Penetration Behavior into Connected Porosities of Plasma Sprayed Al_2O_3 Coatings with Liquid Mn†

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KEY WORDS :(Penetration)(Liquid manganese)(Al_2O_3 coating) (Plasma spraying)(Heat-treatment)($MnAl_2O_4$ spinel)

Plasma sprayed Al_2O_3 ceramic coatings have been widely applied in many industrial fields because of an excellent wear and heat resistance which ceramics possess by themselves. However, the mechanical properties of plasma sprayed Al_2O_3 coatings declined by some defects of the connected porosity,etc. in the coatings such as nonbonded area among the particles and microcracks in particles.[1)2)] In this study, penetration behavior of liquid Mn into connected porosities of Al_2O_3 coatings and densification of the coatings during heat treating Al_2O_3 coatings with liquid Mn in order to improve the properties of the coatings were examined.

Al_2O_3 spraying powder with a diameter 10～40 μm, SS41 steel as the substrate and Mn plates with purity of 99.9% were used in this experiment. **Figure 1** shows a schematic diagram of prossess used for Mn penetration method. After Al_2O_3 coatings with thickness of about 200 μm were sprayed onto sand- blasted SS41 steel by using the plasma spraying, Mn plate contacted with surface of Al_2O_3 coatings was heated at 1573K in 1.33×10^{-1}Pa and 1.33×10^{-3}Pa.

Figure 2(a) shows a example of the result of optical microscopic observation for Al_2O_3 coating as-sprayed on a SS41 steel substrate. **Fig 2(b)** shows a result of a Al_2O_3 coating heated without Mn at 1573K and 10.8ks in 1.33×10^{-3}Pa. In both caces, a lot of porosities and defects in the Al_2O_3 coating were recognized.

Figure 3 shows wetting images of pure Cu, Ni and Mn on the Al_2O_3 coatings after heating for 0.3ks at temperature of 50K over melting point of each metal. The contact angles of Mn, Cu and Ni were about 0° , 140° and 115° respectively. It was recognized that the wettability of Mn on the Al_2O_3 coatings is better compared with those of Cu and Ni, because Mn was penetrated into inside of the coatings.

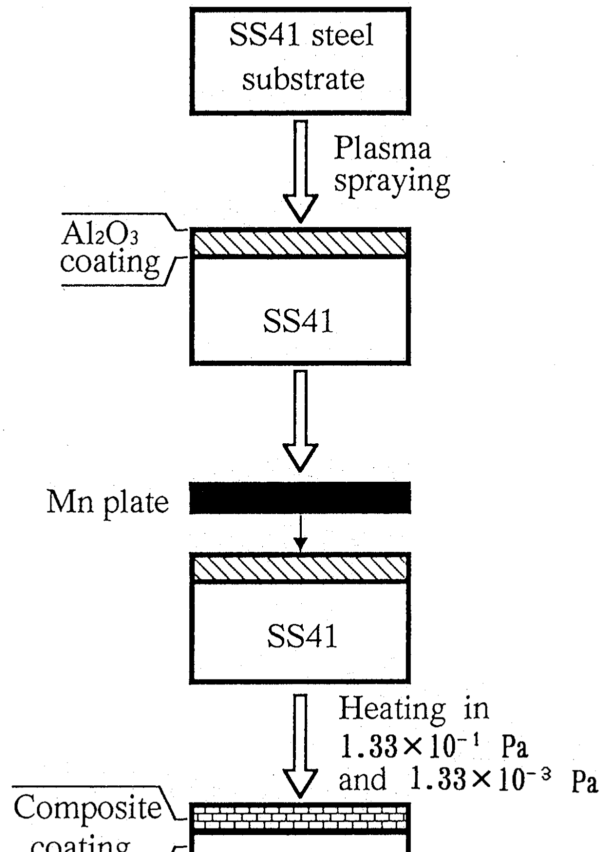

Fig.1 Processes of thermal spray and heating treatment with Mn.

