Simulation of the effect of wear in the journal bearings of a marine engine

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Wear in the bearing is one of the biggest problem in an engine. It can cause failure of the system without prior notice. Especially for a big engine like the marine engine, bearing wear can cause severe problem regarding significant performance drop and accidents. So knowing the bearing wear condition every moment is very important. Continuous monitoring can give a warning of this kind of failure. One of the biggest problem for wear detection is that, there isn`t any sensor to detect wear directly. And in case of an engine, mounting any kind of sensor becomes difficult. So in this paper we will discuss the bearing wear measurement procedure and analysis the simulation results of different worn out bearings of the engine to predict the wear condition in them.

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1. Introduction

In a mechanical body one of the most significant criteria is that there will be relative motion between the two bodies, which is a source of wear. According to the standard DIN 50320, wear can be defined as "the progressive loss of material from the surface of a solid body due to mechanical action, i.e. the contact and the relative motion against a solid, liquid or gaseous counter body" [1]. In other words, wear is quantified by the loss of material from contacting surfaces when they are subjected to relative motion. Thus it is obvious that where there is a mechanical joint there will be wear.

Even in revolution joints where bearings are used to compensate the wear and frictional loss in mechanical parts, the wear can be a very big issue. For a large engine like the marine engine the bearing wear in the engine shaft, connecting rod can be a big concern. The wear will cause to increase the clearance of the revolute joints which will gradually start to misguide the force component of the piston force in the engine and in extreme case can cause the engine to fail. Beside that when bearing is worn out the power loss of the engine also increases. The presence of clearances in the joints of the mechanical systems has been noted to retard system performance. Often, vibration, noise and joint reaction forces characterized by large instantaneous value are experienced as a consequence of joint clearance. The problem is further compounded when the clearance size is increased and its shape altered by wear [2]. So after certain period of wear the bearings should be replaced. Thus the key issue is to know the wear condition of the bearing so that we can replace the bearings before it causes any threat and significant performance loss. Many researchers have gone through to find out the mechanism of wear and prediction of wear. They have gone through the effect of clearance due to wear. S. Mukras et al. analyzed the planer multibody system with revolute joint wear [2]. P. Flores has modeled and simulated wear in revolute clearance joint in multibody system [3]. P. Flores et al. also studied the dynamics of mechanical system including joints with clearances and lubrication [4]. K. Soong and B. S. Thompson has gone through the dynamic response of a slider crank mechanism with radial clearances [5]. But there isn't any significant study to know the after effect of the wear and thus detect the amount of wear in the journal bearing in an engine.

In this study we will analysis the effect of wear in the engine bearings by simulating the wear in a simulator prototype in a CAD software. We will analysis the physical changes due to bearing wear to measure wear in the bearing. We will also validate the use of our proposed method of measuring the wear in practical case with a gap sensor.

2. Simulation

2.1 Procedure and theory

Basically an engine has three main bearing. i.e. Main Bearing (MB), Crankpin Bearing (CPB), Crosshead Bearing (CHB). Because the major thrust and power transfer depends on these three bearing so wearing out of these bearing can cause a big damage.

