Journal of Manufacturing Engineering, September 2016, Vol. 11, Issue. 3, pp 157-160

SLIDING WEAR STUDIES OF PUMP LINER MATERIAL (GCI 26) BY POD TRIBOMETER

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ABSTRACT

Rotary piston vacuum pumps are used in NFC, Hyderabad in large numbers to create vacuum in various systems and furnaces. Due to continuous operation, the liner component of the pumps got worn out resulting in failure in achieving the required vacuum. Efforts were made to repair and refurbish of the pumps by the manufacturer. By metallography, the liner material was found that pump material was gray cast iron (GCI 26). An extensive pin-on-disc experiment was carried out for three loads namely 0.5, 1 and 2 kg for a sliding distance of 1000 m. Two set of sliding velocities 2 and 3 m/s were chosen. GCI 26 showed high friction and wear under dry conditions. It is observed that as the speed increases the coefficient of friction also increases. Use of the vacuum pump for prolonged duration promoted wear leading to deterioration of clearance between the rotary cam and the liner, there by degrading vacuum in the corresponding chamber.

Keywords: *Rotary piston vacuum pump; liner; GCI 26; Sliding wear test; POD tribometer.*

1. Introduction

Cast iron possesses good wear resistance and hence it has been widely employed in many mechanical systems for several years. It is being used in piston rings, bearing, brakes, seals and so forth. Donald carried out repetitive reciprocal sliding friction experiments in argon atmosphere and reported that grey cast irons have lower friction and wear characteristics than white cast iron. With increase in the carbon content, wear was more markedly reduced [1]. Dry sliding wear tests on cast irons were carried out as a function of sliding surface temperature. Wear is low below 250°C and is independent of sliding conditions such as speed, load, ambient temperature and atmospheric pressure. Seizure occurred with high wear when the mean temperature exceeded 400°C [2]. The effect of varying phosphorus weight percentage in grey cast iron during dry sliding wear was studied using a steel-pin-on-ring technique. Severe wear was reported in 0.2wt. % P iron occurred in all stresses. The presence of Phosphorus reduced the wear rate progressively at the lowest stress 1.0 wt. % P resulted in most mild wear and at highest stresses all irons suffered severe wear [3]. Hakan and his co workers studied the severity of the performance requirement of lubricating oils with respect to the reduction in friction and wear of the components in internal combustion engines. At different velocities and temperatures, sliding tests were carried out in cast iron and the effectiveness of the additives was found to be less at low speeds and temperatures [4]. Sliding wear behaviour of gray cast iron was studied by Prasad, over a range of sliding speed and applied pressures in dry and wet lubricated conditions. The cast iron revealed various forms of graphite particles in matrix of pearlite and limited quantity of ferrite. The wear rate of the cast iron increased with speed and pressure of sliding due to increase in severity of wear condition [5]. The effect of parameters like shape of graphite phase on the sliding wear characteristics were studied and reported. The better wear resistance of grey cast iron over spheroidal cast iron was due to the effect of harder and stronger matrix and flaky graphite having large surface area [6]. Five kinds of cast irons having different structure, component, hardness and thermal conductivity were tested by varying friction force, wear rate and temperature rise. The wear rate of each cast iron was strongly influenced by the hardness change with the friction induced temperatures rise. The frictional coefficient converged to some constant value with increment of sliding distance which is independent of contact pressure [7]. The effect of suspended lubricant, namely graphite in oil on the sliding wear response of a cast iron was reported. Formation of stable lubricating film was responsible for the improved wear performance [8]. The influence of applied load, sliding speed and test environment on the sliding wear behaviour of a grey cast iron was reported. The wear loss increased with sliding speed and load which was the main reason for frictional heating during sliding wear [9]. The effect of manganese and wear parameter on the abrasive wear on grey cast iron was reported. The

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addition of 75% ferro manganese grade decrease the carbon equivalent and fortify the matrix with the formation of $(FeMn)_3C$ inter-metallic leading to increased wear resistance [10]. A rotary piston pump is a positive displacement mechanical pump which transports the gas from the vacuum system by compressing it and expelling it to the atmosphere. In this paper, the liner material of the rotary piston vacuum pump was studied with tribological perspective to overcome the vacuum pump failure which leads to the non achievement of the required vacuum.

