

DETECTION AND ANALYSIS SIGNAL ENERGY OF PISTON RING DAMAGES ON FOUR STROKES ENGINE

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ABSTRACT

The purpose of this study is to develop the piston ring damage detection technique using vibration analysis. Vibration analysis was performed by measuring vibration in four stroke engine which were worn and scratched on its piston ring, then compare it with the vibrations generated by engine which had a good conditions.

Tests carried out on engine rotations of 750, 1500, and 2250 rpm, where the sensor were placed on the cylinder head and cylinder block. Vibration measurement produced a signal in the time domain, which then be analysed their signal energy by manual calculation which based on trapezoidal rule.

Result of the research showed that the vibration signal energy decrease in all of the strokes of the defect piston ring. It was caused by the pressure of the defect piston ring smaller than the good piston ring. The decrease of vibration signal energy in suction and compression stroke were greater than the power and exhaust stroke. Indication of piston ring defect could be shown from the decrease in the vibration signal energy in all of the strokes.

Key Word: Vibration Signal, Signal Energy, Piston Ring Condition, Pressure down, Amplitudo

1. INTRODUCTION

1.1 BACKGROUND

The development of motor fuel in the automotive world today is increasing. Combustion engine is a type of engine utilizing heat energy from the combustion process in the cylinder into mechanical energy. Motor fuel composed of the major components that have an important role, such as crankshaft, connecting rods, pistons, valves, camshaft and cam chain.

The piston is a component that functions as a suppressor and receiver inlet air pressure of combustion in the combustion chamber. The piston is connected to the crankshaft through the piston (connecting rod), so that the power generated after combustion can be channeled. In piston ring fitted separating the two parts of the piston and the cylinder liner. Piston rings are made of cast iron or steel used as a suppressant mixture and the radial direction to the cylinder wall to form a seal.

1.2 PROBLEM LIMITATION

1. Engine tested in no-load conditions or in neutral gear position.
2. Damage is assumed to occur only in compression piston rings, the other components well conditioned.
3. In this research, author only calculated magnitude of signal energy

1.3 OBJECTIVES

1. Detecting the damage piston rings that occur in a single-cylinder four-stroke engine.
2. Assessing the energy vibration signals generated when the damaged piston ring components.
3. Analyzing the affection of decreasing signal energy to others involved parameters

2 BASIC THEORY

2.1 LITERATURE REVIEW

Douglas, R.M, and friends, (2006), examines the relationship between piston ring and cylinder liner ship in a series of diesel engines using sound signals. This study discusses possible mechanisms as the source of the sound signal

contacts the piston and liner, lubricant flow, as well as the back pressure of air. The method was tested on two small diesel engines and one diesel engine is great. Data acquisition system used in this test series diesel engines. Addition shaft Encoder necessary to know the position of the piston and the crank angle. For a small diesel engine, the onset of the sound signal is proportional to the velocity of the piston when the cylinder pressure increased. Friction acting on the oil ring is the most likely cause sound. Compression provided by the piston rings to the cylinder pressure is found as a sound source on machine 2 steps, and the piston speed is a factor that affects the amplitude of the sound.

Research Klinchaeam, et al., (2009) with the time domain method and the crank angle domain is used to analyze the mechanical vibrations of the gasoline engine 100 cc 4 stroke and fluid flow in the engine cycle. Vibration signal was detected using an accelerometer and signal dead spots over the proximity sensor detected using a given pulse per revolution of the crankshaft. Gasoline engines run at normal speed 1500 rpm, with variations errors entrance slit and exhaust valve and spark plug gap error conditions. Entrance slit valves are smaller than normal gap, will result in the intake valve open amplitude is small so it is difficult to be identified. Small slit valve open amplitude is small so it is difficult to be identified. Small slit valve exhaust valve closure generates signals are not clear.

