Transactions of the Materials Research Society of Japan. Vol. 20

LIFE CYCLE ASSESSMENT OF THERMAL SPRAY COATINGS FOR BOILER COMPONENTS

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Abstract

LCA (Life Cycle Assessment) is a systematic process used to understand and identify opportunities for reducing the environmental impacts of products, processes, or services. Improved boiler performance has meant higher operating temperatures thus boiler components are now exposed to a more severe erosion/corrosion environment than in the past. As a result, It is expected the use of thermal spray coatings will increase significantly. Therefor applying thermal spray coatings are tend to increase significantly. This paper will present LCA results for various thermal spray coatings for boiler components.

Introduction

Environmental protection and natural resource shortages have emerged as significant issues in industrial society. Recently, it is thought that reduction of CO2 emissions, which causes the green house effect, can occur by the improving efficiency of thermal power plants. For example, the PFBC (Pressurized Fluidized-Bed Combustion) co-generation system is gaining prominence due to its higher efficiency (about 8 to 10% higher than conventional systems) and low impact gas emissions (such as SOx and NOx). However,the component materials of PFBC are subjected to severe damage from combined erosion and oxidation. Therefore, thermal spray coatings are applied to these components in order to protect the underlying metal. It is known that Life Cycle Assessment (LCA) is a method which quantitatively calculates and evaluates the environmental impacts of a production system from "cradle to grave". In this study, we attempt to apply the LCA method to various thermal spray coatings for PFBC's and to evaluate the eco-friendly coating.

Experimental procedure

(1) LCA of environmental load factor

The life cycle of erosion-resistant coatings is shown in fig.1. In this study, we evaluated the energy consumption, environmental load factor and cost from the powder manufacturing stage to the service stage. The consumption energy values were calculated using electric power units (kWh), so that comparisons could be made.

(2) Thermal spray coatings

Cylindrical specimens (1Cr-0.5Mo steel) were coated by various materials as shown in table.1. After coating, the surface of the specimens was ground and polished. The coating thickness was 250 microns.

(3) Erosion test

The coated specimens were erosion tested at elevated temperature using a fluidized-bed type erosion tester. Test conditions simulated an actual PFBC plant.

Results

(1) LCA of environmental factor

(a)Energy consumed in producing coating materials

We asked some powder making companies about the energy consumed in making coating materials, however, the data obtained was only approximate. Therefore we set reliable values as standard values (table 1). Fig.2 shows a comparison of the energy consumed in producing various coating materials. Compared with the value of the self fusing alloy, chromium carbide consumed about twice as much energy. On the other hand, it is seen that alumina coatings consume less energy than that of self fusing alloy.

(b) Thermal spray coating process

A comparison of energy consumption for various thermal spray equipment is shown in fig.3. The HVOF and APS processes required much more energy than the conventional gas flame spray system for the self fusing alloy. Fig.4 shows the energy consumption of gas. It is clear that HVOF process required significantly more energy (about 15 times higher) than other methods.

Fig.5 shows the total energy consumption during the spray process. The lowest energy consumption coating was the self fusing alloy and the highest one was chromium carbide by HVOF (it takes about 4 times as much energy as self fusing alloy. Other alumina coatings show relatively low energy consumption.

(2) Erosion behavior of various coatings

Fig.6 shows the erosion behavior of various coatings. The self fusing alloy showed the least erosion resistance.While alumina coatings (especially Al_2O_3-40%ZrO_2) show better erosion resistance.

(3) Characteristic comparison considered erosion behavior

1mm thick coating of the self fusing alloy was used as a standard to judge the performance of the other coatings. It is seen that the energy consumption of the chromium carbide coating far exceeds that of self fusing alloy. On the other hand, the alumina coatings by APS show less energy consumption than the bench mark. On other point is the amount of fume emmision. It is seen that chromium carbide by HVOF and APS emit large amounts of fume while the alumina coatings emit significantly less.

