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LASER CLADDING OF WC/T-800 CERMET: FABRICATION, MICROSTRUCTURE AND WEAR PROPERTIES

This study fabricated a WC/T-800 cermet coating layer with Co-Mo-Cr (T-800) powder and WC powder using laser cladding, and analyzed its microstructure, hardness and wear properties. For comparison, casted bulk T-800 was used. Laser cladded WC/T-800 cermet coating layer showed circular WC phases in the Co matrix, and dendritic laves phases. The average laves phase size in the cermet coating layer and bulk T-800 measured as 7.9 μm and 60.6 μm, respectively, indicating that the cermet coating layer had a relatively finer laves phase. Upon conducting a wear test, the cermet coating layer added with WC showed better wear resistance. In the case of laser cladded WC/T-800 cermet coating layer, abrasion wear was observed; on the contrary, the bulk T-800 showed pulled out laves phases. Based on the above findings, the WC/T-800 cermet coating layer using laser cladding and the relationship between its microstructure and wear behavior were discussed.

Keywords: CoMoCr alloy, WC, Cermet, Laser cladding, Microstructure, Wear properties

1. Introduction

Co-Mo-Cr alloy is a material with outstanding corrosion, oxidation and wear resistances, and it is being used in different forms, including tribaloy T-400, T-700 and T-800 [1-4]. Among them, tribaloy T-800 is a material with greater Cr content compared to T-400 and T-700, and this is known to contribute to relatively greater corrosion and wear resistance [1]. Based on such advantages, tribaloy T-800 is applied in components such as sink rolls and bearing components during Al or Zn-Al coating for fabricating hot dip aluminum-coated steel and hot dip zinc-coated steel plates [5-7]. Sink rolls and bearings are components that require frequent replacement due to partial damages, so their price and durability are critical aspects to consider. However, as tribaloy T-800 has a high price due to the use of expensive alloying elements (Co, Cr, Mo), many attempts are being made to resolve the issue of high cost occurring when such components are replaced. One of these attempts is laser cladding, because it is capable of fabricating a coating layer that adds better properties to a substrate, extending the component replacement cycle, and allowing component repairs.

Laser cladding process is a technology that uses a high-power laser to directly melt and solidify feedstocks (powder or wire) on a substrate, and fabricate a coating layer [8-10]. This process can be applied to various materials ranging from metal or ceramic to complex materials, and it is also a process that resolves issues of processing, bonding and repairing with fast layering speed [11]. Furthermore, as it is capable of applying the physical property of the feedstock directly to the surface of the substrate, it is possible to significantly improve the corrosion and wear resistance of a component, even if it is based on an affordable substrate. Due to this, many attempts have been made to fabricate a tribaloy T-800 coating layer using laser cladding, and there are studies that report the microstructure and wear properties of the coating layer fabricated using the process [12,13]. However, the major disadvantage of fabricating the same T-800 coating layer is that while it is capable of obtaining positive aspects in terms of repair, its durability still remains the same. Due to this, it is possible to fabricate a cermet coating layer with a similar composition as the substrate as an alternative, but there is no study related to this.

This study fabricated a cermet coating layer from a mixture of T-800 and the commonly used reinforcement phase (WC) via laser cladding. Then the microstructure, hardness and wear resistance of the manufactured cermet coating layer were compared and analyzed with bulk T-800 (comparison material).

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In addition, we attempted to identify the wear mechanism of the laser cladded WC/T-800 cermet coating layer based on its microstructural characteristics.