2.2 Four Stroke Engines

The basic principle of the reciprocating engine is air and fuel mixture is injected into the cylinder, this mixture will be burned using a spark to explode it, style combustion pushes the piston moves that occur over and over again (Reciprocal), and this movement is converted into circular motion by the crankshaft

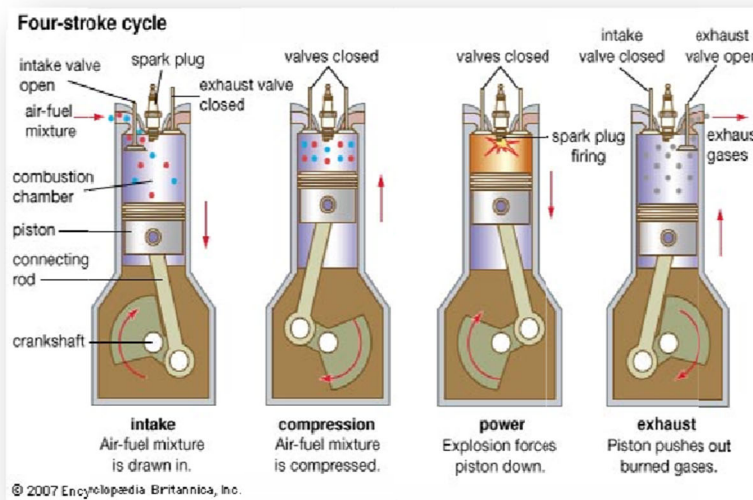


Figure 2.1 four-stroke cycle (Klinchaeam and Nivesrangsan, 2010)

2.3 Damage Piston Ring

Cause of disability in the piston rings can beclassified into several types, among others, the less fuel mixture or ignition too early, lack of oil, dirt in the cylinder resulting in localheat, dirt Deposition on the piston grooves resulting from oil or fuel will not burn completely. It may cause the piston rings become worn and jammed. When the piston operating continuously jammed piston rings would have broken even scratches and damage resulting complex in the cylinder.

2.4 Vibration

Any motion that repeats itself after an interval of time is called *vibration* or *oscillation*. Vibratin machine is a part machine movement forward and backward (back and forth) from rest or neutral ($F = 0$). A simple example is to demonstrate a vibrati n spring on images 2.7 and 2.8.

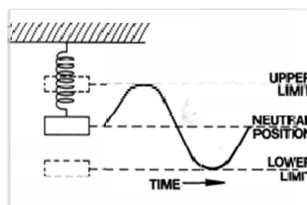


Figure 2.2 Vibration spring (Sunarko, KB., 2010)

¹ Singiresu s. Rao, Mechanical Vibration, fifth edition, page 558.

Equation 1 is the free vibration component consisting of the mass matrix, damping, and stiffness. It used to determine the level of engine vibration amplitude acceleration due to a force that works. {F (t)} in the above equation indicates that the style is derived from the combustion and inertial forces of the dynamic components of the engine.

2.5 Time Domain

Vibration data are expressed as a graph or plot of amplitude versus time profile called time domain data. Deviation of the vibration changes with time can be observed in detail with time domain graph Examples of complex time domain data, shown in Figure 2.12.

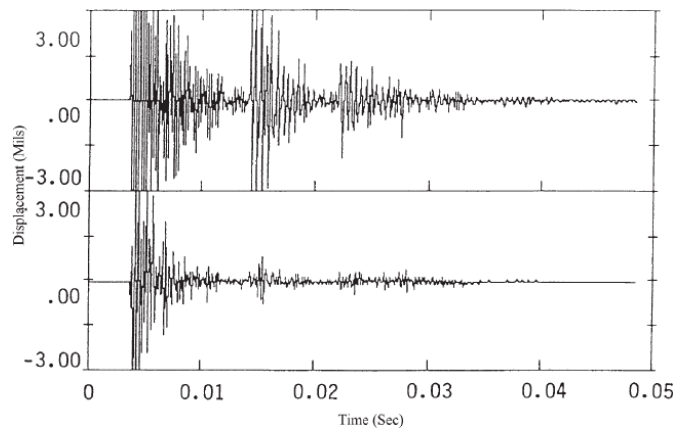


Figure 2.3 Profile of a time domain vibration machine industry(Hidajat.R.L.G, 2009)

2.6 Signal Energy

Energy is energy-limited signal from a signal or in other words satisfy $0 < E < \infty$. Instantaneous power absorbed at a bottleneck is defined as

$$E_x = \int_{-\infty}^{\infty} x^2(t) dt \dots \dots 2$$

Trapezoidal rule is used for the completion of the above integral equation. With this rule, the function f (x) on [a, b] is divided in some interval (n), for more details can be seen in Figure 2.14.

