FATIGUE PROPERTIES OF THERMAL SPRAYED STEEL WITH CO-BASED SELF-FLUXING ALLOY

J. KOMOTORI, *N. QU*, and M. SHIMIZU
Department of Mechanical Engineering, Keio University,
Hiyoshi 3-14-1, Kohoku-ku, Yokohama 223, Japan
K. SHIRAI
Thermal spray technic group ceramics department, Showa Denko Co.Ltd.,
Soga 1, shiojiri-shi, Nagano 399-64. Japan

ABSTRACT

Rotational-bending fatigue tests were performed on a specimen having Co-based self-fluxing alloy thermally sprayed coating, with special focus on the effect of mixed NiCr weight ratio on coating microstructure and on fatigue properties. Effects of post heat treatment (fusing treatment) on coating microstructure and on fatigue strength for 10^7 cycles were also discussed. It was found that (1) there is considerable scatter in observed fatigue life for specimens sprayed with Co-based self-fluxing alloy. This is because each specimen has its own fatigue strength associated with different porosity and microstructure of coatings. (2) Fusing treatment temperature strongly affects the characteristics of sprayed coating in terms of microstructure and porosity. A great improvement of fatigue strength of a sprayed specimen having poor fatigue property has been achieved through well controlled fusing treatment.

KEYWORDS

Fatigue, Combustion Flame Spraying, Co-based Self-fluxing Alloy, Microstructure of Coating, Porosity, Fusing Treatment

INTRODUCTION

Thermally sprayed coatings have been increasingly used in many engineering fields (Borbeck, 1990 ; Höhle, 1993) for surface buildup and for repair of machine parts such as paper mill rolls, shafts and large bearings. With an increased demand for application of thermal spraying process in several industries, it has become important to clarify the characteristics of the fatigue resistance of a thermally sprayed coating. However, because the properties and microstructure of coatings are dependent on various factors such as spray material and processing parameters, the fatigue

fracture mechanism of thermally sprayed specimen has not been well understood.
The aims of present study are (1) to clarify the effect of thermally sprayed coatings on the characteristics of fatigue life, with special interest in the effect of NiCr alloy contents on fatigue properties and (2) to discuss the effect of fusing treatment on coating microstructure and on fatigue strength of a thermally sprayed specimen.

EXPERIMENTAL PROCEDURE

A medium carbon steel having a carbon content of 0.35% C with dimensions as illustrated in **Fig. 1** were used in this study as a substrate. Coatings were applied by Gas Flame Spray Technique (see **Table 1**) after blasting the surface of the substrate with high strength steel grid. Schematic illustration of the thermally sprayed specimen is shown in **Fig. 2**, and the chemical composition of the thermal spray material used and the mix ratio of NiCr alloy particle to the thermal spray material are given in **Table 2** and **3**. After polishing the specimen surface with alumina powder, rotational-bending fatigue tests (3000 rpm) were carried out at room temperature.

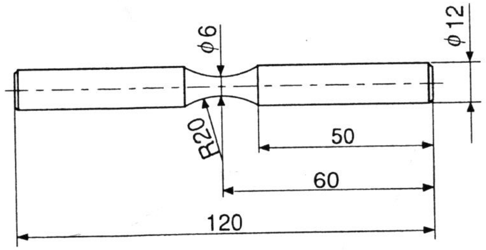


Fig.1 Configuration of substrate

Table 1 Processing parameters

Primary Gas	Oxygen (0.5MPa)
Secondary Gas	Acetylene (0.1MPa)
Powder Carrier Gas	Air
Spraying Distance	150 ~ 200 mm
Rotational Speed of Specimen	300 rpm
Spraying Speed	5.0 $\times 10^{-3}$ mm/r

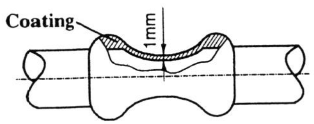


Fig.2 Schematic illustration of sprayed coating

Table 2 Chemical composition of STELLITE No.6 SF (wt.%)

Cr	Ni	W	Fe	Si	B	C	Mn	Co
18.80	13.10	7.68	2.25	2.28	1.78	0.74	0.39	bal.

Table 3 Mixed ratio of NiCr alloy

A series	Stellite No.6 SF
B series	Stellite No.6 SF + NiCr (1%)
C series	Stellite No.6 SF + NiCr (5%)
D series	Stellite No.6 SF + NiCr (10%)
E series	Stellite No.6 SF + NiCr (20%)

RESULTS AND DISCUSSION

Fatigue properties of thermally sprayed specimen

Fig. 3 shows the results of fatigue tests for thermally sprayed specimens represented in **A** and **E series** with NiCr alloy mixture ratio of 0% and 20 % respectively. A considerable scatter in fatigue lives can be observed in both **A** and **E series**. To clarify the reason for this , observations of the characteristics of the coating microstructure were performed using an Optical Microscope.

