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FEM analysis of single impacts of spherical particles on SUS630 stainless steel at elevated temperature

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A surface damage that caused by impact of solid particles is called erosive wear. High temperature erosive wear is one of the main failures of industrial plants. This study investigated that impact angle dependently on high temperature erosive wear by Finite-element-method (FEM). LS-DYNA suitable for contact problems was used in this study. As a result of focused on equivalent plastic strain and Mises stress, the more increase of temperature, the higher equivalent plastic strain and the more increase of impact angle dependency. Therefore, it's possible to test the efficacy of FEM analysis of impact angle dependency for high temperature erosive wear.

Keywords: *erosive wear, impact angle dependency, equivalent plastic strain, mises stress.*

1. Introduction

Wear is divided into adhesive wear, corrosive wear and abrasive wear [1]. Abrasive wear refers to a solid particles causing damage, which can be subdivided by the type of wear. Among them, a surface damage that caused by impact of solid particles is called erosion or erosive wear. The phenomenon becomes a serious problem for bended section of pneumatic transportation pipe, valve, turbine blade and fun, and so on. The dominant factors that influence erosion have been reported by many researchers that there have features of erodent, impact angle, impact speed, and mechanical properties of target material, e. g. hardness, microstructure, rigidity, young's rate, etc.. Many researchers reported that erosive wear of materials is greatly influenced by erodent features[2]. Shimizu and his coworkers investigated the dependency of impact angle on erosive wear based on 2D Finite element model[3], the results uncovered the variation of plastic deformation with respect to different impact angles. However, because the Finite element model was established in 2D axial symmetry way, the particle was simplified as cylinder instead of sphere, so it was difficult to get the stress distribution.

This study investigated impact angle dependently on erosive wear by Finite-element-method (FEM). LS-DYNA suitable for contact problems was used in this study.

2. Experimental procedure

2.1 Analysis method

Analysis conditions are shown below of specimens. Impact velocity of the particles was 20m/s. The contact time of the collision is 0.01ms. The dimensions of the impact material are 10 × 10 × 10mm. Test specimen was SUS630 stainless steel. The erodent particle used in this study was a 1mm alumina ball. Impact angle was analyzed from 10deg. to 90deg..

The particle was assumed to be rigid. However, since a prescription of the elastic material properties was needed for the contact algorithm, the elastic constants of SUS stainless steel (according to the results of tensile test at each temperature) were used to define the particle material. Table 1 shows the analysis conditions of the material.

Table 1 Analysis conditions of the material.

Temperature, K	Mass density , kg/mm^3	Young's modulus , GPa	Poisson ratio	Yield stress , MPa
R.T.	7.74	300	0.272	950
573		250	0.272	820
873		210	0.300	510
1173		72.3	0.320	110

2.2 Experimental method

In the present research, to understand the erosive wear in the region of high temperature, a new high temperature erosion test machine was manufactured.

A high temperature erosion machine was used to test the single impact and erosive wear of target materials in the present study. Spherical shaped erodent particles (alumina ball) were used, they are spherical shaped steel grits with average diameter 1.16mm, Vickers hardness 1140HV. The examined air speed was 100m/s, and impact angle ranged 30, 60 and 90 deg. respectively. Test Pieces size were 10×10×10mm and 50×50×12.5mm. All the erosion tests were conducted at sevaral temperature. Before and after the test the amounts of specimens were weighed with an electronic scale and then calculate volumetric loss. Erosion rate refers to a value calculated from the volumetric loss divided by total feed of erodent. After the single impact test, the indentation of the material surface was observed by microscope._Impression of depth, mises stress and equivalent plastic strain were analyzed. For verification of the analysis result, a single impact experiments were conducted. The Correlation was obtained in result of experiment and analysis.

3. Results and discussion

The results of a single particle impact test and the finite element analysis were compared. As a result, they showed a good correlation (coefficient of correlation value was 0.96~0.99 elevated temperature). Therefore, it's determined that the analysis result is reasonable.

Then, shear strain energy and Mises stress of the material surface has been focused, impact angle dependency of erosive wear of SUS630 was verified.

Results of erosive wear tests were shown in Fig. 1. Mises stress and erosion rates were the largest at low angle side. Similar trends were observed in the ratio of Mises stress and impact angle dependence of the erosive wear test. Also, it showed the same tendency even at room temperature, 573K and 873K. Since a good correlation has been obtained, the calculation of the equivalent plastic strain of the material surface was performed. The result is shown in Fig. 2. From Fig. 1 and Fig. 2, erosion rate and the amount of equivalent plastic strain increased at a low angle side. Also, with increasing test temperatures, the amount of equivalent plastic strain increased. From these, result of experimental and analysis were similar trend. From these results, erosion rate and impact angle dependency were closely related to the plastic deformation of the material surface. It's possible to verify the impact angle dependence of erosive wear at high temperature by performing a single impact analysis considering mechanical properties.

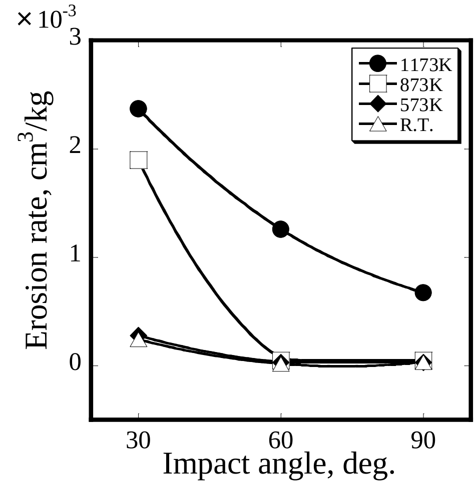

Fig. 1 Experimental result.

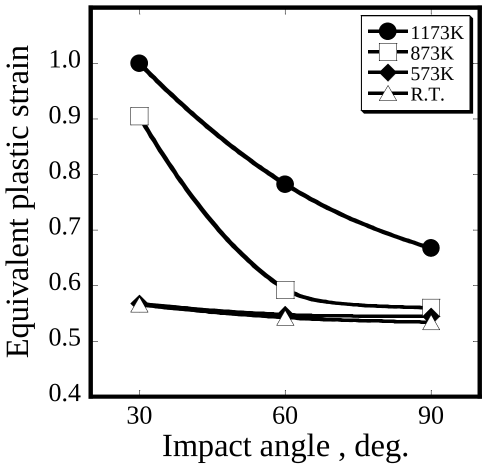

Fig. 2 3D FEM analysis result.

4. Conclusion

In this study, it was to clarify the relationship between the impact angle dependence of erosive wear and the mechanical properties at high temperature.

(1) An impact angle dependency at high temperature environment is mechanically verifiable by performing a single impact FEM analysis.

(2) With increasing temperature, the ratio of the Mises stress and amount of equivalent plastic strain wear increased. These are the factors that erosion rate increases at the low angle side at elevated temperature.

Reference

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