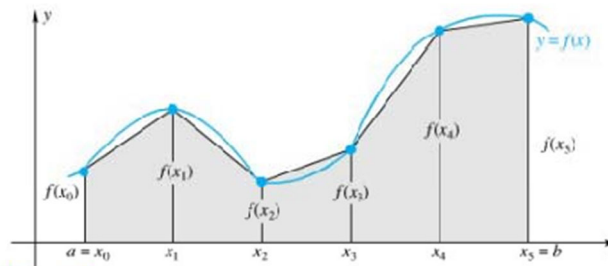


Figure 2.4 trapezoidal rule on a signal (Fauzi, A, F., 2012)

$$\int_a^b f(x) dx = h (f(x_0) + f(x_1)) + h (f(x_1) + f(x_2)) \dots h (f(x_{n-1}) + f(x_n))$$

$$f(x_n) \dots \dots \dots \frac{b-a}{2} \dots \dots \dots \frac{b-a}{2}$$

Where: $h = b - a$

² Fendi A. Fauzi, Penggunaan Aturan Trapezoidal (Aturan Trapesium) Sebagai Hampiran Dalam Integral Tentu

³ Ibid, Page

3 RESEARCH METHODOLOGY

3.1 Flow Chart Diagram

The series of research activities in general can be seen in figure 3.1 below:

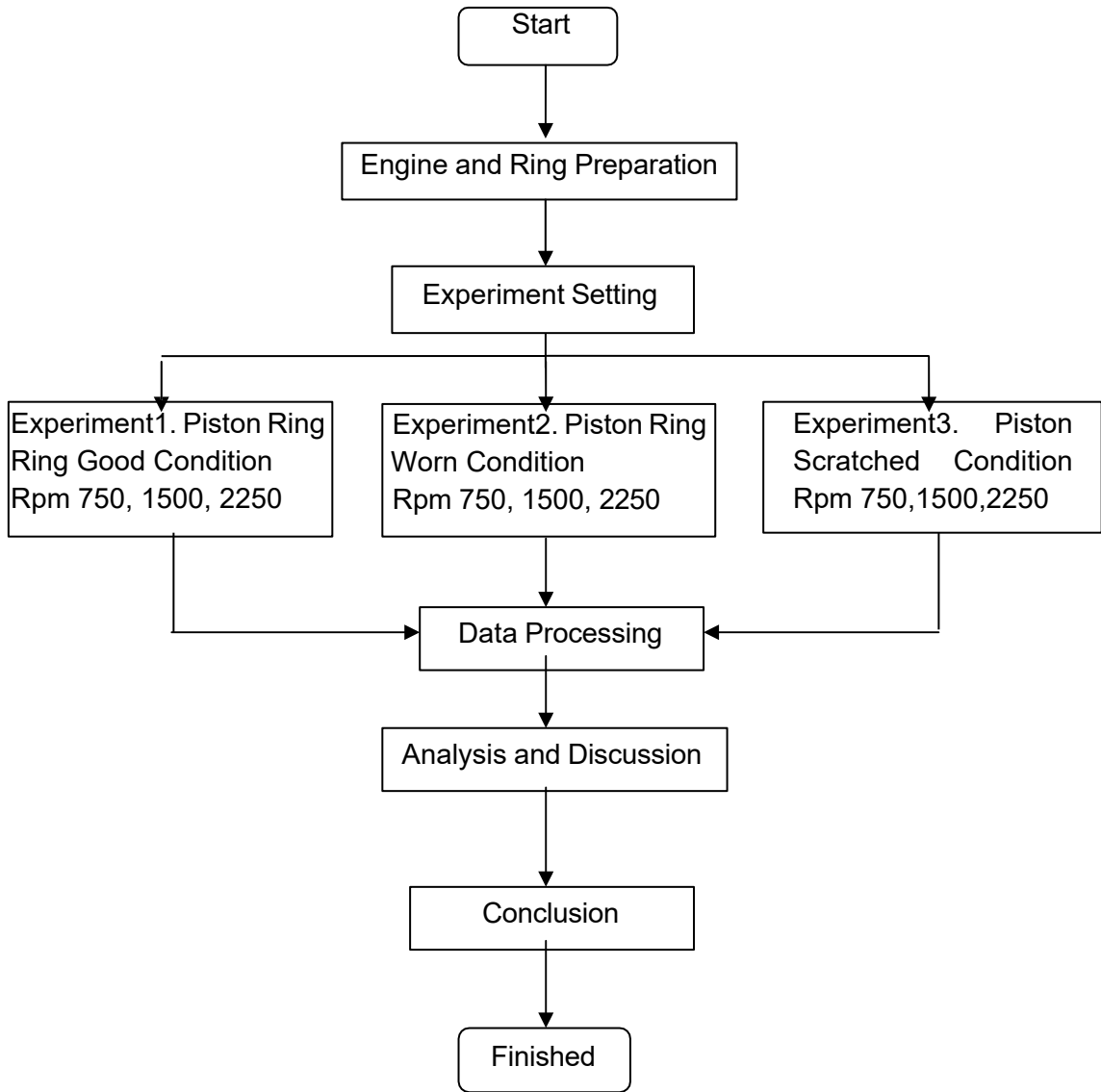


Figure 3.1 Flow Chart Diagram

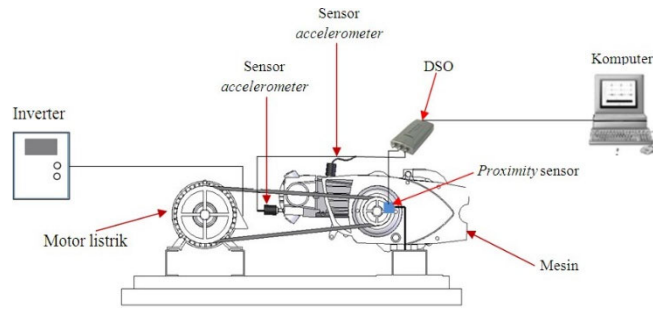
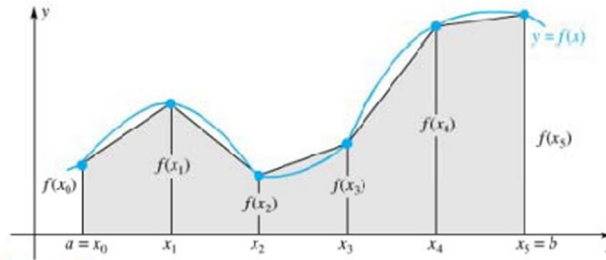


Figure 3.1 Schematic process of data collection

4. DATA AND ANALYSIS

4.1 Data Analysis

Analyzing of vibration signal data is carried out by using signal energy method. Energy signal is obtained by applying numeric method of trapezoidal rule. The obtained energy of every cycles in good, wear, and scratched condition are compared each other. Signal energy can be determined by this following formula.



- Trapezoidal rule,

$$E_x = \frac{h}{2} [f(x_0) + 2 \sum_{i=1}^{n-1} f(x_i) + f(x_n)]$$

- Signal energy formula,

$$E_x = \int x^2(t) dt$$

Where x(t) is time domain signal and t is time. Here are signal energy graphs for different condition and sensor location.

N	time (s)	Volt (x)	Degree	I	x ²	t * i	h[(b-a)/n]
1	0	0.1	0 ⁰	1	0.01	0	0.0012
2	0.00156	0		2	0	0.00313	
3	0.00313	0.15		2	0.0225	0.00625	
4	0.00469	-0.15		2	0.0225	0.00938	

...
100	0.12	0		1	0	0.12	

$$E = h [x(t_2)]^2 \sum_{i=1}^{n=1} x(t_2) x(t_2)]$$

100

$$E_x = 0.3642 \times 100 = 364.2 \text{ mv}^2\text{s}$$

Signal Energy for Sensor Set on Head Cylinder Energy is taken from the sum of signal energy for every cycle (every 180°) represent four-strokes engine namely intake, compress, power, and exhaust. Graph 4.21 shows signal energy for every cycle with sensor set on head cylinder.

