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Failure Analysis of Bearings in Air Conditioning Compressor

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Abstract

Two journal bearings of a compressor were failed in service. The wear which led to crack was observed at the internal surface of both bearings. The objective of this analysis is to evaluate the reason for the wear found on the internal bearings surface. Two bearings were returned from field and others in several conditions were examined. Electron probe micro analyzer and microhardness was used for metallurgical analysis. It revealed that bearing consisted of two different layers: 1) Fe-base and 2) Al-Sn alloy. Surface worn at the internal surface which composed of Al-Sn alloy was found. The results also showed that the phase transformation of the internal surface of the bearing in service was occurred as same as the bearing used without oil lubrication. The lack of oil lubrication is therefore the main reason for the wear found at the bearing in service.

Keywords : Failure analysis, Bearing, Wear, Al-Sn alloy, Lubrication

Introduction

The scroll compressor is a mechanical device which increases pressure of fluid. It consists of the vane geometry which may be involute, or Archimedean spiral, curves. They operate more smoothly, quietly, and reliably than other types of compressors in the lower volume range. For this compressor, it was a component in air conditioner. It worked regularly only a few months. In this compressor, although, it consisted of complex component but there was an important vane which was connected to the rotating shaft which was supported by two types of journal bearings: orbiting bearing and compliant bearings (upper and lower position respectively).

All journal bearings were failed in service. The wear sign was observed at the internal surface of both bearings as shown in Figure 1.

Figure 1: The observation of bearing worn in service.

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The objective of this work is to evaluate the reason for the wear found on the internal bearings surface in order to determine the best solution of this failure.

Materials and Experimental Procedures

Two bearings and others in several conditions were prepared for metallurgical examination. The bearing designations and their conditions are shown in Table 1.

Table 1: The bearing designations and their conditions.

Sample No.	Sample designation	Conditions
1	382	from industrial area
2	208	from another industrial area
3	A22W-new	new bearing
4	A22W-oil	work in compressor with regular lubrication
5	A22W-no-oil	work in compressor without lubrication

In this analysis, the sample No. 1 and 2 (382 and 208) were mainly examined. Samples No. 3, 4 and 5 (A22W-new, A22W-oil, and A22W-no-oil) were also investigated as the reference.

The bearing worn was cut, then ground and polished with Al_2O_3 particles. Finally, the samples were performed with the equipment as follows:

1. Electron probe micro analyzer (EPMA) was used in back-scattering electrons mode for the metallographic and composition analysis.
2. Microhardness with Vickers indentation was used for the hardness of bearing.

The chemical composition of the studied bearing is shown in Table 2. From the Table 2, it was found that the bearing consisted of 2 layers. The inner one was made of Al-Sn alloy. In the other hands, the external one was composed of C and Fe.

Table 2: Chemical composition of the studied bearing for industrial data (in wt.%).

Part	Sn	Cu	Si	Al	C	Fe
External	-	-	-	-	0.05	bal.
Internal	12	1	3	bal.	-	-

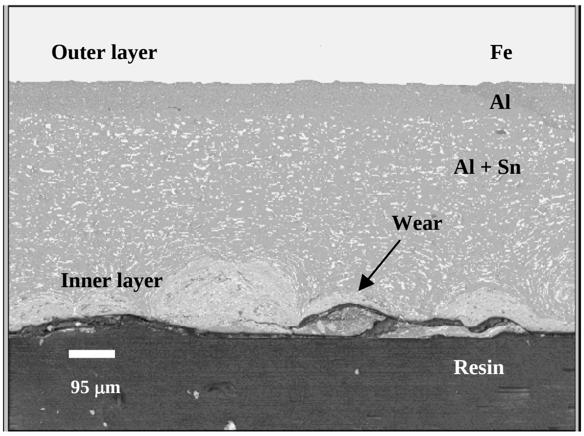
Results and Discussion

Visual Examination

The wear area was observed at inner surface of bearing as shown in the Fig.1. The surface damage appearing as scoring was found in many perimeter of inner surface. However, there were no cracking and contaminated particles observed.

Metallurgical Examination

The microstructure of bearing with several conditions, as described in Table 1, are consequently shown in Figure 2, 3, and 4. The chemical analysis was also performed as shown in Figure 5.



