# Wear characteristics of a combustion liner for power generation gas turbine

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**ABSTRACT** – The occurrence of wear damage was observed on a combustion liner of a power generation gas turbine. The combustion liner is made of nickel based superalloy (Hastelloy X). The worn surface generally occurred at mating surfaces of the combustion liner. The purpose of this study is to determine the types of wear at three different mating surfaces (connected to a SS304 stainless steel, Nimonic C263 and carbon steel) after being exposed to 8,000 of running hours at high temperature and vibration. The affected areas of the mating surfaces were analyzed and the wear mechanism was discussed.

## 1. INTRODUCTION

Nickel base superalloys are widely used in extreme applications such as the combustor components of a power generation gas turbine. The components had experienced up to 1100 °C in the gas turbine [1] leading to severe surface degradations on the combustion liner after 8,000 hours in service. Many combustion liners suffered severe operation conditions due to the following factors: operation environment (high temperature and vibration) and mechanical action (relative movement between mating surfaces and forces between mating surfaces) [2].

The combustion liners are subjected to heavy repair processes thus increasing the cost of the refurbishment [2]. The contacting materials comprised of four vital components, which are the fuel nozzle, the flow sleeve, the transition piece and the crossfire tube. Detailed analyses of wear on the components related to hardness, microstructure characteristics and wear mechanisms, and wear measurement have been considered to predict the wear characteristics of the components. Tucker [3] had revealed that the processes of accurately detailing wear consist of a series of defined tasks undertaken by several tribologist and each task is designed to obtain specific information from the worn components and system.

Detailed wear analysis is very crucial as it cannot be relied only to visual observation and measurement, but deep understanding in wear mechanisms, hardness factor and wear microstructures in order to evaluate the severity of wear and thus improve the current practices (repair and replace) [1]. To date, little and insufficient data is available for wear mechanisms, microstructure analysis and remaining life calculation particularly on the combustor liners. Bernstein [4] had revealed that in gas turbine hot section components, wear had become the main problem for combustion hardware. The contacting surfaces of the combustion liners were continually rubbing against each other due to the combustion pulsations. During the start-stop operation of the engine, these surfaces can underwent large relative motion. The ability to predict the wear of gas turbine combustor components is still in infancy with very limited data. The objective of this paper is to study the characteristics of wear on combustion liner after being exposed to 8,000 running hours in order to predict the dominant wear mechanism and identify surface protection that has been applied on the component.

## 2. METHODOLOGY

In this work, the combustion liner was taken from a 97MW gas turbine. The process took place due to a reaction between fuel and gasses inside the combustion liner. The involved temperature was 1100°C. Figure 1 shows the 4 mating surfaces on a combustion liner. These 4 surfaces were selected based on their wear severity and consistency for the refurbishment processes [2].

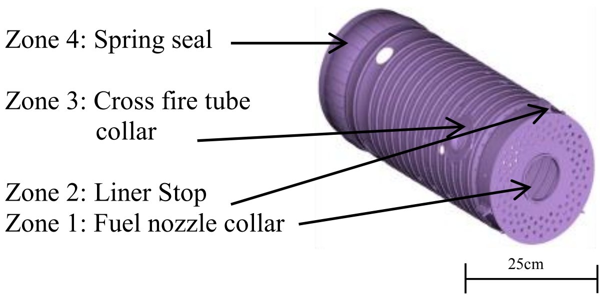



Figure 1 Selected components of a combustor liner.

The wear analysis was carried out after the operating 8,000 hours of combustion operation. The combustion liner mating surfaces are made of a nickel base Hastelloy X [1]. The chemical composition result for the combustion liner is shown in Table 1.

A hardness test was carried out on the mating surfaces using a 1 kg load of Vickers hardness with 4 seconds of indentation. An average of 5 indentations on each component was carried out. The mating surfaces were then characterized by using an optical microscope. The microstructures of the combustion liner were recorded before the installation and after its removal from the gas turbine for a comparison purpose.

Table 1 Chemical composition of Hastelloy X combustion liner.

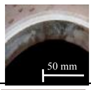
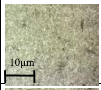
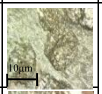
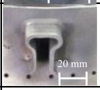
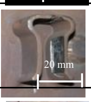
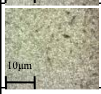
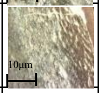
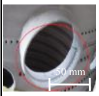
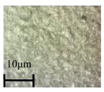
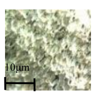
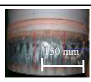
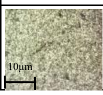
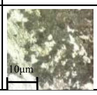
| Element | Hast X |
|---|---|
| Cr | 22 |
| Ni | 47 |
| Co | 1.5 |
| Fe | 18 |
| W | 0.6 |
| Mn | 1 |
| Si | 1 |
| Mo | 9 |
| C | 0.1 |
| B | 0.0008 |

## 3. RESULTS AND DISCUSSION

### *3.1 Visual Observation*

Visual observation was performed on four components of the combustion liner mating surfaces. Table 2 shows the changes that had occurred before and after the standard operating hours.

Table 2 Visual observation of combustion liner mating surfaces (before installation and after removal).

| Mating surface | Visual observation | | Microstructure | | Hardness (HV) | |
|---|---|---|---|---|---|---|
| | Before | After | Before | After | Before | After |
| Fuel nozzle collar |   |   |   |   | 594 | 334 |
| Liner stop |   |   |   |   | | 379 |
| Cross fire tube collar |  |   |   |   | | 237 |
| Spring seal |   |   |   |   | | 370 |

### *3.2 Wear Mode and Symptoms*

It was found that all four components had experienced severe surface damages. These components were subjected to a high oscillatory motion due to vibration during operation [5, 6]. Both fuel nozzle collar and the cross fire tube collars that are connected to fuel nozzle and cross fire tube showed similar symptoms in which significant localized damages had occurred. Materials loss with the evidence of colored debris arising was observed on these components. Only little wear debris was retained on the surfaces due to high amplitude of sliding [5, 7]. For the liner stop, significant loss of surface material was observed and resulted a mirror surface finish on its surface. As for the spring seal, corroded stained surfaces was observed with adherence of the counterface materials on the surface. With different contrast appearances, it was suspected that an adhesive wear mechanism had existed [8].

### *3.3 Hardness and Wear Resistance*

Miller [8] stated that the harder the material, the greater the wear resistance. From this study, the hardness of the connected components had decreased in the average of 45% after 8,000 hours in operation which was most likely due to high cyclic loading and repeated action that generated severe wear, reducing the wear resistance, thus reduced the hardness of the components [9]. Chromium carbides in nickel base superalloy are very oxidation corrosion resistant. Above the temperature of 870 °C, the chromium carbides will start to oxidise and soften. The hardfacing coating are widely used in gas turbine combustor components application. The optimum coating hardness that can be recommended for higher temperature wear, erosion and cavitation is more than 698 HV [10]. Other example of application to reduce wear of combustor components is encapsulation of with wear resistance materials such as Haynes 25 plate [11].

## 4. CONCLUSIONS

It was observed that the dominant wear mechanism of the combustor liner is adhesive wear. No sign of work hardening had occurred. This was most likely due to lack of knowhow of wear reduction application in gas turbine combustion section and too rely on the existing repair practices.

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