a. Rotation 750 rpm

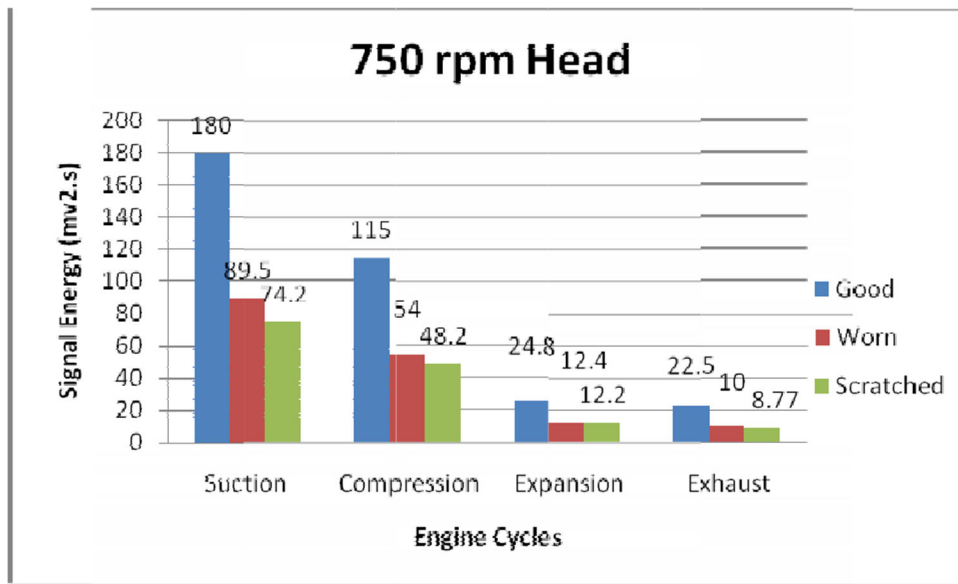


Fig 4.1 Total signal energy of 750 rpm rotation for every cycle with the location of sensor on head cylinder for the three rings

b. Rotation 1500 rpm

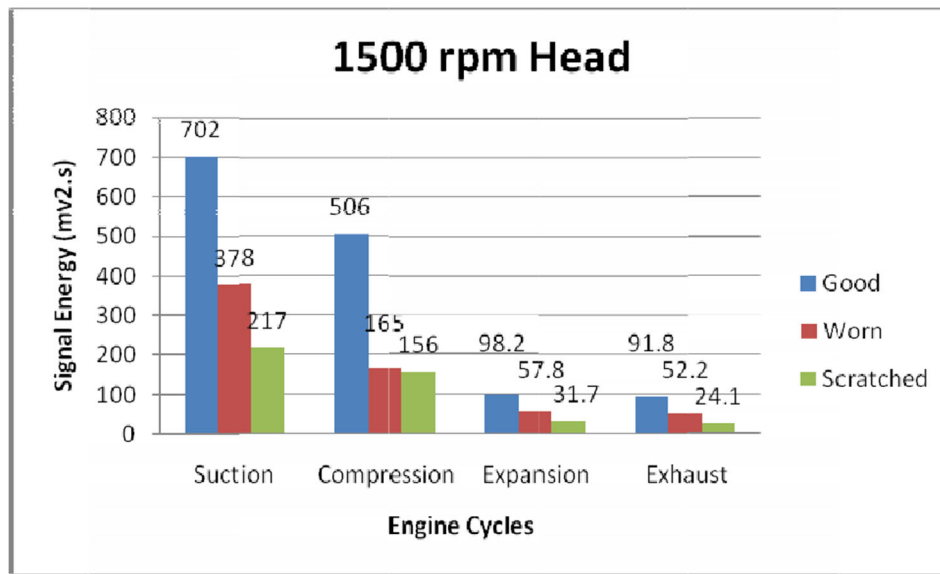


Fig 4.2 Total signal energy of 1500 rpm rotation for every cycle with the location of sensor on head cylinder for the three rings

