



**Makale
(Article)**

Experimental Spectral Analysis of Split Sleeve Bearing Clearance Effect on a Rotating Shaft System

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Abstract

Bearing are one of the most widely used elements in rotating shaft systems with great risk of failure that can affect the systems. There are two broad types of bearings used in rotating shaft system: sleeve bearings or journal bearings and rolling element bearings. Split sleeve bearings are used for application where it is necessary to remove a cap for servicing or replacing bearing. Proper clearance between the shaft and the bearing is necessary to avoid vibration or loss of concentric orbit. The performance of rotating shaft system is very dependent on vibration generated by bearings. The use of vibration signal analysis is one of the most reliable measurement for this purpose. The main objective of the present study is experimentally to investigate the role of bearing clearance that is a critical parameter affecting dynamic characteristics of rotating shaft systems. The vertical bearing clearance through introduction of additional shims is operand to simulate a loose -worn- split sleeve bearing. Wear is responsible for many problems and large cost in rotating shaft system. Three different clearances configurations using shims have been tested. The results showed that a worn bearing will have a significant influence on the stability of rotating shaft system.

Keywords: Sleeve bearings, Rotating shaft, Vibration analysis, Bearing clearance, Worn bearing.

1. INTRODUCTION

There are two broad types of bearings used in rotating shaft systems; rolling element bearings and plain bearings known as journal bearings or sleeve bearings [1]. Sleeve bearings have been used in many of today's rotating shaft systems especially those running at relatively low speeds. Low speeds sleeve bearings are generally lubricated with thickened oil called grease [2] rather than oil. Sleeve bearings consist of a shaft and a shell called sleeve around the shaft. Sleeve is made of soft metal named Babbitt an alloy made mostly of tin and lead [3]. In a split sleeve bearing, the shaft fits in two half shells. Split bearings are used when the shaft cannot be easily pulled out of the bearings and eliminates removing components from the shaft when replacement is required. Design and construction of split sleeve bearings may be relatively simple, but the operation of these bearings can be complex. Dynamic behavior of rotating shaft supported by sleeve bearings has remarkable history but one could argue that it has been studied more by experiment than by theory. Although there have been relatively few studies published about spectral analysis of rotating shaft mounted on split sleeve bearings with grease lubrication, several important facts concerning these

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bearings can be obtained from the literature [4-8]. One of the most important parameters when performing dynamic analysis of rotating shaft supported in sleeve bearings is bearing clearance. Proper clearance between the shaft and bearing keeps the shaft position stable. Improper clearance can lead to unwanted vibration due to unbalance rotating shaft loading causes the shaft to orbit in the bearing. In this study, three different clearances provided with plastic shims were used to investigate the effects of clearance on the dynamic behaviors of rotating shaft. Split sleeve bearing is utilized so that plastic shims are used to open clearance to simulate worn bearing. Wear can induce vibration, fatigue, and consequently failure of the parts [9]. Wear is progressive loss of material from one or both the surfaces in contact [10].

2. EXPERIMENTAL SETUP

The experimental setup used in this study is schematically shown in Figure 1. The rotating shaft system is supported by two Babbitt lined split sleeve bearings mounted on the bearing pedestals. The rotating shaft is coupled to an induction motor with a self-aligning coupling utilized to minimize the effect of the driving component vibration. The motor shaft to the shaft alignment is conducted using the reverse dial indicator technique. The indicator is used for proper alignment that the axial rotating shaft separation is within tolerance.