Conclusion

These results lead to the conclusion that all the alumina coatings have good characteristics. In fact, the Al_2O_3-40%ZrO_2 coating by APS has the lowest environmental impact and the best erosion resistance,therefore it may be considered the most effective coating.

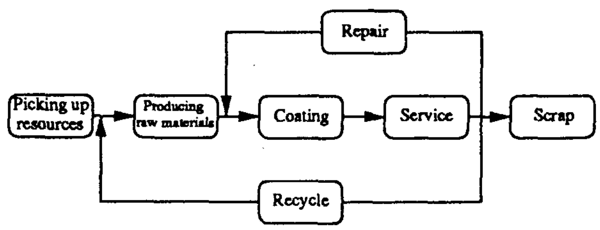

Fig.1 Life cycle of thermal spray coatings for boiler components

Table 1 Coating materials and applied process

	Materials	Spray process
Metal	Self-fusing alloy (14Cr-4.5Fe-4.4Si-3.15B-0.65C-2Mo-2Cu-Ni bal)	GS*1+Fusing
Cermet	Chromium carbide - nickel chromium (75%Cr_3C_2+25%Ni-Cr)	HVOF*2
		APS*3
Ceramics	Al_2O_3+50%Cr_2O_3	APS
	Al_2O_3+25%Self fusing alloy	
	Al_2O_3+40%ZrO_2	
	Al_2O_3+40%TiO_2	
	Al_2O_3+13%TiO_2	
	Al_2O_3	

*1;Gas frame Spraying, *2;High Velocity Oxgen Fuel spraying, *3;Air Plasma Spraying