c. Rotation 2250 rpm

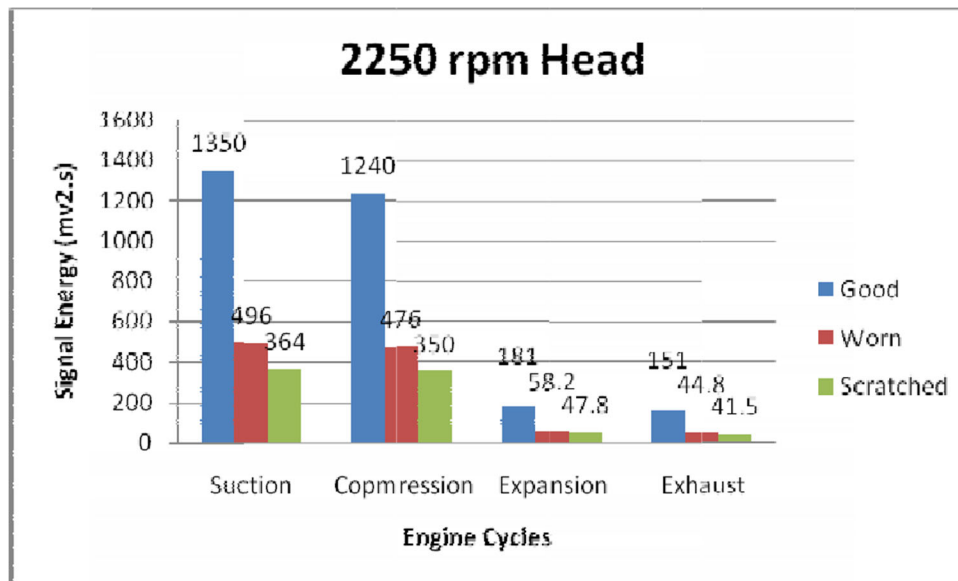


Fig 4.3 Total signal energy of 2250 rpm rotation for every cycle with the location of sensor on head cylinder for the three rings

D. Energy with the Location of Sensor on Block Cylinder

1. Rotation 750 rpm

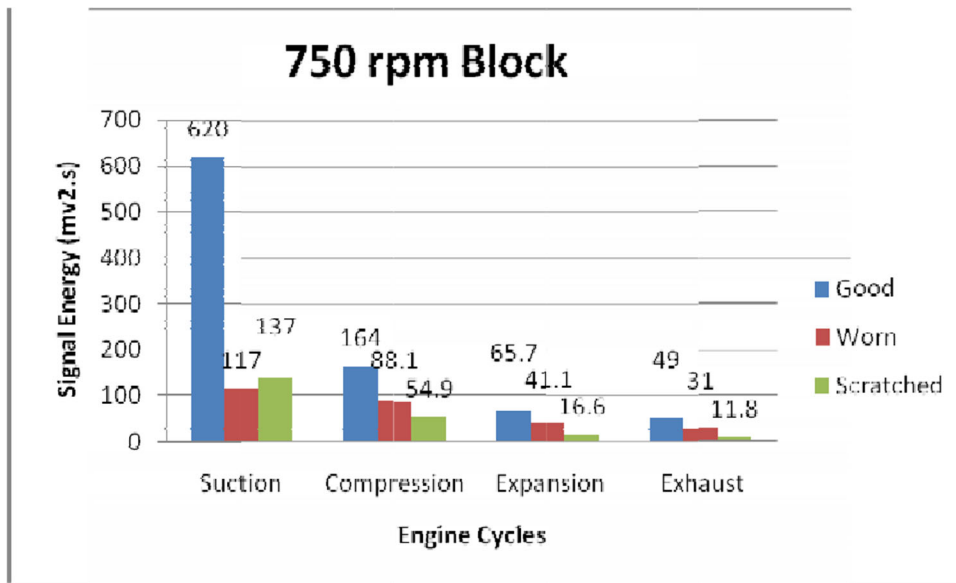


Fig 4.4 Total signal energy of 750 rpm rotation for every cycle with the location of sensor on block cylinder for the three rings

