

Study on Tribological Characteristics of Lubricant by Adding Foaming Agent in Hermetically Sealed Compressor

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ABSTRACT

The lubricating oil plays very significant role in the overall performance of the hermetically sealed compressor by reducing wear of compressor components, cooling of mechanism, and dampening of the noise and vibrations etc. by various properties of lubricating oil.

Despite good lubrication majority of hermetically sealed compressors exhibit unpleasant noise and vibration. Thus, in order to control the noise and vibrations of the compressors it is essential to enhance the dampening of compressor shell. The authors of this paper thought that the easiest way to increase the dampening of compressor shell is by filling it with foam. Though foaming in the lubricating oils is undesirable as it leads to bad lubrication and shortens the life span of lubricated components. Even knowing the consequences of foaming of oil reported in published papers, in this work the authors have evaluated the performance of compressor along with tribological studies of its lubricated contacts by creating foam in the lubricant.

Here the study and comparison of the compressor by using standard lubricant (POE) and after mixing foaming agent in the standard lubricant (POE) has been carried out. Moreover, presence of foaming agent by volume has been optimized for better performance results.

It was found through the experiments that by adding optimized quantity of foaming additive the sound level decreased by about 6.85% as compared to pure POE. The four-ball wear test revealed that the scar diameter decreased a little but there was little increase in coefficient of friction.

The FTIR tests were conducted to observe the degradation of lubricant (before and after full load test) and find the compatibility of the foaming additive with the POE the lubricating oil. It was found that even after

adding the foaming agent; the change in transmittance was negligible which indicates that there was not much degradation of POE oil even after running the full load test. This also shows that additive was compatible with the lubricating oil.

In this paper, mainly tribological related results are being reported before and after adding foaming additive in the POE oil of the compressor. Results have been found very encouraging.

KEYWORDS

Hermetic Compressors, Foaming Additives, Wear, Friction, Lubricating Oils, Noise And Vibration.

1. INTRODUCTION

The commonly used household appliances like refrigerators and air-conditioners use chloro-fluorocarbon (CFC) or hydro-chlorofluorocarbon (HCFC) as refrigerants. But the use of these refrigerants has led to Ozone layer depletion. Hence, an apt decision to phase out these refrigerants was consciously taken by the international body for conservation of environment. In the interim period, the hydro-fluorocarbon (HFC) refrigerant has been introduced as alternative to CFC/HCFC refrigerant in hermetic refrigerating systems as working fluid [1-5]. Its physical and thermo-hydrodynamic properties are almost equivalent to those of chloro-fluorocarbon (CFC) and hydro-chlorofluorocarbon (HCFC) refrigerants. The effect of the removal of chloro-fluorocarbon (CFC) and hydro-chlorofluorocarbon (HCFC) will have a positive contribution to our environment. But, there is a requirement for the development of new lubricants with good compatible additives having compatibility with HFC for retaining good tribological performance of hermetically sealed compressors which are used in these applications for wide range of operating conditions. The effect of fluorides in HFC on tribological behavior of lubricating contacts is unknown. But it is more likely to be detrimental since it offers little boundary protection to aluminums [1].

Initially Polyalkylene glycol (PAG) oil was developed as an ideal substitute to the lubricating oil due to its miscibility with HFC [2]. However, chemical instability of Polyalkylene glycol (PAG) led to the development of another synthetic lubricating oil i.e. poly-ol ester (POE), for lubrication of moving contacts among the compressor components. Currently, POE is being utilized in various vapor compression refrigeration systems with HFC refrigerant [3, 4]. But in practice it is generally seen that with the combinations of HFC and POE, compressors of refrigerators and air-conditioners create undesirable noise and vibrations during the operation of appliances.

Lubrication within the compressor is not just a function of the lubricant; it is also governed by the selected refrigerant. Foaming in lubricating oils generally leads to bad lubrication. It shortens the life span of lubricated components. Thus, in the past many anti-foaming additives have been developed and used by various researchers. In spite of proper lubrication majority of hermetically sealed compressors tend to run with undesirable noise and vibration. Therefore it is imperative to reduce the vibration and noise in the system.