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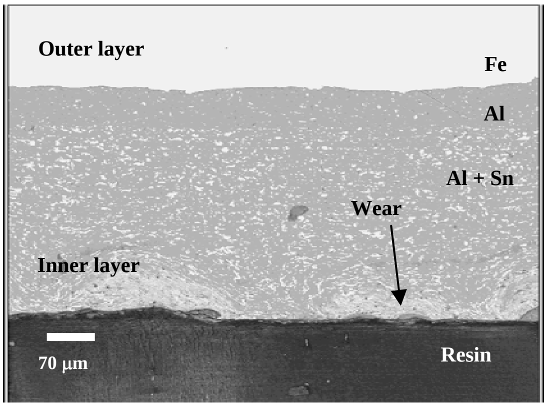

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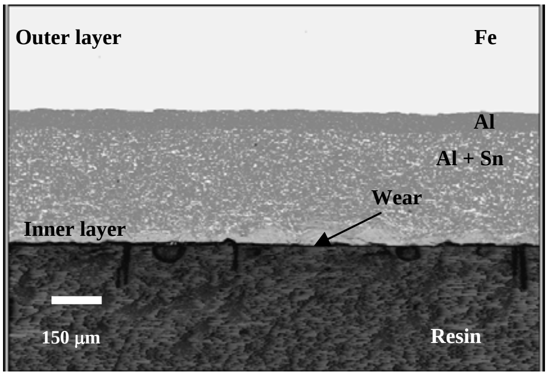
Figure 2: Microstructure in cross section of bearing 382 : a) Compliant b) Orbiting



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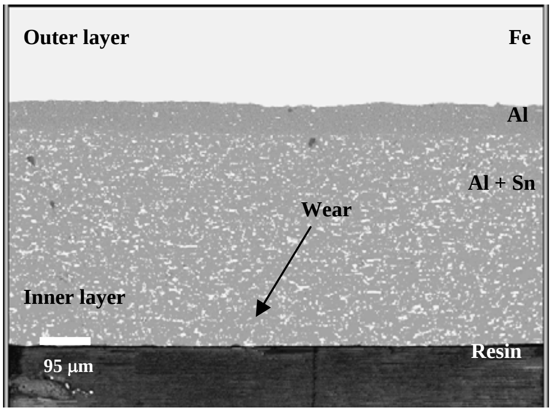

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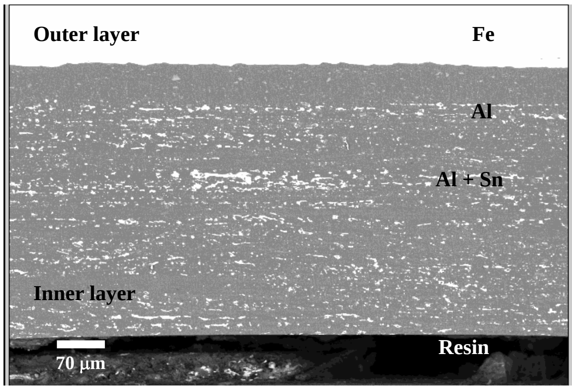
Figure 3: Microstructure in cross section of Bearing 208 : a) Compliant b) Orbiting



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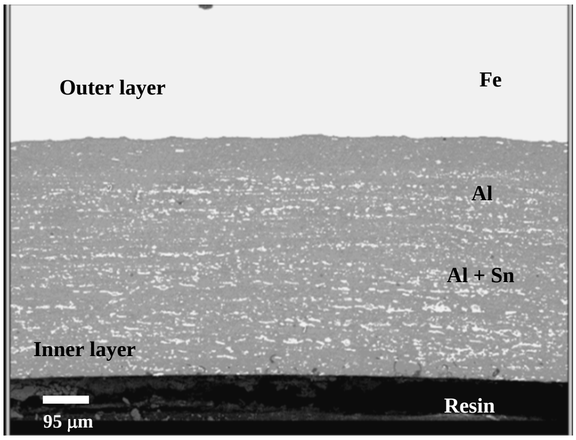

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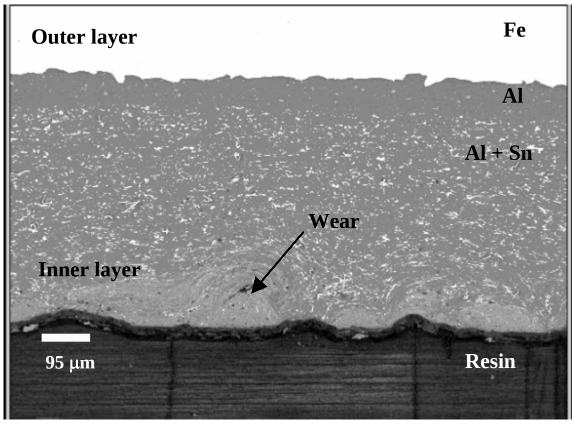

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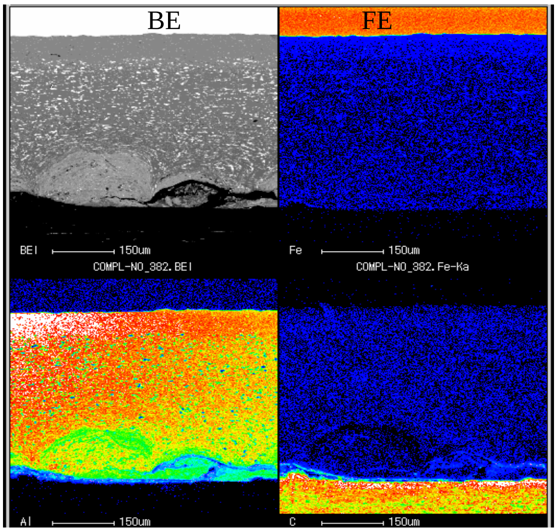
Figure 4: Microstructure in cross section of compliant bearing a)A22W-new b) A22W-oil c) A22W-no-oil.



