.98 dB, followed by a Standard Piston of 93.97 dB, and the last Piston -1 of 93.97 dB. Piston +1 has the highest noise level because it has a higher power compared to the standard piston and -1.

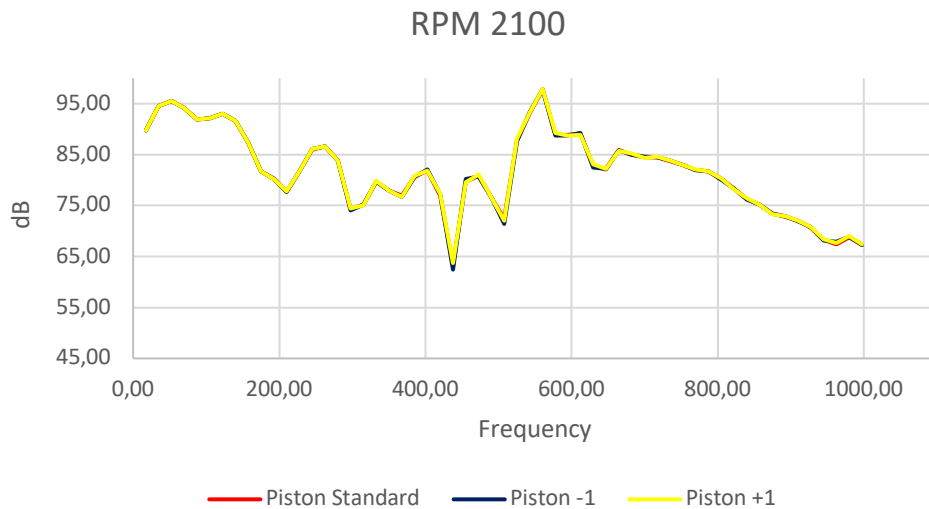
#### 4.3.5. Full Load Graph Analysis 1 Meter Distance with B30 Fuel Diesel Engine RPM 2000.



Graph 4. 7 Graph of Sound Pressure B30 Diesel Fuel RPM 2000 Full Load with All Variant Piston

In the graph 4.7 Graph of Sound Pressure B30 Diesel Fuel RPM 2000 Full Load with All Variant Piston, it can be seen the comparison of the noise level at 2000 RPM Full Load conditions with 3 variations piston of the B30 diesel fuel. The highest noise level occurs at a frequency of 50 Hz with a Piston +1 of 94.79 dB, followed by a Standard Piston of 94.78 dB, and the last Piston -1 of 94.77 dB. Piston +1 has the highest noise level because it has a higher power compared to the standard piston and -1.

#### 4.3.6. Full Load Graph Analysis 1 Meter Distance with B30 Fuel Diesel Engine RPM 2100.

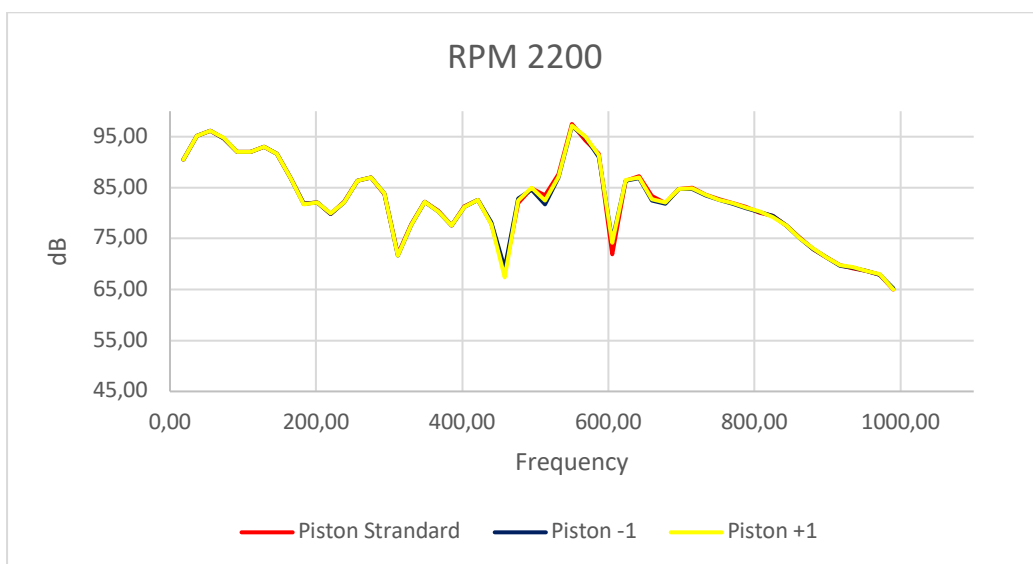


Graph 4. 8 Graph of Sound Pressure B30 Diesel Fuel RPM 2100 Full Load with All Variant Piston

In the graph 4.8 Graph of Sound Pressure B30 Diesel Fuel RPM 2100 Full Load with All Variant Piston, it can be seen the comparison of the noise level at 2100 RPM Full Load conditions with 3 variations piston of the B30 diesel fuel. The highest noise level occurs at a frequency of 52.5 Hz with Piston +1 of 95.51 dB, followed by a Standard Piston of 95.50 dB, and finally at Piston -1 of 95.49 dB. Piston +1 has the highest noise level because it has a higher power compared to the standard piston and -1.



#### 4.3.7. Full Load Graph Analysis 1 Meter Distance with B30 Fuel Diesel Engine RPM 2200



Graph 4. 9 Graph of Sound Pressure B30 Diesel Fuel RPM 2200 Full Load with All Variant Piston

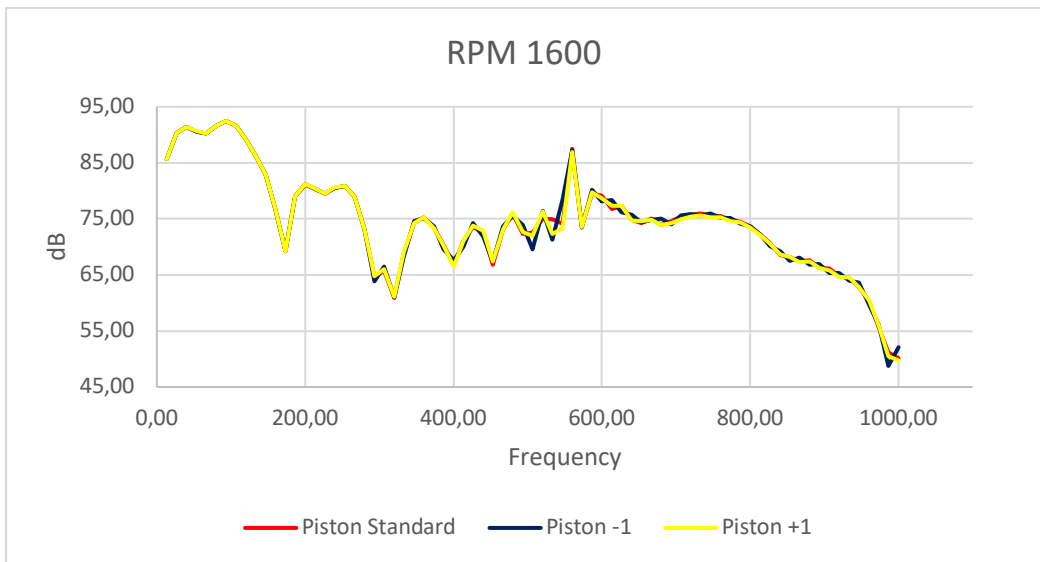
In the graph 4.9 Graph of Sound Pressure B30 Diesel Fuel RPM 2200 Full Load with All Variant Piston, it can be seen the comparison of the noise level at 2200 RPM Full Load conditions with 3 variations piston of the B30 diesel fuel. The highest noise level occurs at a frequency of 55 Hz with +1 Piston of 96.18 dB, followed by a Standard Piston of 96.18 dB, and the last Piston -1 of 96.17 dB. Piston +1 has the highest noise level because it has a higher power compared to the standard piston and -1.

#### 4.4. Noise Analysis Data Results for High Speed Diesel (HSD) Fuel.

In this simulation the level of noise testing of diesel engines is done using a variation of the piston with High Speed Diesel (HSD) Fuel. Obtained data in the form of Sound Pressure Level (SPL).

The variables used are RPM 1600, 1700, 1800, 1900, 2000, 2100 and 2200 by showing the SPL graph on each piston and fuel form being tested.

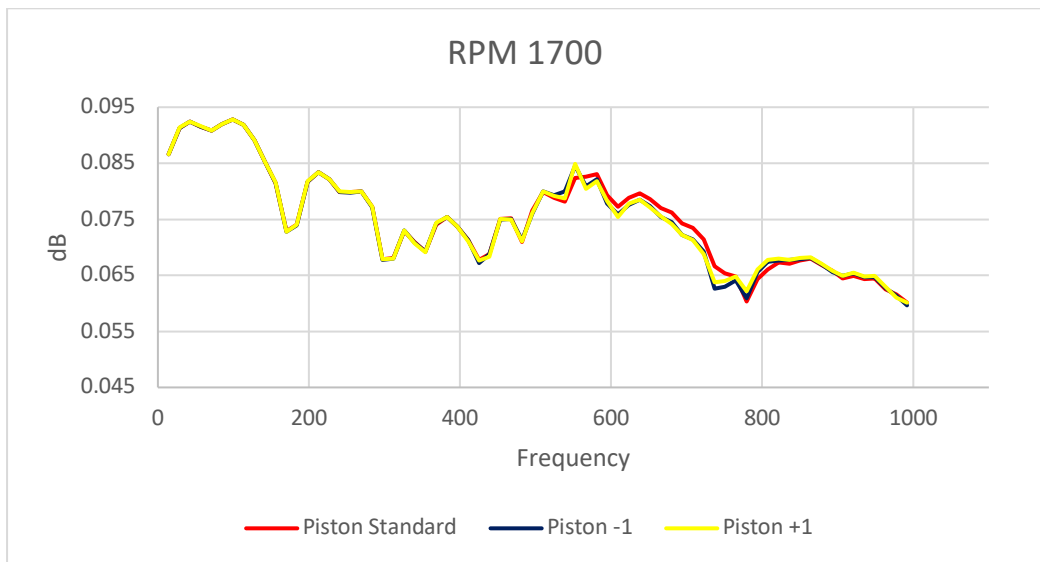
##### 4.4.1. Full Load Graph Analysis 1 Meter Distance with HSD Fuel Diesel Engine RPM 1600.



Graph 4. 10 Graph of Sound Pressure High Speed Diesel (HSD) Fuel RPM 1600 Full Load with All Variant Piston

In the graph 4.10 Graph of Sound Pressure High Speed Diesel (HSD) Fuel RPM 1600 Full Load with All Variant Piston, it can be seen the comparison of the noise level at 1600 RPM Full Load conditions with 3 variations piston of the High Speed Diesel (HSD) Fuel. The highest noise level occurred at a frequency of 93.3 Hz with +1.44 dB Pistons, followed by a Standard Piston of 92.46 dB, and finally on Piston -1 of 92.46 dB. Piston +1 has the highest noise level because it has a higher power compared to the standard piston and -1.

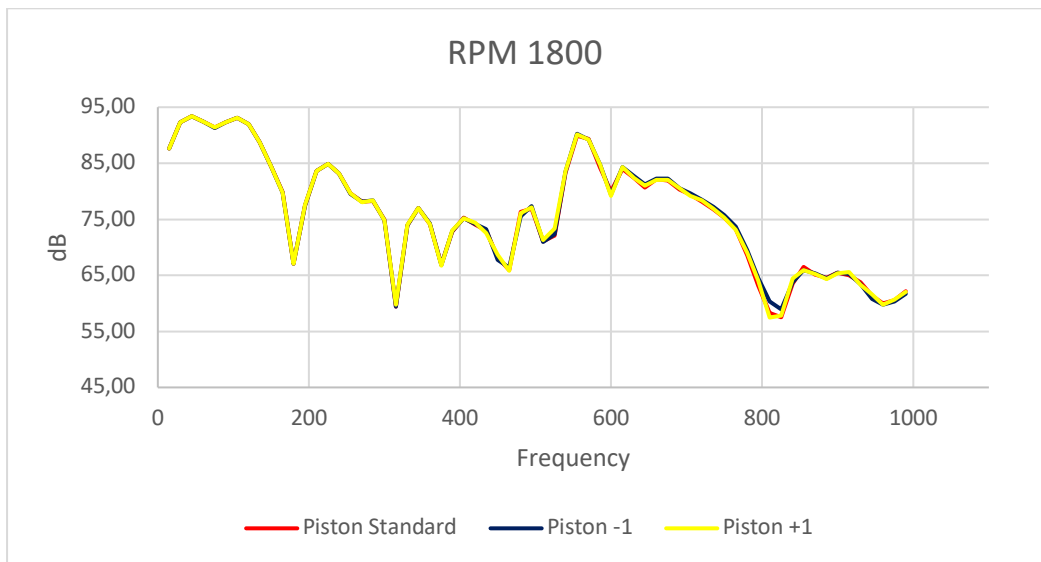
#### 4.4.2. Full Load Graph Analysis 1 Meter Distance with HSD Fuel Diesel Engine RPM 1700.



Graph 4. 11 Graph of Sound Pressure High Speed Diesel (HSD) Fuel RPM 1700 Full Load with All Variant Piston

In the graph 4.11 Graph of Sound Pressure High Speed Diesel (HSD) Fuel RPM 1700 Full Load with All Variant Piston, it can be seen the comparison of the noise level at 1700 RPM Full Load conditions with 3 variations piston of the High Speed Diesel (HSD) Fuel. The highest noise level occurs at a frequency of 99.16 Hz with a +1 Piston of 92.83 dB, followed by a Piston of a Standard of 92,819 dB, and finally of a Piston -1 of 92.18 dB. Piston +1 has the highest noise level because it has a higher power compared to the standard piston and -1.

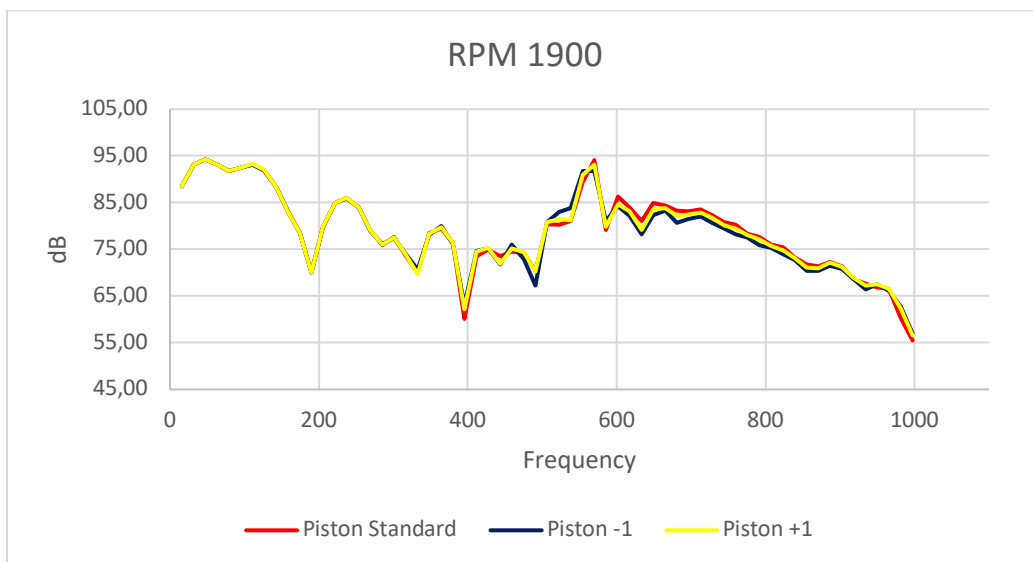
#### 4.4.3. Full Load Graph Analysis 1 Meter Distance with HSD Fuel Diesel Engine RPM 1800.



