A Review Paper on Research Work Done in Hardfacing of Stellite-6 Alloy

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Abstract— Stellite 6 is a most widely used Cobalt based super alloy in industries, due to its outstanding behavior against high temperature oxidation and excellent wear resistance. Stellite 6 is a very versatile material that is used for hardfacing of various component parts for applications requiring wear resistance. It is a mixture of cobalt and other elements like nickel, chromium, tungsten, carbon and molybdenum. Chromium is added to form carbides and to provide strength to the cobalt matrix as well as to enhance the resistance against corrosion and oxidation. Tungsten and molybdenum have large atomic sizes and give additional strength to the matrix. They also form hard brittle carbides. Nickel is added to increase the ductility. The microstructure of Stellite 6 contains hard M7C3 carbides in interdendritic regions in both as-cast and as welded conditions. Stellite 6 cobalt base alloys consist of complex carbides in an alloy matrix. Their exceptional wear resistance is due mainly to the unique inherent characteristics of the hard carbide phase dispersed in a CoCr alloy matrix. Stellite 6 is the most widely used of the wear resistant cobalt based alloys and exhibits good all-round performance.

Key words: Hard Facing, Coating, Stellite 6, Heat Treatment, XRD Phase and Stress, Microstructure, Wear

I. Introduction

Weld hardfacing or fusion surfacing is a technique, primarily done to enhance the surface properties of substrate and hardfaced materials which generally exhibit better wear, corrosion and oxidation resistance than the substrate. And also this process exhibits a good surface appearance without the presence of porosities of crackles. Nevertheless, this process is more economical than improving the desired properties of the entire component because hardfacing involves the application of a coating to a low cost base material. The desired coating properties, quality, performance and of reducing the consumption of hardfaced metal can be achieved by proper selection of the hardfacing material to be deposited and welding process. Cobalt based alloys are widely employed as wear-resistant hardfacing materials for combating wear in corrosive mediums and find applications in chemical, petrochemical, medical and food processing industries Stellite 6 is very popular to improve the wear resistance of mechanical parts, especially in hostile environments.

II. Literature review

A. Microstructure:

V. Kuzucu et al. [4] reported the cobalt-rich main matrix in the cast sample has an unstable fcc structure at and around room temperature. In this sample, different kinds of carbides have been distributed over the inter-dendritic regions as granular shapes, In samples cooled in water after annealing, a large part of the cobalt-rich main matrix has transformed to ε phase with hcp structure. The microstructure of these samples has the appearance of dendritic structure. The carbide phases are distributed more homogeneously in the inter-dendritic regions. The cooling in the liquid nitrogen has caused an increase in the amount of the ε phase, a more homogeneous distribution of carbides in the inter-dendritic regions. At the same time, the fast cooling of the samples has also assisted the occurrence of the (Co-Mo) inter- metallic compound and some carbides such as Cobalt and chromium carbides. The rapid cooling after annealing has increased the hardness of the samples.

Mohammed mohaideen ferozhkhan1, et al. [5] showed the microstructure of Stellite 6 deposit for different welding processes consists of dendrites of Co solid solution) and inter dendrites formed from the eutectic Co and Cr with carbides . The light etched regions are Co solid solution, and the dark etched phases are identical to carbide segregation which has formed due to precipitation on solidification. These carbides are located in the grain boundaries or in the interdendritic regions .The intermetallics react with carbon to form the necessary carbides which is responsible for hardness, abrasion and corrosion resistance at high temperature.

Buta singh sidhu et al. [6] showed that Nickel alloy and Stellite-6 coatings could be successfully process on the given boiler tube. Laser remelting of the coating was found to be effective in reducing this porosity to a very lesser amount. However laser remelting further led to the significant dilution of the coating due to surface alloying of the coating with the bond coat and substrate. Laser remelting of the coatings led to decrease in microhardness as compared to original coating and might be attributed to the internal stresses and disordered arrangement of atoms in the as-coated material. After laser remelting atoms arrange themselves in order and internal stresses gets relaxed.

D'Oliveira et al. [7] compared as-deposited laser hardfacing result on finer solidification structures with higher hardness than PTA coatings because of changes on carbides morphology and also to precipitation. PTA coatings exhibit hardness stability after high temperature exposure whereas laser deposits present a decrease on hardness.

B. XRD Phase Analysis:

Zhiyuan zhu et al. [8] showed the results of XRD analysis of Stellite 6 alloy coating .The phases of deposited coating are α-Co and M_7C_6 , which are determined by comparison with the lattice parameter. The highest peak intensity is recorded for the α-Co and $(Cr, Fe)_7C_3$ phases, and the peaks of these two phases overlap. The presence of $(Cr, Fe)_7C_3$ plays a key role in increasing the hardness of the coating. The cellular–dendritic carbides are surrounded by the solid solution of Co and Cr, which solidifies toward the surface.. The dendritic carbides can play a key role in increasing the hardness and wear resistance of the coating.