2. Experimental procedure

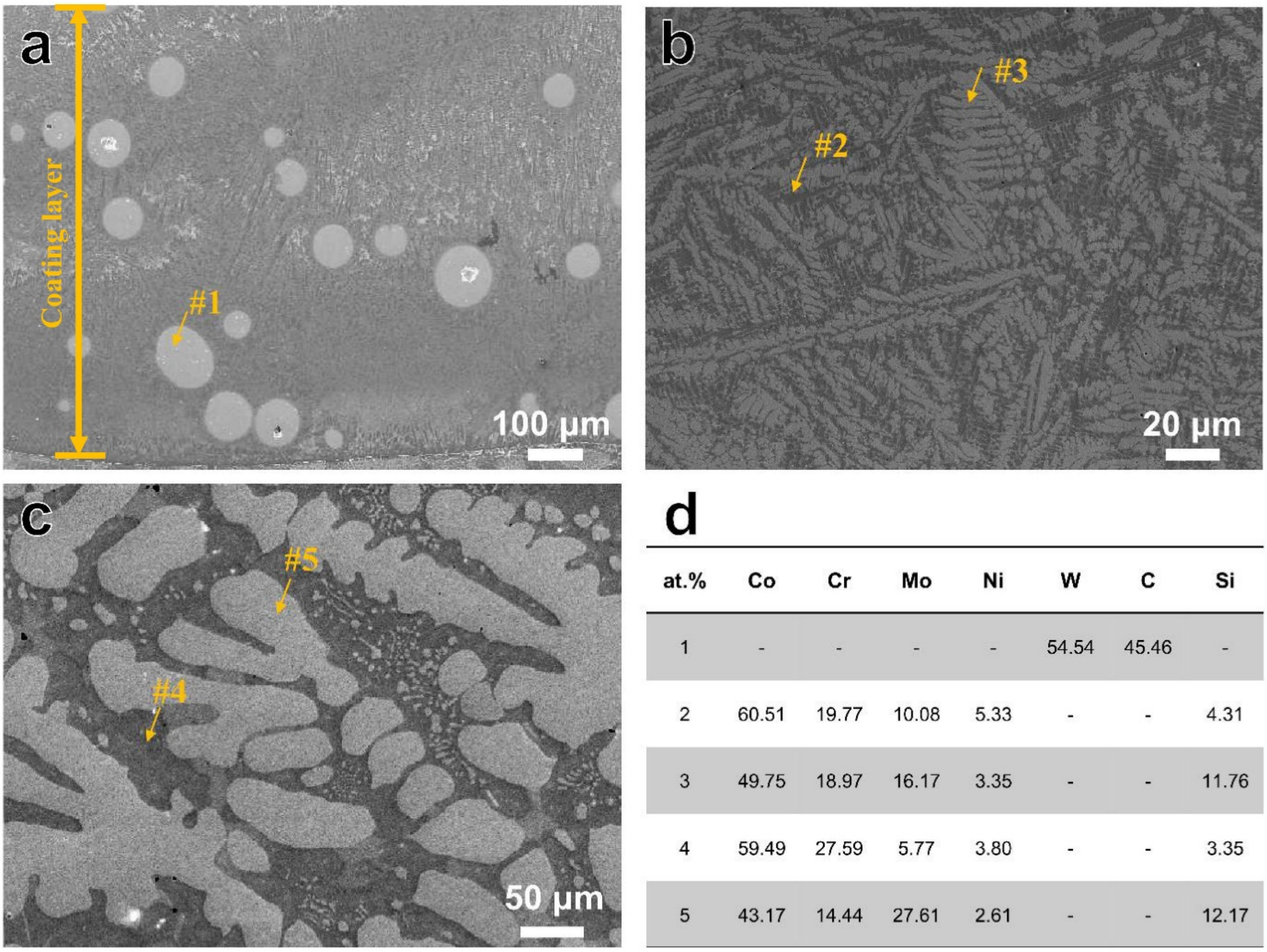
In the present work, the Metco's tribaloy T-800 (68F-NS-1) powder with the average size of 45 μm and the WC powder the average size of 71 μm were used. By using these feedstocks, WC/T-800 cermet coating layer was fabricated by laser cladding process. Here, AISI 316L was used as the substrate. In order to conduct microstructural observation and phase analysis, the laser cladded WC/T-800 coating layer and the comparison material (bulk T-800) underwent mechanical grinding using silicon carbide papers (#400-1200). Then the samples were fine-polished with 1 μm diamond suspension, and were observed using a field emission scanning electron microscope (FE-SEM, Tescan, MIRA 3).

To measure the mechanical properties of the cermet coating layer, microhardness and room-temperature wear tests were conducted. Microhardness was measured using Vickers hardness tester (Akashi, AVK-C100) and a total of 12 measurements were made for each alloy; from the results an average value (excluding the minimum and maximum values) was calculated. The room-temperature wear test was conducted using the pin on disk method (RB-102PD), and Si_3N_4 (which is most commonly applied) was used as the counterpart. For the pin on disk wear test, sliding speed = 50 rpm, load = 2 kgf and distance = 900 m were employed.