Graph 4. 12 Graph of Sound Pressure High Speed Diesel (HSD) Fuel RPM 1800 Full Load with All Variant Piston

In the graph 4.12 Graph of Sound Pressure High Speed Diesel (HSD) Fuel RPM 1800 Full Load with All Variant Piston, it can be seen the comparison of the noise level at 1800 RPM Full Load conditions with 3 variations piston of the High Speed Diesel (HSD) Fuel. The highest noise level occurs at a frequency of 45 Hz with Piston +1 of 93.40 dB, followed by a Standard Piston of 93.39 dB, and the last Piston -1 of 93.39 dB. Piston +1 has the highest noise level because it has a higher power compared to the standard piston and -1.

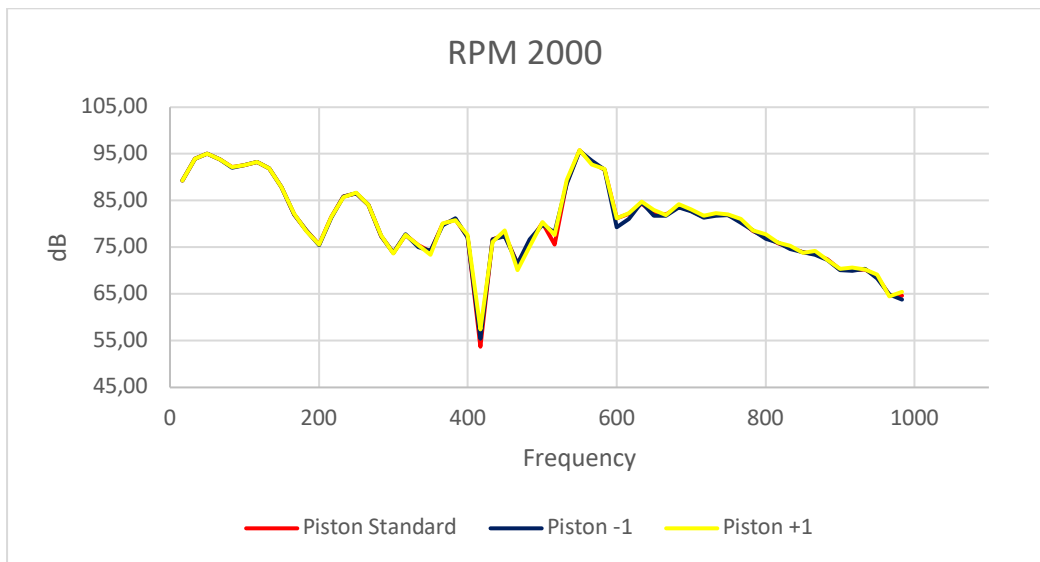
#### 4.4.4. Full Load Graph Analysis 1 Meter Distance with HSD Fuel Diesel Engine RPM 1900.



Graph 4. 13 Graph of Sound Pressure High Speed Diesel (HSD) Fuel RPM 1900 Full Load with All Variant Piston

In the graph 4.13 Graph of Sound Pressure High Speed Diesel (HSD) Fuel RPM 1900 Full Load with All Variant Piston, it can be seen the comparison of the noise level at 1900 RPM Full Load conditions with 3 variations piston of the High Speed Diesel (HSD) Fuel. The highest noise level occurred at a frequency of 47.5 Hz with a Piston +1 of 94.27 dB, followed by a Standard Piston of 94.26 dB, and finally of the Piston -1 of 94.25 dB. Piston +1 has the highest noise level because it has a higher power compared to the standard piston and -1.

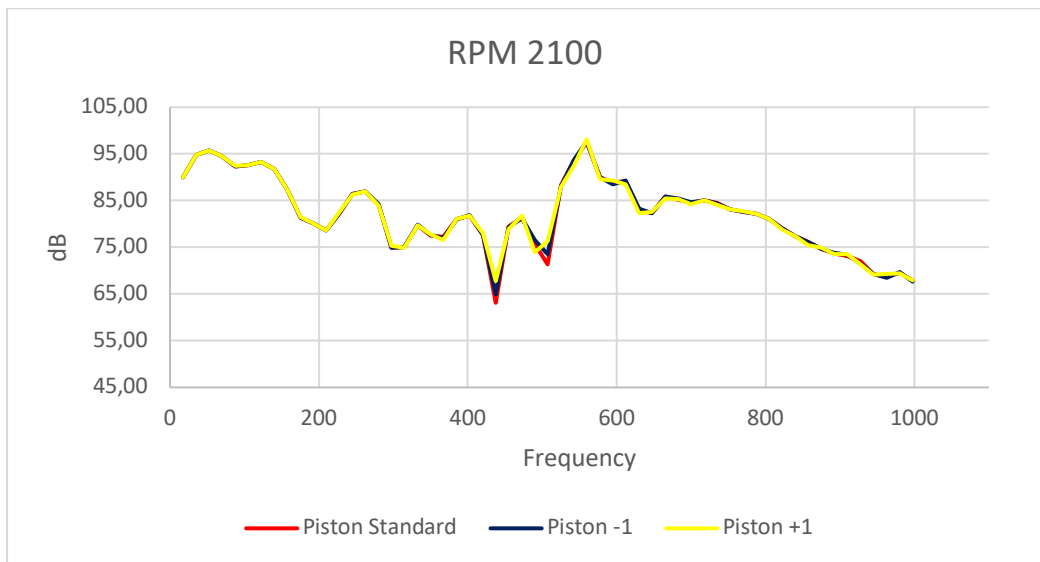
#### 4.4.5. Full Load Graph Analysis 1 Meter Distance with HSD Fuel Diesel Engine RPM 2000.



Graph 4. 14 Graph of Sound Pressure High Speed Diesel (HSD) Fuel RPM 2000 Full Load with All Variant Piston

In the graph 4.14 Graph of Sound Pressure High Speed Diesel (HSD) Fuel RPM 2000 Full Load with All Variant Piston, it can be seen the comparison of the noise level at 2000 RPM Full Load conditions with 3 variations piston of the High Speed Diesel (HSD) Fuel. The highest noise level occurs at a frequency of 50 Hz with Piston +1 of 95.07 dB, followed by a Standard Piston of 95.06 dB, and finally at Piston -1 of 95.05 dB. Piston +1 has the highest noise level because it has a higher power compared to the standard piston and -1.

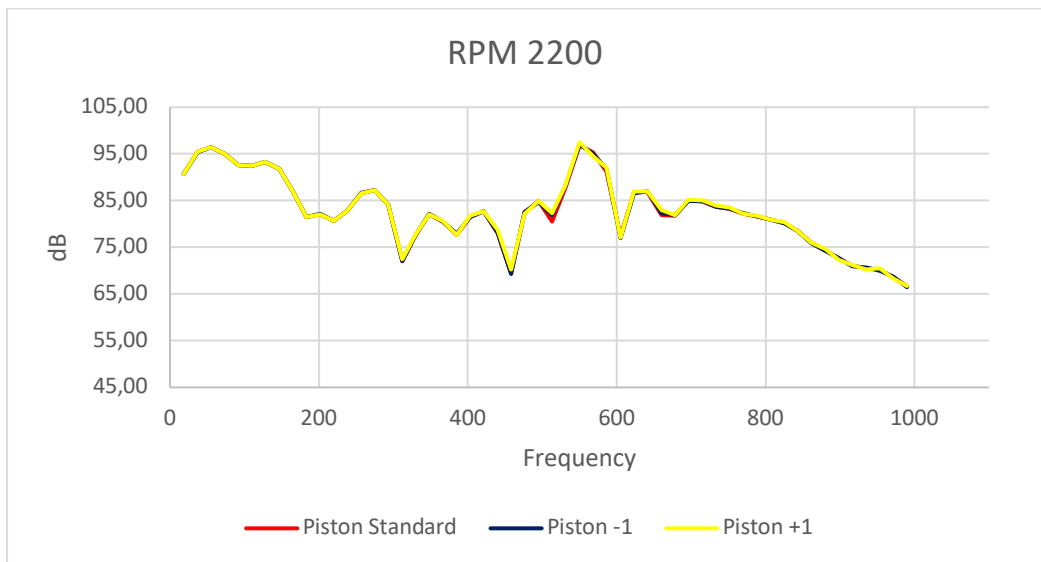
#### 4.4.6. Full Load Graph Analysis 1 Meter Distance with HSD Fuel Diesel Engine RPM 2100.



Graph 4. 15 Graph of Sound Pressure High Speed Diesel (HSD) Fuel RPM 2100 Full Load with All Variant Piston

In the graph 4.15 Graph of Sound Pressure High Speed Diesel (HSD) Fuel RPM 2100 Full Load with All Variant Piston, it can be seen the comparison of the noise level at 2100 RPM Full Load conditions with 3 variations piston of the High Speed Diesel (HSD) Fuel. The highest noise level occurs at a frequency of 52.5 Hz with Piston +1 of 95.80 dB, followed by a Standard Piston of 95.79 dB, and the last Piston -1 of 95.78 dB. Piston +1 has the highest noise level because it has a higher power compared to the standard piston and -1.

#### 4.4.7. Full Load Graph Analysis 1 Meter Distance with HSD Fuel Diesel Engine RPM 2200.

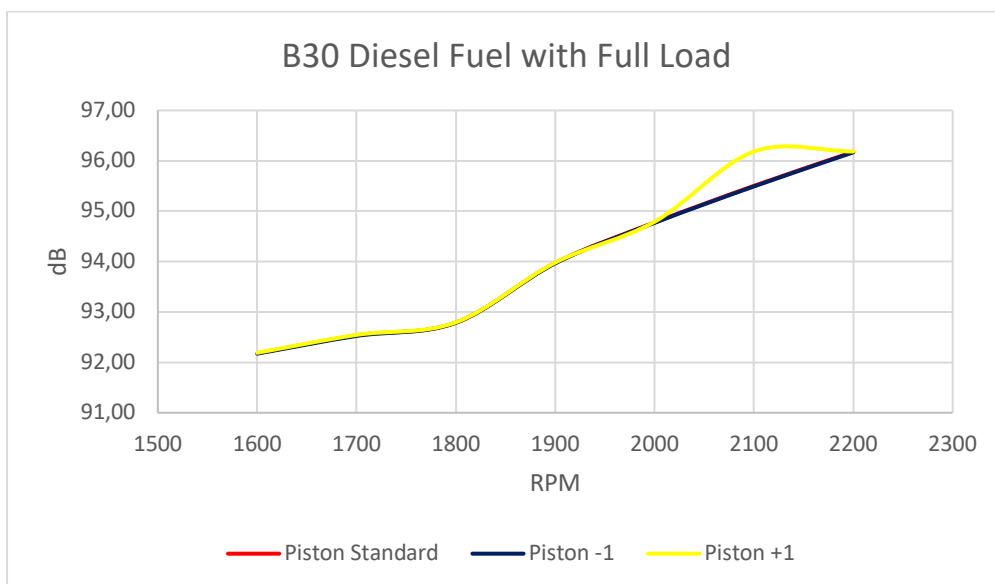


Graph 4. 16 Graph of Sound Pressure High Speed Diesel (HSD) Fuel RPM 2200 Full Load with All Variant Piston

In the graph 4.16 Graph of Sound Pressure High Speed Diesel (HSD) Fuel RPM 2200 Full Load with All Variant Piston, it can be seen the comparison of the noise level at 2200 RPM Full Load conditions with 3 variations piston of the High Speed Diesel (HSD) Fuel. The highest noise level occurs at a frequency of 55 Hz with +1 Piston of 96.47 dB, followed by a Standard Piston of 96.46 dB, and finally at Piston -1 of 96.45 dB. Piston +1 has the highest noise level because it has a higher power compared to the standard piston and -1.



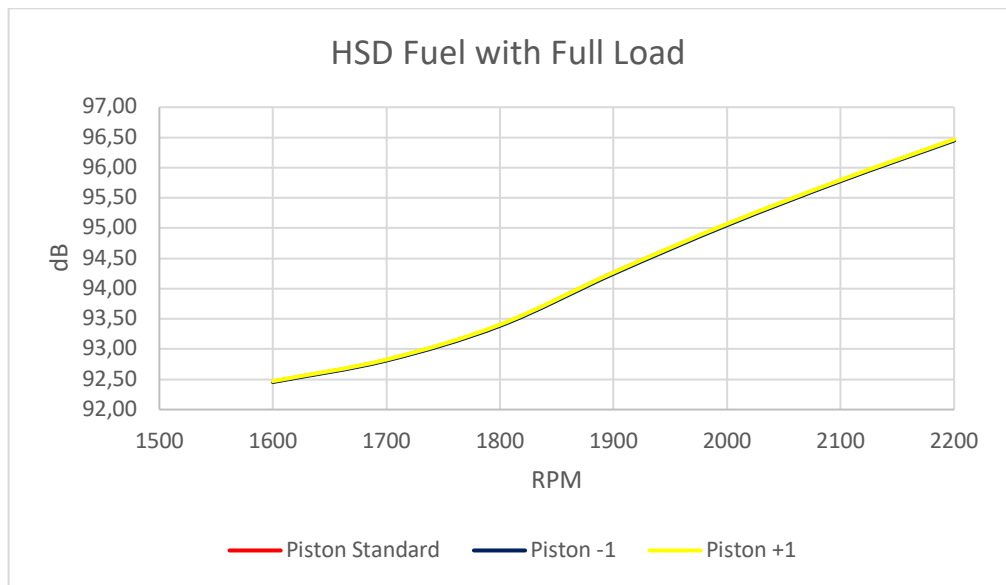
#### 4.5. Graph Noise Comparison Full Load Condition with B30 Diesel Fuel.



Graph 4. 17 B30 Diesel Fuel with Full Load

In the graph 4.17 B30 Diesel Fuel with Full Load, it can be seen the comparison of the noise level to RPM with B30 diesel fuel. Piston +1 has a higher noise compared to Standard piston and Piston -1. Can be seen the increase in engine rotation speed has an impact on the increase in the level of noise produced by the engine. That is caused by the increase in engine rotation speed, the pressure in the combustion chamber increases and the power produced by the engine is greater, this has an impact on the sound or noise produced by the engine itself.