2. EXPERIMENTAL PROCEDURE

2.1 Metallography

In-house chemical analysis and microstructural investigations were carried out in Control Laboratory of Nuclear Fuel Complex (NFC) to ascertain the details of the pump materials. On the basis of analysis/result report and metallographic observation the material of pump was identified. The metallographic samples were mounted, polished and etched with Nital (100 ml Ethanol and 10 ml Nitric acid), before viewing through optical image analyzer.

2.2 Hardness test

Vickers hardness of the Cam material as well as fabricated Piston material was measured with 10 kg load.

2.3 Dry Sliding wear tests on Pin on Disc apparatus

The pump is typically operated at 400 rpm. The sliding speeds and contact pressures between the rotary cam and the piston were determined elsewhere [11] from FEA of the full scale pump model. The components of ULVAC PKS-70 are shown in Fig.1. The average sliding speed of the pump corresponding to 400 rpm shaft speed was 2 m/s and maximum contact pressure was 1.52 GPa. Using Hertz contact theory for elastic contact between sphere and flat plate, POD tests were designed [12]. Dead weight, representing normal force on the pin in the POD test, was arrived at by calculating the normal force required to produce Hertz contact stresses on ball on flat configuration in the range of contact pressures between the cam and piston [13]. Pin-on-disc experiments were carried out for three loads namely 0.5, 1 and 2 kg for a sliding distance of 1000 m. Two set of sliding velocities 2 and 3 m/s were chosen. The sliding speed was controlled by changing the rpm of the machine with respect to the diameter of the test track on the disc.

Cylindrical pins of 10 mm diameter with hemispherical tip of 5 mm diameter were fabricated from the ULVAC PKS-70 vacuum pump components. Discs 120 mm diameter and 10 mm thickness were fabricated from specially melted gray cast iron GCI-26 heat resembling the material of the rotary cam and piston of the pump in terms of composition and microstructure. Table 1 lists the POD test matrix.

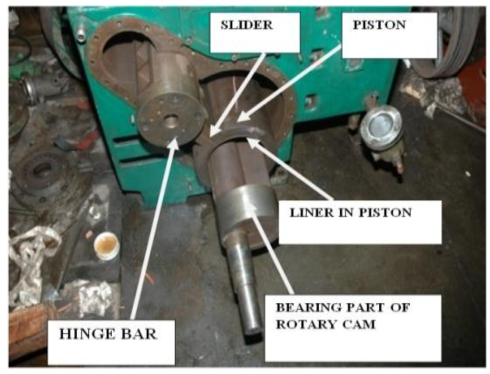


Fig.1 Components of ULVAC PKS-70

Table1. Pin on Disk test matrix

Sl No	Pin and Disc Material	Normal Load kg	Sliding velocity m/s	Sliding distance
1	GCI -26	0.5	2	1000
2	GCI -26	0.5	3	1000
3	GCI -26	1	2	1000
4	GCI -26	1	3	1000
5	GCI -26	2	2	1000
6	GCI -26	2	3	1000

3. RESULTS AND DISCUSSION

3.1Metallography and Hardness test

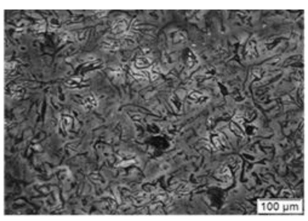
As per the composition of the piston material resemble to gray cast iron, grade-FC250 (JIS) and similarly for rotary cam, gray cast iron-grade-FC150 (JIS). Table 2 resembles Table 3 in chemical composition. Test report and microstructures of gray cast iron are as follows. The microstructures shown in Fig. 2 showed the close resemblance of size and distribution of graphite flakes in cam and piston with the GCI 26 microstructure. The hardness values of GCI -26 were found experimentally. GCI-26 exhibited an average hardness value of 210 VHN.

