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Comprehensive study on thermal erosion characteristics of typical gas turbine blades

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Abstract: as a kind of energy conversion device, gas turbine is widely used in industry. Because the gas turbine operation process, high temperature dust gas produced by erosion of the inevitable experience of gas turbine blade surface and wear, not only damage the aerodynamic performance, serious when still can make components and equipment failure, resulting in economy and reliability were decreased. Therefore, it is very necessary to optimize the comprehensive erosion experiment of the typical blade material under the condition of multi temperature, full impact angle and variable particle size. Through the comparison of steel substrates (1Cr12Mo, X20Cr13, 2Cr12NiMo1W1V, GH738) at different temperature and rate of change analysis of impact angle and impact of different particle size of quartz sand erosion, and obtained the following results:

(1) leaf mass loss and erosion of the sand quality linearly. The erosion rate of the blade in the 0 degree to 90 degree increases with the increase of the impact angle firstly increases and then decreases. The erosion rate is the maximum in the range of 10 degrees to 35 degrees, and the erosion rate is the smallest in the range of 80 degrees to 90 degrees.

(2) the erosion rate of different blade materials varies with temperature, and the erosion rate is not increased with the increase of temperature, or the opposite conclusion.

Key words: gas turbine; blade; gas solid two phase; thermal erosion; comprehensive experiment

I. INTRODUCTION

As China's economic development and energy consumption continues to rise, energy saving and environmental protection requirements continue to increase. Blast furnace gas compressor turbine power plant is two times the energy recovery device recognized, widely used in energy, metallurgy, petroleum, chemical industry, aviation and other modern industrial fields. It is the use of blast furnace top gas pressure energy and heat energy, they will be converted into mechanical energy by gas turbine expansion work, so as to drive the generator, the energy recovery and reduce the harm from NOx. However, after long-term operation of dust containing gas on gas turbine blade erosion of its type, increase the surface roughness and the gap, the gas turbine efficiency is reduced obviously, the forced outage rate, outage time, serious threat to the safety of the blade strength, accidents. According to the literature [1] survey, the solid particle erosion of the United States each year caused by the electricity industry up to $200 million loss. Therefore, the study of multiple particle erosion characteristics under the condition, is to focus on the basic application research on the good sustainable development of materials science and surface technology, is of great practical significance to improve the blast furnace gas generator compressor turbine economic efficiency and safety performance.

II. SELECTION OF EXPERIMENTAL MATERIALS

The experimental study on the substrate material are: 1Cr12Mo, X20Cr13, 2Cr12NiMo1W1V, GH738, and C1 coating (spray on the surface of 1Cr12Mo and X20Cr13) by strengthening steel specimens. In which the substrate steel grades and parts of physical parameters see table 2-1.

Table 2-1 main parameters of experimental materials.

Serial number	Grade	Principal component	Upper temperature limit	Apply
1	1Cr12Mo	Cr 11.5-13.0 Mo 0.3-0.6 Ni 0.3-0.6 Si<0.5 Cu<0.3 C 0.1-0.15 P<0.04 S<0.03	≤450℃	It has the characteristics of high strength,corrosion resistance, high temperature resistance and good technology. It is a very common blade of gas turbine and compressor guide vane material.
2	X20Cr13	C0.16-0.25Si<1Mn <1Cr12-14 S<0.03 P<0.04	＜420℃	Is a kind of turbine blade steel, which is imported from German SIEMENS, which is a kind of martensitic stainless steel.
3	2Cr12NiMo1 W1V	Cr 11-12.5 Mo0.9-1.25 W0.9-1.25Ni0.5-1 Si<0.5 Mn0.5-1 Ni0.5-1 C0.2-0.25	≤560℃	For the 560℃ below the blade, the circumference of the belt and bolts, the valve stem, etc..
4	GH738	Fe<2.0,Mn<0.10,Si <0.15 P<0.015,S<0.15,Cu <0.10	≤850℃	GH738 is a nickel based high-temperature alloy gamma prime precipitation hardening, widely used in aero engine rotating components.

SiO2 is the most important component of the coal fly ash in the western Kingston coal mine, according to the Virginia. In order to make the experiment more close to the actual working conditions, the experiment selected quartz sand particles

III. EXPERIMENTAL SCHEMES AND METHODS

Experiment: (1) compare the weight loss of quartz sand particles in different impact angles. (2) compared with the same kind of material at different temperature by the erosion of quartz sand particles.

