# To Study the Effect of Piston Scratching Fault on Vibration Behaviour of An Ic Engine

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***Abstract***- *In this paper, the effect of scratching of a piston on the behaviour of IC Engine was checked and noted. There may be abrasive wear in the IC Engine which might occur between the piston and cylinder these processes involve deformation and fracture of materials, ultimately leading to poor engine performance or in some cases severe breakdown. For the detection of fault, vibration tests were conducted as vibration is an effective tool in detecting and diagnosing some of the growing failures of machine and equipment. There were two sets of tests conducted named as health and faulty piston. To conduct the faulty piston test number of grooves were scratched on the piston skirt of third piston. The vibration analysis of IC engine is done with the help of LabView software. Numbers of readings to measure mean vibration have been taken. The scratching of piston showed maximum vibrations in the readings than the healthy piston. This experimentation showed the excitement of the vibrations when the piston was faulty and hence vibration analysis could be effectively used for detection of piston scratching fault in IC engine.*

***Keywords***- Healthy piston, faulty piston, RMS, FFT

## I. INTRODUCTION

IC engines can be considered as heart of vehicles as they provide the power required to drive the vehicle. In an IC engine there are hundreds of mechanisms running and thousands of components are there. Among these components piston is important one as it is subjected to high thermal and mechanical stresses and reciprocates in a very tight gap inside the cylinder. Due to this, there are maximum chances of it to get fail. Wear mechanisms are common in case of piston.
There are three types of wear mechanisms in an IC engine namely abrasion, adhesion and corrosion. Among these three, abrasion is dominant one. Abrasive wear is the damage to the component surface caused by the hard particles trapped between the two surfaces. Again, there are two types of abrasive wear namely two-body abrasive wear and three body abrasive wear. Two body abrasive wear occurs when hard surface slides over soft counter surface. Three body abrasive wear is due to the free particle trapped in between the two sliding surfaces.

Abrasive wear could be the root cause of different piston faults such as scratching, scuffing and scoring. These failures might seriously damage the piston-cylinder system. Due to these destructive effects of abrasive wear there is a need to develop a method to detect such faults at an early stage. Since, vibration is an effective tool to detect such faults, vibration analysis is used to as a method in this research.

In this research, two tests were conducted on a four-stroke four-cylinder petrol engine in healthy and faulty conditions and engine vibrations were measured during the tests. In the analysis phase, the effect of piston scratching failure is measured by comparing the readings obtained from the tests

## II. LITERATURE REVIEW

**Introduction:**

Due to the scratches that develop on the piston skirt over a period of time, develops turbulence in the IC engine. This turbulence might lead to failures or any other type of deformations.

As a result of this turbulence vibration is generated in the engine and might cause damage to the engine and the engine might breakdown.

**Literature survey:**

The attempt made by earlier researchers to find out the effect of piston scratching fault on the vibration behaviour of IC engine is briefly summarized below:

**Moosavian A, Najafi G, Ghobadian B, Mirsalim M. The effect of piston Scratching fault on the vibration behavior ofan IC engine. Appl Acoust 2017; 126:91-100.**

This paper investigates the effect of piston scratching fault on engine vibration with the purpose of developing a practical way to detect it in IC engines. To simulate scratching fault in the piston cylinder system of the engine, a groove with 0.15mm depth was cut into the skirt of piston. To analyse the vibration data, STFT and CWT methods were employed. The results indicated that ‘‘dmey” wavelet was a worthy case for piston scratching fault identification. The results showed that the scratching fault increased the overall engine vibration and excited the frequency band of 3– 4.7 kHz. Moreover, scratch fault increased the maximum, mean, RMS and impulse factor of the engine vibrations in the founded frequency band by about 143%, 162%, 106% and 45%. From the results, the vibration analysis is highly capable of identifying abrasive wear in the piston/cylinder system. Furthermore, the results showed the effectiveness of the proposed diagnostic procedure for early detection of piston failures caused by wear mechanisms

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From the Experimentation and Analysis of Diesel Engine carried out it is observed that as cooling water temperature increases, mean values of velocity and displacement are increasing. This ultimately indicates that vibration levels are increasing with increase in temperature of cooling water. On an exceptional note, mean values of acceleration are found to be decreasing with increase in cooling water temperature. This effect of increase in mean vibration levels of engine with respect to increasing cooling water temperature is considered sufficient to require a control of water temperature when conducting investigations related to the other causes of engine vibrations and their effects on engine vibration levels. Also, from respective spectrums of displacement, velocity and acceleration obtained at different cooling water temperatures it is found that most of the top peaks are seen in the initial frequency range of 10 Hz to 150 Hz, indicating maximum vibrations of engine in that range.