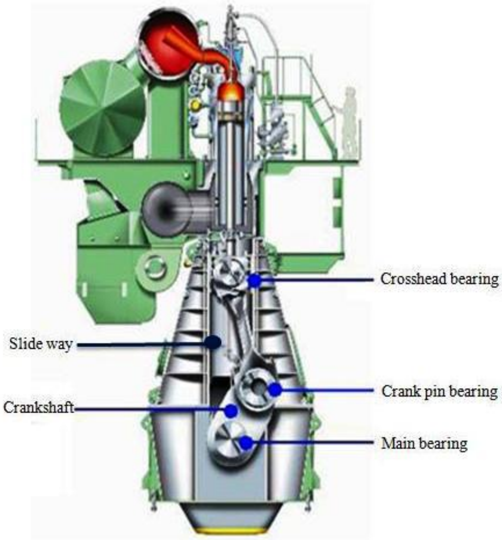


Fig. 1 Over view of a marine engine

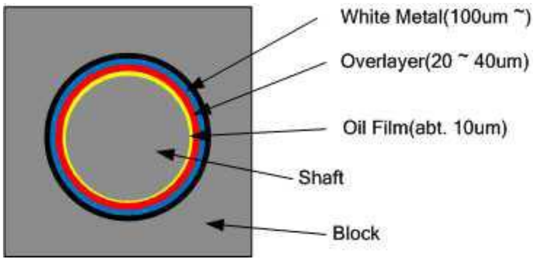


Fig. 2 Schematic of an individual bearing

Fig. 1 shows an marine engine. Normally a marine engine is very big so the piston is followed by a long piston rod attached with a Crosshead Bearing. To prevent buckling and for proper oscillation of the piston the Crosshead Bearing is guided by a slider in the engine casing. Thus the slider is also having the same piston movement. So at the slider end i.e. bottom part of the engine slider, if we mount a gap sensor then we can detect the slider movement along the guide way. So we can detect the slider position without wear and with wear. Because, due to bearing wear the slider will deviate from its original position.

From Fig. 2 we can see the internal configuration of a journal bearing. It has Three layers to wear out before it touches the bearing structure. So it is very obvious that if 10um oil film, 40um of overlayer and 100um of white metal wears out, then the system performance can decrease rapidly or sever damage can occur. To prevent this continuous monitoring of the bearings are needed. So to detect wear as a physical phenomenon we will use a gap sensor mounted in a fixed position underneath the slider guide way. It is very obvious that in this position we will be able to detect the wear of the all three bearings together. Because the three bearings will be in a line at this position, as shown in Fig. 3.

Fig. 4 we can see where the gap sensor will be mounted. Each piston-slider will be mounted with two gap sensors to monitor the slider movement. The sensors are fixed in a constant position. So when no wear, ys is the normal distance covered by the slider. But when there will be wear the sensor data will add Δys with ys when coming down. This ys will be some value within the range of the gap sensor. We will

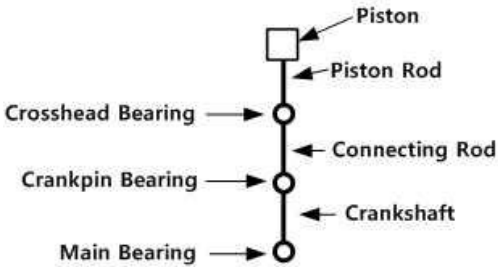


Fig. 3 Schematic of the three bearings position

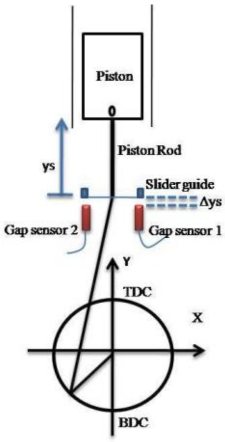


Fig. 4 Schematic of the mechanism of a marine engine with the gap sensor

use and eddy current sensor as a gap sensor. The eddy current sensor will have a resolution of 1um at 10 kHz and a range of 1-6mm. The major wear can be detected when the bearings are inline. Fig. 3 shows the inline condition of the three bearing. So in case of bearing wear the sensor will detect different data. This different data will depend on the wear condition in the bearing.

2.2 Modeling the simulator

The slider guide way is taken for the simulation part. Fig. 5 shows the slider simulator. In real life a slider mechanism was made to check the slider simulation result. So the slider model used in the simulation is a replica of that simulator. All the components in the simulator were made of S45C material except the crank shaft and the bearings were made of SCM440 material. In the model to make simulation simple and save computation we have assumed uniform wear in the bearing inner diameter and no wear along the shafts. We were not concern about the Crosshead Bearing to make the simulation simpler. To simulate wear situation the inner radius of the bearing was increased individually by 1 to 200 um in a random way. Also combinations of different wear in the two bearing were used to validate the study more effectively.