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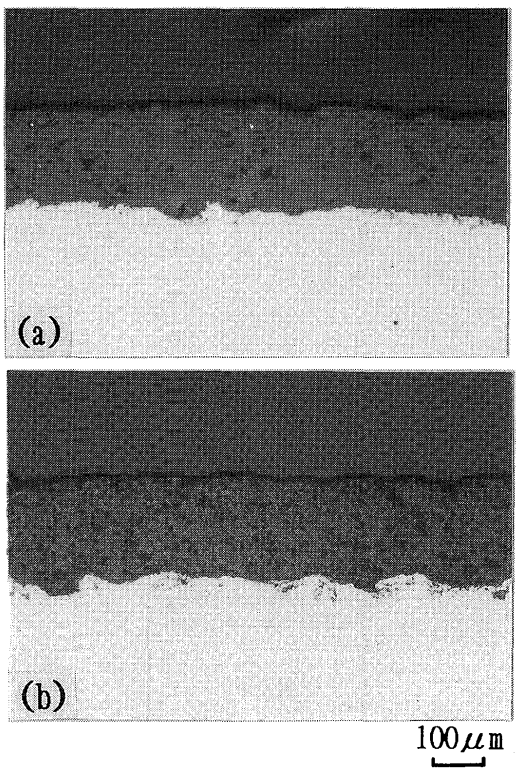

Fig.2 Microphotographs of Al_2O_3 coatings. (a),as-coat;(b), heat-treatment (1573K,10.8ks,1.33×10^{-3}Pa).

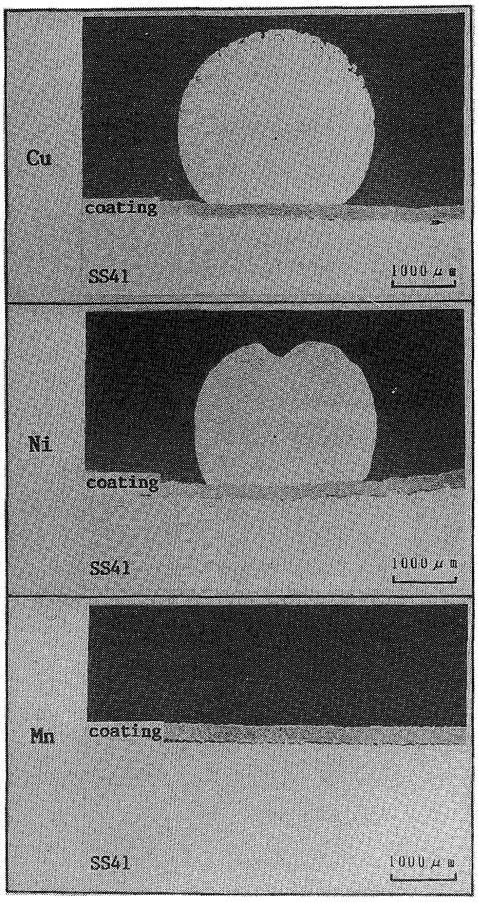

Fig.3 Wettability of Cu, Ni and Mn to the surface of Al_2O_3 coatings.

Figure 4. shows the results of SEM observation and image analysis of Mn, O and Al elements by means of EPMA for the cross section of Al_2O_3 coatings after heat-treatment with Mn at 1573K and 1.33×10^{-3}Pa. From this figure, it was recognized that Al_2O_3 coating after heat-treatment with liquid Mn become dencer compaired with as-sprayed coating and heat-treated Al_2O_3 coating as shown in **Fig.3**. Moreover, the interface between Al_2O_3 coating and SS41 steel substrate strengthened. As a result of elements analysis of EPMA, it was observed that thick rich-layer of Mn with Al and O not only existed on surface of the coating, but distributed like net throughout grain boundary (or the connected porosities) inside of the coating. **Figure 5**. shows XRD results of surface layer and inside of the Al_2O_3 coatings of **Fig.4**,compared with the as-coat. The new dence surface layer of the Al_2O_3 coating after heat-treatment with Mn was mainly composed of $MnAl_2O_4$ spinel phase and α-Al_2O_3 phase as shown in **Fig.5(b)**. The inside of the Al_2O_3 coatings,where a little $MnAl_2O_4$was existed as shown in **Fig.5(c)**, was composed of α-Al_2O_3 as main phase and $MnAl_2O_4$ spinel. It may be considered that $MnAl_2O_4$ is formed by reaction of liquid Mn, contained oxygen in vacuum atmosphere and Al_2O_3, depending on oxygen quantity dissolved in liquid Mn. These results show that, by applying the heat-treatment with Mn to Al_2O_3 coatings at 1573K in vacuum of over 1.33×10^{-3} Pa, liquid Mn dissolving oxygen which remained in vacuum penetrated easily into the connected porosities of the coating and formed $MnAl_2O_4$ spinel around Al_2O_3 particles by reaction between Mn(O) and Al_2O_3. Vickers hardness of Al_2O_3 coatings increased to ~1500Hv from 700Hv ~ 800Hv of as-sprayed and heat-treated Al_2O_3 coatings after heat-treatment with Mn for over 3.6ks at 1573K. The hardness of 1500Hv is similar as that of sintered Al_2O_3. It is considered that such effective increase of hardness is due to the formation of $MnAl_2O_4$ at the connected porosities in Al_2O_3 coating by the reaction of Mn(O) and Al_2O_3.