Table 2. Chemical composition of Cam and Piston

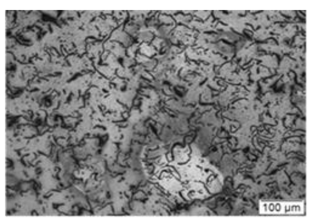
Rot Cam	El	C	Si	Mn	Mo	Ni	Cr	Co	Fe
	Wt%	3.8	2.4	1.02	0.1	.05	.07	0.05	Bal
Rot Die	El	C	Si	Mn	Mo	Ni	Cu	Nb	Fe
	Wt%	3.3	1.5	0.8	0.1	.05	.07	0.07	Bal

Table 3. Chemical composition of GCI-26

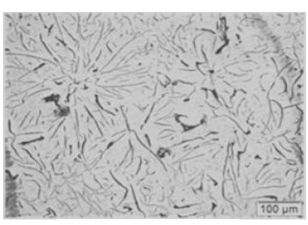
Material	C	Si	Mn	P	S	UTS (MPa)
GCI 26	3.2-3.5	1.8-2.4	0.8-0.9	≤0.2	≤0.12	≤150



Rotary Cam



Rotary Piston



GCI 26

Fig. 2 Microstructure of Cam and piston components and GCI -26

3.2 Dry Sliding wear tests

Sliding wear tests of GCI-26 carried out on POD tribometer revealed that the wear loss was more in dry conditions. Use of the pump for extended duration promotes wear leading to decline of clearance between the rotary cam and the liner, there by degrading vacuum in the corresponding chamber. Fig. 3 showed the wear versus time plot for 0.5 kg applied load and 2 m/s sliding velocity. The maximum wear recorded was 140 microns. The frictional coefficient was also shown in Fig.4 ranging between 0.2 to 0.25. Fig. 5 showed the wear versus time plot for 2 kg applied load and 3 m/s sliding velocity. The maximum wear recorded was 600 microns. The frictional coefficient was also shown in Fig.4 with a maximum value of 0.35. The results showed that the wear and the frictional coefficient was more at higher load and high sliding velocity. The frictional heating at higher sliding speed may be attributed for the higher wear loss.

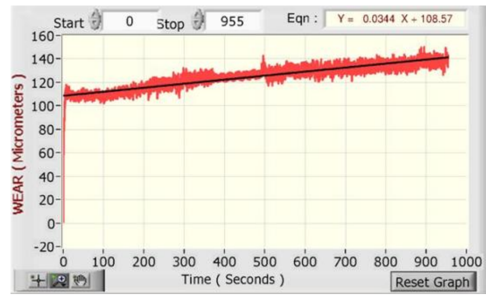


Fig. 3 Wear plot of GCI -26 at 0.5 kg load and 2 m/s speed

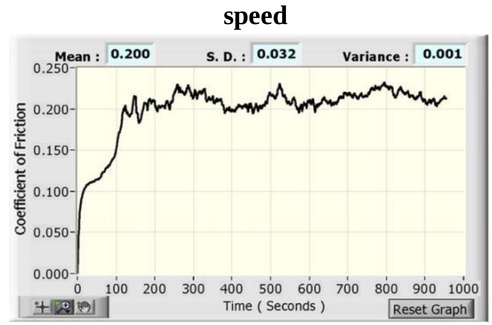


Fig. 4 COF plot of GCI -26 at 0.5 kg load and 2 m/s speed

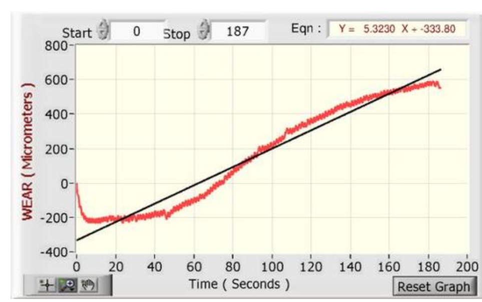


Fig. 5 Wear plot of GCI -26 at 2kg load and 3 m/s speed

Fig. 6 COF plot of GCI -26 at 2kg load and 3 m/s speed

4. CONCLUSIONS

- From the above investigations the following conclusions were made:
- The wear loss between the rotary cam and the piston liner caused the increase in the clearance, which degraded the development of necessary vacuum in the chamber.
- The piston liner material was metallurgically investigated and it was conclusively identified as GCI 26.
- In sliding wear test, GCI 26 showed high friction and wear under dry conditions.
- The coefficient of friction increases with the increasing sliding speed.
- The wear loss increased with increasing sliding speed and load due to the frictional heating.

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