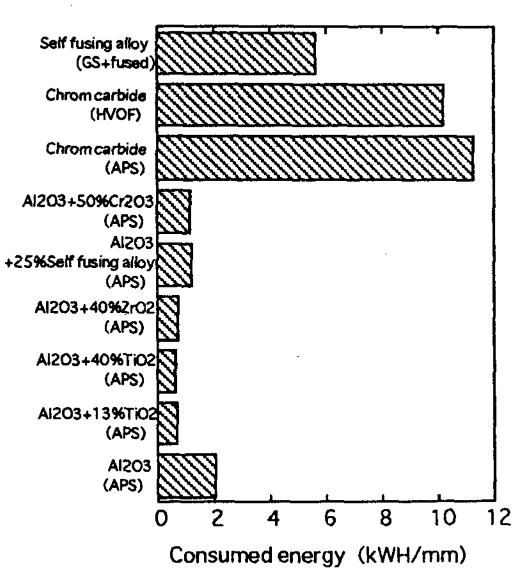

Fig.2 Comparison of energy consumption in producing raw materials

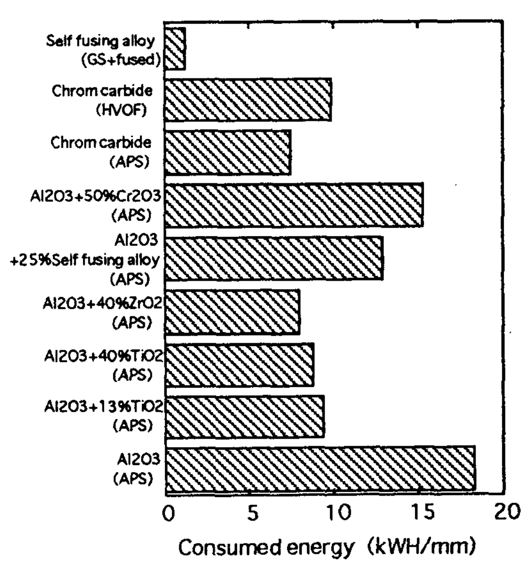

Fig.3 Comparison of energy consumed by different spray equipment

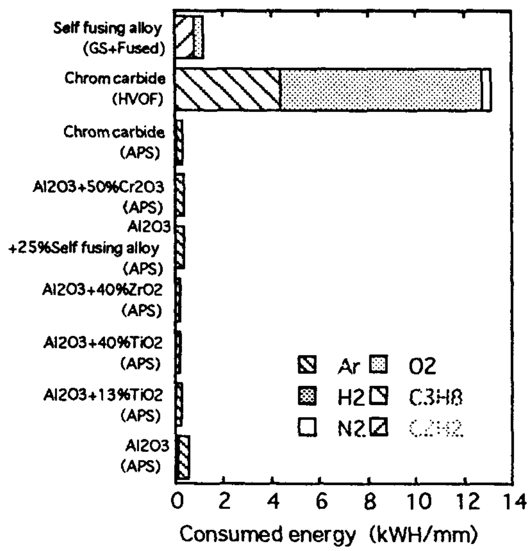

Fig.4 Comparison of gas energy consumed in various spray processes

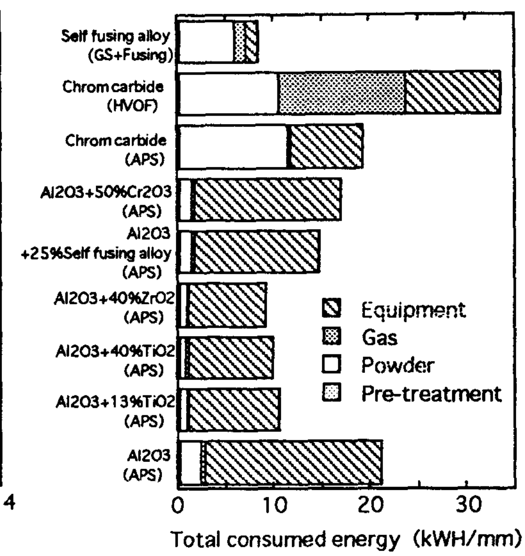

Fig.5 Comparison of total energy consumed in various spray processes

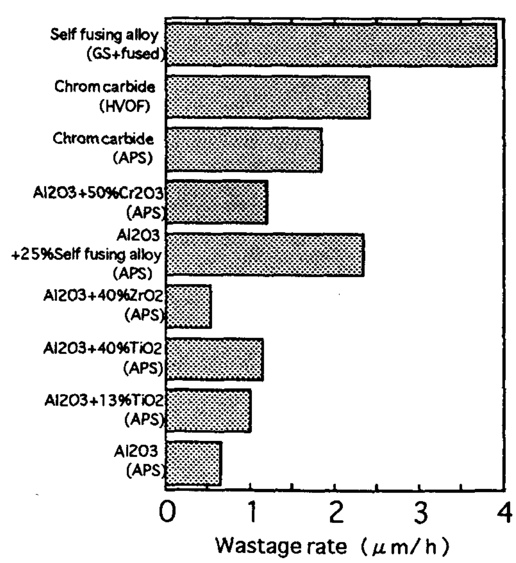

Fig.6 Comparison of erosion behavior

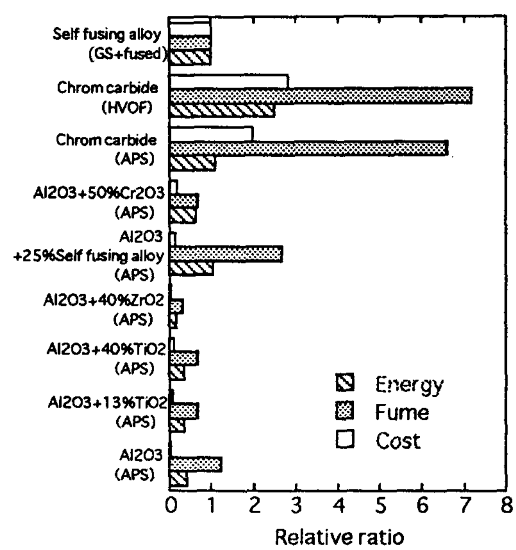

Fig.7 Comparison of characteristics per need thickness