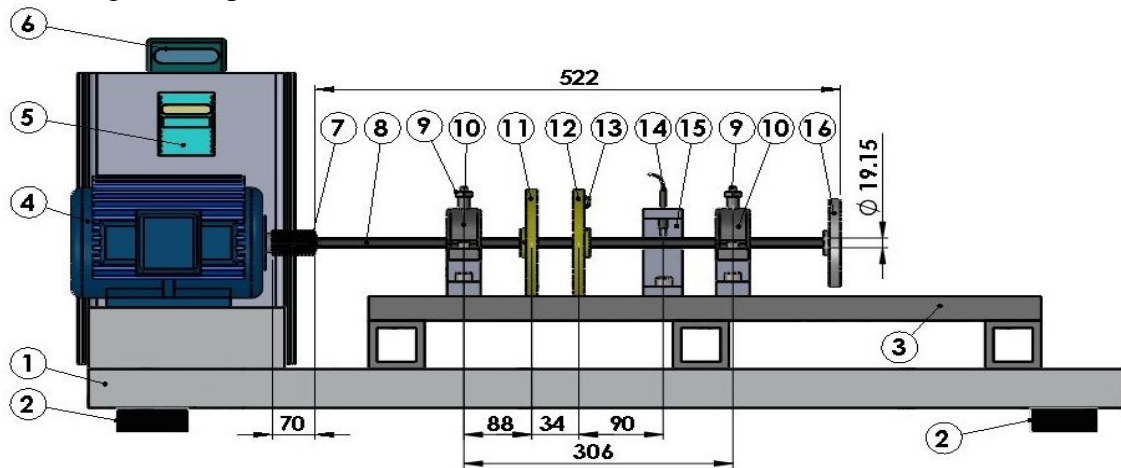


Figure 1. Experimental test rig: (1) Base; (2) Rubber isolators; (3) Extended rotor deck; (4) 0.5 hp Motor; (5) Variable speed controller; (6) Tachometer; (7) Flexible coupling; (8) Shaft; (9) Grease fitting; (10) Sleeve bearing; (11) Aluminum disk ; (12) Aluminum disk; (13) Unbalance screw; (14) Proxy probe; (15) Rigid support for proxy probe; (16) Overhung disk.

Figure 2 shows bracket and dialing indicator arrangements for rotating shaft alignment. Alignment brackets are secured to the motor shaft and extend over the alignment bracket of the rotating shaft to bring the shaft into alignment.

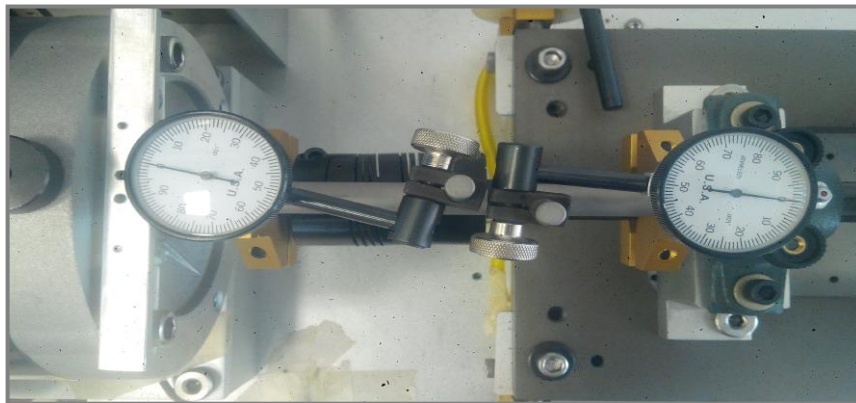


Figure 2. Dial indicator arrangement for rotating shaft alignment.

The setup consists of a shaft having length of 550 mm and diameter of 19.15 mm. As can be seen in Figure 3, load is provided by two aluminum removable disks with 151.8 mm diameter and 0.668 kg weight and 18 equally spaced holes in two rows to unbalance load using a screw. These disks are mounted on the shaft at different locations between the bearing supports and the other disk having diameter of 115 mm and weight of 0.278 is overhung. The unbalance load is introduced to disk close to outboard sleeve bearing to excite the rotating shaft system. The shaft speed is controlled by a speed controller. The experimental test rig is connected to a data acquisition system. All experimental data have been collected and analyzed using VibraQuest™ software. Sleeve bearings shells are made of soft metal called Babbitt. The bearings conform to the shape of the shaft. The proper clearance between the shaft and the bearing keeps the shaft position stable. Mostly used minimum allowable clearance is the shaft diameter in inches times 0.001 mil plus 0.001 mil [11]. Additional various plastic shims are used to open the vertical bearing clearance to simulate worn bearing. A shot of standard lithium base grease is pumped through grease fittings. Non-contact Eddy current proximity probes are used to determine the vibration level since the geometric center of the shaft seldom follows perfect circular orbit. In Figure 3, two proximity probes with resolution of 1 μ m for measuring the shaft relative displacements are mounted on rigid support between the outboard disk and sleeve bearing in the vertical (Channel 1) and the horizontal (Channel 2) directions. The distance between the probe tip and shaft surface is 0.156 mm.