Experiment method: firstly, the material is cut into a specimen of geometric size 15mm*15mm*2mm, and the test piece is placed in the experiment seat with adjustable punching angle. Due to the short time erosion caused by the quality of the test piece is very small, in order to improve the accuracy of the experiment, the use of precision 0.01mg balance, before and after the erosion test parts quality were M1, M0, then the experiment in the weight loss is recorded as. Before and after weighing to be cooled, washed, dried, to reduce the error of the measurement, each time the test weighing record three times the average, each piece of test piece under each impact angle accumulated six times under the same conditions of the experiment.

3.1.Calculation of erosion rate

Weight loss of specimen: $\Delta\text{m}=M_0-M_1$ 3-1

Equivalent weight loss: $$\text{X}=\frac{\Delta\text{m}}{\sin\alpha}$$ 3-2

Weight loss per unit area: $$\text{Y}=\frac{X}{S_1}$$ 3-3

IV. EXPERIMENTAL RESULTS AND ANALYSIS

4.1 Impact of impact angle on erosion rate

In order to shield the specimen by the erosion area of erosion rate, all the vertical axis in the chart specimen mass loss were converted into a weight per unit area. Figure 4-1 to 4-4 respectively for four kinds of material at 300 DEG weightlessness with impact angle changes, can see the accumulation of four kinds of material at different temperatures on a unit area of quality and weight loss cumulative particle erosion linearly; figure 4-1 to 4-4 respectively. 300 ℃ four material erosion characteristic curve, can see the curve of erosion characteristics of two kinds of temperature material are increased firstly and then decreased, the maximum appeared between 10 and 35 degrees, the minimum value appeared between 80 and 90 degrees, that the material has the characteristics of shaping experiment. The main reason of the occurrence of this phenomenon is the appearance of quartz prism, small angle, quartz sand shovel cut, plough cause material loss, large angle of attack, because of the plastic characteristics of metal forging, the impact is not prone to crack or debris, so weight loss is smaller.