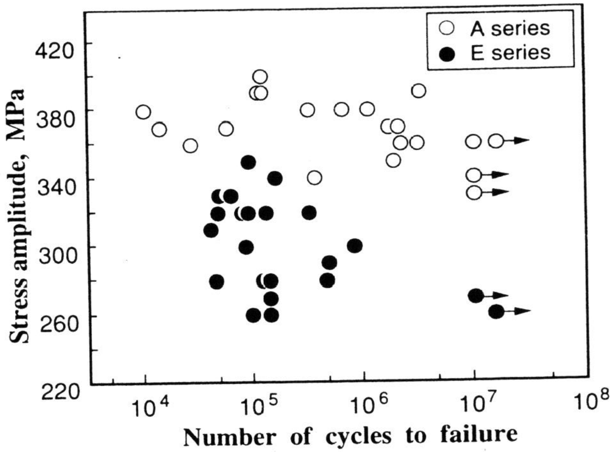


Fig.3 Results of fatigue test for A and E series

From the results, it has become clear that (i) the thermally sprayed coatings contain a large amounts of micropores and (ii) the volume fraction and maximum size of the micropores are different in each specimen. This implies that each specimen has its own fatigue strength associated with different porosity and microstructure of coatings and this is closely related to a great amount of scatter in the observed fatigue lives as shown in **Fig. 3**.

Effect of NiCr Content on Fatigue properties

Fig. 4 represents the relationship between the level of fatigue strength*1 and NiCr alloy content. It is clear that the fatigue strength decreases with an increase in NiCr alloy content. Comparisons of coating microstructure and measurement of coating porosity (volume fraction of micropore) in **A** and **E series** were made to discuss the cause for the difference of fatigue strength.

As a result, it has become clear that a significant change in surface microstructure of coatings can be observed with an increase in NiCr mixed ratio (see **Fig.5 (a)** and **(b)**) and the porosity of the coating also increases with an increase in NiCr mixed ratio (see **Table 4**). Since crack initiation occurs preferentially at a micropore as shown in **Fig.6**, the decrease in fatigue strength with an increase in NiCr mixed ratio (see **Fig.4**) can be caused by the increase in coating porosity.

These findings suggest that an excellent fatigue property of high fatigue strength and less scatter of fatigue lives could be expected in the specimen with micropore free coatings. In the next

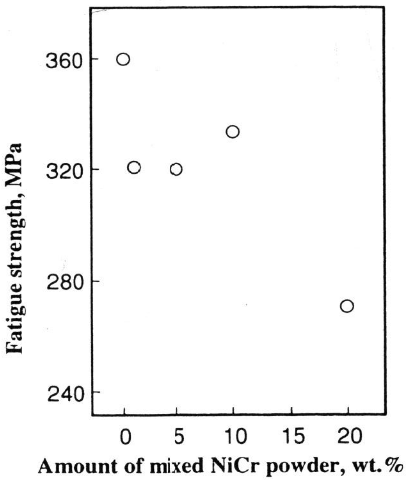
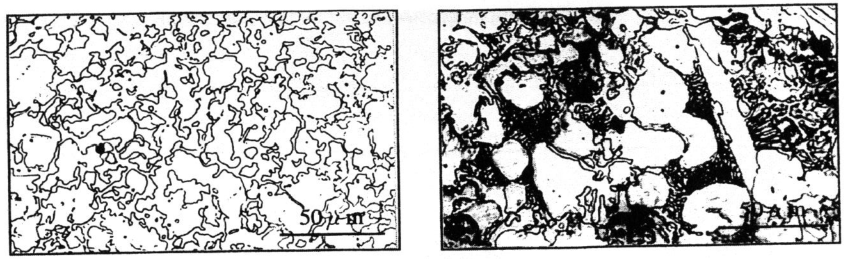


Fig.4 Effect of NiCr content on fatigue strength and on Vickers hardness

*1 Fatigue strength is defined as the maximum value of the stress amplitude when even one unfailed specimen beyond 10^7 cycles is observed.



(a) A series *(b) E series*

Fig.5 Comparison of surface microstructures

Table 4 Comparison of the porosity

	Porosity
A series	**0.25 %**
E series	**1.47 %**

Fig.6 Typical feature of fatigue crack originating form micro pore

chapter, an attempt was made to reduce the micropore in the coating microstructure through the control of fusing process after spraying and to improve the fatigue property of the sprayed specimen.