#### 4.6. Graph Noise Comparison Full Load Condition with High Speed Diesel (HSD) Fuel.

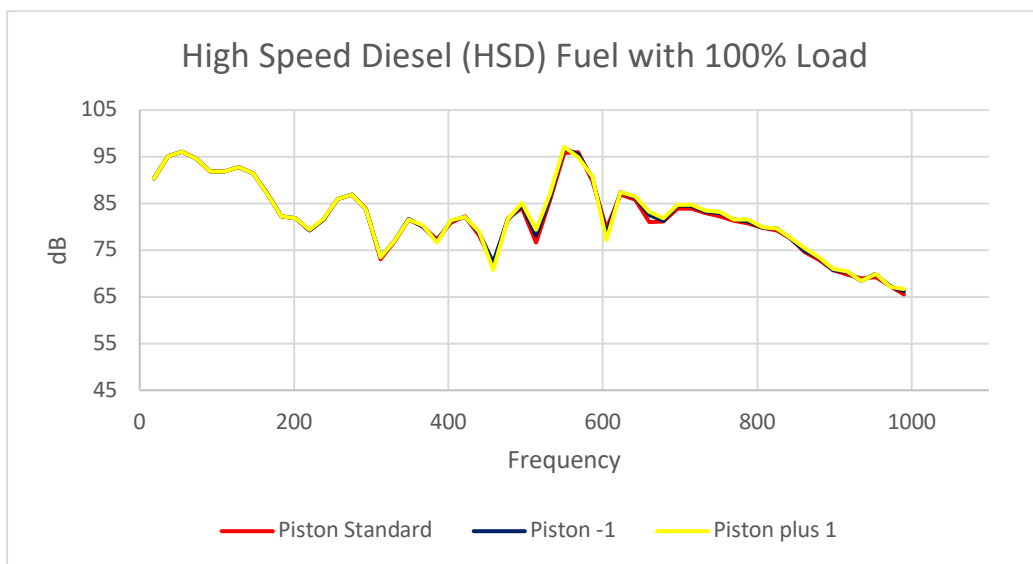


Graph 4. 18 High Speed Diesel (HSD) Fuel with Full Load

In the graph 4.18 High Speed Diesel (HSD) Fuel with Full Load, it can be seen the comparison of the noise level to RPM with High Speed Diesel (HSD) Fuel. Piston +1 has a higher noise compared to Standard piston and Piston -1. Can be seen the increase in engine rotation speed has an impact on the increase in the level of noise produced by the engine. That is caused by the increase in engine rotation speed, the pressure in the combustion chamber increases and the power produced by the engine is greater, this has an impact on the sound or noise produced by the engine itself.

## 4.7. Analysis Variation Load Graph with High Speed Diesel (HSD) Fuel

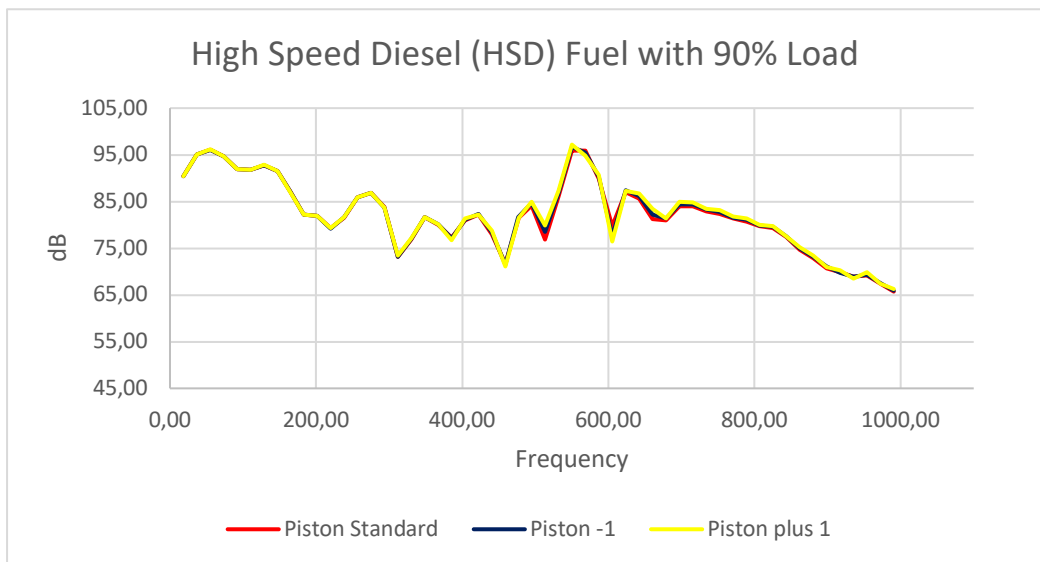
### 4.7.1. 100% Load Graph Analysis 1 Meter Distance with HSD Fuel Diesel Engine at RPM 2200.



Graph 4. 19 High Speed Diesel (HSD) Fuel with 100% Load

In the graph 4.19 High Speed Diesel (HSD) Fuel with 100% Load, it can be seen comparing the noise level at 2200 RPM 100% Load condition High Speed Diesel (HSD) Fuel. Noise on Piston +1 is higher compared to standard Piston and Piston -1. At a frequency of 54.9 Hz the Piston +1 has a noise of 96.11 dB. For standard pistons at a frequency of 54.9 Hz it has a noise of 96.09 dB and a Piston -1 at a frequency of 54.9 Hz also has a noise of 96.09 dB. Piston +1 has a higher noise level than the standard piston and piston -1 because it has a higher power compared to the standard piston and piston-1.

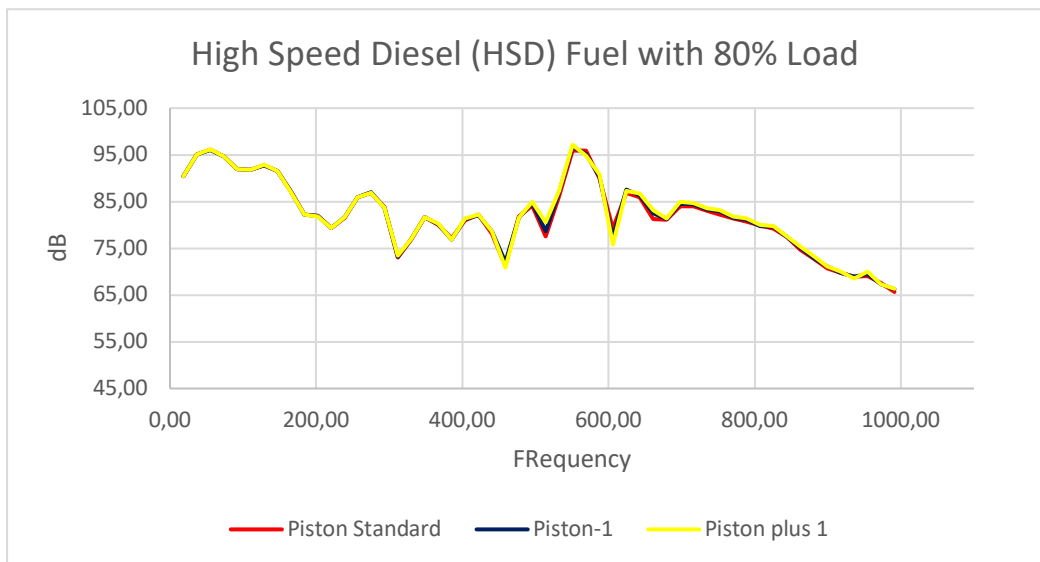
#### 4.7.2. 90% Load Graph Analysis 1 Meter Distance with HSD Fuel Diesel Engine at RPM 2200.



Graph 4. 20 High Speed Diesel (HSD) Fuel with 90% Load

In the graph 4.120 High Speed Diesel (HSD) Fuel with 90% Load, it can be seen comparing the noise level at 2200 RPM 90% Load condition High Speed Diesel (HSD) Fuel. Noise on Piston +1 is higher compared to standard Piston and Piston -1. At a frequency of 55.03 Hz the Piston +1 has a noise of 96.12 dB. For the Standard Piston at 55.03 Hz frequency has a noise of 96.11 dB and Piston -1 at the frequency of 55.03 Hz has a noise of 96.10 dB. Piston +1 has a higher noise level than the standard piston and piston -1 because it has a higher power compared to the standard piston and piston-1.

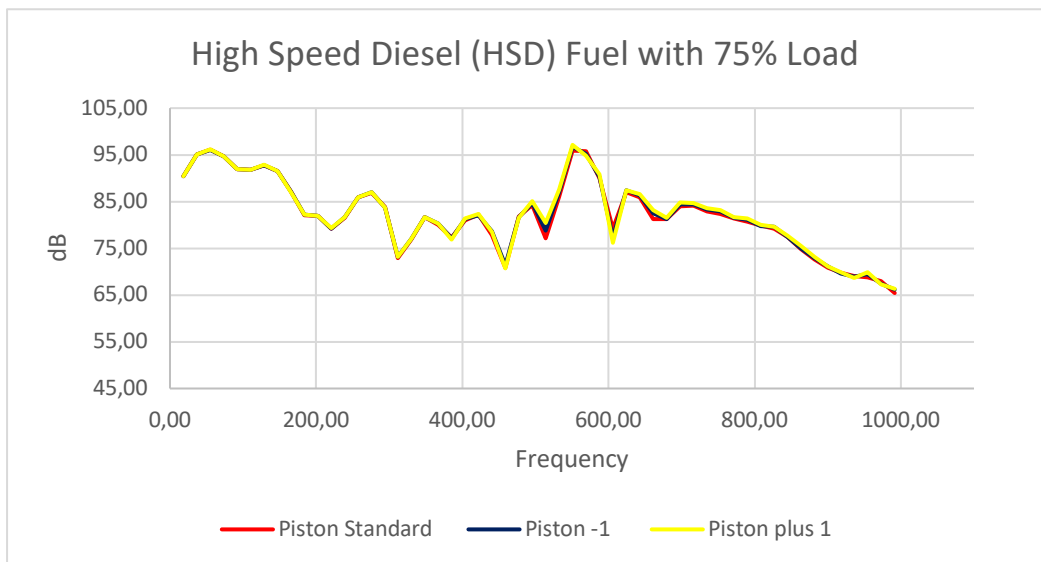
#### 4.7.3. 80% Load Graph Analysis 1 Meter Distance with HSD Fuel Diesel Engine at RPM 2200.



Graph 4. 21 High Speed Diesel (HSD) Fuel with 80% Load

In the graph 4.21 High Speed Diesel (HSD) Fuel with 80% Load, it can be seen comparing the noise level at 2200 RPM 80% Load condition High Speed Diesel (HSD) Fuel. Noise on Piston +1 is higher compared to standard Piston and Piston - 1. At a frequency of 55.07 Hz Piston +1 has a noise of 96.13 dB. For Piston Standard at 55.07 Hz frequency has a noise of 96.11 dB and Piston -1 at frequency 55.07 Hz also has a noise of 96.11 dB. Piston +1 has a higher noise level than the standard piston and piston -1 because it has a higher power compared to the standard piston and piston-1.

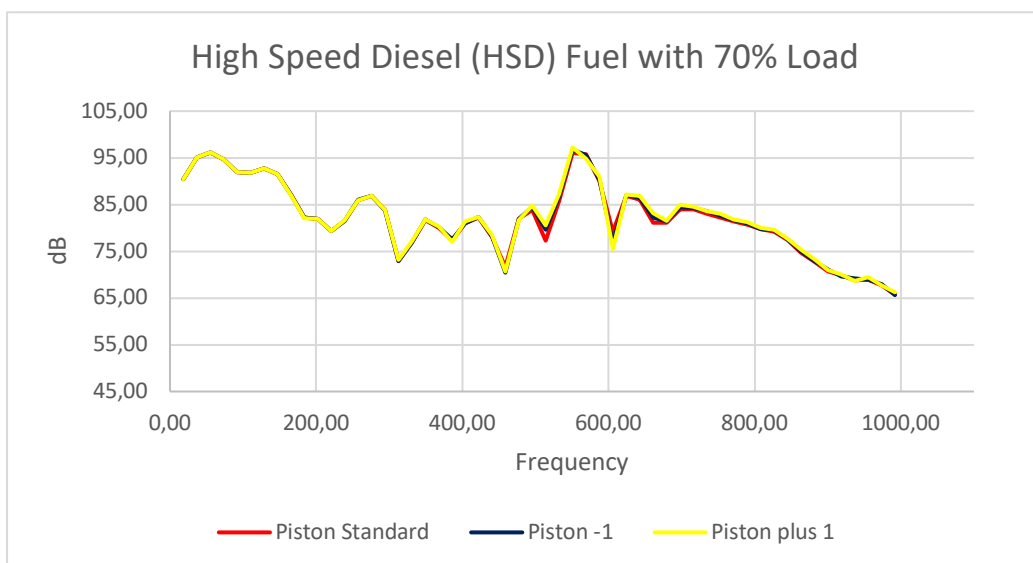
#### 4.7.4. 75% Load Graph Analysis 1 Meter Distance with HSD Fuel Diesel Engine at RPM 2200.



Graph 4. 22 High Speed Diesel (HSD) Fuel with 75% Load

In the graph 4.22 High Speed Diesel (HSD) Fuel with 75% Load, it can be seen comparing the noise level at 2200 RPM 75% Load condition High Speed Diesel (HSD) Fuel. Noise on Piston +1 is higher compared to standard Piston and Piston -1. At frequency 55.09 Hz Piston +1 has a noise of 96.13 dB. For Piston Standard at frequency 55.09 Hz has a noise of 96.12 dB and Piston -1 at frequency 55.09 Hz also has a noise of 96.12 dB. Piston +1 has a higher noise level than the standard piston and piston -1 because it has a higher power compared to the standard piston and piston-1.

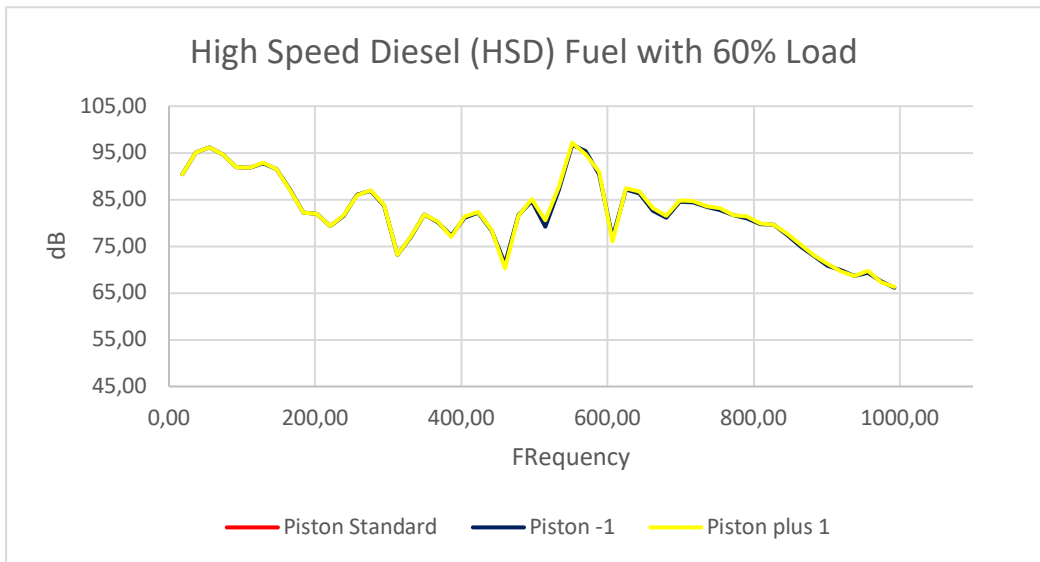
#### 4.7.5. 70% Load Graph Analysis 1 Meter Distance with HSD Fuel Diesel Engine at RPM 2200.



Graph 4. 23 High Speed Diesel (HSD) Fuel with 70% Load

In the graph 4.23 High Speed Diesel (HSD) Fuel with 70% Load, it can be seen comparing the noise level at 2200 RPM 70% Load condition High Speed Diesel (HSD) Fuel. Noise on Piston +1 is higher compared to standard Piston and Piston -1. At a frequency of 55.10 Hz Piston +1 has a noise of 96.14 dB. For the Standard Piston at 55.10 Hz frequency has a noise of 96.12 dB and Piston -1 at a frequency of 55.10 Hz also has a noise of 96.12 dB. Piston +1 has a higher noise level than the standard piston and piston -1 because it has a higher power compared to the standard piston and piston-1.