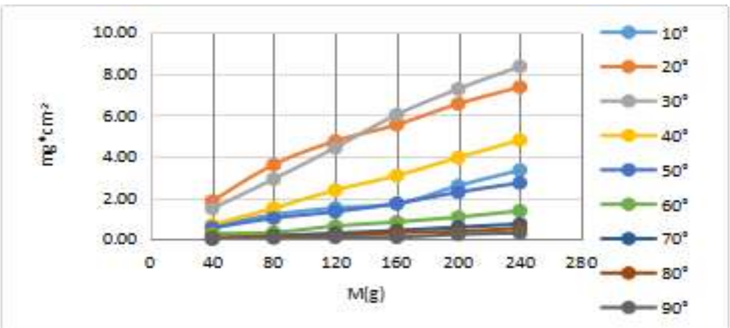

Figure4-1 1Cr12Mo 4-1 300 unit area equivalent cumulative weight loss

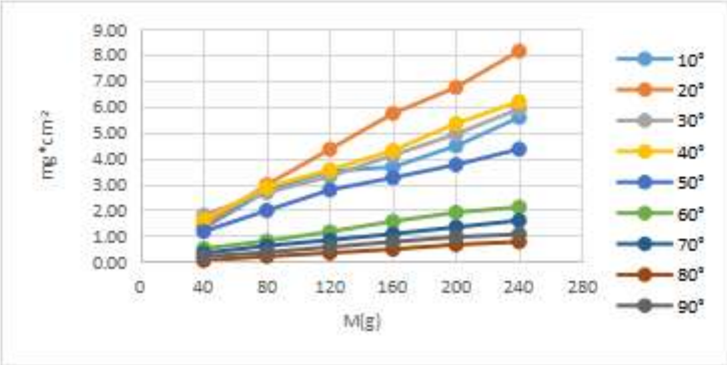

Figure 4-2 2Cr12NiMo1W1V 4-2 300 unit area equivalent cumulative weight loss

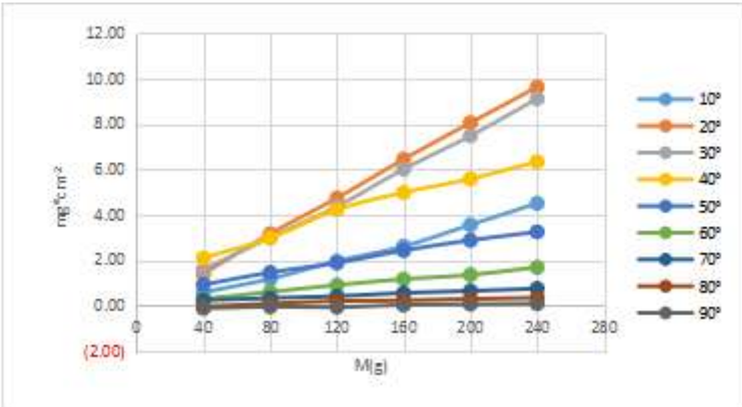

Figure4-3 GH738 4-3 300 unit area equivalent cumulative weight loss

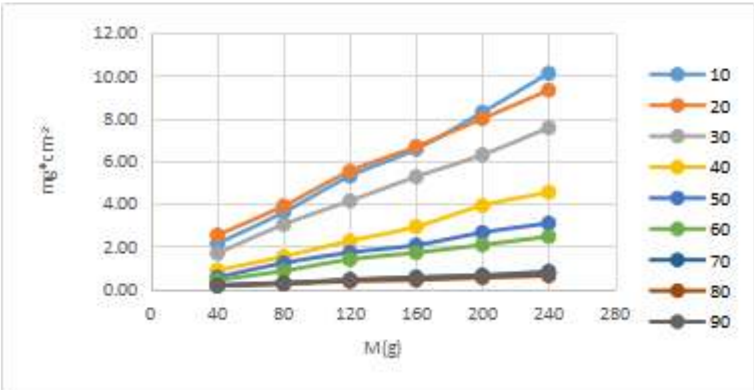

Figure4-4 X20Cr1 300 unit area equivalent cumulative weight loss

4.2 Effect of temperature on erosion rate

Figure 4-5 to figure 4-8 are four kinds of materials at different temperatures of the erosion rate with the change of the curve. In the figure we can see that the four materials are plastic materials of the erosion characteristics, the maximum erosion angle at 20 degrees or 30 degrees, the minimum erosion angle at 80 degrees or 90 degrees. The experiment shows that the temperature of the complexity of the influence of erosion rate, it is difficult to use simple rules to generalize some increased with the increase of temperature, while increases with increasing temperature increased first and then decreased, and is very similar to the experimental phenomena of literature [3], conclusions need more extensive experiments to further summarize. Can see, at 500 C, 2Cr12NiMo1W1V material at 70 degrees, 80 degrees, 90 degrees under the impact angle, the erosion rate is negative. Through the SEM observation, found that 2Cr12NiMo1W1V in 70 degrees, 80 degrees, 90 degrees under the impact of the erosion, wash, the surface of white particles residue. So the erosion rate causes negative weight loss may be smaller than the residual in the surface of the specimen when the sand erosion. Literature [4] also had a similar phenomenon has been related to the analysis: the blade in the high angle of the dust by the erosion, will form a small pit, fall into the dust is not easy to rush to. But at least it shows that the erosion resistance of this material is not good. Figure 4-7 and figure 4-8, because the material is subject to the maximum temperature limit, the experiment can only be carried out and compared to the temperature.

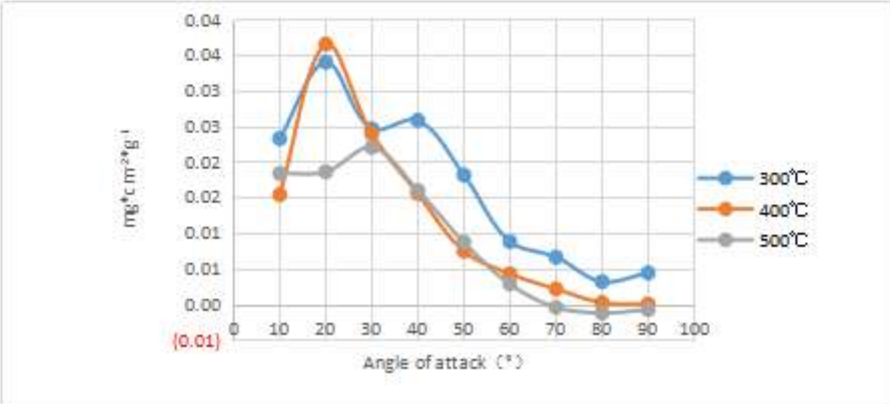

Figure 4-5 2Cr12NiMo1W1V material at different temperatures compared to the erosion rate.