**Somashekar V.**

The chosen measurement technique was based on vibration signature analysis. The sensors are attached to the engine by a magnet without an intrusive approach. The experiments that were done showed that there is a more vibration at the starting of engine and that may the vibrations in whole body of the vehicle and that may cause to discomfort of the passengers. The results show that the system is capable of identifying fault engine operation and can direct the user to the source of the problem. The results presented in this paper are for engine working without load under steady engine speed and also under various load and speed conditions. But this technique works for a variety of engines speeds and loads, under steady operation conditions or under varying operation conditions. This method may be implemented as a test system for an engine, or as a feedback to an ignition system.

## III. EXPERIMENTAL WORK

**Experimentation:**

The experiments were performed on inline four-stroke four-cylinder petrol engine. The engine specifications are given in table 1. All the readings were taken at 1500rpm and by applying different loading conditions. For loading the engine water brake dynamometer was used.

To measure the vibrations piezoelectric accelerometer was installed on M6 fine threaded bolt present at cylinder block. The position for mounting of accelerometer is shown in fig.3

Fig. 1 Four-stroke four-cylinder petrol engine.

Table 1 Engine specifications

| | |
|---|---|
| **Engine Make** | Premier Padmini |
| **No. of cylinders** | 04 |
| **Power** | 44 BHP at 5000 rpm |
| **Bore Diameter** | 68mm |
| **Stroke Length** | 75mm |
| **Compression Ratio** | 7.8:1 |
| **Fuel** | Petrol |
| **Cubic Capacity** | 1089cc |
| **Type of Dynamometer** | Water brake |

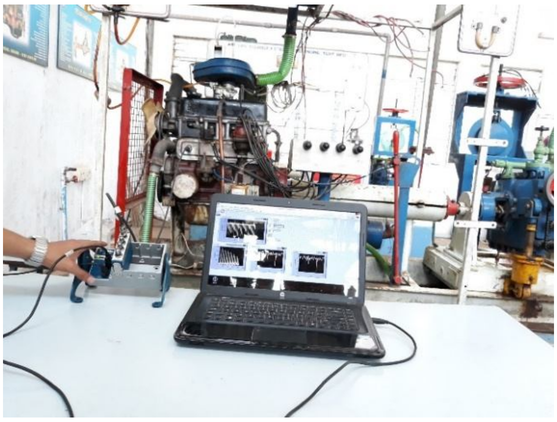

**Fig. 2 Experimental setup**

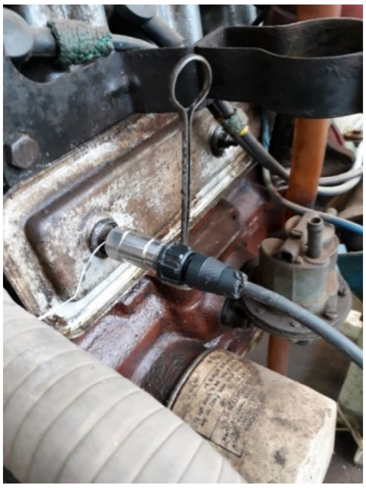

**Fig. 3 Location of an accelerometer**

### Statistical analysis of signal:

The most common signal processing technique is time domain statistical analysis. Signal analysis in time domain has been used to monitor simple machine conditions and faults utilizing statistical parameters. Sample of measured vibration signals for the purpose of statistical analysis are illustrated. In this section the most common vibrations statistical parameters, fast Fourier transform, maximum amplitude, root mean square (RMS), kurtosis, skewness and crest factor are used for statistical analysis of the measured vibration signals of healthy and faulty piston**.**

