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Aspects of a Co-free hardfacing Materials Development to Reduce the Radioactivity in NPPs.

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1. Introduction

For the last one or two decades, active researches to develop Co-free hardfacing materials in order to replace Co-base stellite alloys have been done to reduce the radioactivity in the primary systems in nuclear power plants(NPPs). However, Co-free materials having superior mechanical properties to stellite alloys have not been developed up to now. There are two ways to increase the performance characteristics of the key parts needed to be coated with hardfacing materials, thus resulting in replacing the Co-base stellite alloys with superior mechanical properties; one of them is to develop new Co-free materials with a better quality in performance than that of satellite alloys. The other is to use new coating techniques developed to increase the coated surface properties of already developed Co-free materials. In this study, the aspect of newly developed Co-free materials is reviewed and the necessity of the development of new Co-free materials is emphasized for the replacement of Co-base satellite alloys. In addition, a new coating technique, which is called a laser hardfacing(cladding) technique(LHT), is introduced and its advantage and applicability to the key parts in NPPs are discussed using our experimental results to improve the properties of a surface coated with existing Co-free harfacing materials. The coating technique using a laser beam having a high energy density has unique advantages to obtain various microstructures such as crystalline, amorphous, porous, and nano structures and also to get coating layers having high a hardness to result in an excellent resistance to erosion-corrosion and wear.

2. Methods and Results

In this section, the results obtained from a review of published literatures on Co-free hardfacing materials and from the laser hardfacing experiments done by authors of this study are described.

2.1 Fe-base hardfacing alloys

Active researches on the development of Fe-base, Co-free or reduced Co containing, alloys have been performed by European countries and EPRI from the late 1960s and early 1980s, respectively, in order to reduce the radioactivity in the primary side systems in NPPs. Latter, Japan conducted researches to develop Co-free hardfacing alloys because of the unsatisfactory properties of the developed alloys.

Typical Fe-base hardfacing alloys developed by European countries[1] were Everit 50, Antinit DUR 300, and Cenium Z 20, while those by EPRI[2, 3] were NOREM and Tristelle 2. MA-CS was developed typically by Japan.[4] According to the test results, Everit 50 and Cenium Z 20 showed wear rates and a surface roughness similar Stellite 6 at room temp., while Antinit DUR 300 showed higher wear rates. However, at a high temp.(280°C) and pressure, these three Co-free alloys showed somewhat higher wear rates than Stellite 6.[1] Of the alloys developed by EPRI, NOREM 02 showed a good resistance to galling up to a load of 60ksi and to a sliding wear up to 15 ksi loading at a temp. lower than 180°C. With an increasing temp., however, its wear mode changed abruptly to a severe adhesive wear at 190°C and galling occurred at above 200°C.[5, 6] Many operating nuclear power plants in the world have adapted or plan to apply this alloy to parts operating at a relatively low temperature in order to replace Stellite alloys. MA-CS alloy was observed to have lower specific wear coefficients than NOREM 02 even though the tensile strength and elongation of MA-CS were measured to be higher than NOREM 02. Operating plants in Japan are considering adapting this alloy(MA-CS) to reduce the radioactivity in the primary side system.[4] From an extensive review of the literatures, it can be concluded that in spite of active studies for long time, no Fe-base Co-free alloys show a better performance compatible to Co-base stellite alloys at a wide range of temperatures.

2.2 Ni-base hardfacing alloys

So far, many Ni-base Co-free hardfacing alloys, such as, Deloro, Colmony, Tribaloy T700, MHA, etc., have been developed by developed countries in nuclear technology in the world.[3-5] According to the test results, in general the Ni-base Deloro alloys showed a galling resistance inferior to Stellite 6 and Fe-base Co-free alloys developed for replacing Co-base Stellite alloys, but a higher toughness than Fe-base Co-free alloys.[7] Instead, Deloro 50 showed the best performance in a sliding wear among the developed Ni-base alloys. So, some commercial nuclear power plants in Canada are using this alloy for the parts of the valves operating at a relatively lower load than 15ksi.[2,3,5]

2.3 laser hardfacing(or cladding) experiments[8]

It is known that it is a very man power, money and time consuming job to develop new alloys with the better characteristics needed for the wanted purposes. One way to achieve the purposes is to develop a new coating technique using existing alloys which can endow the parts with the excellent surface properties wanted. In this study, a laser hardfacing(cladding) technique(LHT) was applied to increase the hardness, corrosion and wear resistance of the surfaces of the parts using several different hardfacing alloys such as Stellite 6, Armacor M, NOREM 02, and Deloro 50. Type 316 stainless steel was used as a substrate. The properties of the surfaces coated by the conventional TIG welding (GTAW) and laser hardfacing techniques were compared. As shown in Fig. 1, the surface roughness of the specimen coated using LHT is very smooth when compared to that of the specimen coated using GTAW).

The measured hardness of the various coated layers is represented in Fig. 2, which shows the surface coated using LHT to have a maximum hardness with Armacor M compared with the hardness of the surface coated using GTAW with Armacor M. As a matter of course, the surface coated by LHT showed the highest resistance to a sliding wear tested at room temperature and 300°C in air, and also at room temperature in water as shown in Fig. 3

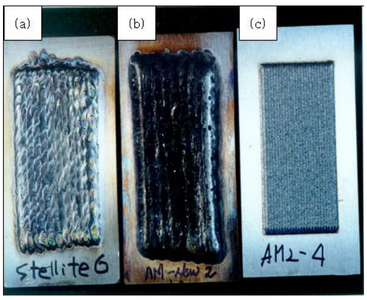

Fig. 1 Appearance of the TIG-welded (a) Stellite 6, (b) Armacor M, and (c) the laser-coated Armacor M specimens.

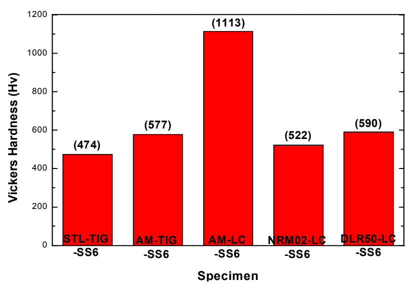

Fig. 2 Microhardness measured from the specimen surfaces coated with various alloys(Stellite 6, Armacor M, NOREM 02, Deloro 50, etc.) using LHT and GTAW.

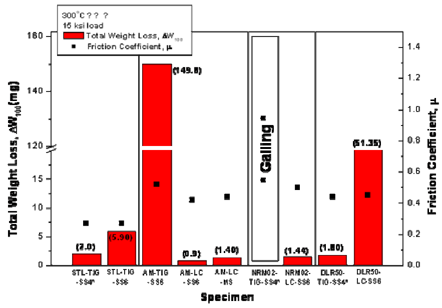

Fig. 3 Total weight loss and friction coefficient of the specimens coated with various alloys(Stellite 6, Armacor M, NOREM 02, Deloro 50, etc.) using LHT and GTAW, measured by sliding wear test at 300℃ and 15 ksi load in air

3. Conclusion

Various Co-free hardfacing alloys have been developed to replace Co-base Stellite alloys in order to reduce the radioactivity in the primary side systems in nuclear power plants. According to an extensive literature survey, however, it is concluded that no Fe- and Ni-base Co-free alloys showing a better performance compatible to Co-base stellite alloys at a wide range of temperatures have been developed, yet. The laser hardfacing technique was confirmed to show the best properties when compared to the conventional TIG welding(coating) method.

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