It can be easily visualized that if compressor shell should be packed (fully by some material) from inside, the vibration and noise can be minimized due to enhanced damping in the system. Hence, performance evaluation of hermetic compressors using foaming additives to reduce noise and vibration was under taken.

The present work has been divided into following parts:

- (a) Study of phenomenon of wear and friction in compressors before and after adding foaming additive in the compressor.
- (b) Evaluation of noise levels.
- (c) Comparison with existing standard compressor.

2. Experimental Studies

Exhaustive experimental work has been carried out to ascertain the suitability of the selected foaming agent. Following tests has been conducted:

- Compatibility test
- Sound/Noise test
- Wear & Friction tests

This project is basically to reduce the noise level of compressors by adding foaming additives to POE, which is the lubricating oil and to evaluate the tribological characteristics. The tribological characteristics and the effects on sound and vibrations by adding foaming additives to POE are being reported here.

2.1 Selection of Foaming Agent

A thorough review of literature was carried out to look for non-silicon based foaming agents. The important properties like non-toxic, non-flammable, less abrasive and good foaming characteristics were used as the selection criteria for the foaming agents. Based on the review and preliminary elimination, a Na based foaming agent was selected for this study, which was less abrasive and a strong foaming additive.

This compound is commonly used in shampoos, shaving cream, bubble bath, toothpastes etc. It is non-corrosive, non-flammable and non-toxic.

2.2 Initial tests Procedure

Initially tests were conducted on pure POE (lubricating oil) and after adding different percentages of foaming additives by volume to pure POE oil. Four compressors were taken from production line and sound level was measured. The composition for each compressors were pure POE and adding 0.4%,0.8%,1% of Na based foaming additives by volume to pure POE oil.

First compressor was tested with pure lubricant and then second by adding 0.4% foaming additives to pure lubricant, third with pure lubricant and then by adding 0.8% foaming additives. Finally, the fourth compressor was tested with pure lubricant and then adding 1% foaming additives. The tests were repeated after the full load test of these compressors. This approach was also used to assess any deterioration in performance after full load test of the compressor

3. Experimentation and Tribological Analysis

3.1 General

For tribological analysis with and without adding foaming additives following procedures (based on Standard) was followed.

a. Sound/Noise tests: The method adapted to measure sound level was as per Annexure B of ISO 3744:1994(E).

b. Analysis of fluid property: Analysis was carried out to evaluate the compatibility of the additive with the lubricating oil on percentage of additive added by FTIR.

c. Wear analysis: The extent of wear and its concentration on various moving and effected parts such as piston head, cylinder block, crank shaft, crank case, etc. was analyzed by the Four-ball test, SRV test and SEM.

3.2 Sound/Noise test

An important series of test was the noise/sound tests. The method adopted to measure sound level was as per annexure B of ISO 3744:1994(E). These tests were carried out on the same four compressors with the same amount of foaming additives by volume to pure POE oil as stated above. The noise tests were carried out at Tecumseh Products India Limited, Ballabgarh where all cooperation was extended for this work.

3.3 Compatibility test

To assess the compatibility of foaming additives with the lubricant, the FTIR tests were conducted. The results of tests confirm that there is a compatibility of the SLS with the POE (lubricants). The FTIR tests were conducted on pure POE and after adding foaming additives 0.4%, 0.8% by volume to POE.

3.4 Wear & Friction tests

The four-ball wear tester has three stationary balls in the horizontal plane and fourth ball on top, which spins. The load is applied to top rotating ball. The speed of the rotation can be selected in the range of 60 rpm to 3000 rpm. Due to the load applied and the speed there is wear on the three stationary balls, which are measured by microscope. Then the scar diameter of all the three balls are calculated and average value is taken. Here, the tests conducted were four-ball wear test, SRV test and SEM test. The results indicate that there is reductions in wear while the friction increases but not much in magnitude. The SRV tester is used for performance evaluation of various wear modes such as fretting wear, reciprocating and tribo-corrosion. Load can be applied ranging from 20 Newton to 1200 Newton with test duration of 1 second to 99 hours. The output parameters obtained are coefficient of friction μ as a function of time on chart paper, wear by diameter of scar and rise in temperature of pin as a function of time. The Ferro scope was used to take photographs of crankshaft and piston

head before and after the full load tests. The Ferro scope consists of bi-chromatic microscope, a camera and a photo detector and employs the transmitted and reflected lights simultaneously. There is not much deterioration between the surfaces of new and used components

4. Results and Discussions

4.1 Sound/Noise test

Fig.4.1 shows the test results on noise with different amount of additive. It may be observed that there is a maximum reduction in noise by adding 0.8% foaming agent. It is seen that there is a substantial reduction in noise; 2.5db at a level of 36.5 db.