In Table 1 the dimension of the shaft and bearings are given. Table 2 shows the simulation software specification that was used for the simulation. This is very important because motion simulation is a very complex method. So by changing these parameter we can get more accurate data with the cost of computation time.

To rotate the crank shaft, a motor of 60 rpm was used. To detect the slider deviation the upper surface of the slider was used as a reference in the simulator. All the simulation data corresponds to this plane taking the slider bottom plate as the datum. While the crank shaft

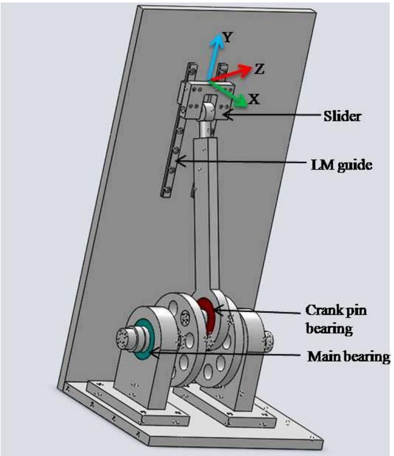


Fig. 5 Slider for the simulation

Name of the component	Inner diameter (mm)	Outer diameter (mm)
Main Bearing	50	78.50
Crankpin Bearing	35	80
Crank shaft	50	-
Crankpin	35	-

Table. 1 Bearing and shaft specification

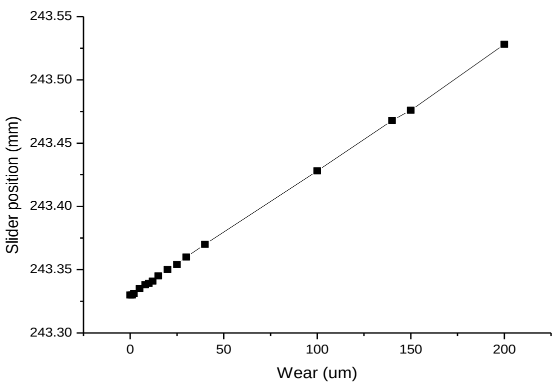
Software	Solidworks
Motion Integrator	GSTIFF
Maximum Iteration	25
Frames Per Second	25
Accuracy	.0001
Initial Integrator Step Size	0.0001
Minimum Integrator Step Size	0.0000001
Maximum Integrator Step Size	0.01
Jacobean Re-evaluation	100%

Table. 2 Simulation specifications

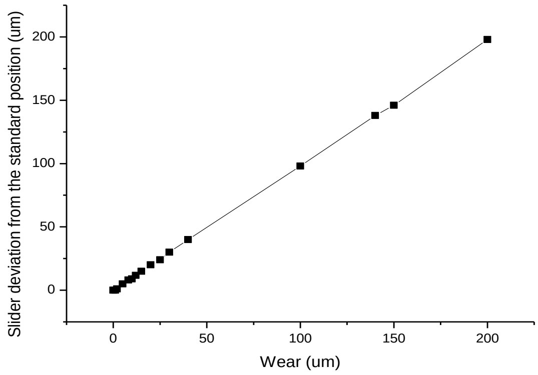
rotated the slider oscillated along the Y axis. The slider movement along the Y axis was recorded and was used as the analysis data in the simulator. In no wear condition the slider will reach its top most position which is the standard position. In case of wear the slider will reach some position near the standard position. This is the desired slider deviation, Δys.