#### 4.7.6. 60% Load Graph Analysis 1 Meter Distance with HSD Fuel Diesel Engine at RPM 2200.

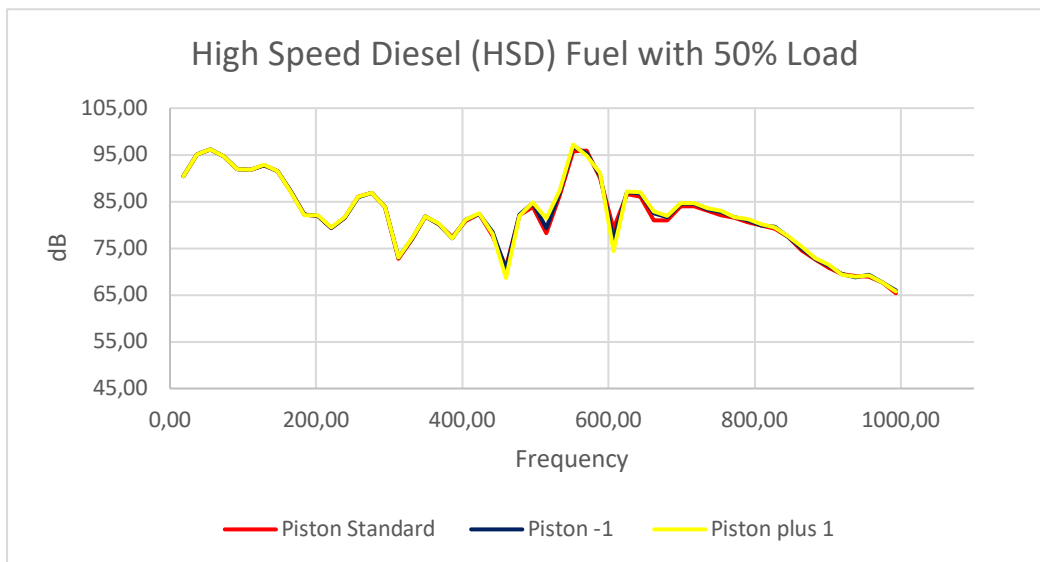


Graph 4. 24 High Speed Diesel (HSD) Fuel with 60% Load

In the graph 4.24 HSD Fuel with 60% Load, it can be seen comparing the noise level at 2200 RPM 60% Load condition High Speed Diesel (HSD) Fuel. Noise on Piston +1 is higher compared to standard Piston and Piston -1. At a frequency of 55.14 Hz Piston +1 has a noise of 96.15 dB. For the Standard Piston at a frequency of 55.14 Hz has a noise of 96.13 dB and a Piston -1 at a frequency of 55.14 Hz also has a noise of 96.13 dB. Piston +1 has a higher noise level than the standard piston and piston -1 because it has a higher power compared to the standard piston and piston-1.



#### 4.7.7. 50% Load Graph Analysis 1 Meter Distance with HSD Fuel Diesel Engine at RPM 2200.

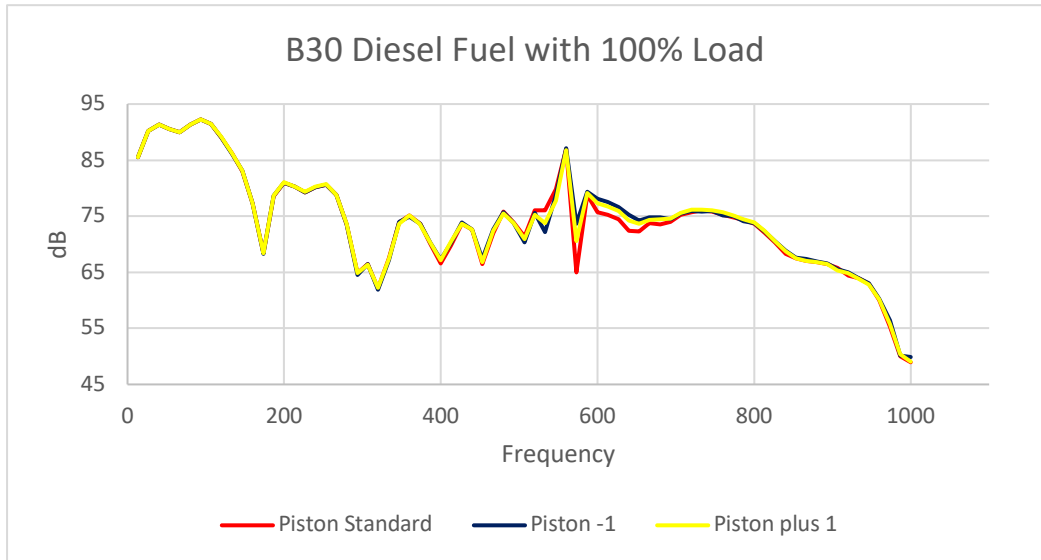


Graph 4. 25 High Speed Diesel (HSD) Fuel with 50% Load

In the graph 4.25 High Speed Diesel (HSD) Fuel with 50% Load, it can be seen comparing the noise level at 2200 RPM 50% Load condition High Speed Diesel (HSD) Fuel. Noise on Piston +1 is higher compared to standard Piston and Piston -1. At a frequency of 55.18 Hz Piston +1 has a noise of 96.15 dB. For the Standard Piston at a frequency of 55.18 Hz has a noise of 96.14 dB and a Piston -1 at a frequency of 55.18 Hz also has a noise of 96.14 dB. Piston +1 has a higher noise level than the standard piston and piston -1 because it has a higher power compared to the standard piston and piston-1.

#### 4.8. Variation Load Graph with B30 Diesel Fuel

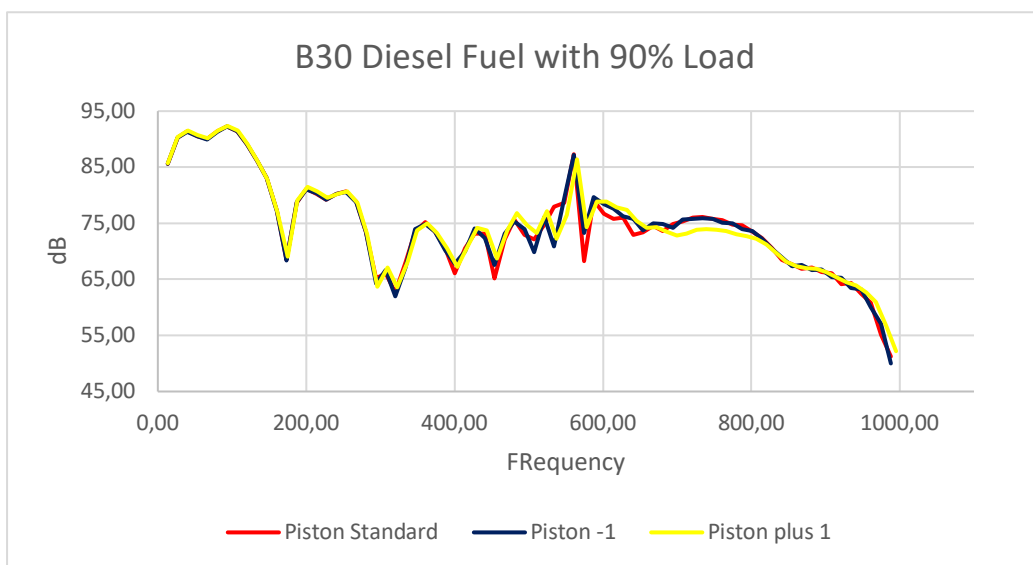
##### 4.8.1. 100% Load Graph Analysis 1 Meter Distance with B30 Fuel Diesel Engine.



Graph 4. 26 B30 Diesel Fuel with 100% Load

In the graph 4.26 B30 Diesel Fuel with 100% Load, it can be seen comparing the noise level at 2200 RPM 100% Load condition B30 diesel fuel. Noise on Piston +1 is higher compared to standard Piston and Piston -1. At a frequency of 93.3 Hz +1 piston has a noise of 92.27 dB. For Piston Standard at 93.3 Hz frequency has a noise of 92.26 dB and Piston -1 at 93.3 Hz frequency has a noise of 92.25 dB. Piston +1 has a higher noise level than the standard piston and piston -1 because it has a higher power compared to the standard piston and piston-1.

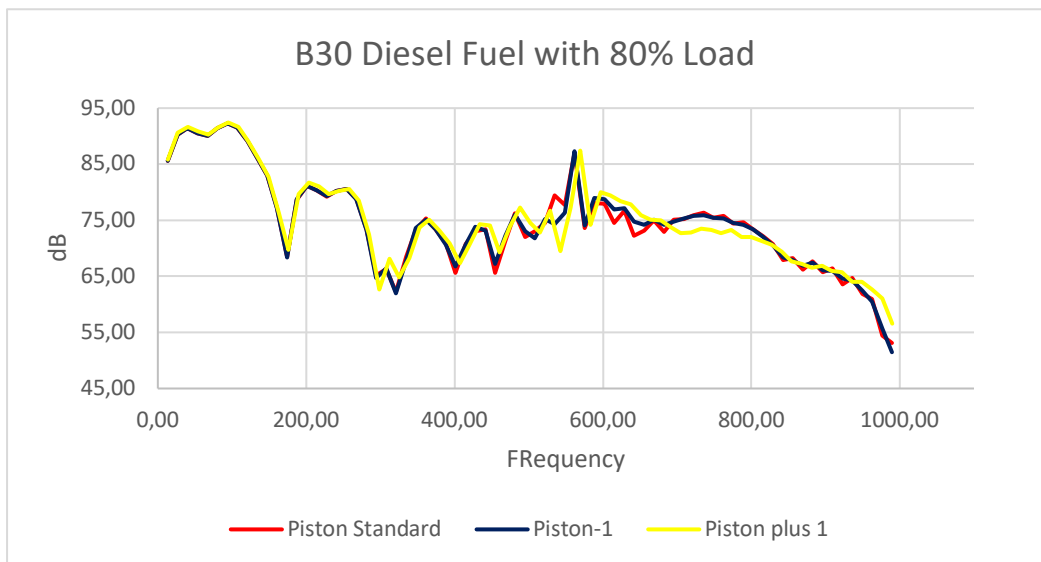
#### 4.8.2. 90% Load Graph Analysis 1 Meter Distance with B30 Fuel Diesel Engine.



Graph 4. 27 B30 Diesel Fuel with 90% Load

In the graph 4.27 B30 Diesel Fuel with 90% Load, it can be seen comparing the noise level at 2200 RPM 90% Load condition B30 diesel fuel. Noise on Piston +1 is higher compared to standard Piston and Piston -1. At a frequency of 93.3 Hz +1 piston has a noise of 92.27 dB. For Piston Standard at 93.3 Hz frequency has a noise of 92.26 dB and Piston -1 at 93.3 Hz frequency has a noise of 92.25 dB. Piston +1 has a higher noise level than the standard piston and piston -1 because it has a higher power compared to the standard piston and piston-1.

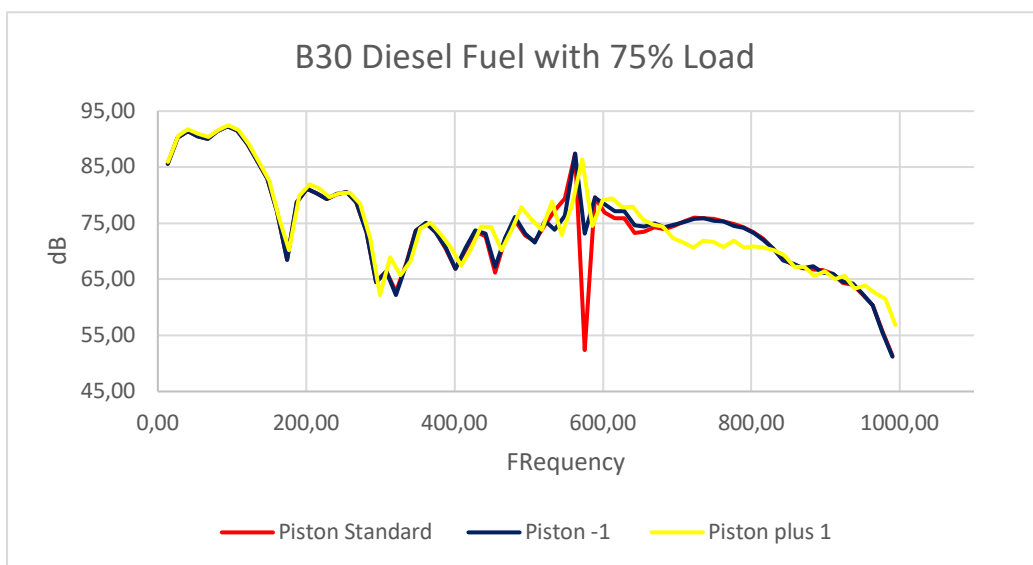
#### 4.8.3. 80% Load Graph Analysis 1 Meter Distance with B30 Fuel Diesel Engine.



Graph 4. 28 B30 Diesel Fuel with 80% Load

In the graph 4.28 B30 Diesel Fuel with 80% Load, it can be seen comparing the noise level at 2200 RPM 80% Load condition B30 diesel fuel. Noise on Piston +1 is higher compared to standard Piston and Piston -1. At 94.92 Hz frequency the Piston +1 has a noise of 92.44 dB. For Piston Standard at 93.59 Hz frequency has a noise of 92.28 dB and Piston -1 at 93.59 Hz frequency also has a noise of 92.28 dB. Piston +1 has a higher noise level than the standard piston and piston -1 because it has a higher power compared to the standard piston and piston-1.

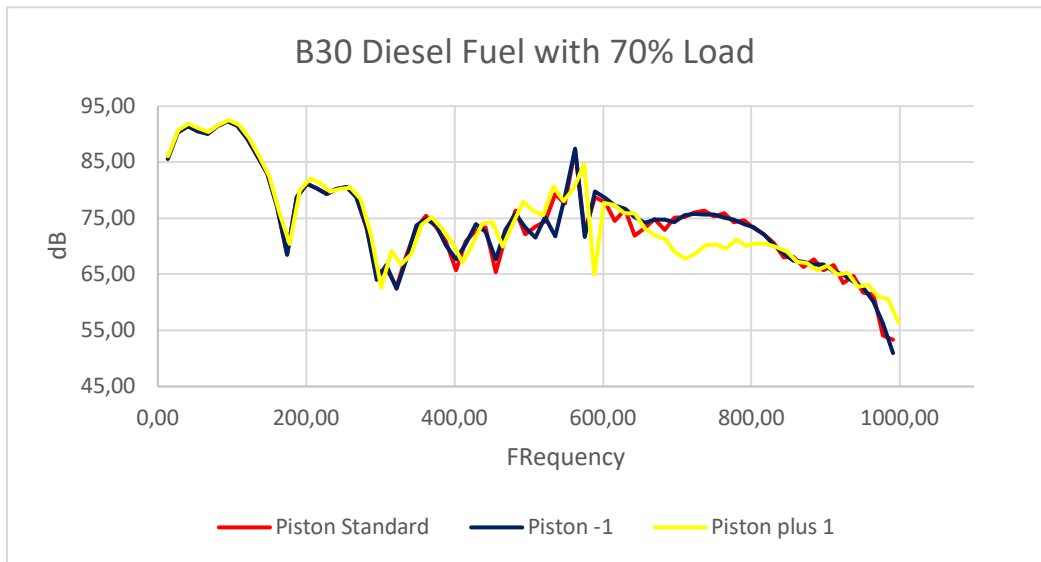
#### 4.8.4. 75% Load Graph Analysis 1 Meter Distance with B30 Fuel Diesel Engine.



Graph 4. 29 B30 Diesel Fuel with 75% Load

In the graph 4.29 B30 Diesel Fuel with 75% Load, it can be seen comparing the noise level at 2200 RPM 75% Load condition B30 diesel fuel. Noise on Piston +1 is higher compared to standard Piston and Piston -1. At a frequency of 95.32 Hz Piston +1 has a noise of 92.49 dB. For the Standard Piston at 93.66 Hz frequency has a noise of 92.29 dB and Piston -1 at a frequency of 93.66 Hz also has a noise of 92.28 dB. Piston +1 has a higher noise level than the standard piston and piston -1 because it has a higher power compared to the standard piston and piston-1.

