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Erosive wear characteristics of heat treated multi-component cast iron containing Cr, V, Mn and Ni at elevated temperature

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High chromium cast iron, spherical vanadium carbide cast iron and multi-component white cast iron are used as wear resistant materials recently. However, they are extremely expensive because of the addition of Cr, Ni, Mo, V and W, etc. It's expected to reduce costs by suppressing the addition of these elements to develop an inexpensive wear resistant material which can be used at elevated temperature.

In this study, erosive wear characteristic at elevated temperature was investigated with 9 kinds of multi-component cast irons of varying V and Cr content after heat treatment. It has been found that erosive wear property increased with the increase of Cr addition and material with 9 mass % Cr showed the best erosive wear resistance at 873 K. There's no differences between erosive wear property of 5V-9Cr, 7.5V-9Cr and 10V-9Cr. So that, 5V-9Cr with excellent erosive wear property can reduce the amount of expensive vanadium which makes the production cost reduction possible by increasing the amount of relatively inexpensive chromium.

Keywords: *erosive wear, multi-component, cast iron, heat treatment, elevated temperature.*

1. Introduction

Wear is often divided into three types which are adhesive wear, corrosion wear and abrasive wear. Abrasive wear which is caused by solid particles can be further classified by the difference in wear type [1]. Among them, there is one type called erosion which is the phenomenon of damage or peeling of part of the material surface caused by the repeat collision of particulate material. Erosive wear happens not only at room temperature, the damage could be more serious at elevated temperature. Erosion that occurs in the inner surface of conduit cannot be judged from the appearance, so that periodic replacement and buildup welding in the thinning section are necessary ways to prevent accidents. From the viewpoint of reducing the manufacturing cost and maintenance fee, the development of wear resistant material is an urgent issue to be solved.

In previous research, high chromium cast iron, spheroidal vanadium carbide cast iron and multi-component white cast iron which contains carbides with high hardness showed small impact angle dependence and good erosive wear resistance. The reason for the wear resistance improvement is that the stress caused by the particle collision is dispersed and the plastic deformation of the material surface is also suppressed by the crystallized spheroidal vanadium carbides (VC). However, these wear resistant materials are extremely expensive because of the addition of Cr, Ni, Mo, V, W or other rare elements. It's expected to reduce manufacturing cost and maintenance fee by suppressing the addition of rear metals to develop an inexpensive wear resistant material[2-5].

In this study, erosive wear property of multi-component cast irons with varying V and Cr content was investigated at elevated temperature.

2. Experimental Method

2.1 Experimental Materials

9 kinds of multi-component cast iron with addition of about 3.0 mass % C, 4 mass % Mn, 1 mass % Si and varying V and Cr content (5, 7.5, 10 mass % V and 0, 4.5, 9 mass % Cr) were used as experimental materials. 50 kg raw materials were melted in high frequency induction furnace at 2023 K and then poured into a sand mold with a Y-shape of 53×113×125 mm after the process of spheroidizing by 95 mass % Ni - 5 mass % Mg. The specimens used in the erosion test were mechanically machined into flat plate with diameter of 50×50×10 mm. The condition of heat treatment was air-cooling after keeping the specimens for 7200 seconds at 1043 K for 10V-0Cr and 10V-4.5Cr, 1133 K for 7.5V-0Cr, 1193 K for 7.5V-4.5Cr, 1253 K for 10V-9Cr, 7.5V-9Cr, 5V-9Cr, 5V-4.5Cr and 5V-0Cr of which temperature is the best heat treatment temperature for each material [6].

2.2 Experimental Method

A high temperature erosive wear setup was used in this study. Alumina ball (Ø1.16 mm) which hardness is 1140 HV was used as impact particle. The velocity of the erodent particles was 30 m/s. The total amount of erodent particles was 8 kg. Erosive wear property of different multi-component cast irons was investigated at 873 K. The mass of the specimen was measured by electronic scale before and after each erosion test. Erosion rate was used to judge the erosive wear property[7]. Microstructure analysis, Vickers Hardness test, Energy Dispersive Spectrometer (EDS) and X-ray Diffraction (XRD) were undertaken to analysis the property of material.

3. Experimental results and discussion

According to microstructure analysis and X-ray diffraction results, the matrix of material is pearlite and austenite. According to EDS results, all the materials contain spheroidal vanadium carbides, and materials with Cr addition also contain lamella carbides which can be considered as M_7C_3. The hardness of the experimental materials is between 360~570 HV10 at room temperature.

Erosion rates of experimental materials at 873 K are as shown in Fig. 1. For materials with the same V additions (10, 7.5 and 5 mass %), erosion rates showed a smooth decrease with Cr content increased from 0 to 4.5 mass % (except for 10V-4.5Cr, which would be explained later), and followed by a sharp decline when Cr content continually increased to 9 mass %. Material with 9 mass % Cr addition revealed the best erosive wear performance, which has been improved approximately 44.7% (10V-9Cr), 41.1% (7.5V-9Cr) and 31.6% (5V-9Cr), comparing to 0 mass % Cr addition material separately.

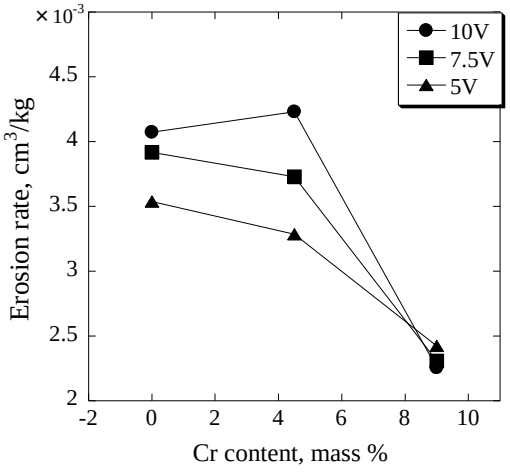

Fig. 1 Erosion rates of experimental materials.

For materials with 0 and 4.5 mass % Cr addition, erosion rates showed a slight decrease with the V content reduced which revealed a slight improvement in erosive wear resistance. While, for material with 9 mass % Cr, no differences were illustrated in erosion rate for materials with different V content. 10V-9Cr, 7.5V-9Cr and 5V-9Cr displayed the same high level in erosive wear resistance which indicated that the V addition can be reduced from 10 mass % to 5 mass % without any bad influence in erosive wear property.

On the other hand, according to the oxidation results, for materials with the same V content, the amount of oxidation was decreased with Cr addition increased, which can explain well that why erosive wear property increased with Cr addition increased. (Except for 10V-4.5Cr which had more defects than the other specimens to increase the area ratio of surface making the oxidation rate unusually high). Furthermore, for material with 0 and 4.5 mass % Cr, V promoted the formation of oxidation which reduced the erosive wear resistance. However, for material with 9 mass % Cr, the formation of oxidation was controlled and the oxidation amount of 5V-9Cr, 7.5V-9Cr and 10V-9Cr was extremely little at the same level.

4. Conclusions

In this study, erosive wear property of 9 kinds of multi-component cast iron at 873 K was investigated. It has been found that erosive wear property was improved with the increase of Cr addition and material with 9 mass % Cr showed the best erosive wear property. There's no significant differences between erosive wear property of 5V-9Cr, 7.5V-9Cr and 10V-9Cr. Therefore, 5V-9Cr with excellent erosive wear property makes the cost reduction possible that the amount of expensive vanadium can be declined from 10 mass % to 5 mass %.

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