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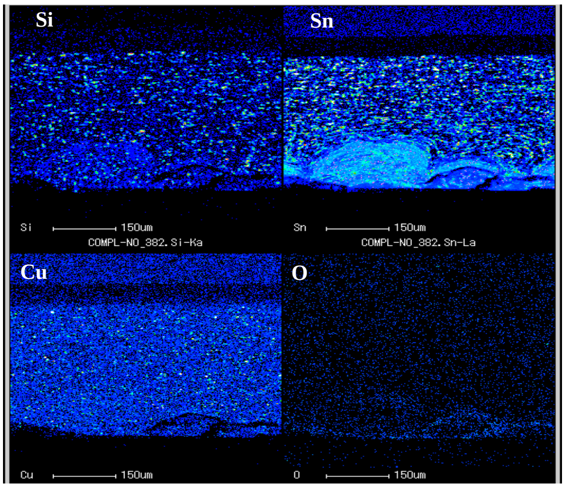

b)

Figure 5: Elements distribution analysis of compliant bearing 382 by WDS mapping.

It was found that the bearing consisted of mainly 2 layers: outer and inner layers as shown in the figure 2, 3 and 4. According to WDS mapping analysis as depicted in Figure 5, the outer one composed mainly of Fe was used as the external bearing. In the other hands, the inner one consisted of the Al-Sn alloy. It was also composed of Sn precipitation distributed in entire coating layer. In addition, the interaction phase, as called bonding layer, consisted of mainly Al. The wear sign was found in the homogeneous Al-Sn phase (bright zone near wear sign).

From the Figure 3, the microstructure of bearing 208 was similar to that of 382. The wear sign was also found in the homogeneous Al-Sn phase.

Comparing to the unused, regularly used bearing, and bearing without lubrication (Figure 4a, 4b, 4c), Figure 4a and 4b show that no wear sign was observed at the Al-Sn layer. Contrarily, with the lack of oil, the microstructure of bearing in service (382 and 208) was similar to that in condition without oil lubrication.

Hardness Test

The microhardness measurements were performed using Vickers method with 500 g load on polished samples in accordance with ASTM E384-10. The measurements were conducted at the inner and outer surface of the bearings. The test results are shown in Table2.

Table2 : Hardness measurement on the coating and base layer.

Sample Designation	Hardness, HV	
	Inner layer	Outer layer
382	48.3	203.5
208	49.2	198.1
A22W-new	45.3	212.3
A22Woil	46.7	204.7
A22W-no-oil	47.2	196.7

The results show that the hardness of inner layer (Al-Sn alloy) of bearings in service (382, and 208) were greater than the others. In the other hands, the hardness of outer layers for all were variable. However, their hardness can be categorized in the same range. It revealed that the microstructure change a little the properties of bearing materials.

Results and Discussion

From the EPMA analysis, the results revealed that the internal layer of all bearings consisted of Al-Sn alloy with Sn precipitations distributed in layer. The Sn precipitations play an important role for a self lubrication when oil lubricant in bearing is not sufficient. It is according to the general bearings which were patented by Isaac Babbit in 1839.(1) They were often based on the Pb–Sb–Sn system. If used as overlays, they are directly cast onto the steel strip.(2)

The microstructures of bearings (382 and 208) in service were identical to that of A22W without oil lubrication. It can be firstly assumed that they may be in the same condition.

Normally, the journal bearing is designed to support a radial load in the presence of a lubricant. The lubricant film plays a key role for this bearing. In normal operation, a converging wedge of lubricant generates sufficient pressure to support the load hydrodynamic. However, when the lubricant is not enough or lacking, this type of bearing cannot work regularly,(3) resulting in the increasing friction.

Due to the high friction between the bearing and shaft, the temperature will increase continuously. This phenomena led to the transformation of Sn solubility in Al matrix during the increasing temperature (650°C),(4) showing the homogeneous phase of Al and Sn.

The damage of bearing surface occurred firstly with the adhesion wear, then the abrasive particles, from bearing, will be driven across the rubbing surfaces, and surface damage appears as a scoring.

The hardness values of bearing were in the same range. There is a little effect of structure on the hardness measurements due to solid solution.

Conclusion

The lack of oil lubricant is the main reason for the wear found at the bearing in service. It led to the transformation of Al-Sn solution due to the increasing temperature till to melting point of alloy.

Acknowledgments

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