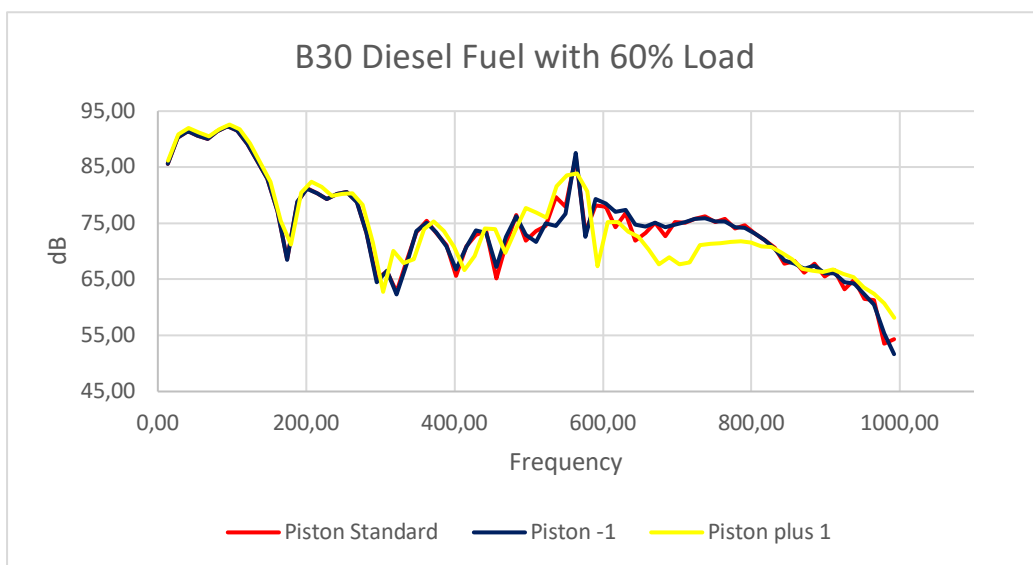
#### 4.8.5. 70% Load Graph Analysis 1 Meter Distance with B30 Fuel Diesel Engine.



Graph 4. 30 B30 Diesel Fuel with 70% Load

In the graph 4.30 B30 Diesel Fuel with 70% Load, it can be seen comparing the noise level at 2200 RPM 70% Load condition B30 diesel fuel. Noise on Piston +1 is higher compared to standard Piston and Piston -1. At a frequency of 95.71 Hz Piston +1 has a noise of 92.53 dB. For the Standard Piston at 93.73 Hz frequency has a noise of 92.30 dB and Piston -1 at 93.73 Hz frequency also has a noise of 92.29 dB. Piston +1 has a higher noise level than the standard piston and piston -1 because it has a higher power compared to the standard piston and piston-1.

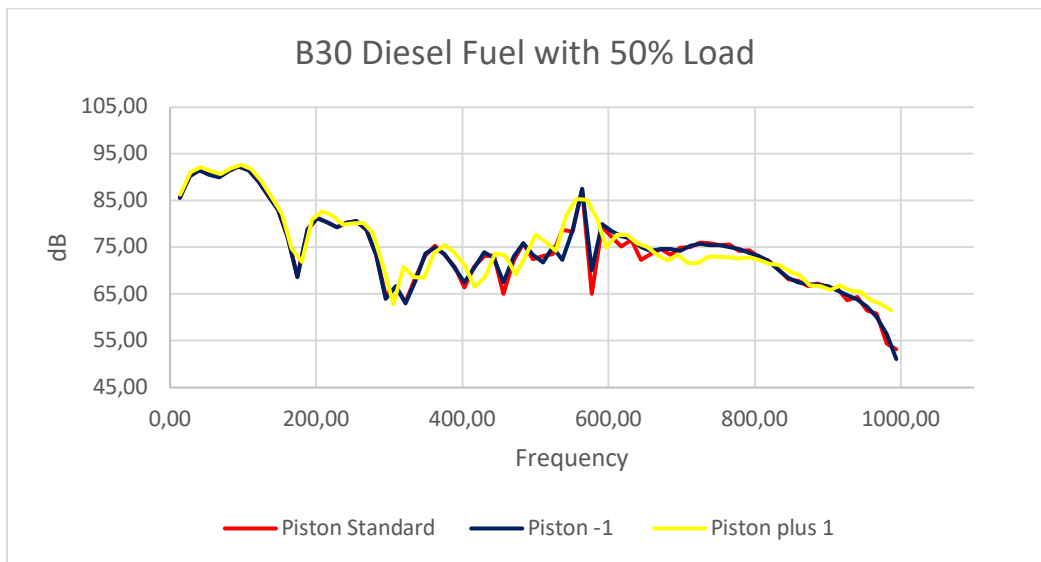
#### 4.8.6. 60% Load Graph Analysis 1 Meter Distance with B30 Fuel Diesel Engine.



Graph 4. 31 B30 Diesel Fuel with 60% Load

In the graph 4.31 B30 Diesel Fuel with 60% Load, it can be seen comparing the noise level at 2200 RPM 60% Load condition B30 diesel fuel. Noise on Piston +1 is higher compared to standard Piston and Piston -1. At a frequency of 96.50 Hz the Piston +1 has a noise of 92.61 dB. For the Standard Piston at 93.87 Hz frequency has a noise of 92.31 dB and Piston -1 at a frequency of 93.86 Hz also has a noise of 92.30 dB. Piston +1 has a higher noise level than the standard piston and piston -1 because it has a higher power compared to the standard piston and piston-1.

#### 4.8.7. 50% Load Graph Analysis 1 Meter Distance with B30 Fuel Diesel Engine.

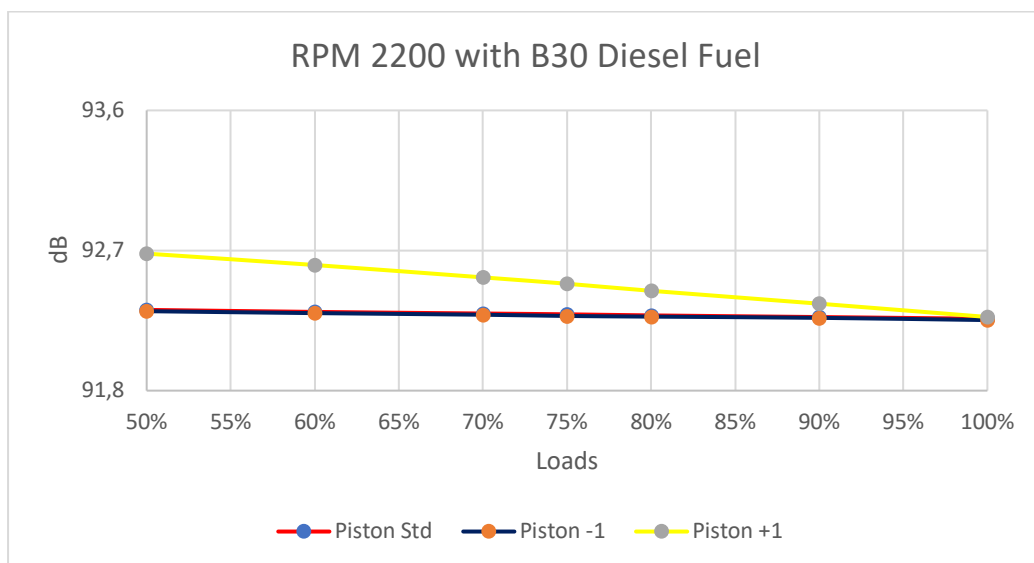


Graph 4. 32 B30 Diesel Fuel with 50% Load

In the graph 4.32 B30 Diesel Fuel with 50% Load, it can be seen comparing the noise level at 2200 RPM 50% Load condition B30 diesel fuel. Noise on Piston +1 is higher compared to standard Piston and Piston -1. At a frequency of 97.28 Hz Piston +1 has a noise of 92.68 dB. For Piston Standard at 94.0 Hz frequency has a noise of 92.32 dB and Piston -1 at 94.0 Hz frequency also has a noise of 92.31 dB. Piston +1 has a higher noise level than the standard piston and piston -1 because it has a higher power compared to the standard piston and piston-1.



#### 4.9. Graph RPM 2200 with Variations Load B30 Diesel Fuel.

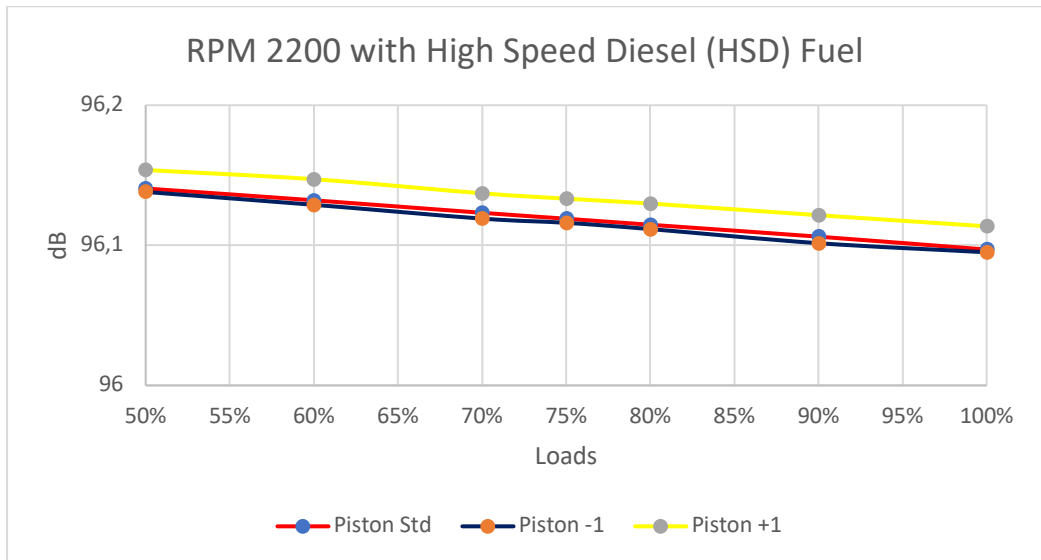


Graph 4. 33 RPM 2200 with B30 Diesel Fuel

In the graph 4.33 RPM 2200 with B30 Diesel Fuel, shows the comparison of the noise level at 2200 RPM using variations load using B30 diesel fuel. Can be seen the level of engine noise that uses type piston +1, piston standard, and piston -1 tends to fall, although the noise level is different but the graph still shows a decrease when given load. Piston +1 has a significant reduction while the standard piston and piston -1 are not too significant.

Piston +1 has the highest noise point of 92.68 dB with a minimum point of 92.27 dB, followed by a Standard Piston with a maximum point noise of 92.32 dB and a minimum point of 92.26 dB, then Piston -1 with a maximum point of 92.31 dB and the minimum point of noise 92.25 dB. It can be seen that piston -1 is the piston which has the lowest noise level compared to standard piston +1 and piston standard.

#### 4.10. Graph RPM 2200 with Variations Load High Speed Diesel (HSD) Fuel.



Graph 4. 34 RPM 2200 with High Speed Diesel (HSD) Fuel

In the graph 4.34 RPM 2200 with High Speed Diesel (HSD) Fuel, shows the comparison of the noise level at 2200 RPM using variations load using HSD fuel. Can be seen the level of engine noise that uses type piston +1, piston standard, and piston -1 tends to fall, although the noise level is different but the graph still shows a decrease when given load.

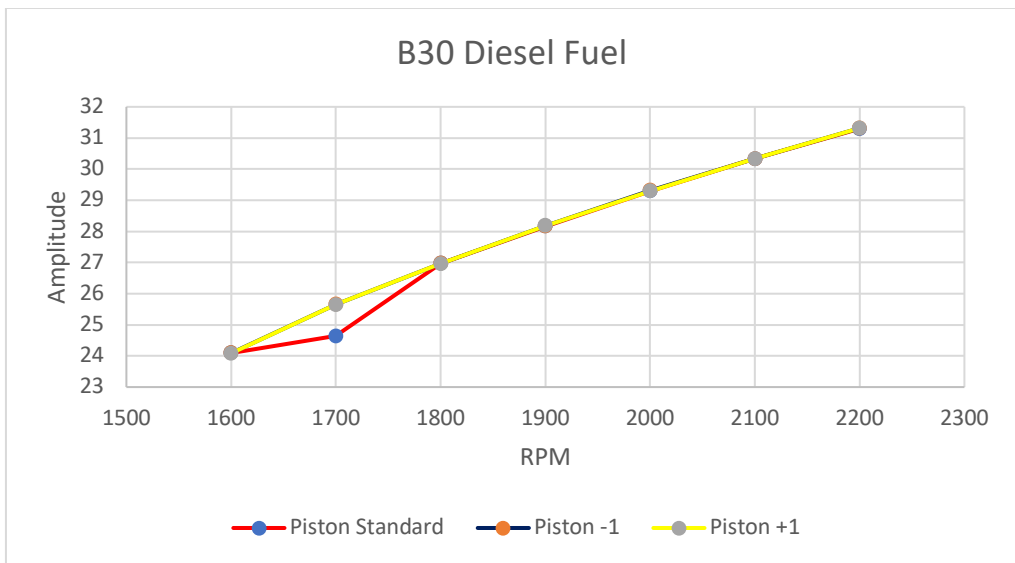
Piston +1 has the highest noise point of 96.15 dB with a minimum point of 96.11 dB, followed by a Standard Piston and Piston -1 of 96.14 dB with a minimum point of 96.09 dB. It can be seen that piston -1 is the piston which has the lowest noise level compared to piston +1 and piston standard.

#### 4.11. Vibration Analysis Data Results with B30 Diesel Fuel.

In this simulation vibration testing is performed on a diesel engine using variations of the piston with B30 Diesel Fuel. By using the FFT component in the simulation. Placement is placed on the axis system in the engine.

The variables used are RPM 1600,1700,1800,1900,2000,2100 and 2200. The input data that is read by the sensor is a displacement (micron) which is then converted into an Amplitude Vs RPM graph.

##### 4.11.1. Graph Vibration with B30 Diesel Fuel.



Graph 4. 35 Vibration B30 Diesel Fuel

In the graph 4.35 Vibration B30 Diesel Fuel, it can be seen the comparison of vibrations to the engine RPM using B30 diesel fuel. Piston +1 has a higher vibration compared to standard piston and piston -1. The input data read by FFT is in the form of displacement, therefore with the increase in RPM the vibrations experienced by the engine are reduced.

