A STUDY ON WEAR RATES OF 100Cr6 STEEL RUNNING AGAINST SINTERED STEEL SURFACES UNDER DRY AND STARVED LUBRICATION

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ABSTRACT

This paper investigates the tribological behavior of 100Cr6 steel pin running against sintered steel bearing material used in hermetic compressors. Tests were conducted under dry and starved lubrication sliding conditions in air at room temperature. Although porous structure acts as crack initiation sites thus limiting the wear resistance of sintered iron in dry sliding conditions under high contact stresses, it is believed to be beneficial in lubricated sliding conditions as it absorbs a large amount of lubricant. Wear tests without lubrication show that these pores are completely filled by abrasive particles in the initial stages of the test and no longer maintain their oil absorption capability. Initial results show that oxidation of frictional surfaces by flash temperature in dry conditions reduces weight loss volume by decreasing the coefficient of friction.

INTRODUCTION

Advanced wear resistant materials with low friction coefficients are being investigated for various applications in literature. This study aims to develop and characterize wear resistant and low coefficient of friction material pairs at hermetic compressors bearings, compatible with new environmentally acceptable refrigerants. Through application of these material pairs, compressors capable of operating under dry or starved lubrication conditions will be realized, thus the power consumption and the amount of oil used will be reduced.

Sintered materials find an increasing application as bearings due to technical and economical reasons. Sintered Fe-based steels are especially preferred and used in the field of high-load carrying applications. Main problem for sintered steels is their high porosity structure which results in lower values in some mechanical properties; consequently, they could not be used without any surface treatment. Their low density, which affects directly the wear rate, could be modified by surface treatment [1-3]. In contrast, their porous structure has alluring features with their lubricant storage characteristics ensuring self-lubrication of the surfaces in contact [4]. Steam surface oxidation is widely applied surface treatment for sintered steels. The lower dry sliding wear rate of a steam treated sintered steel is due to oxidized layer and sealing of porosity [5-6]. In comparison with other studies, the influence of starved lubrication on the wear characteristics of these materials has barely been reported in literature [7].

The work presented in this paper aims to address the tribological behavior of sintered steels under starved lubrication condition. The effect of steam surface treatment on the wear rate, and oil absorption by porous structure was evaluated in terms of transition distance in the coefficient of friction.

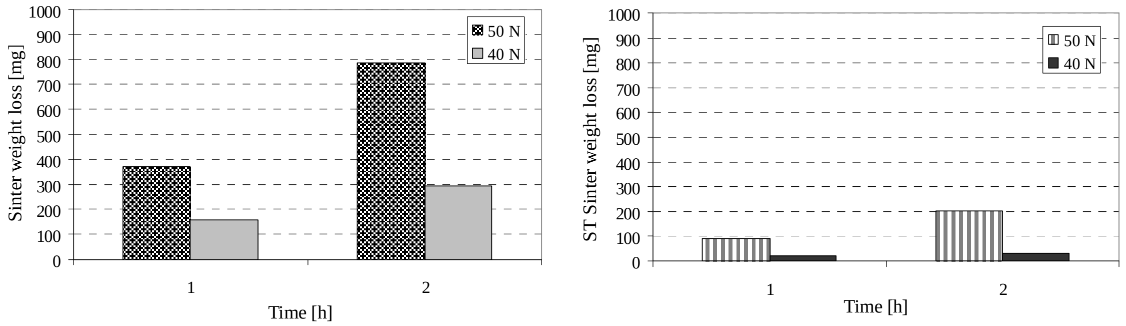
EXPERIMENTAL

The sintered disc material was prepared from the iron powder of 5-100 µm grade size at constant compaction pressure of 475 MPa, containing (wt.%) 0.30C, 0.0043S, 2.44Cu, 0.21Si, 0.54Mn, and the remaining being Fe at a density of 6.8 g/cm^3. Sintering process was conducted in a mildly reducing atmosphere of 75% N_2 + 25% H_2 at a constant temperature of 1120 ^oC for 25-30 min., then samples were cooled at 1.0°C/s to room temperature in a H_2 atmosphere with a low dew point. As sintered samples had a bulk hardness around 85 HRF. The surface roughness (Ra) of 0.50 µm was measured. Steam treatment involved two hours of pre-heat process at 100^{o}C prior to steam oxidation for one hour at 600^{o}C, and following two hours of cool-down process in the furnace. Steam treated samples had a bulk hardness around 102 HRF.