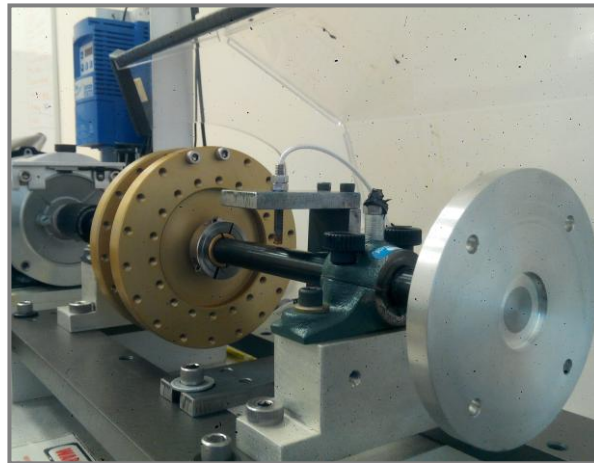


Figure 3. Load arrangement of the rotating shaft system

Table 1 gives experimental sets for the test cases. Three test cases were conducted to observe vibration behavioral changes of the rotating shaft considering vertical bearing clearance effect. No shim was used for the first test case. The second test case was conducted using a shim with 0.14 mm thickness for each side to open bearing vertical clearance. The third test case was conducted using shim with 0.62 mm thickness for each side to open bearing vertical clearance. Three different experimental sets (Set A, Set B, and Set C) were employed for each test case. In the Set A, no unbalance screw is mounted on the outboard disk. In the Set B, an unbalance screw is mounted on the outboard disk. In the Set C, two unbalance screws are mounted on the outboard disk (see Figure 3).

Table 1. Experimental Sets for the Test Cases

	Plastic Shim Thickness, mm		
	No shim	0.14	0.62
No screw	Set A- Test 1	Set A- Test 2	Set A- Test 3
One screw	Set B- Test 1	Set B- Test 2	Set B- Test 3
Two screws	Set C- Test 1	Set C- Test 2	Set C- Test 3

3. RESULTS AND DISCUSSIONS

Direct shaft vibration readings is presenting far more useful vibration data than readings taken from sleeve bearing housing. Vibration were measured in both the vertical and the horizontal directions using proximity probes at rotating shaft running speed of 50 Hz. For each test case with different clearance configuration, three sets (Set A, Set B, and Set C) were used to investigate the effects of vertical bearing clearance on vibration of rotating shaft system. Collected vibration data is examined from time waveform, orbit, and polar perspectives. Figure 4 and 5 give time waveform and orbit plots respectively. It is very important to understand the relationship between the time waveform and orbits. The changes in the waveform cause the orbit to form. The time waveform plots shown in Figure 4 display picture of disturbances over time. Data are presented with amplitude as the vertical axis and elapsed time as the horizontal axis. A series of spikes can be seen in Figure. Each of these spikes is a cycle of vibration. There are many cycles during the 0.64 seconds time period. Some of the spikes appear to be fatter than others. Some of cycles are taking longer than other cycles. This is known as frequency modulation that causes harmonics. Thus, the peaks are changing size. From the Figure 4, the amplitude of the spikes slightly vary comparing Set A, Set B, and Set C for all test cases. Some of spikes appear fatter than others. Thus, particular shaft cycle is taking slightly longer than other cycles known as frequency modulation. There is no obvious sinusoidal waveform since there is unbalance forces in addition to open clearance. Although the time waveform plot provide important and useful information, it is inherently limited to one dimension of rotating shaft motion. However, orbit plot provides enough information to observe the motion since gives the motion of rotating shaft in two dimensions.