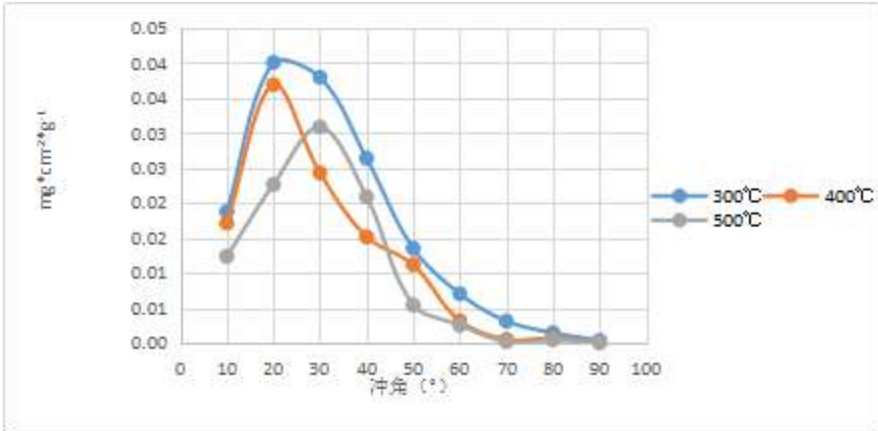

Figure4-6 GH738 material at different temperatures compared to the erosion rate

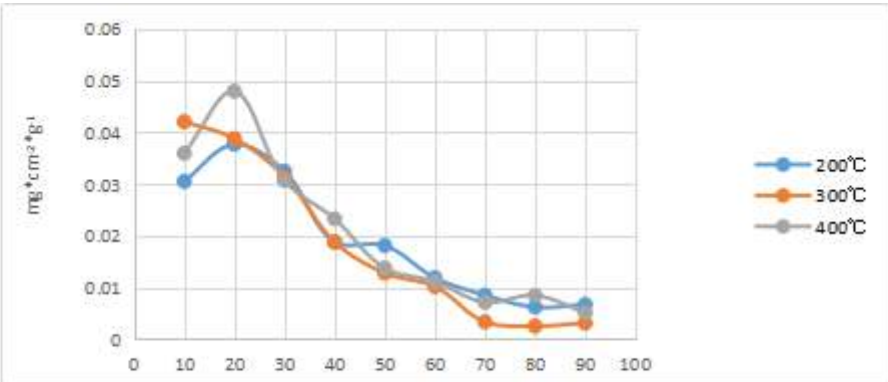

Figure 4-7 X20Cr13 material at different temperatures compared to the erosion rate

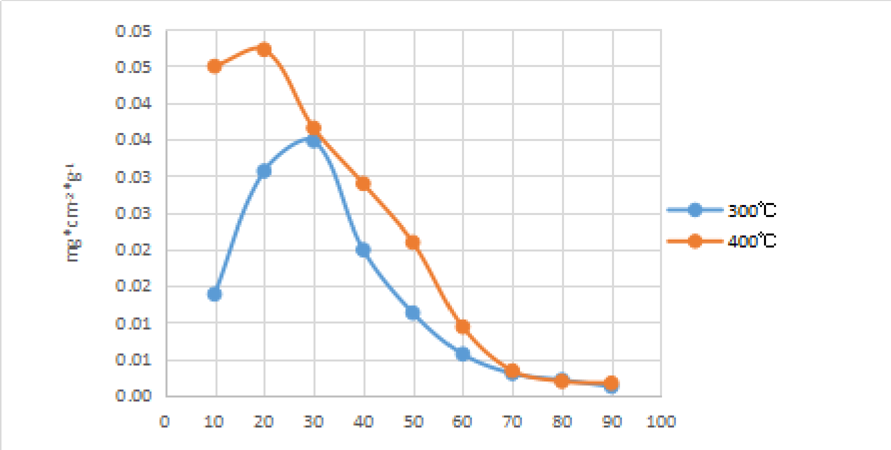

Figure4-8 1Cr12Mo material at different temperatures compared to the erosion rate

V. EPILOGUE

In the self-made gas-solid two-phase thermal erosion experiment in the wind tunnel, by changing the incidence angle and temperature on steel substrates (1Cr12Mo, X20Cr13, 2Cr12NiMo1W1V, GH738)erosion experiments, results showed that: (1 the experimental material in different angle), temperature cumulative mass loss decreases the quality of erosion particles changes linearly; the maximum erosion rate at 10 DEG ~35 DEG angle between the erosion rate, 80 degrees to 90 degrees angle between the erosion rate of the smallest, showed a plastic material characteristic; (2) the temperature of the complexity of the influence erosion rate: some increased with the increase of temperature, while increases with increasing temperature increased first and then decreased;

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