A pin-on-disc test rig was used, 100Cr6 steel pin (1250 HV), 7.89 mm in diameter and of a 5 mm in length, was rubbing sideways against a rotating sinter disc. Prior to each test, samples were cleaned in ultrasonic cleaner at 15 min. in acetone and further 15 min. in ethanol. Dry sliding tests were conducted in an atmosphere at 60-70% relative humidity and a temperature around 23^{o}C, and constant loads of 40 N and 50 N were applied. The sliding speed was 0.26 m/s. For the starved oil lubrication tests, Mineral oil, with a viscosity of 7cSt at 40^{o}C, was misted into the porous structure for 1 second at 30 psi oil pressure by a fully controlled nozzle at the beginning of the each wear test. The amount of oil was measured to be around 100 mg. No other oil was introduced throughout the test. Applied load of 50 N and a speed of 0.8 m/s were chosen for these tests. New pin and disc were used for each test and the track diameter was kept constant for each sliding speed so as to eliminate this as a further variable.

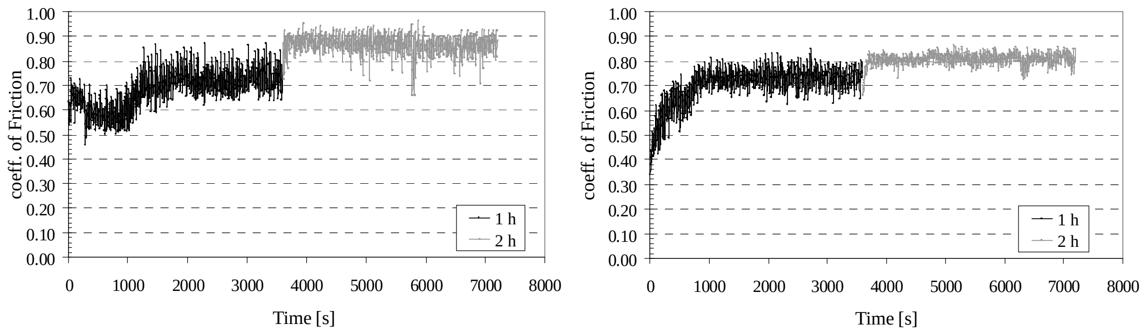
DISCUSSION

The weight loss comparison for the untreated and steam treated sinter steel, plotted against the testing time intervals for applied loads of 40 N and 50 N at a constant sliding speed of 0.26 m/s, is shown in Figure 1. It is evident that wear regime changes while increasing the load from 40 N to 50 N, and the wear rate was more than doubled. However, as shown in Figure 1b, steam treatment had a favorable effect in decreasing the wear rate for both loadings, showing four-fold decrease in the weight loss compare to untreated sinter. The lower wear rate for steam treated sinter sample was due to sealing of pores and formation of oxide layer during steam treatment, which in turn forms a smoother sliding surface. The coefficient of friction was fluctuating more for the untreated sinter sample, as shown in Figure 2, together with an excessive noise and vibration during testing.



(a) (b)

Figure 1 – Sinter weight loss under dry sliding at 40 N and 50 N, at RT and 0.26 m/s,
(a) Sinter vs. 100Cr6, (b) ST-Sinter vs. 100Cr6



(a) (b)

Figure 2 – Fluctuation in coefficient of friction under dry sliding at 50 N at RT and 0.26 m/s,
(a) Sinter vs. 100Cr6, (b) ST-Sinter vs. 100Cr6

The concept of durability distance had been established for starved lubrication sliding; it was expressed as the distance necessary for the generation of the very first wear track marking, as correlated to the first fluctuation of the corresponding friction curve. The micro structural features of the sinter material greatly affect the characteristics of the oil absorbed layer, which in turn influence the durability distance. Figure 3 shows the transition in friction coefficients plotted against the sliding distance under starved lubrication for both untreated and steam treated steels at 50 N and 0.8 m/s. It was found that durability distance is approximately 25% lower for the steam treated sinter steel since the oil absorption is lower due to sealing of the pores. Corresponding weight loss measurements are shown in Figure 4. It is evident that the wear rates were lower for untreated steel as its more porous structure is advantageous for the amount of oil absorbed.

