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LASER CLADDING WITH COBALT-BASED HARDFACING ALLOYS

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Preliminary results aimed at designing Co-based hardfacing alloys specifically for the laser cladding process are reported. Three alloys, ranging from hypo- to hypereutectic were deposited using scanning velocities between 1.7 and 170 mm/s. The microstructures and the dry sliding wear resistances of the clads were investigated. First trends relating composition to dry sliding wear resistance were deduced.

1. Introduction

The blown powder technique /1/ allows clads to be produced with a metallurgical bond and a low level of dilution. The rapid solidification rates associated with laser surface treatments produce very fine microstructures and can lead to transitions between growth morphologies /2/, to extended solubilities and/or to the appearance of metastable phases. As the properties of an alloy are strongly dependant upon the microstructure, it is necessary to study the relationships between composition, solidification speed, microstructure and properties, in order to optimise the composition and processing conditions for a given application.

Cobalt based, Stellite-type alloys are widely used in industry due to their excellent combination of wear and corrosion properties /3/. They usually contain two phases, a ductile cobalt-chromium phase and carbides of the M_7C_3 type. They can be classified as being hypoeutectic, eutectic or hypereutectic, with respect to the analogous pseudobinary system (Co,Cr) - $Cr_{7-x}Co_xC_3$ /4/. This paper presents preliminary results aimed at designing Co-based hardfacing alloys specifically for the laser cladding process.

2. Experiments

Three commercially available Co-based alloys, ranging from hypoeutectic (Stellite 6) to highly hypereutectic (E16019)¹, were deposited onto stainless steel substrates (DIN X2CrNiMo1814) using a 1.5 kW CO₂ laser. The chemical composition of the powders is given in Table 1, as well as their relative carbide fraction, determined using the chemical extraction technique described in /5/. Table 2 gives the

¹ E16001 and E16019 stand for Eutroloy 16001 and Eutroloy 160019 respectively

processing conditions used to produce the clads. The scanning velocities cover the whole range in which clads can be practically produced.

Table 1 : Chemical composition of the powders, in [wt%]

Alloy	Co	Cr	C	W	Mn	B	Ni	Fe	Al	Si	Carb.fraction
Stellite6	Bal.	28.0	1.10	4.54	0.09	-	0.04	0.5	1.28	-	9.3
E16001	Bal.	29.0	2.7	12.6	0.1	-	0.9	0.9	-	1.2	28.7
E16019	Bal.	26.3	3.4	13.1	0.1	0.6	1.4	0.9	-	1.2	40.5

Table 2 : Laser processing conditions

Processing condition	Slow	Intermediate	Fast
Laser power [W]	1500	1500	1500
Beam diameter [mm]	4	2	1
Intertrack adv. [mm]	1.2	0.6	0.1
Scanning speed [mm/s]	1.7	13.3	166.7
Powder feed rate [g/s]	0.03	0.1	0.2
Coverage rate [mm ² /s]	2	8	17
Clad thickness[mm]	0.8	0.6	0.2

The microstructures were examined using optical and scanning electron microscopy and the phases were determined using X-ray analysis. Dry sliding wear experiments were carried out, using a pin-on-disc type machine. Pins 8 mm in diameter were spark eroded from the cladded samples. The discs were made from sintered WC-Co 90/10. Experiments were conducted using loads ranging from 50 to 800 N and sliding velocities from 0.5 to 10 m/s.

3. Results and discussion

The structures obtained in the three alloys deposited using the slow and fast processing speed are shown in transverse micrographs, Figures 1 to 3. Note that there is a factor of 10 difference between the magnifications of the slow and fast processing conditions. The structure of the hypoeutectic alloy, Stellite 6, consists of primary (Co,Cr) dendrites surrounded by a fine eutectic containing M_7C_3 carbides. A marked decrease in the size of the microstructure with the increase in processing speed can be seen. A mean value for the secondary dendrite arm spacing, λ_2 , decreasing from 4.2 to 1.3 and down to 0.9 μm has been measured for the three scanning speeds investigated. For the alloy E16001, a slow processing condition produces a hypereutectic structure in the overlapping areas (where the solidification speed is at the lowest, center part of the Figure), with primary M_7C_3 carbides surrounded by eutectic. However, the structure becomes purely eutectic as the solidification speed increases. The intermediate and fast processing speed leads to a very fine eutectic structure (with an interlamellar spacing λ of about 100 and 50 nm respectively). In the overlapping zones, a thermal coarsening of the structure seems to have occurred. The microstructure of the hypereutectic alloy E16019 is shown in Figure 3. With the low processing speed the structure contains big primary needle-like M_7C_3 carbides surrounded by eutectic. With the fast processing condition, one can still observe big primary carbides in the overlapping areas (lower left corner), but with an increase in the solidification speed, these rapidly transform to primary dendritic carbides before the structure becomes entirely eutectic. The main differences between the deposits are the carbide fraction, clearly related to the carbon content, and the morphology of the phases, which is strongly affected by the processing condition.

Figures 1 to 3 : Microstructures of the alloys deposited using the slow and fast processing condition

However, the carbide fraction is also influenced by the solidification speed. Two effects are known to affect the microsegregation, and therefore the second phase (here the carbide) content in hypoeutectic alloys. Firstly an increase in the dendrite tip concentration with the solidification speed, and secondly, the modification of the partition coefficient due to loss of local thermodynamic equilibrium at the growing interface /6/. A determination of the carbide fraction in the hypoeutectic deposits was carried out /7/ and related to the solidification speed estimated using a numerical model /8/. Figure 4 shows that the carbide fraction decreases by approximately 10% between the slow and fast processing condition.

Figure 4 : Influence of the solidification speed on the carbide fraction in Stellite 6 deposits

Wear experiments were carried out on the clads produced using the intermediate processing condition (i.e. 13.3 mm/s). The results obtained for the three alloys were plotted in the form of wear maps /9/. These maps are shown in Figures 5 to 7. Each point in the XY plane represents a given set of experimental conditions (sliding velocity and applied load), and the corresponding wear rate is given in the Z axis.

In general, the measured wear rates were seen to decrease as the carbide content of the alloy increased. For the three alloys, a more or less regular increase in the wear rate with the load was observed. For the hypoeutectic alloy (Stellite 6), the wear rate passes through a maximum with the sliding velocity under a given load. Using a load of 50 N , observation of the wear debris and worn surfaces indicated that the increase in the wear rate with the sliding velocity could be attributed to a transition from an oxidative to

a metallic wear regime. For the eutectic alloy, E16001, the sliding velocity has little effect on the wear rate under low loads (50 N). However, under high loads (800 N), the wear rate passes again through a maximum. The highly hypereutectic alloy, E16019, exhibits a much flatter map, with a variation in the sliding velocity having little effect on the wear rate. Investigations are currently being carried out to elucidate the wear mechanisms involved in the eutectic and hypereutectic alloy.

Figure 5 to 7 : Dry sliding wear maps for Stellite 6, E16001 and E16019 respectively

4. Conclusions

The microstructures obtained with different Cobalt-based hardfacing alloys, deposited with a CO₂ laser under extreme processing conditions were investigated. Important variations in both the size and morphology of the carbides phases were observed. The dry sliding wear rates of these alloys deposited using intermediate processing speed were determined over a large range of applied loads and sliding velocities. The highly hypereutectic alloy was observed to be the most wear resistant. Future work will concentrate on determining the influence of the processing speed on the wear rate, which will help in the development of new alloys designed specifically for laser cladding.

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