3. Results

Fig. 5(a) and (b) shows the simulation results regarding main bearing wear. In Fig. 5(a) the slider position is compared for different wear of the bearing. Fig. 5(b) shows the slider deviation with respect to the no wear condition. From the two figure we can see that if there is wear in the bearing the slider deviates significantly from the standard position. It is also very clear from the figures that the amount of deviation of the slider in case of wear is nearly or same as the amount of wear in the bearing. Fig. 6(a) and (b) shows the same



(a) Slider position



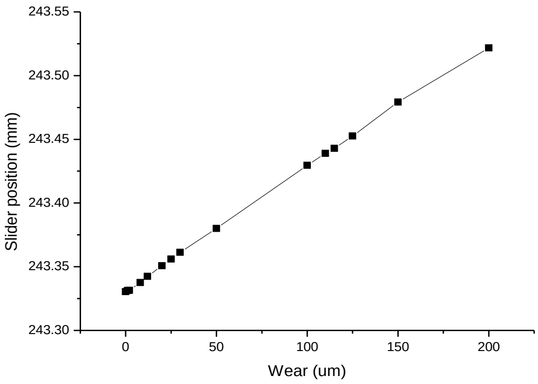
(b) Slider deviation from no wear condition

Fig. 5 Wear in the Main Bearing

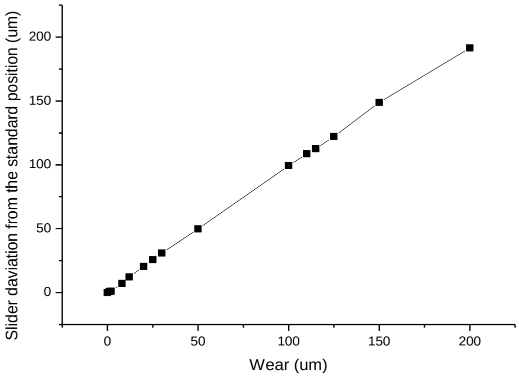
situation for Crankpin Bearing wear as the previous figures in Fig. 5(a) and (b). Both graphs validate the fact that the slider can deviate maximum to the amount of the bearing wear. Table 3 shows the tabular data for 10 um wear in the two bearings. From the slider position and slider deviation column we can see that the deviation is almost equal to the total amount of bearing wear.

Table 4 shows the tabular data for 15 um of wear in the two bearings. Here also the slider position rises according to the bearing wear and thus the slider deviation is almost equal to the total amount of the bearing wear.

From these two table we can see significantly that if the Main Bearing has larger wear the slider deviation is very near to the total bearing wear. But if the main bearing has smaller wear than the Crankpin Bearing then the deviation is smaller. This is because when the slider rises up the first bearing will play a key role in the deviation. The first bearing it is trying to constrain the slider in the first position.



(a) Slider position



(b) Slider deviation from no wear condition

Fig. 6 Wear in the Crankpin Bearing

Wear in each bearing (um)			Slider position (mm)	Slider deviation from the standard position (um)
MB	CPB	CHB		
00	00	00	243.330	00
02	08	00	243.338	08
05	05	00	243.336	09
08	02	00	243.340	10
10	00	00	243.340	09
00	10	00	243.339	09

Table. 3 Slider position and deviation for 10um of bearing wear

Wear in each bearing (um)			Slider position (mm)	Slider deviation from the no wear condition (um)
MB	CPB	CHB		
00	00	00	243.330	00
03	12	00	243.339	09
05	10	00	243.344	14
10	05	00	243.336	11
12	03	00	243.341	11
15	00	00	243.344	14
00	15	00	243.345	15

Table. 4 Slider position and deviation for 15 um of bearing wear

4. Conclusions

In this paper a new method was introduced to detect the wear in the journal bearing of an marine engine. A simulation was done to show if the practical model will work properly in the real life to detect the bearing wear. From the simulation analysis we came up with the following decisions:

1) The slider will maximum deviate as much as the bearing wear from its standard position.
2) All the deviation is in micrometer range so an eddy current sensor of 1um resolution can be easily used to detect the deviation.
3) The wear detection mechanism is very simple considering all the complicated construction of a marine engine and easy to implement and mount because it will not be exposed to the harsh engine environment at that position.

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