2. Rotation 1500 rpm

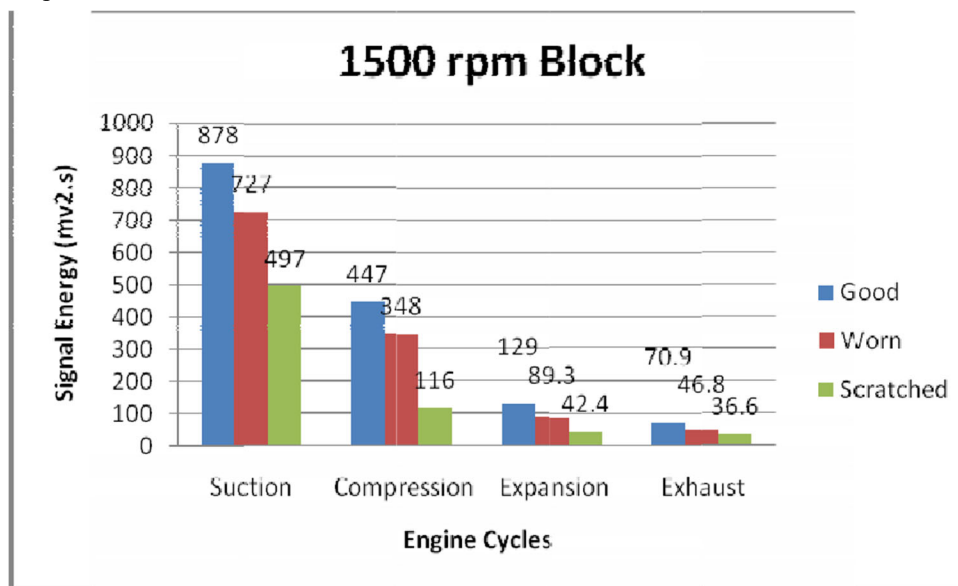


Fig 4.5 Total signal energy of 1500 rpm rotation for every cycle with the location of sensor on block cylinder for the three rings

3. Rotation 2250 rpm

1500	702	506	98,2	91,8	139,8	37,8	165	57,8	52,2	653	21,7	156	31,7	24,1	428,8
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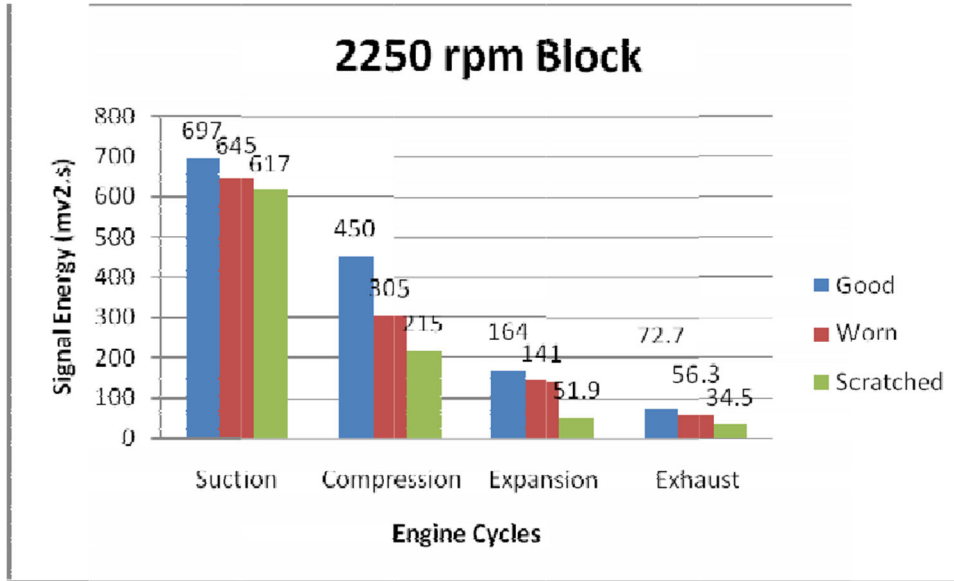


Fig 4.6 Total signal energy of 2250 rpm rotation with the location of sensor on block cylinder for the three rings

Here are resuming table of the research.