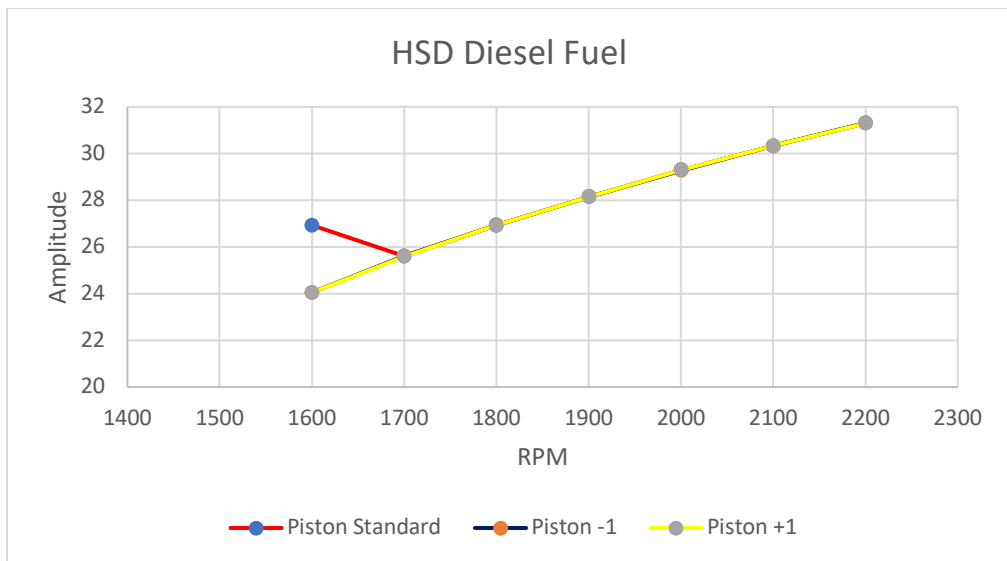
At 2200 RPM the highest vibration amplitude occurred, Piston +1 has a vibration amplitude of 31.316 micronmeter, followed by piston -1 with a vibration amplitude of 31.315 micronmeter and the last piston standard with vibration amplitude of 31.298 micronmeter.

#### 4.12. Vibration Analysis Data Results with High Speed Diesel (HSD) Fuel.

In this simulation vibration testing is performed on a diesel engine using variations of the piston with High Speed Diesel (HSD) Fuel. By using the FFT component in the simulation. Placement is placed on the axis system in the engine.

The variables used are RPM 1600,1700,1800,1900,2000,2100 and 2200. The input data that is read by the sensor is a displacement (micron) which is then converted into an Amplitude Vs RPM graph.

##### 4.12.1. Graph Vibration with High Speed Diesel (HSD) Fuel.



Graph 4. 36 Vibration High Speed Diesel (HSD) Fuel

In the graph 4.36 Vibration High Speed Diesel (HSD) Fuel, it can be seen the comparison of vibrations to the engine RPM using High Speed Diesel (HSD) Fuel. Piston +1 has a higher vibration compared to standard piston and piston -1. The input data read by FFT is in the form of a displacement, therefore with the increase in RPM the vibrations experienced by the engine are reduced.

At 2200 RPM the highest vibration amplitude occurred, Piston +1 has a vibration amplitude of 31,305 micronmeter, followed by standard with a vibration amplitude of 31,303 micronmeter and the last piston -1 with a vibration amplitude of 31,292 micronmeter.

#### **4.13. Discussion Analysis.**

From the results of the analysis, piston +1 which is the result of piston modification on this thesis, is a piston with noise and vibration levels of the highest good in B30 diesel fuel and diesel fuel diesel fuel.

Because the piston +1 which has a greater area compared to other pistons and also has greater power. Power that is largely due to the combustion process generates a large explosion and resulting pressure experienced engine noise and vibration levels are higher.

The noise level is greatly affected by rotation. With increasing rotation, the engine has increased work. Increase in work will increase the amount of fuel that enters the cylinder. Increasing the amount of fuel that enters the cylinder will require greater pressure to ignite.

Increasing the pressure needed for the combustion process will increase the vibration in the engine. Increased vibration caused by the engine causes the noise level to increase as well. Because basically sound is vibrations that travel and are received by the ear. (Arief, 2004).

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## CHAPTER V

### CONCLUSIONS AND RECOMMENDATIONS

#### 5.1. Conclusions.

Based on the simulation results and data obtained during the study, there are some conclusion that the author would summarize:

1. The highest noise level occurs in piston +1 (Case 4) with B30 Diesel Fuel or High Speed Diesel (HSD) Fuel. The lowest noise level occurs in piston -1(Case 3) with B30 Diesel Fuel or High Speed Diesel (HSD) Fuel. The effect of load on RPM 2200 B30 fuel with the highest noise level occurs at 50% load with piston +1 with 92.68 dB noise level, while the lowest noise level occurs at 100% load with piston -1 with 92.25 dB noise level. Effect of load on RPM 2200 HSD fuel with the highest noise level occurs at 50% load with piston +1 with 96.15 dB noise level, while the lowest noise level occurs at 100% load with piston -1 with noise level 96.09 dB. So, the piston modified -1 (Case 3) has more lower noise level rather than piston standard Yanmar TF85 and piston modified +1(Case 4).
2. The highest vibration level occurs in a piston +1 (Case 4) with B30 Diesel Fuel or High Speed Diesel (HSD) Fuel. And the lowest vibration level occurs in a piston -1 (Case 3) with B30 Diesel Fuel or High Speed Diesel (HSD) Fuel. So, the piston modified -1(Case 3) has more lower vibration level rather than piston standard Yanmar TF85 and piston modified +1(Case 4).

#### 5.2. Recommendations.

Based on the simulation results and data obtained during the study, there are some recommendation that the author would suggest:

1. Conducted an experiment to validate the simulation results.
2. Completing the engine calibration data before analyzing the simulation.
3. Measuring factual data of engine components to be included in the simulation data.

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## REFERENCES

- Azwar, n.d. s.l.:s.n. Fahrudin, T., n.d. SISTEM PENDUKUNG KEPUTUSAN MENDETEKSI KERUSAKAN MESIN DIESEL DENGAN METODE K-NEAREST NEIGHBOUR (K-NN).
- Taufik, F., 2015. SISTEM PENDUKUNG KEPUTUSAN MENDETEKSI KERUSAKAN MESIN DIESEL DENGAN METODE K-NEAREST NEIGHBOUR (K-NN).
- Wirawan, S. S., 2008. STUDI PENENTUAN KOMPOSISI OPTIMUM CAMPURAN BAHAN BAKAR BIODIESEL–PETRODIESEL. *Vol. 4 No.2 BPPT, Mahasiswa S3 IPB*.
- Prasetya, F. P., 2013. Monitoring Kebisingan Di Pt.Heinz Abc Indonesia Karawang Tahun 2010-2013.
- ABDILLAH, F., 2010. PERLAKUAN PANAS PADUAN AL-SI PADA PROTOTIPE PISTON BERBASIS MATERIAL PISTON BEKAS.
- Odio Setyawan, A. f. Z. M. I., 2015. Jurnal Teknik Perkapalan, Vol. 3, No 1 Januari 201563 Analisa Estimasi Tingkat Kebisingan di Kamar Mesin dan Ruang Akomodasi pada Kapal Riset dengan Penggerak Motor Listrik. *Jurnal Teknik Perkapalan, Vol. 3, No 1 Januari 201*.
- Hanifa, T. Y. U., 2005. PENGARUH KEBISINGAN TERHADAP KELELAHAN PADA TENAGA KERJA INDUSTRI PENGOLAHAN KAYU BRUMBUNG PERUM PERHUTANI SEMARANG.
- RI, K. K., 2003. Departemen Kesehatan RI, 2003:MI-2:37.
- Utomo, B. L. P. d. A. A., 2002. Hubungan intensitas kebisingan terhadap kelelahan kerja sebelum dan sesudah kerja pada karyawan mekanik maintenance utility compresor di PT. Indo Acidatama, tbk. Kemiri Kebakkramat karanganyar.
- Budiono, A. S., 2003. Pengaruh Kebisingan terhadap Kelelahan pada Tenaga Kerja Industri Pengolahan Kayu Brumbung Perum Perhutani Semarang Tahun 2005..
- Kerja, M. t., 1999. lampiran II Keputusan Menteri Tenaga Kerja No. Kep-51/MEN/1999.
- SOLAS, 2012. *SOLAS Regulation II-1/3-12*. 30 November 2012 ed. s.l.:s.n.
- Utami, A. r. D., 2012. Hubungan antara Beban Kerja dan Intensitas Kebisingan dengan Kelelahan pada Tenaga Kerja Pemeliharaan Jalan Cisolak Kotabima CV Serayu Indah Cilacap.

Royan Hidayat, G. R. W., 2017. ANALISIS GETARAN PADA KOMPRESOR MESIN PENDINGIN DENGAN VARIASI PUTARAN (RPM). *Volume 15 no. 2 Oktober 2017*.

Sunarto, A. I., 2016. PEMANFAATAN HASIL ANALISA VIBRASI UNTUK MENDETEKSI TERLEPASNYA CINCIN MINYAK PELUMAS DALAM BANTALAN POMPA SENTRIFUGAL SEBUAH STUDI KASUS DI PERUSAHAAN PT. PGN SAKA (INDONESIA-PANGKAH) LIMITED. *Volume 05, Nomor 01, Juni 2016*.

Hidup, m. N. L., 1996. *Keputusan Menteri Negara Lingkungan Hidup No. 49 Tahun 1996 Tentang : Baku Tingkat Getaran*. s.l.:s.n.

Priatmoko, D. a. N. T. F., 2012. Analisa Getaran Dan Sistem Perporosan Pada Reduction Gear. *Km.Kumala', pp. 1-14*.

Wahyu, N. a. J. T. R., 2015. Analisa Respon Harmonik Struktur Poros Propeller Kapal Menggunakan Ansys. *Workbench 14.5'.*

Syahrani, A., n.d. ANALISA KINERJA MESIN BENSIN BERDASARKAN HASIL UJI EMISI. *Staf Pengajar Jurusan D3 Teknik Mesin Fakultas Teknik Universitas Tadulako, Palu*.

Sumarsono, M., 2008. ANALISIA PENGARUH CAMPURAN BAHAN BAKAR SOLAR-MINYAK JARAK PAGAR PADA KINERJA MOTOR DIESEL DAN EMISI GAS BUANG. *Peneliti di Balai Besar Teknologi Energi Badan Pengkajian dan Penerapan Teknologi*.

Shipping, A. B., 2017. *ABS GUIDANCE NOTES ON NOISE AND VIBRATION CONTROL FOR INHABITED SPACES*. 2017. s.l.:s.n.

Annur, M. N., 2019. PENGARUH PEMANASAN BAHAN BAKAR B20 DAN B30 TERHADAP NOISE MESIN DIESEL SINGLE SILINDER.

Sukjit, E., 2013. Effect of hydrogen on butanol–biodiesel blends in compression ignition engines. *Volume 38, Issue 3, 6 February 2013, Pages 1624-1635*.

Marviansyah, Y., 1998. STUDI EKSPERIMENTAL PENENTUAN RANTALAN DALAM MEREDAM TINGKAT GETARAN MESIN DIESEL YANMAR YSM8 DI LADORA TORIUM GETARAN DAN KEBISINGAN.

PRABHAKARA RAO GANJI, R. N. S. V. R. K. R. S. S. R., 2018. Design of piston bowl geometry for better combustion in direct-injection compression ignition engine. *Sādhanā (2018) 43:92*.

Narayan, S., 2015. CORRELATION BETWEEN CYLINDER PRESSURE AND NOISE EMISSIONS FROM DIESEL ENGINES. *Journal of KONES Powertrain and Transport*, Vol. 22, No. 1 2015.

Gosh, A., 2016. Combustion Chambers in CI engines : A review. *Processing of National Conf. on Recent Innovations in Science Engineering & Technology*.

Soeharto, A. S., 2012. Studi Eksperimen pada Investment Casting dengan Komposisi Ceramic Shell yang Berbeda dalam Pembuatan Produk Toroidal Piston. *JURNAL TEKNIK POMITS Vol 1, No 1*.

P.K, S., 1996, 58. *Higene Perusahaan dan Kesehatan Kerja*. s.l.:Gunung Agung.

Ogunwole, 2012. Production of Biodiesel from Jatropha Oil (Curcas Oil). *Research Journal of Chemical Sciences ISSN 2231-606X Vol. 2(11), 30-33, November (2012)*.

Matheus M. Dwinanto<sup>1</sup>, D. B. N. R. J. C. A. P. A. Y. T., 2019. PELATIHAN DIAGNOSA, PERBAIKAN, DAN PERAWATAN MOTOR DIESEL DAN MOTOR TEMPEL BAGI KELOMPOK NELAYAN. *JURNAL PENGABDIAN VOKASI*, p. Vol 01.

Arief Hariyanto, W. A. G. G. E., 2007. EFFECTS OF HYDROGEN ADDITION INTO INTAKE AIR ON THE HYDROCARBON EMISSION OF GASOLINE ENGINES AT COLD START CONDITION. *ISSN 0856-6095*, p. Vol 22.

H. Amad Narto, M. M., 2018. *PENGENDALIAN SISTEM PERMESINAN KAPAL*. Semarang: s.n.

Coppenberg, A. D., 2017. Pengaruh Penggunaan Bahan Bakar Solar, Biosolar. *Jurnal Konversi Energi dan Manufaktur UNJ*.

Harrington, R. L., 1992. *Marine Engineering*. s.l.:s.n.

Arief, S., 2004. *Analisa Getaran Dan Kebisingan Pada Motor Diesel Dengan menggunakan Bahan Bakar Jelantah Ethyl Ester*, Surabaya: Institut Teknologi Sepuluh Nopember.

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## ATTACHMENT

### SIMULATION DATA RESULT

**Observation Table and Graph of Noise.**

**Full Load with B30 Diesel Fuel:**

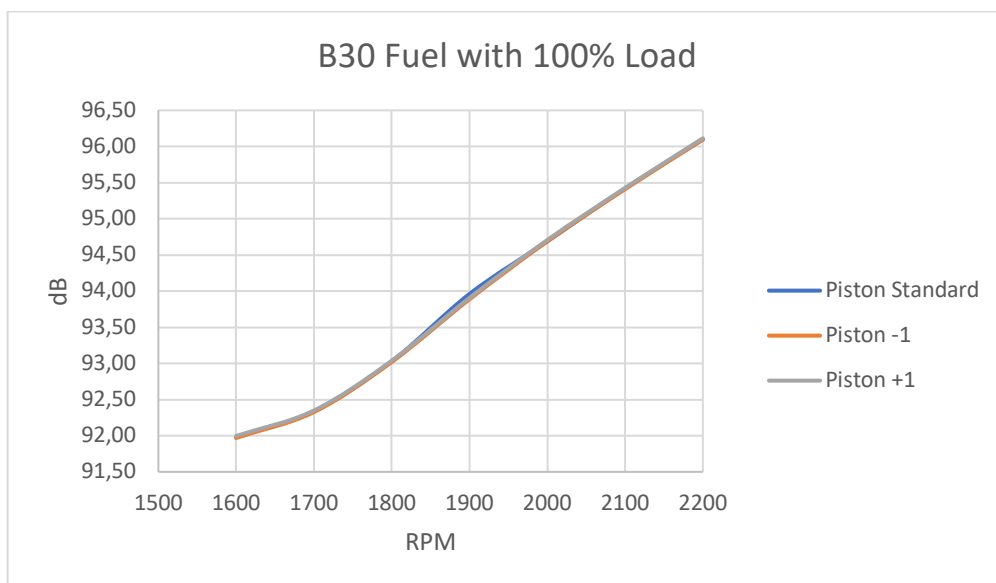
Distance	Fuel	RPM	Piston Standard	Piston -1	Piston +1
1 meter	B30	1600	92,18	92,17	92,19
		1700	92,53591	92,53	92,55
		1800	92,79	92,79	92,79
		1900	93,97	93,97	93,98
		2000	94,78	94,77	94,79
		2100	95,50	95,49	96,18
		2200	96,18	96,17	96,18