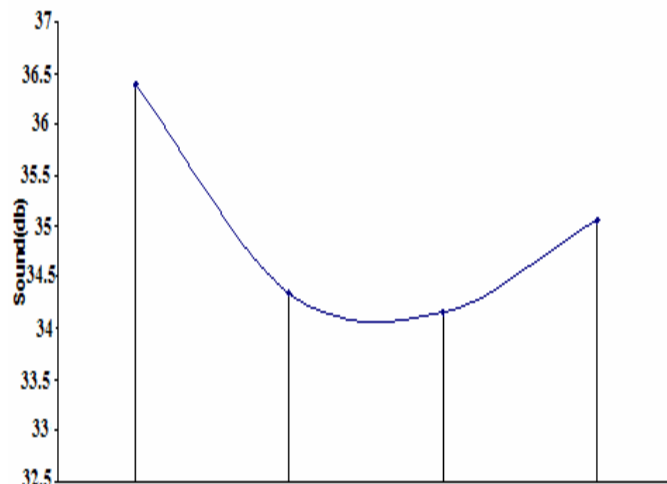


Table 4.1 gives the summary of sound level of the compressor for which performance was evaluated earlier and the sound test was done on the same compressors.

Compressor No.	Sound (db)	% of additive
1	36.39	0 (pure POE)
2	34.35	0.4
3	34.16	0.8
4	34,52	1.0

Table4.1: Final Sound Tests on three compressors

The sound tests were also carried out after the full load test of 168 hours. There is not much of deterioration in sound levels and they were still less than pure POE oil. The results of sound level after full load test are given in Table 4.2.

Compressor No.	Sound (db)	% of additive
1	36.39	0 (pure POE)
2	35.19	0.4
3	34.36	0.8
4	35,09	1.0

Table 4.2: Summary of Results after Full Load Test

4.2 Compatibility test

The FTIR tests were done on pure POE (unused oil) and by adding foaming additive 0.8% to POE (as it gives the optimum results). The results are attached as appendix A. It can be seen that transmittance does not change much i.e. POE remains stable and additive is compatible with POE. The test was also carried after running for 168 hours full load test and after the four – ball wear test, the results are satisfactory and additive is compatible with POE even after full load test.

4.3 Wear & Friction tests

The four-ball wear tests have been carried out on the compressor with a pure POE, 0.4% and 0.8% foaming agent to POE after full load test. The results are attached in table4.3. It can be seen that the scar diameter has decreased with 0.8% foaming agent to POE.

The Test Conditions were: -

- SPEED 1800 RPM
- TIME 1 HOUR
- LOAD APPLIED 40 kg
- TEMPERATURE 55 ± 2 °C

Compressor No.	Average Scar Diameter	% of additive
1	1.0966mm	0 (pure POE)
2	1.07833mm	0.4
3	1.0366mm	0.8

Table 4.3 Results of Four-Ball Wear Test

The SRV tests were conducted for the same composition as above. The friction curve is attached as appendix B. The coefficient of friction found to be 0.27 in case of pure POE oil and coefficient of friction for 0.4% and 0.8% of additive added was found to be 0.283 and 0.285 respectively. It is seen that scar diameter increases slightly in reciprocating motion. This may be due to the high reciprocating motion of the compressor components. The SRV tests have been carried out on the compressor with a pure POE, 0.4% and 0.8% of foaming additive to POE after the full load test. The results are attached in table4.4.

