Wear characteristics on gas turbine fuel nozzle-combustion liner contacting surface at different contact temperatures

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ABSTRACT – The contacting surfaces of gas turbine combustor components experienced high severity of wear during operation. The purpose of this study is to investigate the tribological effect on volume loss and wear coefficient of gas turbine fuel nozzle-combustion liner contacting surface at different temperatures. The tribological test was carried out by using a pin-on-disc tribometer in sliding conditions by applying three different contact temperatures at a constant sliding speed and an applied load. The worn surfaces were investigated by using a Scanning Electron Microscope (SEM) to identify the pre-dominant wear mechanisms of the contacting surfaces. The results showed that the volume loss and wear coefficient increased with an increase of contact temperatures. Adhesive and abrasive wear types were seen on the worn surfaces.

1. INTRODUCTION

Wear is one of the main degradations found in the combustor components of gas turbines during inspection. In addition, wear occurs at each contacting surface of the components [1]. Koiprasert et al. [2] observed that two vital components, namely, the fuel nozzle and combustion liner, which are often severely affected by wear damage, were used in this study. The fuel nozzle, which is slotted inside a nozzle collar, experience high temperature (1100 ºC) from fuel combustion during operations. Vishwanathan [3] stated that the temperatures at the contacting surfaces are slightly lower than 300 °C. Moreover, Dorfman [4] stated that even slight wear damage can have a significant effect on the efficiency of the engine by reducing gas pressure in the combustion chamber. Hence, a study of tribological behaviour of the contacting surface at various temperatures is important to simulate metal-to-metal contact of the fuel nozzle and combustion liner in laboratory scale. Due to the unavailability of scrapped components, wear mechanisms of a gas turbine were examined through a surface diagnosed investigation. In the present test, the contacting materials of the fuel nozzle and combustion liner were subjected to a dry sliding wear test; in which the volume loss and the wear coefficient were calculated as functions of the temperature. The pre-dominant wear mechanisms of this tribo-pair metal were also characterised.

2. METHODOLOGY

2.1 Characterisation of starting materials

A pair of fuel nozzle material and combustion liner material was used in this study. An X-Ray fluorescent (XRF) test was performed on the new components of the fuel nozzle and combustion liner to verify the grade of the materials. Table 1 shows the elemental composition of the fuel nozzle and combustion liner. Fuel nozzle is made of stainless steel grade 304 (SS 304) while the combustion liner is made of Hastelloy X.

Table 1 Elemental composition of gas turbine materials.

Properties	**Fuel Nozzle**	**Combustion liner**
Chromium (Cr)	19.23	22.00
Nickel (Ni)	9.86	47.00
Cobalt (Co)	0.00	1.50
Ferum (Fe)	67.99	18.00
Molybdenum (W)	0.17	0.60
Manganese (Mn)	1.97	1.00

2.2 Wear test

A dry sliding wear test by DUCOM TR-20LE with a pin-on-disc configuration is utilized in this study. A 2 x 35-mm length pin was made to slide against a rotary disc that had a diameter of 165 mm. The schematic diagram is shown in Figure 1. The density of the specimens was tested using a densitometer. The test was carried out in accordance to ASTM G99-05 at room temperature (25 °C), 100 °C and 200 °C to investigate the effect of the contact temperature on the worn surface, volume loss of the tribo-pair samples. All tests were performed at a constant speed of 200 rpm, applied load of 2kg (19.61 N) and a sliding distance of 100 mm. The pins and discs were weighed before and after each test at a sliding time of 5 hours in order to determine the volume loss Equation 1. The worn track and its direction were observed under a scanning electron microscope to identify the pre-dominant wear mechanisms.

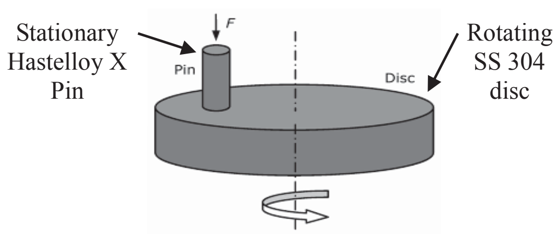

Figure 1 Schematic diagram of pin and disc.

$$\Delta V(\,mm^3) = \frac{\Delta m\,(g)}{\rho(g/mm^3)} \qquad (1)$$

Where ΔV is the volume loss, Δm is the mass loss, ρ is the bulk density.