From above-mentioned results, it was showed that

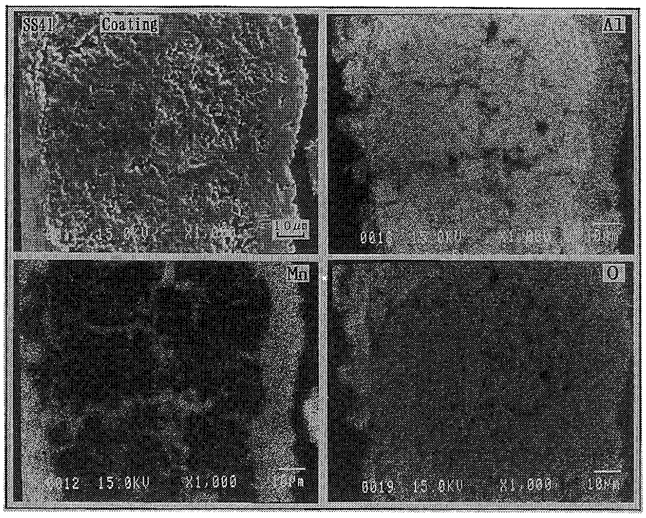

Fig.4 SEM microstructure and EPMA analyses of Mn treated Al_2O_3 coatings.

the improvement of Al_2O_3 coatings is possible by the penetration of the liquid Mn into the connected porosities of Al_2O_3 coatings and the reaction of the liquid Mn and Al_2O_3 particles when Mn heat- treatment was done.

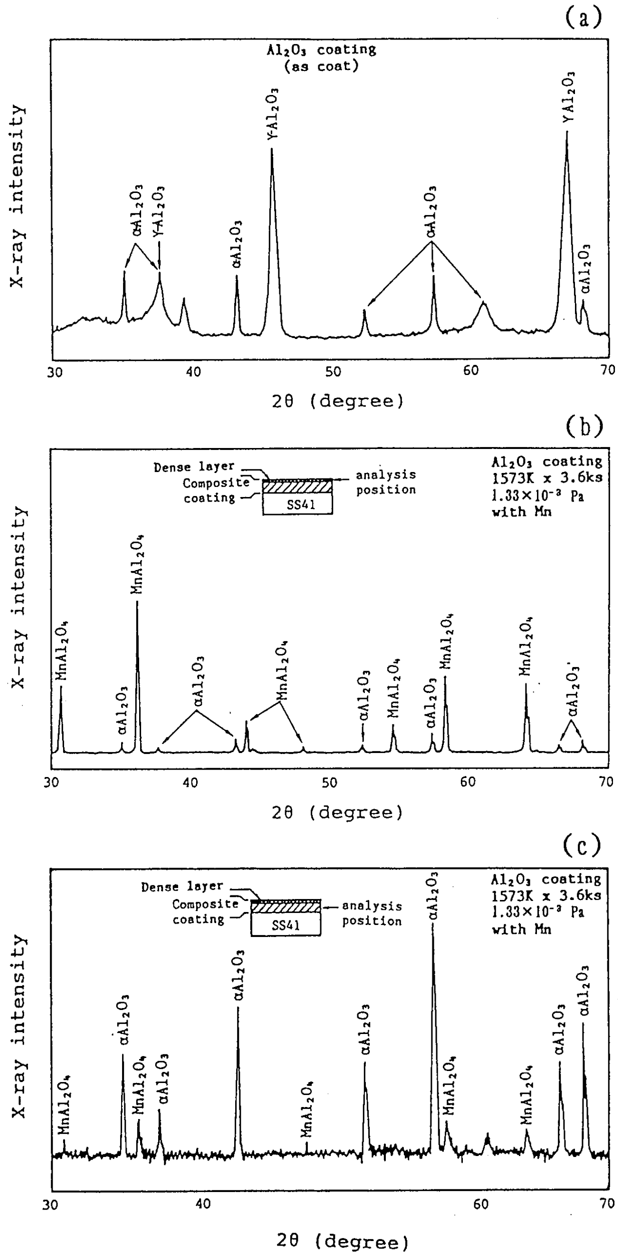

Fig.5 XRD results of Al_2O_3 coatings after heat treatment with Mn.

References

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