Furthermore, it is evident that oil starved sliding tests differed from dry sliding tests since the transition distance, at which the acceptable low wear regime changes to severe wear regime for the performance of the component, are much more extended in starved lubrication case.

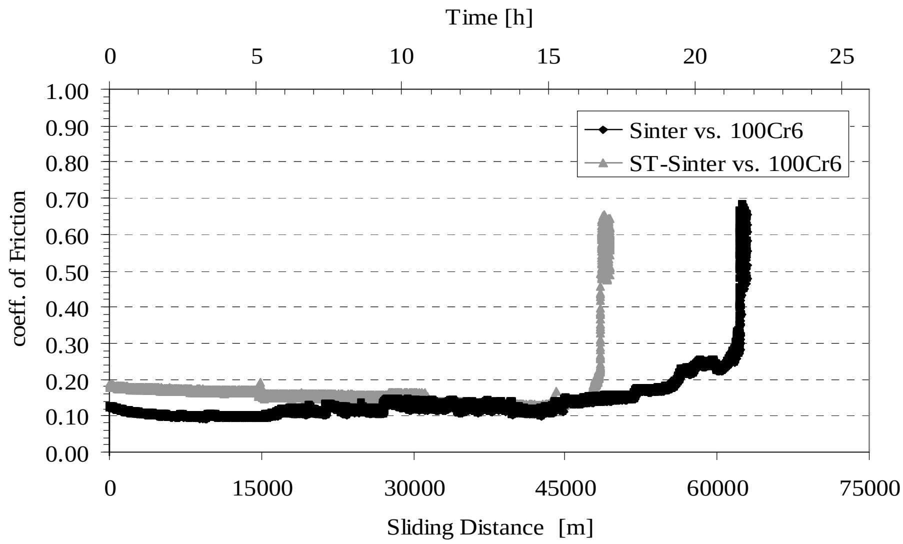


Figure 3 – Transition in friction coefficient under starved lubrication at 50 N and 0.8 m/s

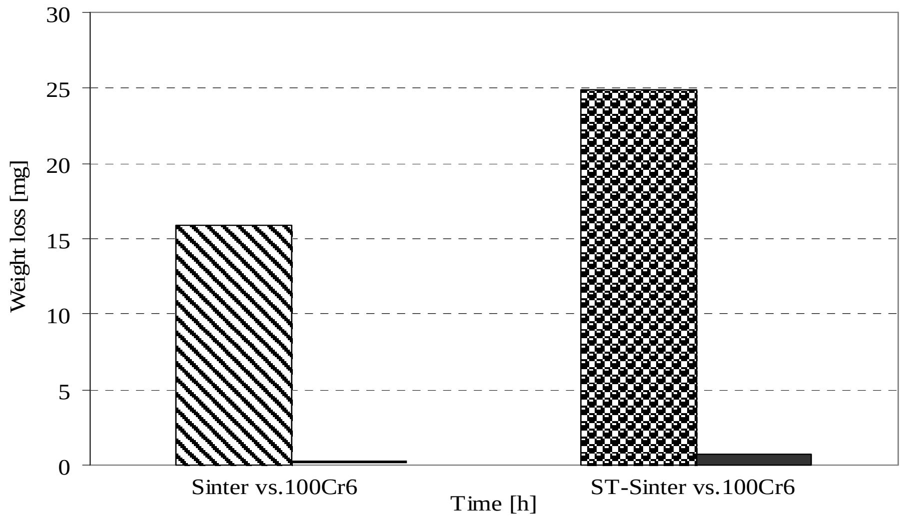


Figure 4 – Comparison of weight loss under starved lubrication at 50 N and 0.8 m/s

CONCLUSIONS

Dry sliding wear rates were doubled as the load was increased form 40 N to 50 N for both untreated and steam treated sinter steels, meanwhile four-fold decrease in wear rates were found in steam treated samples for both loadings compare to untreated steel.

The lower oil absorption of the steam treated samples, due to the sealing of porosity, led to lower transition distance in starved lubrication sliding. Consequently, the wear rate was higher for steam treated sinter steel.

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