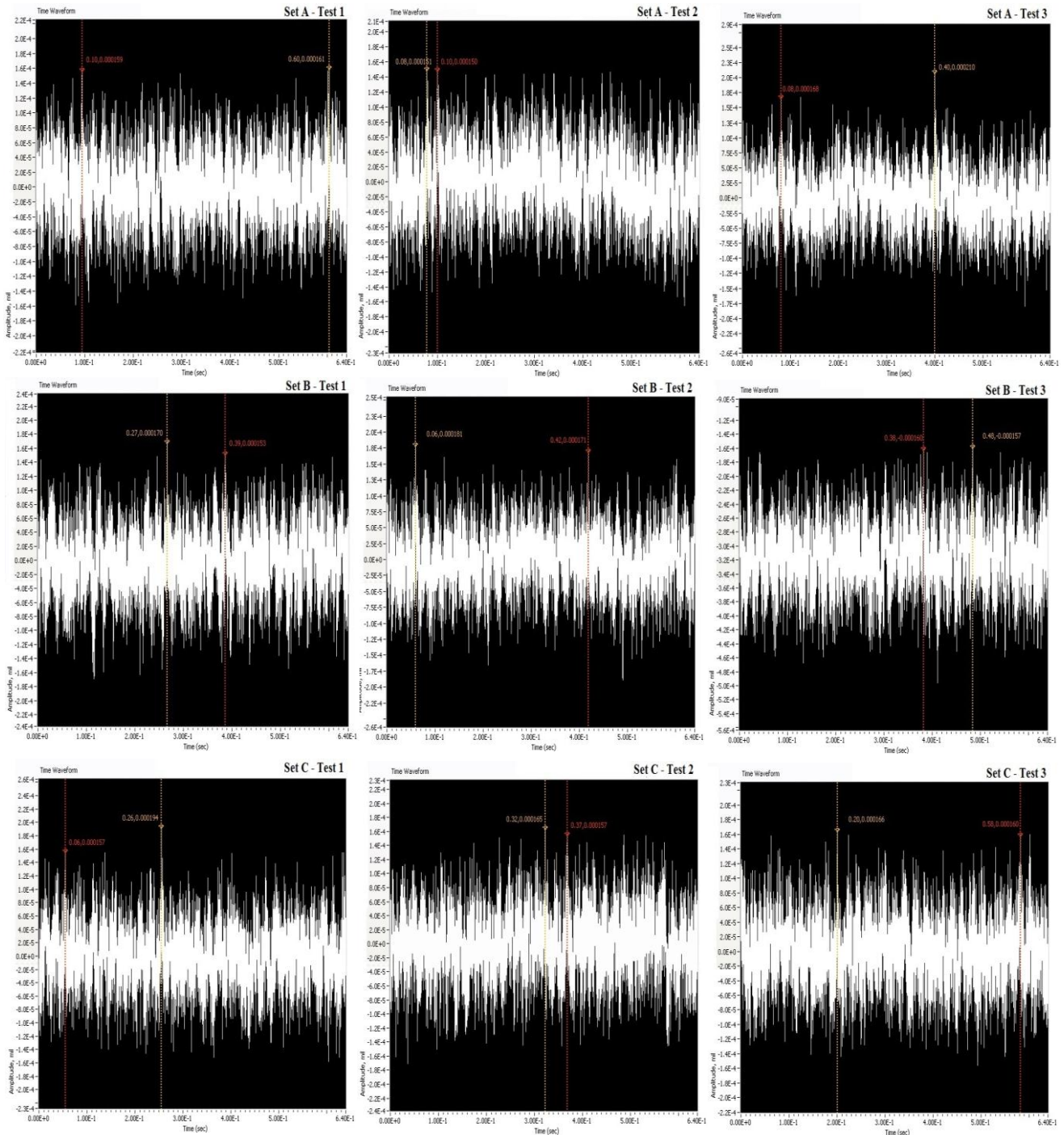


Figure 4. Time waveform plots.

As can be seen in Figure 5, orbit plots show the dynamic motion of the center of the rotating shaft with signal from proximity probes. Orbit plots are given of the horizontal (Channel 2) and the vertical (Channel 1) with zero in the center starting from the center, up and right sides are positive, and down and left sides are negative. The vibration displacement level is measured in mil (one thousandths of an inch). The orbit plots in Figure 5 indicate dynamic characteristics of looser vertical bearing clearances compare to tighter ones. It can be noted that too much clearance merely allowed the loads to throw the rotating shaft around to create higher displacement value but vibration symptoms are not generated as well. From Figure 5, it was seen that the displacement values of the rotating shaft in the vertical and the horizontal directions of Set B for all test cases

were surprisingly higher than the all test cases of Set A and Set C. Thus, it was shown that using two screws for unbalance are not necessary lead to higher displacement values than using one screw. This was because of loading due to one unbalance screw forces the rotating shaft to move freely in bearing clearance. It can be concluded that an increase in clearance will increase the displacement but not necessarily lead to similar increase for vibration level when unbalance loading used.