3. Results and discussion

3.1. Microstructures of WC/T-800 cermet coating layer fabricated by laser cladding

Figure 1 shows the cross-sectional microstructures of the laser cladded WC/T-800 cermet coating layer and the bulk T-800 (reference material). Figure 1a is a low-magnification SEM micrograph of the laser cladded WC/T-800 cermet coating layer, and no defects or delamination phenomenon were observed between the substrate and coating layer. This means that it is possible to fabricate a sound cermet coating layer using laser cladding. Furthermore, cermet coating layer contained coarse circular-shaped phases within the coating layer. EDS point analysis of these phases confirmed that they were WC particles (Fig. 1d). Figure 1b is a high-magnification SEM micrograph of the Co



at.%	Co	Cr	Mo	Ni	W	C	Si
1	-	-	-	-	54.54	45.46	-
2	60.51	19.77	10.08	5.33	-	-	4.31
3	49.75	18.97	16.17	3.35	-	-	11.76
4	59.49	27.59	5.77	3.80	-	-	3.35
5	43.17	14.44	27.61	2.61	-	-	12.17

Fig. 1. FE-SEM micrographs showing the initial microstructures: (a, b) laser cladded WC/T-800 cermet coating layer, (c) bulk T-800 reference material and (d) corresponding EDS point analysis results

matrix within the cermet coating layer, and it had a high fraction of white area, dendrite-shaped phases. EDS point analysis results (Fig. 1d) of these areas (#1) confirmed that the white phases had relatively higher Mo and Si content compared to the Co matrix (#2). This indicates that the white phases were laves phases (Co_2MoCr, Co_3Mo_2Si, #3), which are intermetallic phases commonly formed in Co-Mo-Cr alloy [12,13]. Meanwhile, upon observing the initial microstructure of the bulk T-800 (Fig. 1c), it showed the black area (Co matrix, #4) and white area (laves phase, #5), which are identical to those of the Co matrix of cermet coating layer. However, compared to the laves phases of the laser cladded cermet coating layer, it was confirmed that the size of the laves phases of the bulk T-800 was significantly larger. The average size of laves phases inside the laser cladded cermet coating layer and bulk T-800 measured 7.9 μm and 60.6 μm, respectively. This suggests that fabrication of WC/T-800 cermet coating using laser cladding has a relatively finer phase distribution. This is assumed to be due to the rapid melting and solidification from laser cladding process [14].

3.2. Hardness and wear properties of WC/T-800 cermet coating fabricated by laser cladding

The hardness values of the laser cladded WC/T-800 cermet coating layer and bulk T-800 measured 822.94±88.89 HV and 707.47±24.86 HV, respectively, indicating that the coating layer with WC added had approximately 16% increase in hardness compared to the conventional material. It should be noted that the strengthening phase distribution in cermet coating layer may also impact on the improvement of hardness. However, the standard deviation of hardness values was relatively greater in the cermet coating layer. This is suspected to be due to the hardness difference between the hard WC particles and the relatively softer Co matrix.

Figure 2 shows the pin on disk wear results of the laser cladded WC/T-800 cermet coating layer and bulk T-800. The weight loss values of the two materials were 0.0102 g for the laser cladded WC/T-800 cermet coating layer, and 0.0163 g for the bulk T-800. In general, a smaller weight loss value means greater wear resistance. Based on the wear test results obtained, the laser cladded WC/T-800 cermet coating layer was found to have the wear resistance 1.6 times greater than that of the bulk T-800.

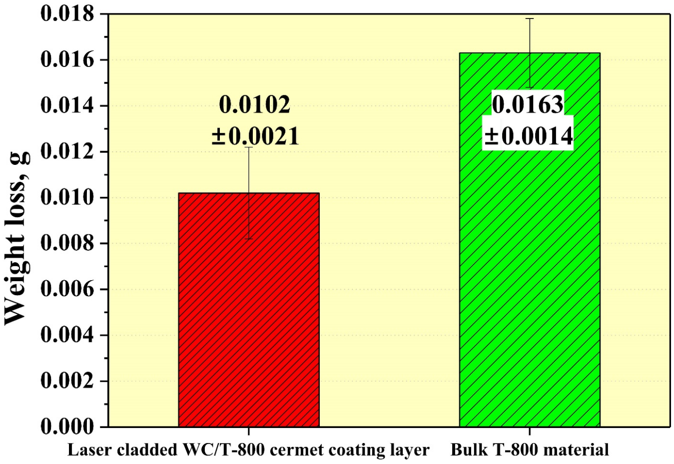


Fig. 2. Pin on disk wear properties of laser cladded WC/T-800 cermet coating layer and bulk T-800 material

To identify the origin of the difference in wear resistance of the two materials, the wear surface was observed after the wear test, and the results are shown in Figure 3. The macro-scale wear surface of the laser cladded WC/T-800 cermet coating layer had