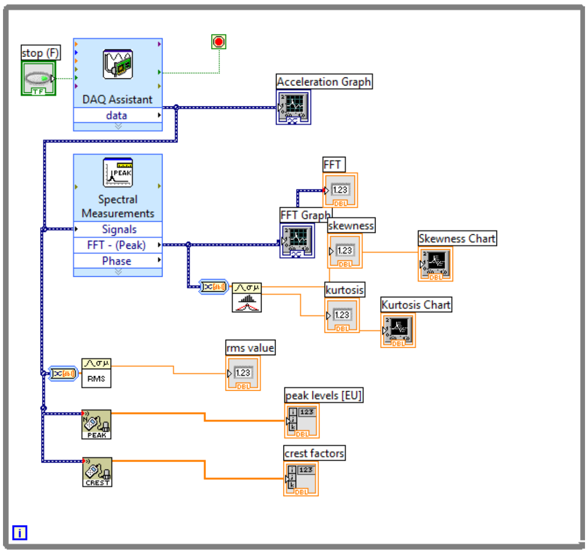


Fig. 4 Experimental block diagram

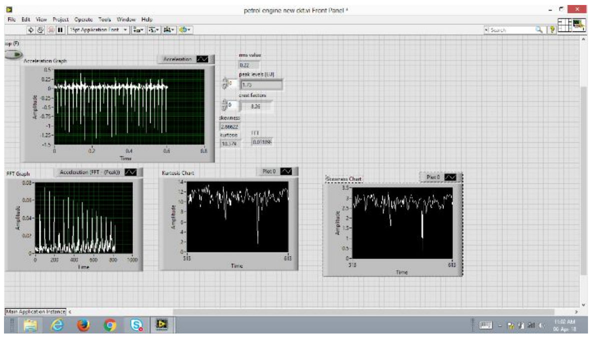

Fig. 5 Experimental front panel

### Analysis of Fast Fourier transform

It can be observed that, the amplitude of vibration varies as different working parameters are varied. This showed that, the amplitude of vibration is sensitive to the varied working factors. It may be happening because the working parameters were varied simultaneously.

### Analysis of kurtosis:

The normalized fourth moment, kurtosis, is the ratio of the fourth moment to the square of the second moment (commonly known as variance). For the detection of defects, kurtosis indicates the probability of the generation of periodic impulses with large amplitudes and is very sensitive to these periodic impulses. Dyer and Stewart first proposed the use of kurtosis fault diagnosis. Kurtosis of the vibration signals has been used to evaluate the working condition. Kurtosis is an indicator used in distribution analysis as a sign of flattening or "peakedness" of a distribution. Kurtosis value greater than 3 indicates leptokurtic distribution of the results, sharper than a normal distribution, with values concentrated around the mean and thicker tails. This means high probability for extreme values.

Kurtosis is defined as:

$$\text{Kurtosis} = \frac{(N-1)\sum_{i=1}^{N}(X_i-\bar{X})^4}{\sum_{i=1}^{N}(X_i-\bar{X})^2}$$

Where X is the arithmetic mean, N is the number of discrete points, and Xi represents the signal from each sampled point. Kurtosis value lesser than 3 indicates platykurtic distribution of the results, flatter than a normal distribution with a wider peak. Kurtosis value equal to 3 indicates mesocratic distribution of the results or normal distribution of the results. As the surface finish deteriorates, the number of periodic impulses with large amplitude will increase within the vibration signal and kurtosis will increase rapidly.

**Analysis of peak value:**

In the time domain, maximum amplitude or peak value is the maximum value of vibration signal. In 1994, Tandon showed increasing peak values as defect diameter increases [Tandon et al, 1997]. Vibration amplitude is also influenced by test conditions, such as the operating frequency of vibration sensor, damping frequency of vibration pulse which is due to the size and geometry of the defect and also location of the defect. The sensitivity of vibration amplitude to various conditions can be investigated for a fabricated setup. It shows that, the peak value is sensitive to the working conditions varied during experimentation. But the comparison between the results of peak values obtained for both dampers. The peak value is observed higher for without damping. Also, it can be concluded that the peak value is sensitive to speed of the shaft and the results shows that it is greater for higher speeds.

**Analysis of root mean square (RMS):**

Root mean square (RMS) is a powerful tool to estimate the average power of a discrete signal and is proportional to the area under the envelope waveform of a discrete signal. Therefore, vibration RMS is a suitable parameter to evaluate the results and is important parameter to be used in non-destructive tests by vibration and acoustic emission techniques. Root mean square is given as:

$$\text{Root Mean Square} = \sqrt{\frac{\sum x_i^2}{N}}$$

Where, N is the number of discrete points and Xi represents the signal from each sampled point. It should be noted that, since arithmetic mean of all measured vibration signals are forced to be zero, standard deviation and RMS can be regarded as one formula given in above equation. It has been seen from the differences in the results for damping and without damping that, the RMS value is sensitive to all factors and varies as different factors are varied. Also, RMS value found greater at lower speeds. The variation of the RMS values as per the increase in the size is somewhat different. It is not showing much deviation in some cases and in some cases, it shows much variation.