Yucel birol et al. [13] reported that in XRD analysis shown the stellite-6 coating to be mainly composed of chromium type carbides with an fcc. Crystal structure (M= Co, Cr, W, Fe, Ni, Si) and Co-rich matrix phase with an FCC Crystal structure. The FCC Structure of the Co-based matrix of the hard facing, instead of the hcp crystal structure of the monolithic alloy is believed to be due to the dilution effect of the deposition process. Fe is known to promote the stability of the FCC Structure of the Co-rich matrix

C. Stress Analysis:

Wei ya, et al. [10] showed the comparison of the residual stresses measured with the layer removal and hole drilling techniques. The residual stresses calculated from the layer removal and hole drilling techniques agree well with each other. The residual stresses are compressive in thin layer from the clad surface, which become tensile and increase in magnitude with increasing depth. The maximum stress level is reached near the clad/substrate interface. The successive layer removal involves mechanical grinding which can introduce stresses and alter the stress due to cladding process alone. Generally such grinding stresses act over a small depth. The results show a good agreement between the stress measurement results of the two techniques. Residual stresses were evaluated with layer removal and hole drilling techniques. The residual stresses along cladding direction are higher than the residual stresses transverse to cladding direction. The measured residual stresses from both techniques agree well with each other.

D. Wear:

Yucel birol et al. [12] reported the sliding wear performance of hot work tool steel is degraded at high temperatures due basically to its inferior oxidation resistance. Extensive oxidation co-occurring with abrasion at high temperatures leads to substantial material loss basically due to the lack of an adhesive oxide scale, sufficiently ductile to sustain the abrasive action without extensive cracking or spalling. Iron oxide fails to survive the abrasion conditions and is readily detached from the surface. The wear resistance of the nickel and cobalt alloys on the other hand, is much better at very high temperatures. The adhesive and the relatively more plastic chromium oxide sustains the sliding wear action without spalling and is claimed to be responsible for the improved wear resistance of these alloys at very high temperatures..

Yucel birol et al. [9] reported the microstructure of the surface layer consisted of carbides embedded in a Co-rich solid solution with dendritic structure. Dendritic growth which occurs in coating is epitaxial. Primary phases formed during the process were identified as Co and lamellar eutectic phases such as chromium carbides. Microhardness profiles showed that hardness increases from interface to the coating surface. This is due to the finer size of the grains at coating surface in comparison to that at interface and also diffusion of Fe adjacent to the interface. The delamination was suggested as the dominant mechanism of the wear. In this regard, plate-like wear debris consisted of voids and cracks. In addition, due to increase in surface temperature, Chromium oxide phase was formed during wear tests. The application of an interlayer was suggested to minimize the dilution in order to improve corrosion resistance and prevent hardness reduction.

H. so et al. [15] reported that as rubbing occurs, oxides immediately form on the rubbed surfaces.. The spalling of the oxides is mainly caused by repeated rubbing of the two contacting surfaces. In other words, the spalling of oxides is obviously fatigue behaviour. The oxides formed on stellite alloy 6 are very tough and bond well to the stellite matrix. Besides, such oxides are not easy to be delaminated. Therefore, the wear rate of stellite 6 is quite mild. When the thickness of the stellite layer is less in µm, the whole layer will be detached due to initiation and growth of cracks along the boundary between the stellite layer and the carbon steel substrate. When the mean surface temperature at the apparent contact area of the pin is at very high temperatures, the wear of laser-clad stellite alloy 6 becomes severe.

Alain kusmokoa et al. [11] showed that the wear rate was lower for P22 coated samples at both heat inputs, with less cracking and pore development in the Stellite 6 coatings. The AFM results also indicated that the surface roughness was lower for P22 coated samples at both heat inputs. It is suggested that these observations are due to different diluted C contents in the two deposits. The lower concentration of strong carbide formers in the P22 substrate, relative to P91, is proposed to reduce carbon loss from the deposit.

E. Heat Treatment:

kuan jiang et al.[1] demonstrated that high temperature exposure of Stellite 6 promoted the coarsening of the microstructure and contributed to the increase in bulk hardness, the heat treatment on the alloy at very high temperatures resulted in the formation of a characteristic texture structure in dendrites. Also, a high temperature promoted bulk diffusion of tungsten from the dendrites to the interdendritic regions forming carbide phases and/or intermetallic phases (within the interdendritic regions). in heat-treated Stellite 6 altogether contributed to the increase in hardness.

S.Kapoor et al. [2] reported the hardness tests at elevated temperatures revealed that the solid solutions of Stellite alloys were affected by temperature, but the temperature effect on carbides was trivial and can be neglected. The solid solutions were softened at elevated temperatures, this may be due to the promoted atomic motion and relief of stress. This can be explained as the structures of the solid solutions were homogenized by the heating/cooling cycle (heat treatment), which increased the overall strength of the solid solutions.

Ana sofia et al. [3] on investigation shows regions where the interface is harder than the external surface. This becomes stronger as the number of deposited layers increases. As more layers were deposited, interdendritic coarsening near the interface with the base material is observed, this is attributed to the longer exposure times at elevated temperature, and slower cooling rates near the interface as more layers were deposited. Dilution level increased as consecutive layers were deposited, as illustrated by the higher levels of Cr of the interdendritic region

III. Conclusion

Hardfacing is one of the efficient process in terms of reducing the cost of replacement. Hardfacing reduces downtime because parts last longer and fewer shutdowns are required to replace them. Different alloying elements can be introduced into the base metal in the form of weld consumables to achieve any favourable properties like hardness, wear resistance, abrasive resistance, crack resistance. In this research studies had done on stellite 6 deposits with respect to wear, heat treatment, Microstructure, XRD phase and residual stress.

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