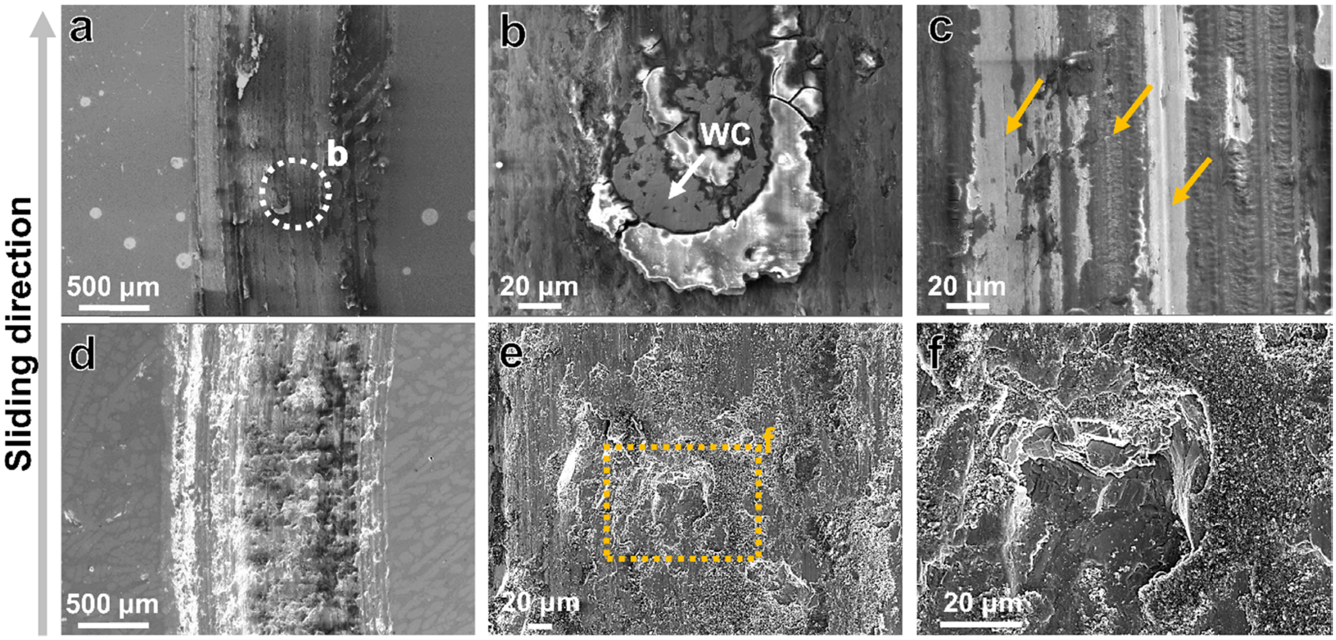


Fig. 3. FE-SEM images showing the surfaces after the pin on disk wear tests: (a-c) laser cladded WC/T-800 cermet coating layer and (d-e) bulk T-800 material