**Analysis of skewness:**

Skewness is an indicator used in distribution analysis as a sign of asymmetry and deviation from normal distribution. Its interpretation can be given by, if skewness is positive, the data is positively skewed or skewed right, meaning that right tail of distribution is longer than left tail. If skewness is negative, the data is negatively skewed or skewed left, meaning that the left tail is longer.

- Skewness > 0 = right skewed distribution- most values are concentrated on left of the mean, with extreme values to the right.
- Skewness < 0 = left skewness distribution- most values are concentrated on right of the mean, with extreme values to the left
- Skewness = 0 - mean= median, the distribution is symmetrical around the

**Experimental Procedure:**

The first experiment was performed on the engine in the healthy condition. The engine health was confirmed before the experiment by checking its different components, especially piston groups and cylinders. All data obtained in the first experiment was employed as reference data for further analyses. After implementing the first experiment, the following procedure was applied to produce deliberately piston scratching fault on the engine:

After disassembling the engine and checking the health of its components especially piston groups and cylinders, third piston was scratched by using nail. The depth value of was adopted from the statistical population of the faulty pistons with similar failure which had naturally been occurred during the real engine operations. Scratching is among the preliminary stages of sliding surface damage. Therefore, if a procedure could effectively detect this stage of surface damage, it will be possible to prevent the progression of surface damage. So, the development of such diagnostic procedure is worthy indeed from this point of view. Based on the following two claims, this scratch could cause the formation of abrasive wear in the area between the piston and third cylinder:

1. This scratch increases the roughness of the piston skirt surface in micro-scale.
2. As the oil film thickness in the central region of the skirt so called load bearing region, is less than that in around the skirt, this scratch is located at the central area of the skirt. In other hand, this scratch could be a channel for the escape of the lubricant from the area between the piston and cylinder. In this condition, due to the boundary lubrication the friction in this area will increase, and the contact between the piston skirt surface and cylinder will be probable, and consequently abrasive wear will occur.

After the above process, the engine was assembled with the faulty piston and prepared for the experiment. Afterward, the engine was tested according to the test plan, and all engine parameters and vibration data were captured during the experiment. From now, the term of ''Healthy'' represents the first experiment, whereas the term of ''Faulty'' denotes the second experiment in which the piston and cylinder#3 were experienced abrasive wear

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**Fig.6 Scratched (Faulty) piston**

## IV. RESULTS AND DISCUSSION

The table below shows the readings obtained from the vibration analysis of an IC engine (four-stroke four-cylinder) when it is running with healthy and faulty piston respectively at 1500 rpm and under different loading conditions.

**Table 2 Readings obtained from vibration analysis of an IC engine with healthy piston**

| Load | FFT | Kurtosis | Skewness | Peak value | RMS | Crest factor |
|---|---|---|---|---|---|---|
| 0 | 0.009339 | 9.89033 | 2.6962 | 1.59 | 0.18 | 8.833 |
| 10 | 0.031899 | 10.3790 | 2.6622 | 1.73 | 0.22 | 7.863 |
| 20 | 0.011044 | 11.4602 | 2.8993 | 1.79 | 0.21 | 8.523 |
| 30 | 0.26008 | 11.58080 | 2.90095 | 1.80 | 0.19 | 9.473 |
| 40 | 0.3025 | 10.83050 | 2.90908 | 1.79 | 0.20 | 8.950 |

**Table 3 Readings obtained from vibration analysis of an IC engine with faulty piston**

| Load | FFT | Kurtosis | Skewness | Peak value | RMS | Crest factor |
|---|---|---|---|---|---|---|
| 0 | 0.0052807 | 8.59937 | 2.4008 | 1.56 | 0.16 | 9.750 |
| 10 | 0.005454 | 6.56630 | 2.8062 | 1.59 | 0.18 | 8.833 |
| 20 | 0.0076669 | 9.75051 | 2.2692 | 1.73 | 0.19 | 9.105 |
| 30 | 0.006278 | 9.83550 | 2.3910 | 1.67 | 0.18 | 9.277 |
| 40 | 0.005634 | 7.634735 | 1.8851 | 1.7 | 0.19 | 8.947 |

Charts below shows the variation of different parameters of engine vibrations with respect to the load applied. It can be easily observed that the values related to engine running with faulty piston are greater than that of the engine running with healthy piston, indicating the increase in the vibrations of an IC engine when the piston is subjected to abrasive wear.