**Full Load with High Speed Diesel (HSD) Fuel:**

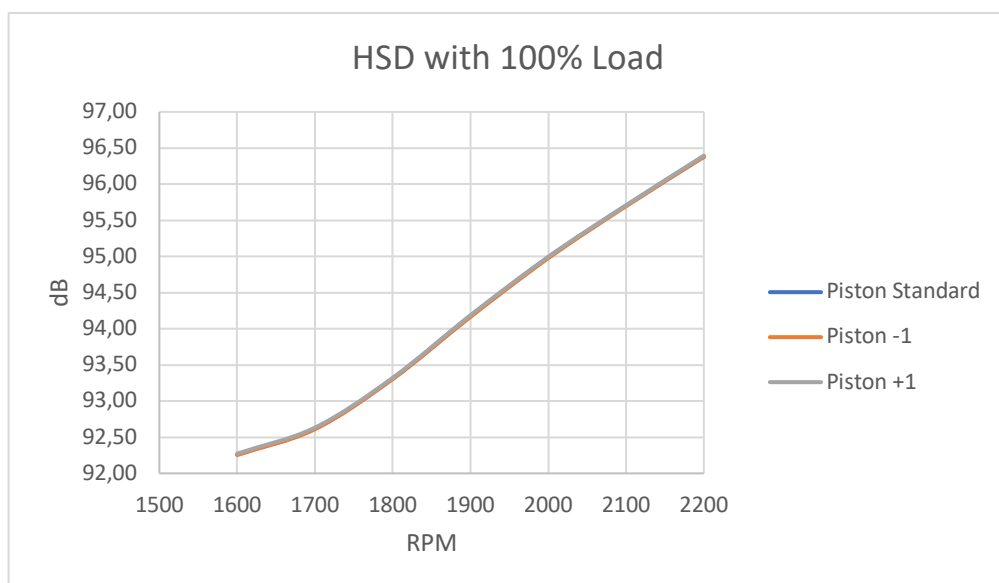
Distance	Fuel	RPM	Piston Standard	Piston -1	Piston +1
1 meter	HSD	1600	92,46	92,46	92,47
		1700	92,8192	92,81	92,83
		1800	93,39	93,39	93,40
		1900	94,26	94,25	94,27
		2000	95,06	95,05	95,07
		2100	95,79	95,78	95,80
		2200	96,46	96,45	96,47

**Load 100%:**

Distance	Fuel	RPM	Piston Standard	Piston -1	Piston +1
1 meter	B30	1600	91,98	91,97	92,00
		1700	92,33698	92,33	92,35
		1800	93,03	93,02	93,04
		1900	93,96	93,89	93,91
		2000	94,69	94,69	94,71
		2100	95,42	95,41	95,43
		2200	96,10	96,10	96,11

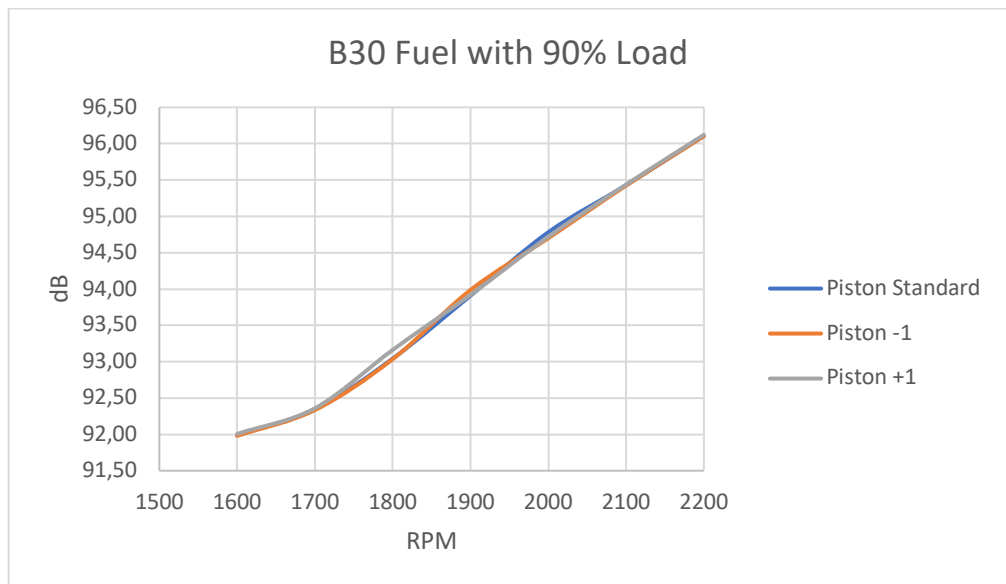


Disntace	Fuel	RPM	Piston Standard	Piston -1	Piston +1
1 meter	HSD	1600	92,26	92,25	92,27
		1700	92,61765	92,61	92,63
		1800	93,31	93,30	93,32
		1900	94,18	94,16	94,19
		2000	94,99	94,98	95,00
		2100	95,70	95,70	95,71
		2200	96,38	96,38	96,40



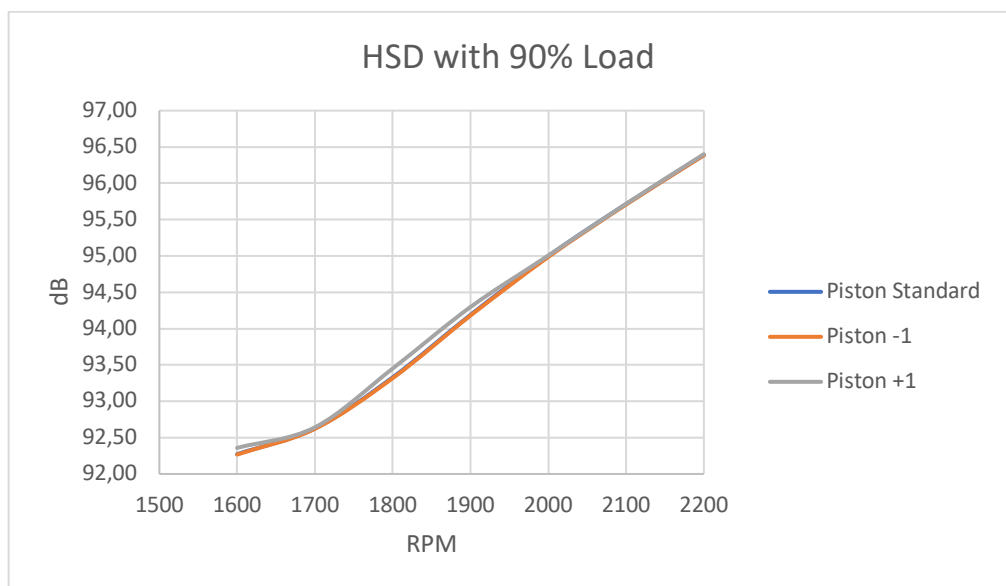
**90% Load:**

Distance	Fuel	RPM	Piston Standard	Piston -1	Piston +1
1 meter	B30	1600	91,99	91,98	92,01
		1700	92,3442	92,34	92,36
		1800	93,04	93,04	93,16
		1900	93,91	93,99	93,92
		2000	94,78	94,70	94,72
		2100	95,43	95,42	95,44
		2200	96,11	96,10	96,12



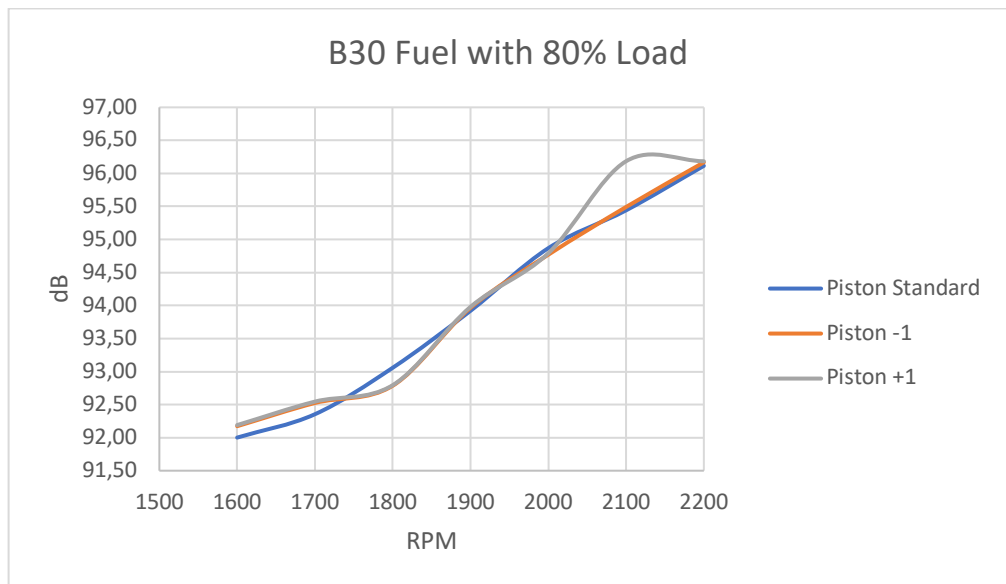


Distance	Fuel	RPM	Piston Standard	Piston -1	Piston +1
1 meter	HSD	1600	92,27	92,27	92,36
		1700	92,63	92,62	92,64
		1800	93,33	93,32	93,45
		1900	94,19	94,18	94,30
		2000	95,00	94,99	95,01
		2100	95,71	95,71	95,72
		2200	96,39	96,38	96,40

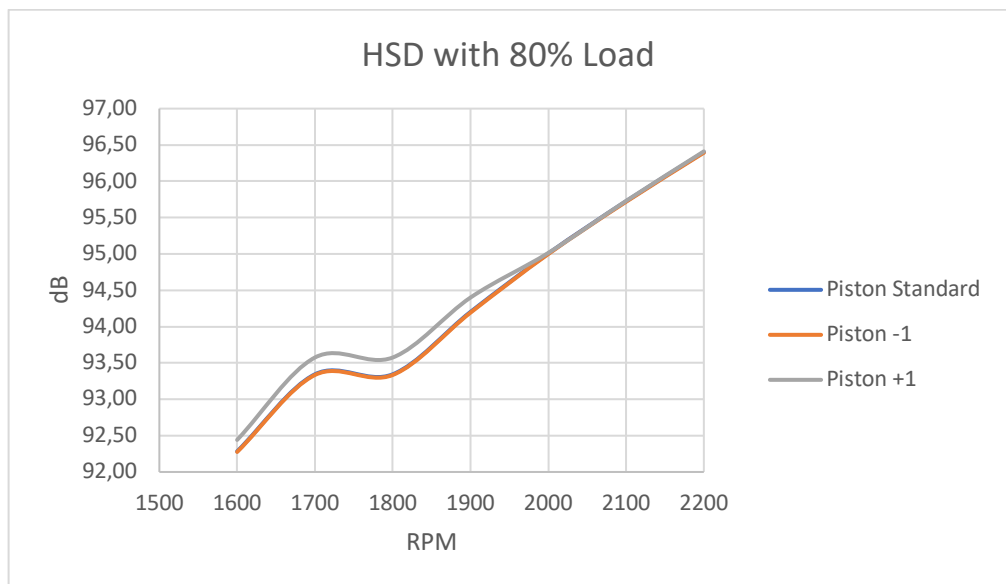


**80% Load:**

Distance	Fuel	RPM	Piston Standard	Piston -1	Piston +1
1 meter	B30	1600	92,00	91,99	92,02
		1700	92,35	92,35	92,37
		1800	93,06	93,05	93,29
		1900	93,92	94,09	93,93
		2000	94,87	94,71	94,73
		2100	95,44	95,43	95,45
		2200	96,11	96,11	96,13

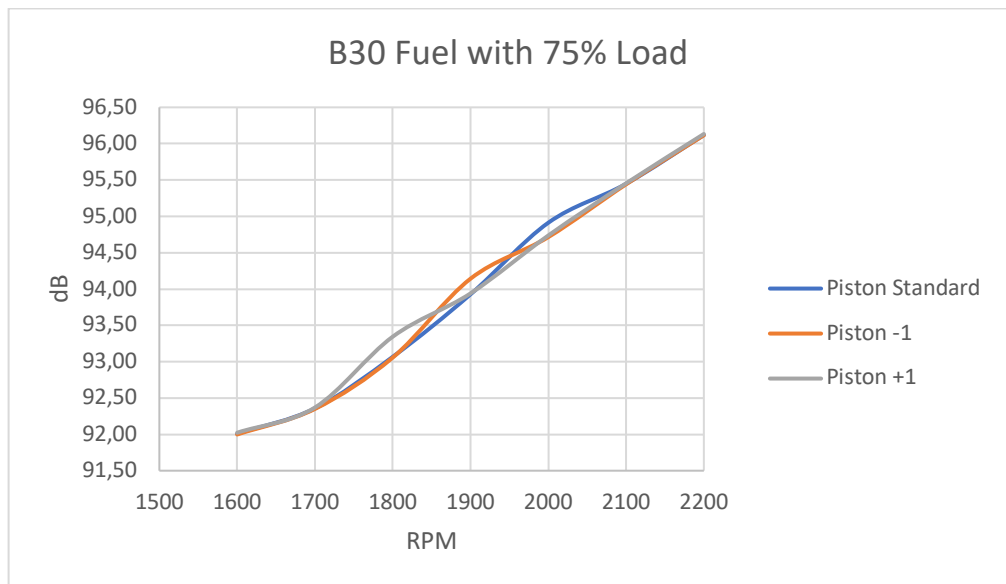


Distance	Fuel	RPM	Piston Standard	Piston -1	Piston +1
1 meter	HSD	1600	92,28	92,28	92,44
		1700	93,34	93,33	93,57
		1800	93,34	93,33	93,57
		1900	94,20	94,19	94,40
		2000	95,01	95,00	95,01
		2100	95,73	95,72	95,73
		2200	96,40	96,39	96,41

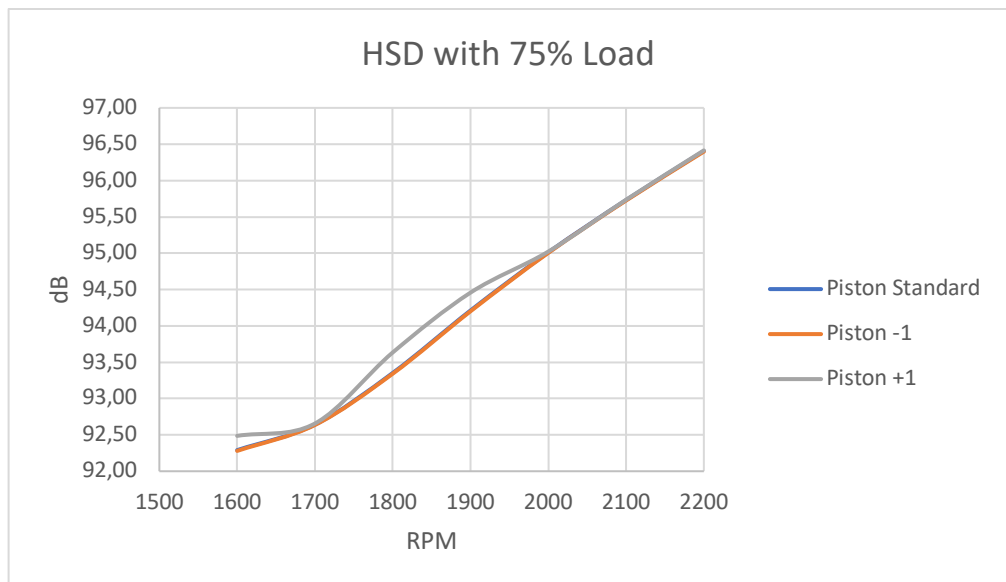


**75% Load:**

Distance	Fuel	RPM	Piston Standard	Piston -1	Piston +1
1 meter	B30	1600	92,01	92,00	92,02
		1700	92,36	92,35	92,37
		1800	93,07	93,06	93,34
		1900	93,93	94,14	93,94
		2000	94,91	94,71	94,74
		2100	95,45	95,44	95,45
		2200	96,12	96,12	96,13