The Test Conditions were: -

- SPEED 1800 RPM
- TIME 2 HOUR
- LOAD APPLIED 100 Newton
- TEMPERATURE 55 ± 2 °C

Compressor No.	Average Scar Diameter	% of additive
1	1.57mm	0 (pure POE)
2	1.61mm	0.4
3	1.61mm	0.8

Table4.4 Results of SRV Test

SEM was carried out for the three sample balls of four-ball wear test and three samples of SRV test with the magnification of 400. The results are attached as figure 4.2. It can be seen from the figures that the wear and scars on the ball for four ball test and also for

the SRV test are least for 0.8% of foaming additive to POE. The results for SRV tests are attached in figure 4.3.

The Ferro scope was used to take photographs of crankshaft and piston head before and after the full load tests. There is not much deterioration between the surfaces of new and used components

Figure 4.4 Photographs of Ferro-scope

5. Conclusion

The objective of the project as stated earlier was to reduce the noise levels in a compressor by adding the foaming additive and also study the effects of the additive on the various tribological properties. The sound tests were done and the reduction in sound was maximum at 0.8% by adding the foaming additive. These tests were repeated after full load test and there was not much of degradation noticed in the sound levels. For tribological studies, many tests were conducted like FTIR, SEM SRV and four- ball wear test were conducted. It was found by the FTIR test that the foaming agent is compatible with POE and there is not much degradation after full load test was conducted. It was found that the scar diameter decreased with the addition of b% of the foaming additive but the coefficient of friction increased a little as found by the SRV test. The Ferro-scope photographs of crankshaft and piston head were taken before and after the full load test. They also reveal that there is not much of deterioration in component surface before and after the full load test.

These results are encouraging as the foaming agent is non-flammable, non-silicon based and compatible to the existing lubricant. It was found that there was decrease in sound level by about 6.85%.

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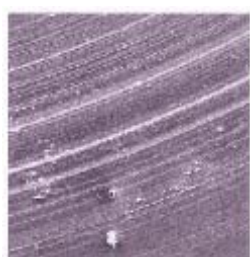
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Pure POE



POE+ 0.8%additive



POE+ 0.4 %additive

SEM Results of Four-Ball Test

Figure 4.2



Pure POE



POE+ 0.8%additive



POE+ 0.4%additive

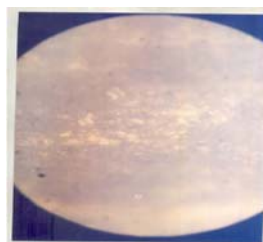
SEM Results of SRV Tests

Figure 4.3

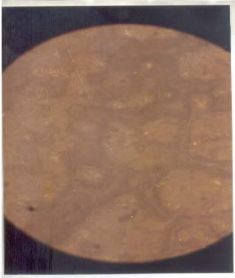
The Ferro scope was used to take photographs of crankshaft and piston head before and after the full load tests. There is not much deterioration between the surfaces of new and used components



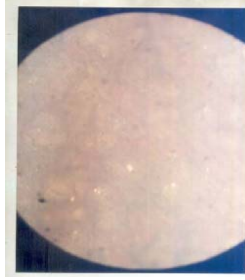
Crank shaft (new) near bottom hole (400 magnification)



Crankshaft (after life test) near bottom hole (400 magnification)