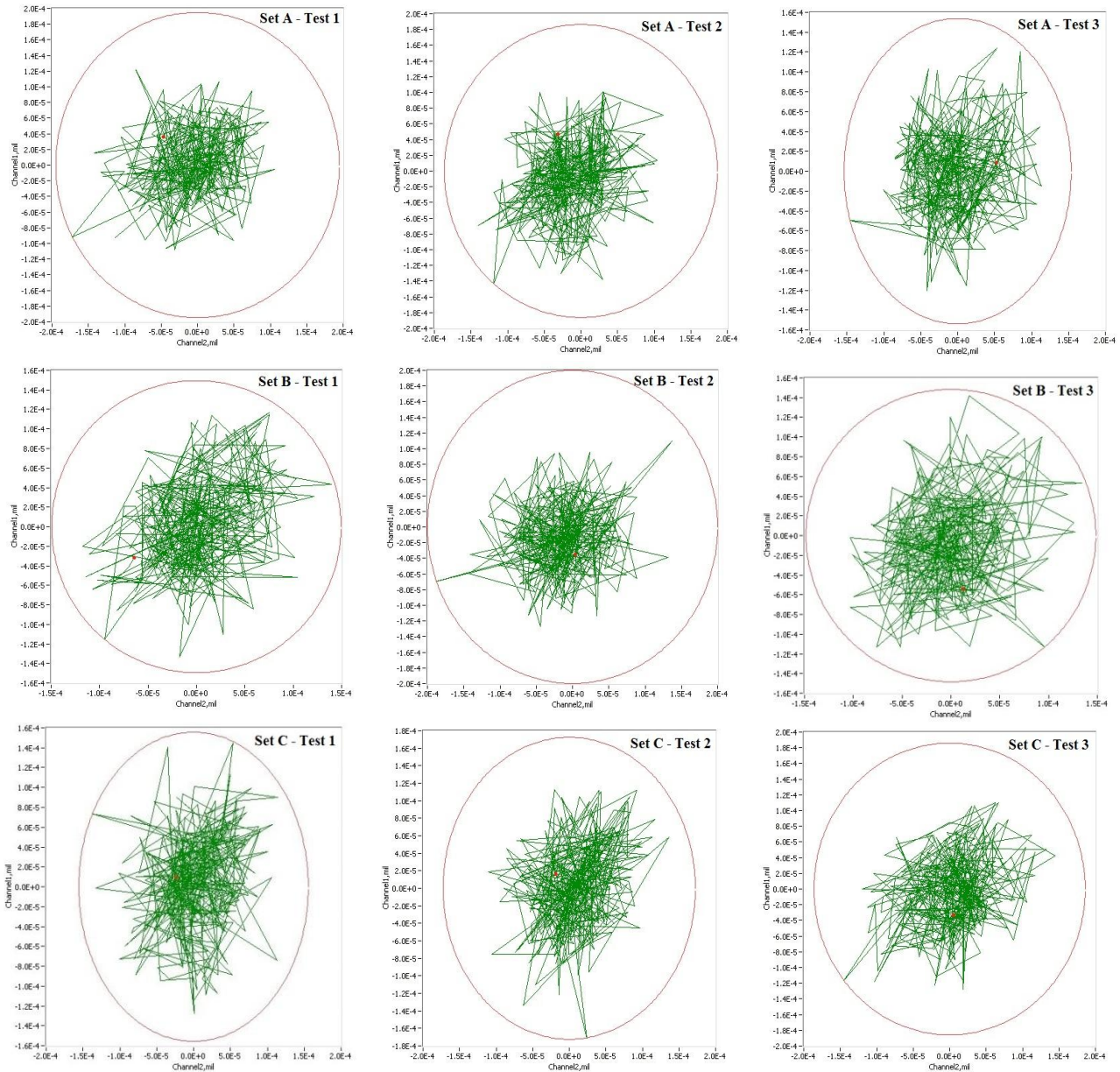


Figure 5. Orbit plots.

Figure 6 gives polar plots for vibration amplitude in mil and phase (vector) information of order one. It can be seen how the zero degree position changes according to the angular position of displacement probe and how the phase changes against the shaft rotational direction. The polar plot is a presentation of vector monitoring to ensure the vector move in the acceptance region. It can be seen from Figure 6 that value of vectors are in safe region.