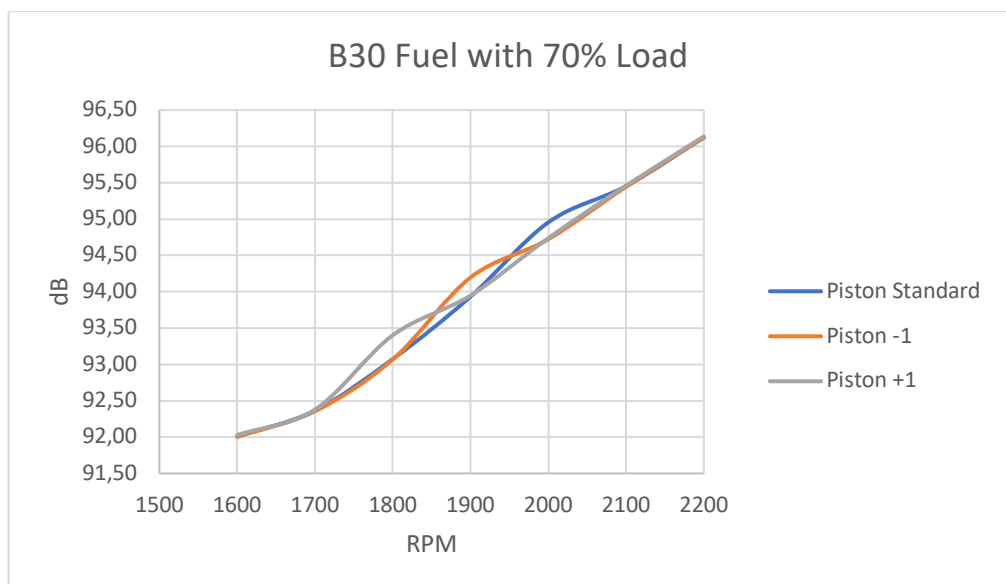


Distance	Fuel	RPM	Piston Standard	Piston -1	Piston +1
1 meter	HSD	1600	92,29	92,28	92,49
		1700	92,64	92,64	92,66
		1800	93,35	93,34	93,63
		1900	94,21	94,20	94,46
		2000	95,01	95,00	95,02
		2100	95,73	95,73	95,74
		2200	96,41	96,40	96,41

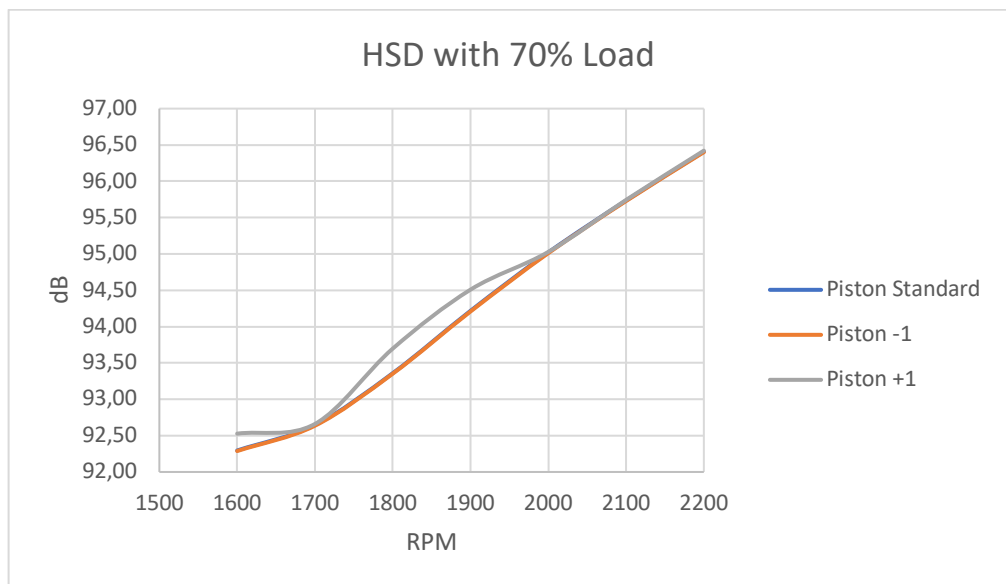


**70% Load:**

Distance	Fuel	RPM	Piston Standard	Piston -1	Piston +1
1 meter	B30	1600	92,01	92,00	92,03
		1700	92,36	92,36	92,38
		1800	93,07	93,07	93,40
		1900	93,93	94,20	93,95
		2000	94,95	94,72	94,74
		2100	95,45	95,44	95,46
		2200	96,12	96,12	96,14

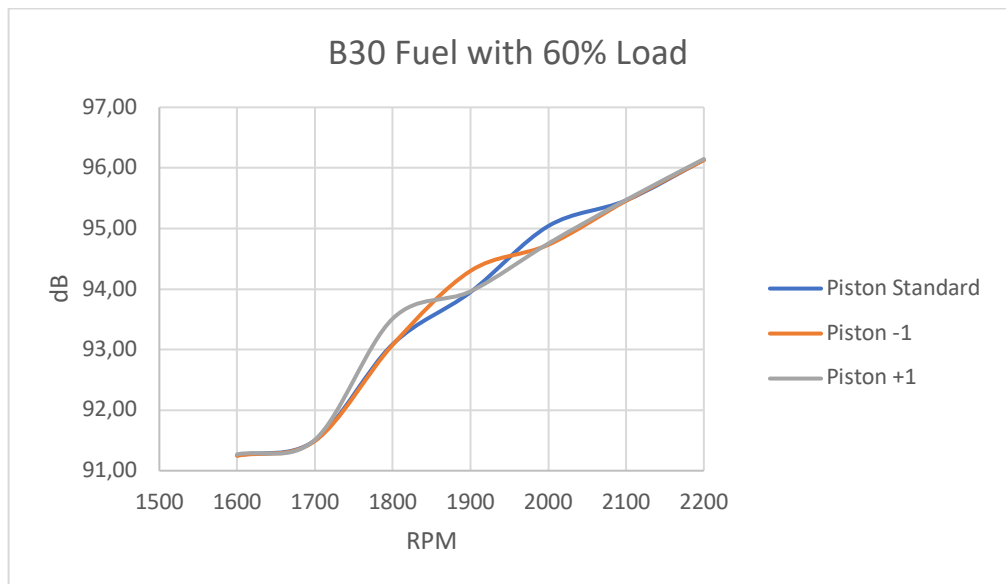


Distance	Fuel	RPM	Piston Standard	Piston -1	Piston +1
1 meter	HSD	1600	92,30	92,29	92,53
		1700	92,65	92,64	92,66
		1800	93,36	93,35	93,70
		1900	94,22	94,21	94,51
		2000	95,02	95,01	95,03
		2100	95,74	95,73	95,74
		2200	96,41	96,40	96,42



**60% Load:**

Distance	Fuel	RPM	Piston Standard	Piston -1	Piston +1
1 meter	B30	1600	91,25	91,25	91,27
		1700	91,50	91,49	91,51
		1800	93,09	93,08	93,51
		1900	93,95	94,30	93,96
		2000	95,04	94,73	94,75
		2100	95,46	95,46	95,47
		2200	96,13	96,13	96,15



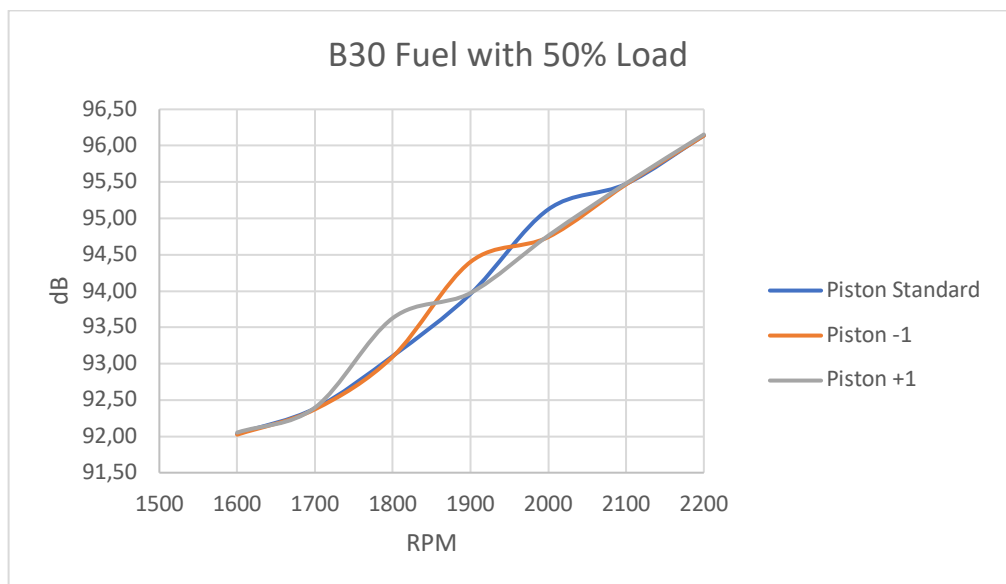


Distance	Fuel	RPM	Piston Standard	Piston -1	Piston +1
1 meter	HSD	1600	92,31	92,30	92,61
		1700	92,65	92,65	92,67
		1800	93,38	93,37	93,82
		1900	94,23	94,22	94,62
		2000	95,03	95,02	95,04
		2100	95,75	95,74	95,75
		2200	96,42	96,41	96,43

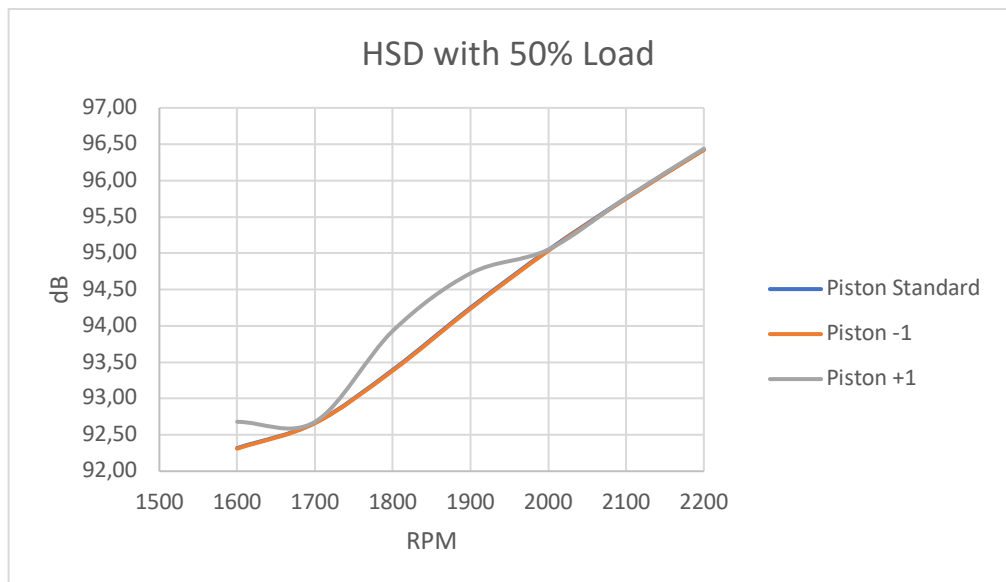


**50% Load:**

Distance	Fuel	RPM	Piston Standard	Piston -1	Piston +1
1 meter	B30	1600	92,03	92,02	92,05
		1700	92,38	92,37	92,40
		1800	93,11	93,10	93,63
		1900	93,96	94,40	93,97
		2000	95,12	94,74	94,76
		2100	95,47	95,47	95,48
		2200	96,14	96,14	96,15



Distance	Fuel	RPM	Piston Standard	Piston -1	Piston +1
1 meter	HSD	1600	92,32	92,31	92,68
		1700	92,67	92,66	92,68
		1800	93,39	93,38	93,93
		1900	94,25	94,24	94,72
		2000	95,04	95,03	95,05
		2100	95,76	95,75	95,76
		2200	96,43	96,42	96,44



**Observation Table of Vibration.****Table of B30 Diesel Fuel:**

Fuel	RPM	Piston Standard	Piston -1	Piston +1
B30	1600	24,093	24,084	24,09
	1700	24,635	25,647	25,65
	1800	26,966	26,962	26,972
	1900	28,16	28,188	28,171
	2000	29,295	29,293	29,315
	2100	30,334	30,334	30,335
	2200	31,298	31,316	31,315

**Table of High Speed Diesel (HSD) Fuel:**

Fuel	RPM	Piston Standard	Piston -1	Piston +1
HSD	1600	26,92	24,044	24,05
	1700	25,606	25,601	25,61
	1800	26,928	26,925	26,935
	1900	28,149	28,15	28,151
	2000	29,294	29,292	29,275
	2100	30,326	30,326	30,329
	2200	31,303	31,292	31,305

### Obervaion Table of Power vs RPM.

#### Table of B30 Diesel Fuel:

RPM	Power B30		
	Piston Standard	Piston -1	Piston +1
1600	5,0686827	5,078213	5,083528
1700	5,319884	5,31619	5,321063
1800	5,5203915	5,516299	5,52183
1900	5,746062	5,742148	5,747469
2000	5,9333067	5,929659	5,934646
2100	6,09897	6,095468	6,100162
2200	6,250701	6,24715	6,251984

#### Table of High Speed Diesel (HSD) Fuel:

RPM	Power HSD		
	Piston Standard	Piston -1	Piston +1
1600	5,2826295	5,29359	5,298836
1700	5,5461783	5,542448	5,547545
1800	5,757523	5,774765	5,758719
1900	5,992	5,989534	5,966785
2000	6,1874795	6,151824	6,190249
2100	6,363473	6,360031	6,364765
2200	6,5222964	6,518699	6,523669

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## AUTHOR'S BIOGRAPHY



Ilham Rezandhi Akbar was born in Kediri, 27 February 1998, the firstborn of three siblings. Author father's name is Luthfie Sulistya Hadi, S.E and mother's Nina Emilia. He grew up in South Tangerang, Banten. Author's was Studying at SD Islam Al-Azhar 17 Bintaro (2015-2010) and then he continued his study ad SMP Islam Al-Azhar 3 Bintaro (2010-2013), followed by entering a higher education level, namely at SMA Islam Al-Azhar 3 Pusat (2013-2016), majoring in Science Study. Author's then continue his education in Marine Engineering Departement, Faculty of Marine Technology, Sepuluh Nopember Institute of Technology Surabaya, joining the Joint Degree Program with *Hochschule Wismar*, Germany. During his study , author had been actively involved in some organization, competition, and activities. In the first year of collage he was the Security and Licensing of Marine Icon 2016, and be the 2<sup>nd</sup> Place of ITS Futsal Competition 2016-2017 ( IFC 2016-IFC 2017). He was also member of Institute of Marine Engineering, Science and Techonology (IMarEST). He was active in *Himpunan Mahasiswa Teknik Sistem Perkapalan* (HIMASISKAL FTK-ITS) as staff of Internal Affair in 2018 and he be the Head of Internal Affair HIMASISKAL FTK-ITS in 2019. Author was active in participating in softskills development activities in collage such as *Latihan Keterampilan Manajemen Mahasiswa Tingkat Pra-Dasar*. Author has done his internship in two times ; 1) *PT. Yasa Wahaya Tirta Samudera, Semarang* in Semarang, Central Java in 2018, 2) *PT GMF AeroAsia, Tangerang* in Soekarno Hatta International Airport, Tangerang in 2019. Author is very passionate about engine, author was a member of Marine Power Plant (MPP) Laboratory in Marine Engineering Departement. Author can be reach at [ilhamakbarrezandhi@gmail.com](mailto:ilhamakbarrezandhi@gmail.com) or phone call 081295389627.