Table 4.1 The result of research head cylinder sensor set

Rotati on (rpm)	Good Piston Ring (mv ² .s.)					Wear Piston Ring (mv ² .s.)					Scratched Piston Ring (mv ² .s.)				
	In	Com	Pow	Ex	Tot	In	Com	Pow	Ex	Tot	In	Com	Po w	Ex	Tot
750	180	115	24,8	22,5	342,3	89,9	54,4	12,4	10,3	166,3	74,2	48,2	12,7	8,77	143,8

2250	1350	1240	181	151	2922	496	476	58,2	44,8	1075	364	350	47,8	41,5	803,3
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Table 4.2 result of research block cylinder sensor set

Rotation (rpm)	Good Piston Ring (mv ² .s.)					Wear Piston Ring (mv ² .s.)					Scatched Piston Ring (mv ² .s.)				
	In	Com	Pow	Ex	Tot	In	Com	Pow	Ex	Tot	In	Com	Pow	Ex	Tot
750	620	164	65,7	49	898,7	117	88,1	41,1	31	277,2	137	54,9	16,6	11,8	220,3
1500	878	447	89,3	70,9	1485,2	497	348	129	46,8	1020,8	727	116	42,4	36,6	922
2250	617	450	164	56,3	1287,3	645	305	141	72,7	1163,7	697	215	51,9	34,5	998,4

Table 4.3 Total decreasing energy with the location of sensor on head cylinder

Rotation (rpm)	Wear Ring (mv ² .s.)	Scatched Ring (mv ² .s.)
750	176	198,4
1500	745	969,2
2250	1847	2118,7

Table 4.4 Total decreasing energy with the location of sensor on block cylinder

Rotation (rpm)	Wear Ring (mv ² .s.)	Scratched Ring (mv ² .s.)
750	621,5	678,4
1500	464,4	563,2
2250	123,6	288,9

3.2 Analyzing

After vibration signal energy has been analyzed, wear and scratch piston rings have less energy than good piston ring. It was caused compression ring as part to prevent gas leaks by closing the gap between the piston and cylinder. If the compression ring has defects, gas will get leaks and the pressure that produced in chamber of combustion gets decreased. Gas leak usually has a long periodic and reduces the number of amplitude. Klinchaeam and Niverangsan in their book said “*Condition monitoring of valve clearance fault on a small four strokes petrol engine using vibration signals*”, if the amount of pressure goes down, the compression force will decrease as well. So that the results of this condition are amplitude and signal energy are lower than the good condition one.

5. CONCLUSION AND SUGGESTION

5.1 Conclusion

1. Analysis of vibration signal energy can be applied to check piston ring condition of one cylinder four-strokes engine.
2. The assesing of piston ring conditions are effectively done at lower rotation and sensor location at head cylinder.
3. Damages of piston ring affect decreasing of pressure, As the amount of pressure goes down, the compression force will decrease. It obtains the lower amplitude and energy.

5.2 Suggestion

1. To get more efficient in maintaining the condition of motorcycle can be checked by energy signal analysis.
2. Need to conduct the next project regarding signal energy analysis of engine part using the most recent engine.
3. In experimental procces, required the expert to keep away from miss understanding of project.

References

Aji, K., 2007, *Deteksi Kerusakan Bearing menggunakan Sinyal Getaran*, Jurusan Teknik Mesin, Universitas Sebelas Maret.

Douglass R.M., 2007, *Monitoring of the piston ring-pack and cylinder liner interface in diesel engines through acoustic emission measurements*, School of Engineering and Physical Sciences, Heriot-Watt University.

Fauzi, A.F., 2012, *Penggunaan aturan trapezoidal (aturan trapesium) dan aturan simpson sebagai hampiran dalam integral tentu*.

Hidajat,R.L.G., 2009, *Perawatan Prediktif Penerapan Getaran Mekanis*, LPP UNS dan UNS Press,Surakarta.

Klinchaeam, S., and Nivesrangsan, P., 2010, *Condition monitoring of valve clearance fault on a small four strokes petrol engine using vibration signals*, Songklanakarin J. Sci. Technol.32

Klinchaeam, S., Nivesrangsan, P., and Lokitsangthong, Ming., 2009, *Condition Monitoring of a Small Four-stroke Petrol Engine using Vibration Signals*, KMITL Sci. Tech. J. Vol. 9 No. 1.

Peters, Jack D., 2009, *Beginning Vibration Analysis with Basic Fundamentals*, Vibration Institute, USA.

Rao,S.S., 2010, *Vibration Analysis*, 5th ed, University of Miami, United State. Sunarko, K, B., 2010, *Analisa*

Getaran Pada Mesin Kendaraan Bermotor Berbasis Labview, Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Indonesia. Yamaha Motor, 2000, Motorcycle Service Engineering General.