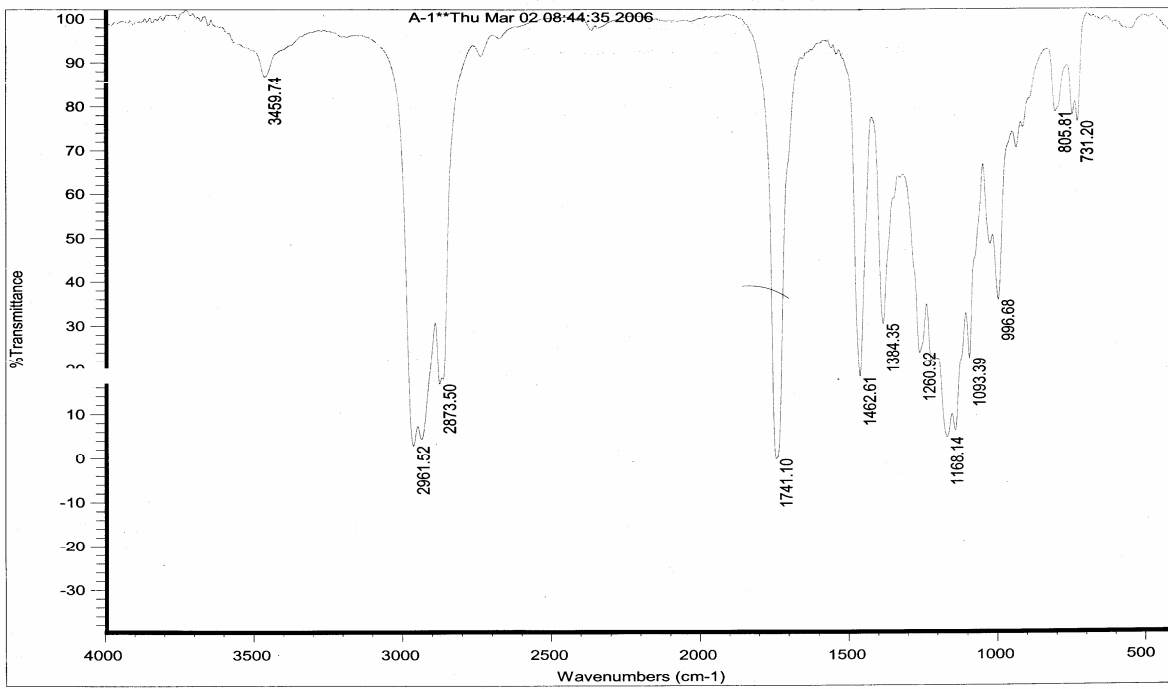
Piston head (new) top
(400 magnification)



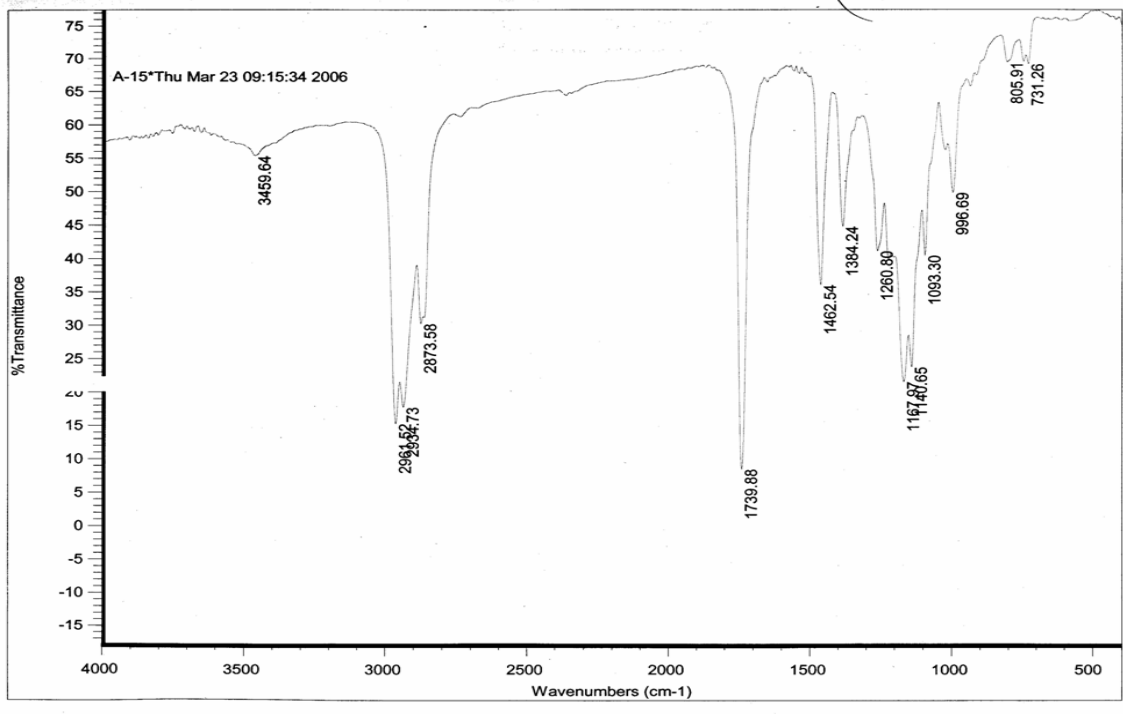
Piston head (used) top
(400 magnification)