3. RESULTS AND DISCUSSION

3.1 Volume loss

Figure 2 shows the overall graph of volume loss as a function of contact temperature. The volume loss of the disc was found higher than the volume loss of the pin up to 71.289 mm^3. The volume loss increased proportionally with an increase in the temperature due to an increase in the micro-cutting of the worn surface [5]. It was noted that the volume loss at 200 °C was greater due to a large displacement of materials on the worn surfaces, thus resulting in wider delamination areas [6]. It was in agreement with an observation by Chen et al. [7] which stated that during the wear process, the wear particles played a significant role and affected the wear behaviour. The wear particles changed the displacement zone of the materials and increased the volume loss.

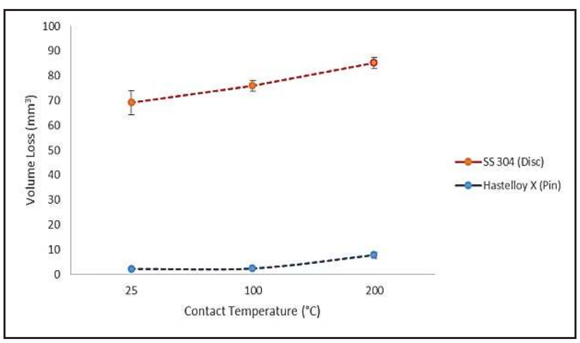

Figure 2 Volume losses against contact temperature of SS304-Hastelloy X tribo-pair.

3.2 Surface morphology

The morphologies of worn SS304-Hastelloy X tribo-pair sliding under three different temperatures are shown in Figure 4. Two different symptoms were detected, namely an adhesive behaviour, which occurred at temperatures of 25 °C and 100 °C; and an abrasive behaviour, which occurred at a temperature of 200 °C. The clear-cut adhesive behaviour was obvious from the marks of transferred materials on the pin side while the counterface (disc side) showed delamination of the materials. When the contact temperature was increased to 200 °C, sharp edge provided evidence that abrasive behaviour existed on the worn surfaces. Chen et al. [8] stated that with an increase in temperature, the wear particles became larger. This was in agreement with the finding on the contacting surfaces, where the volume loss at 200 °C was higher due to the larger displacement of materials on the worn surfaces. In addition, the counterface materials showed a sharp sliding direction in the shape of a cutting form. It was suggested that the SS304-Hastelloy X tribopairs experienced the same wear behaviour at low temperature, and gradually changed to an abrasive at higher temperatures. This is in agreement with findings by Mi et al. [9] which found that the wear particles influenced the friction and wear behaviour, where they played an important role in removing the materials in the displacement zone, thereby affecting the volume loss.

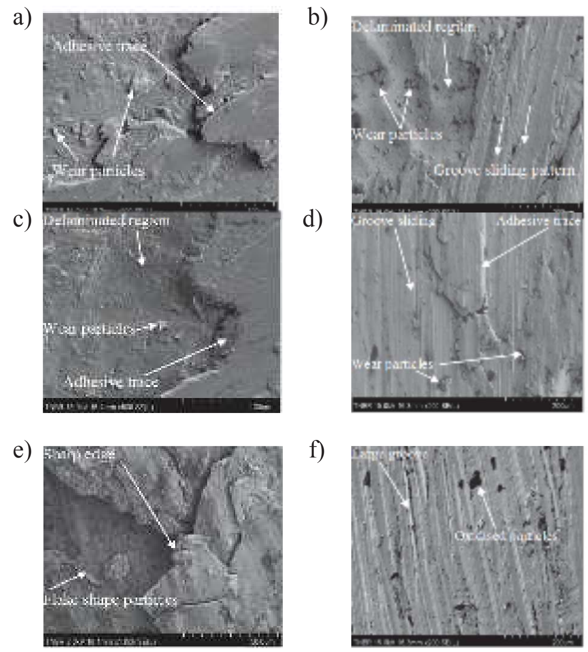

Figure 4 Morphologies of worn surfaces for SS304-Hastelloy X tribo-pair at 25°C pin (a), 25 °C pin (b), 100 °C pin (c), 100 °C disc (d), 200 °C pin (e) and 200 °C disc (f).

4. CONCLUSION

A transition of wear mechanism was found with increasing temperatures. At low temperature, 25 ºC and 100 ºC, adhesive was the main mechanism while when temperature heated up to 200 ºC, abrasive was the main mechanism. Adhesive wear and abrasive wear were the pre-dominant mechanisms at the contacting surfaces between the fuel nozzle and combustion liner (SS304-Hastelloy X tribopair).

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