Effect of fusing treatment on fatigue strength

First, the effects of fusing treatment on coating microstructure and porosity were examined. **Fig.7** shows the microstructure of coating after and before fusing treatment. It should be noted that (i) there is no noticeable change in coating microstructures obtained by the fusing treatments performed

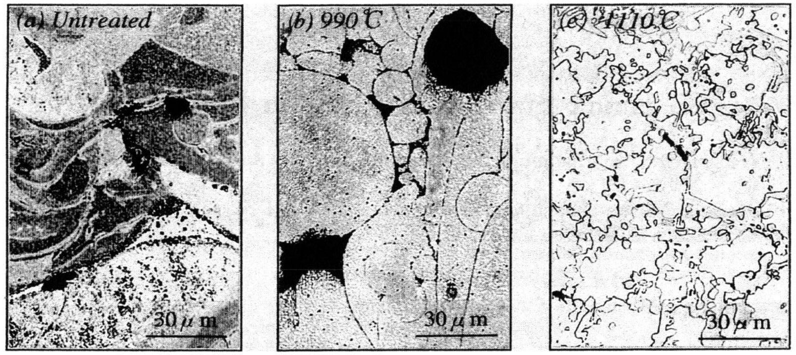


Fig.7 Effect of fusing treatment on coating microstructure

at 990°C, while a significant change in coating microstructure can be observed after fusing treatment at 1110 °C and (ii) the value of coating porosity decreases with an increase in fusing temperature.

To clarify the effect of fusing treatment on fatigue properties, rotational bending fatigue tests

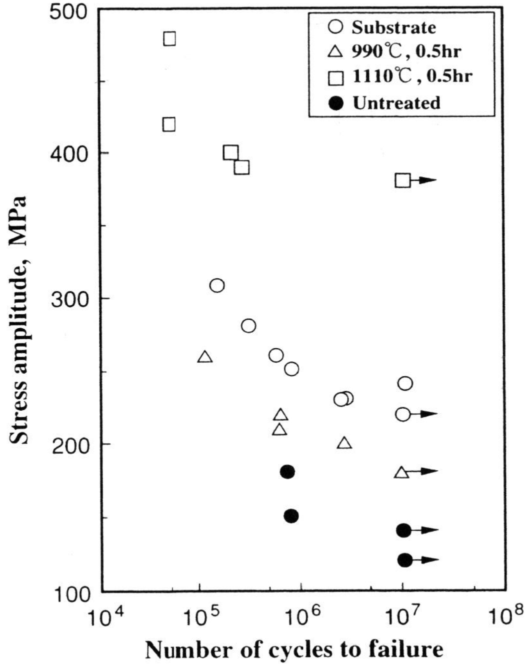


Fig.8 Effect of fusing treatment on fatigue properties

were carried out. **Fig. 8** shows such a result. It is clear that the fatigue strengths for 10^7 cycles of a sprayed specimen without fusing treatment (marks ● in **Fig. 8**) and fused at 990°C (△) are much lower than that of a steel substrate(○). This is due to the presence of a great amounts of micropores in both the spray coatings of untreated specimen and the fused specimen at 990°C (see **Fig. 7**). In the case of the sprayed specimen with fusing treatment performed at 1110°C (marks □ in **Fig. 8**), however, significant increase in fatigue strength can be observed. This is because of a decrease in the porosity of coating with the increase in fusing temperature.

From these results, it can be concluded that the fatigue strength of thermally sprayed steel specimens with Co-based self-fluxing alloy coating can be improved by high temperature fusing treatment and such an improvement of fatigue strength is a result of a decrease in coating porosity.

CONCLUSION

Rotational-bending fatigue tests were performed on Co-based alloy thermally sprayed specimens with special focus on the effect of mixed NiCr weight ratio on coating microstructure and on fatigue properties. The effects of fusing treatment on coating microstructure and on fatigue strength were also discussed. The results obtained are summarized as follows;

(1) There is a considerable scatter in the observed fatigue lives for specimens sprayed with Co-based self-fluxing alloy. This is caused by the fact that each specimen has its own fatigue strength associated with different porosity and microstructure of coatings.

(2) Fusing treatment temperature strongly affects the characteristics of sprayed coating in terms of microstructure and porosity. The fatigue strength of a sprayed specimen without fusing treatment is much lower than that of a steel substrate. However, great improvement of fatigue strength has been obtained with a well controlled fusing treatment.

ACKNOWLEDGMENTS

The authors wish to thank Mr. N. Sato and T. Takeshita for their experimental support. This work was supported by The Ministry of Education, Science and Culture under Grant-in-Aid for Scientific Research (A) and Co-operative Research (A).

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