Figure 4.4 Photographs of Ferro-scope

Appendix A

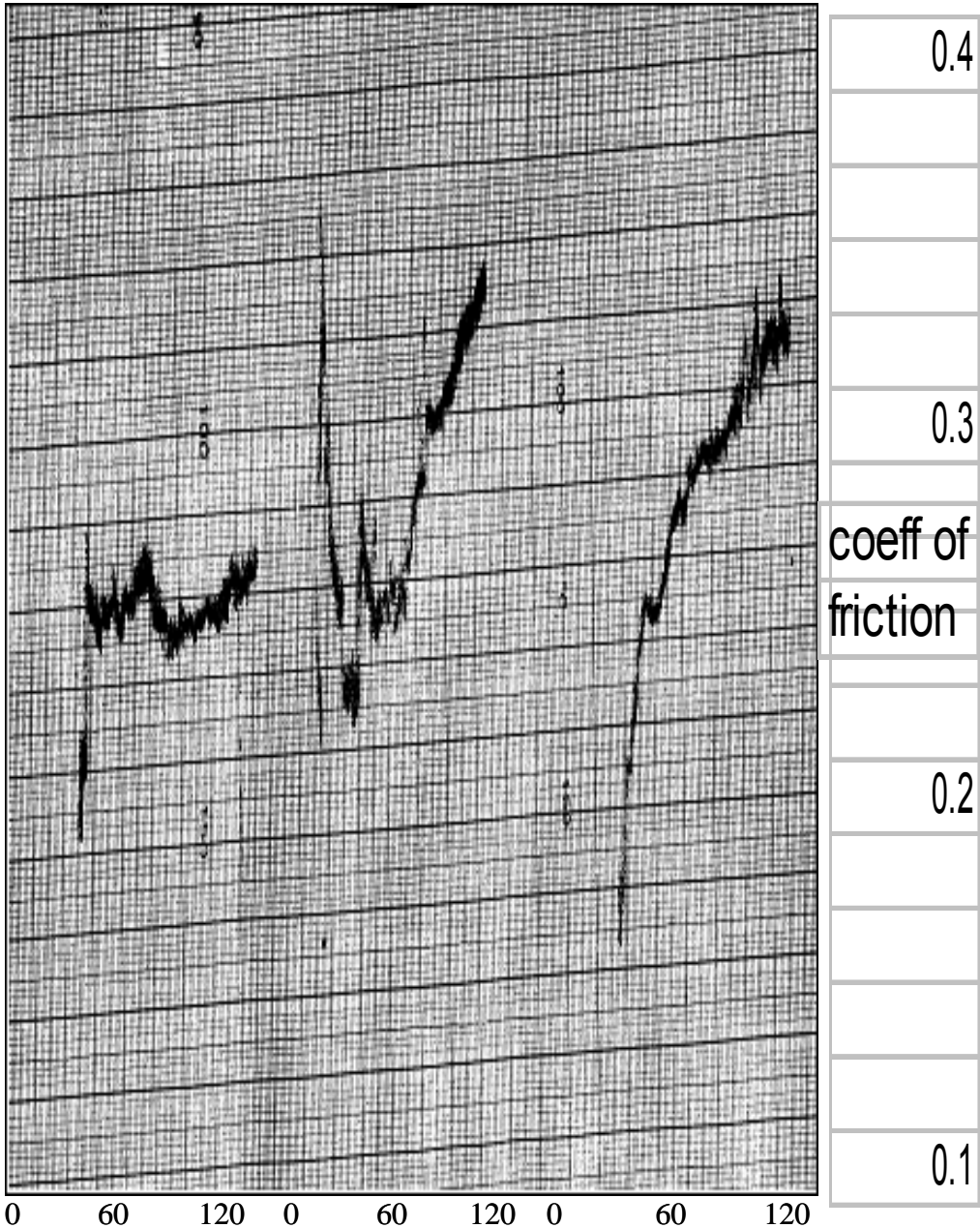


pure POE (unused)



PDE + 0.8% (after four ball wastest)

FTIR TESTS



Time(mins)

SRV TEST