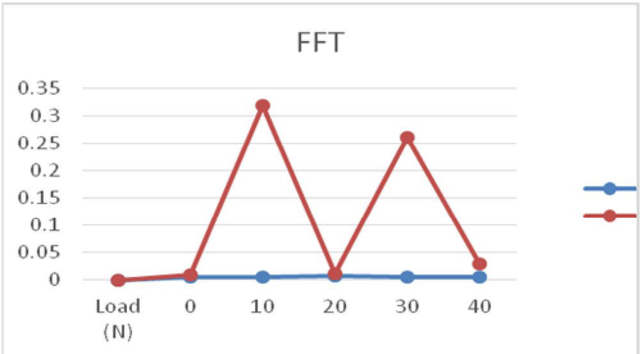


**Fig. 7 Load vs FFT**

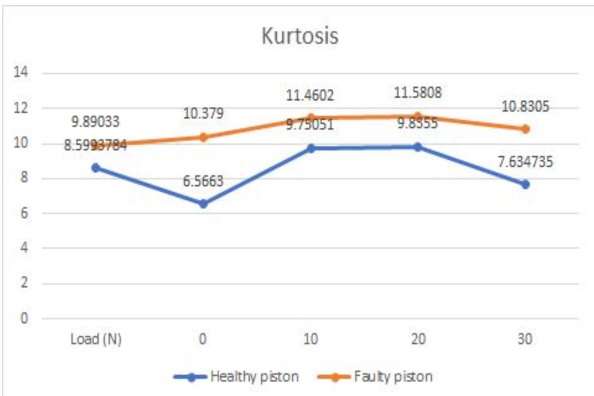


**Fig. 8 Load vs Kurtosis**

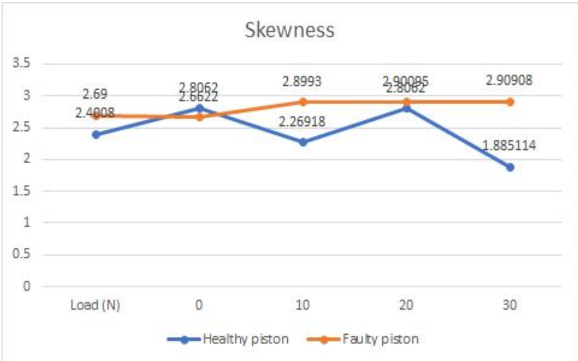


**Fig. 9 Load vs skewness**

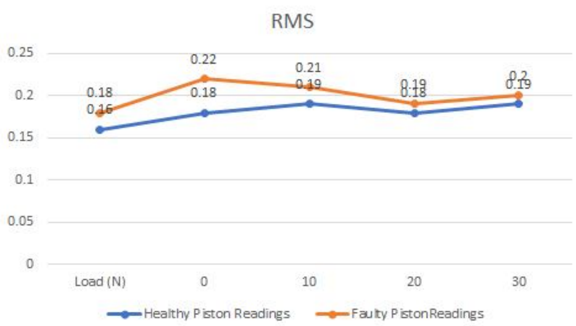


**Fig. 10 Load vs RMS**

## V. CONCLUSION AND FUTURE SCOPE

The IC engine was tested under healthy and faulty piston conditions. The results presented are an outcome of a series of experiments that were made on different loading conditions like combinations of all loads and piston conditions.

**Conclusion:**

The chosen measurement technique was based on vibration signature analysis. The sensor was attached to the engine on M6 bolt available on the cylinder head. The experiments that were done showed that there is a more vibration at the starting of engine and that may the vibrations in whole body of the vehicle and that may cause to discomfort of the passengers

1. Peak values are increased.
2. Kurtosis values are increased.
3. FFT values are increased.
4. RMS values are increased.

Hence, piston scratching has significant and detectable effects on the engine vibrations.

The results show that the system is capable of identifying fault piston operation and can direct the user to the source of the problem. The results presented in this report are for engine working without load under steady engine speed and also under various load and speed conditions. But this technique works for a variety of engines speeds and loads, under steady operation conditions or under varying operation conditions. This method may be implemented as a test system for an engine.

**Scope for further work:**

We conducted experiments using healthy and faulty piston. In our case, we made scratches on the piston in order to make it faulty one. The patterns of scratches were limited but, there is further scope of improvement by taking multiple pistons and making different patterns of scratches for the testing purpose. In future there may be the new methods for early detection of the piston scratching fault. Hence, increasing the service life of the engine.

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