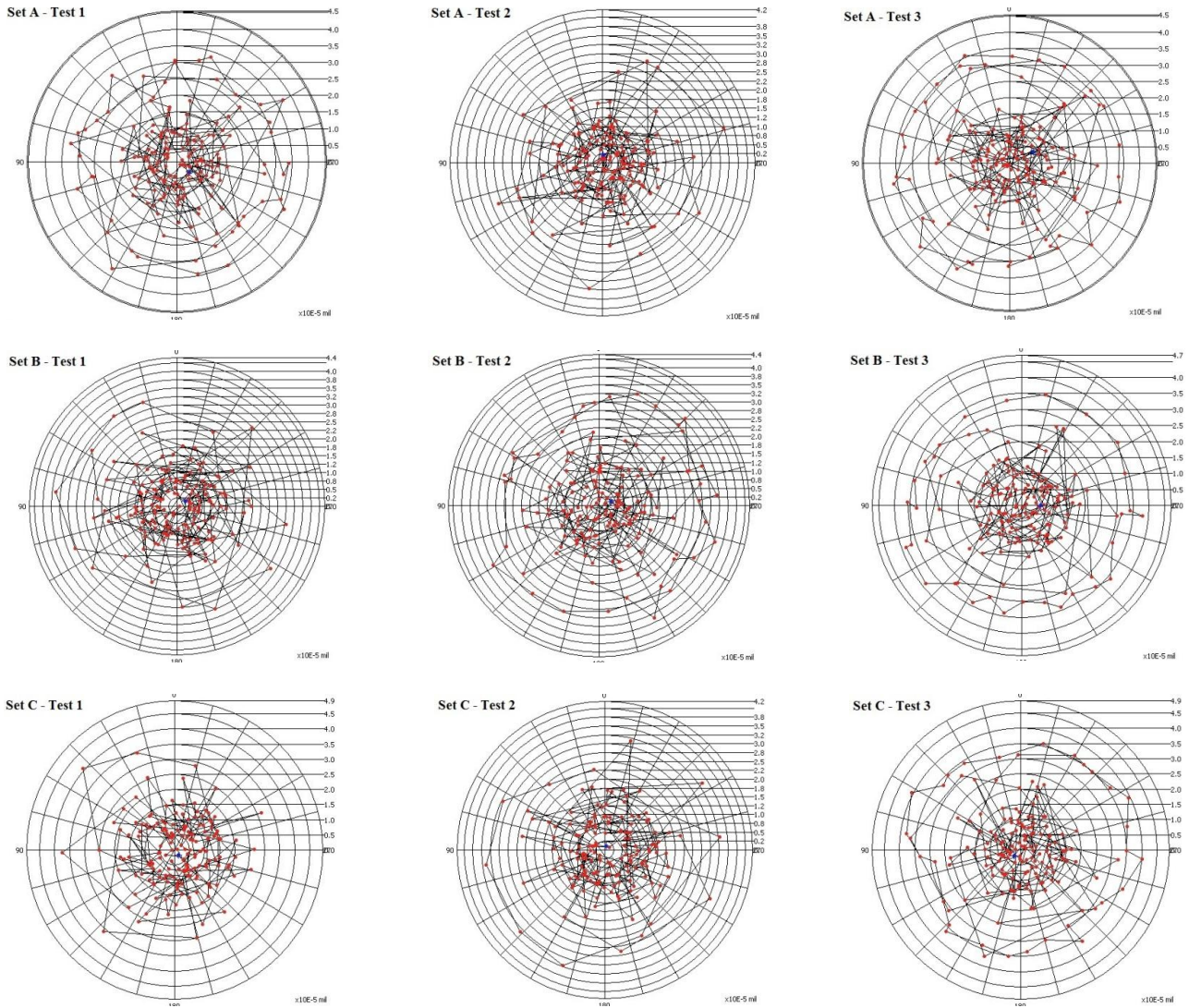


Figure 6. Polar plots.

4. CONCLUSION

Rotating shaft systems are extremely used in diverse engineering applications. Sleeve bearings have been widely used in rotating shaft systems. Split sleeve bearings are used when the rotating shaft cannot be easily removed out of the bearing. Proper clearance between rotating shaft and the sleeve bearing is necessary to avoid vibration in the rotating shaft system because excessive vibration can cause the system failure. Generally, since the geometric center of the rotating shaft seldom follows a perfect circular orbit, it causes an oscillatory dynamic pressure to act on the Babbitt surface leading wear. Therefore, in this study a series of experiment were conducted to simulate a worn split sleeve bearing dynamics characteristics. Three different clearances configuration using shims for wear simulation have been tested and examined from time waveform, orbit, and polar perspectives. The results showed that an increase in clearance will increase the displacement but not necessarily lead to similar increase for vibration level when centrifugal forces due to unbalance loading presented. Also, it can be concluded that using two screws for unbalance are not necessary lead to higher displacement values than using one screw. This was because of loading due to one unbalance screw forces the rotating shaft to move freely in bearing clearance.

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