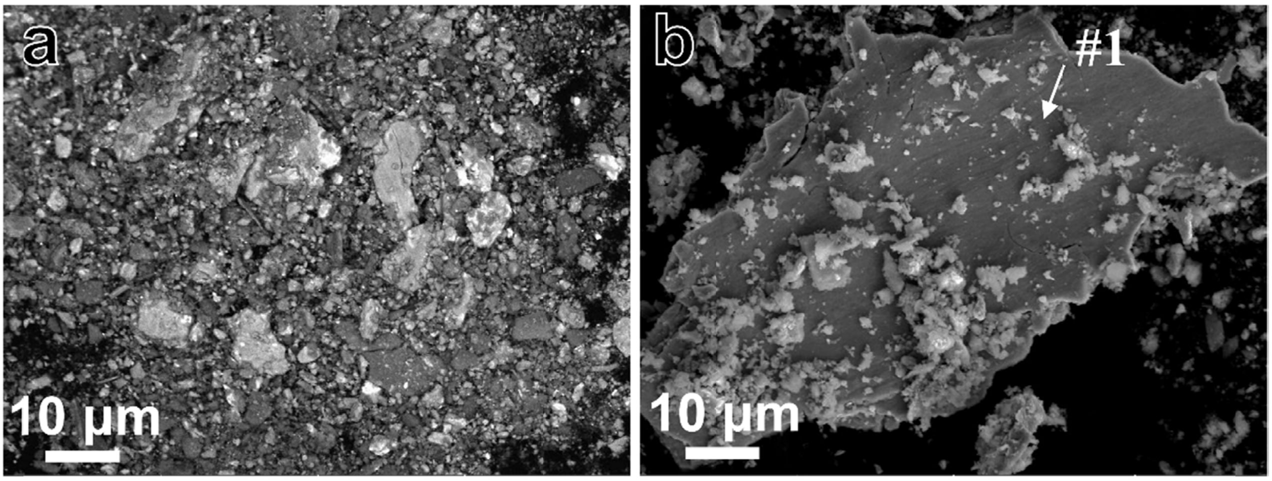
a wear track width of 1107 μm (Fig. 3a), and it had smooth wear traces. Meanwhile, the bulk T-800 had a wear track of 1238 μm (Fig. 3d), with relatively rougher wear traces. High-magnification cermet coating layer observation confirmed abrasion wear of WC particles (Fig. 3b), and clear abrasion wear traces (Fig. 3c). As a result, it was suspected that the fine and evenly distributed softer Co matrix in the cermet coating layer did not show significant interactions with WC particles, resulting in grinding wear only. Meanwhile, high-magnification of the bulk T-800 wear surface identified cracking and delamination of certain areas (Fig. 3e). Zooming in on such areas (Fig. 3f), the presence of brittle laves phases was identified. In other words, the bulk T-800, which had coarse laves phases and an uneven microstructure, suffered concentrated stress, crack initiation and partial delamination in laves phases, resulting in rougher wear surfaces.

Figure 4 shows the observation results of debris generated from the wear tests of the two materials. In the case of the laser cladded WC/T-800 cermet coating layer, debris size measured 1-10 μm, showing a significantly fine characteristic (Fig. 4a). On the other hand, the bulk T-800 had relatively coarse debris (Fig. 4b). Furthermore, debris content analysis identified high Mo and Si content, and debris size measured approximately 60 μm, leading to the assumption that the debris was mainly composed of the laves phase. As mentioned above, the laser cladded WC/T-800 cermet coating layer had outstanding hardness due to the addition of WC particles. Also, the laves phases which can cause brittle fracture in the microstructure were fine and evenly distributed. Therefore, it is possible to infer that in the case of WC/T-800 cermet coating layer, adhesive wear is suppressed by fine-sized laves phase, which in turn improves wear resistance. Based on these findings, the fabrication of cermet coating layer using laser cladding is expected to not only achieve outstanding mechanical properties, but also greater product durability.

4. Conclusion

This study was able to fabricate a sound WC/T-800 cermet coating layer using powder feedstock and laser cladding process, and by comparing and analyzing the microstructure and wear behavior with bulk T-800 (comparison material), the following conclusions were reached:

1. Microstructure analysis of the laser cladded WC/T-800 cermet coating layer did not show any defects between the substrate and coating layer. In addition, WC particles were evenly distributed throughout the coating layer. Upon observing the Co matrix within the cermet coating layer, fine and evenly distributed laves phases with high Cr, Mo and Si content were present. While bulk T-800 also had a clear differentiation between the Co matrix and laves phase, its laves phases were relatively larger and more uneven. The laves phase size measured 7.9 μm and 60.6 μm in the laser cladded WC/T-800 cermet coating layer and bulk T-800, respectively.
2. Hardness tests of the two materials measured 822.94 ±88.89 HV for the laser cladded WC/T-800 cermet coating layer and 707.47 ±24.86 HV for the bulk T-800. With WC particles added, the cermet coating layer achieved approximately 16% of increased hardness. Wear tests conducted on the two materials measured wear loss values of 0.0102 g for WC/T-800 cermet coating layer and 0.0163 g



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at.%	Co	Cr	Mo	Ni	Si	O
1	44.55	13.47	11.12	3.36	6.77	20.73

Fig. 4. SEM micrographs showing the wear debris of (a) laser cladded WC/T-800 cermet coating layer and (b) bulk T-800 material

for the bulk T-800 respectively, indicating that the laser cladded WC/T-800 cermet coating layer had wear resistance 1.6 times greater than the existing material. The cermet coating layer had evenly distributed fine, brittle laves phases, and its main wear mechanism was identified as abrasion wear. Meanwhile, the bulk T-800, which had coarse laves phases, had adhesive wear where cracks initiated and developed from the laves phases. In addition, it was identified that the WC particles that were added to the laser cladded cermet coating layer were effective in improving the wear resistance of the layer.

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