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Development of Cored Wires for Improving the Abrasion Wear Resistance of Austenitic Stainless Steel

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Arc-sprayed coatings are an attractive means to protect components from abrasive wear provided they contain enough hard phases. Because of their hardness and toughness, 316L-TiB_2 cermets were selected as the basis for developing wear-resistant coatings. Cored wires composed of type 304 stainless steel sheaths filled with 10 to 65 wt% TiB_2, 1 to 15 wt% additives, and the balance with 316L stainless steel were fabricated and arc-sprayed with air. The arc-sprayed stainless steel-TiB_2 coatings were abrasion tested and the volume loss measured with an optical profilometer. The volume loss decreased as the proportion of TiB_2 increased. However, large differences in volume loss between coatings that contain about the same volumetric proportion of hard phases cannot be explained by a linear relationship. An inverse rule of mixing was proposed and found useful in determining the influence of different additives. Tin, added in the core as a fugitive liquid transfer agent, was the most powerful additive for improving the wear resistance of stainless steel-base coatings. These advanced arc-sprayed stainless steel-TiB_2 coatings exhibit greater wear resistance than those obtained by arc spraying commercial solid and cored wires.

Keywords 316L stainless steel, abrasion wear resistance, arc-spraying, cored wires, TiB_2

1. Introduction

Abrasion-wear-resistant coatings can be obtained by arc spraying cored wires containing hard ceramic particles (Ref 1-6). The abrasive wear resistance of metal-ceramic composite materials increases with the ceramic content. However, the physical limitations of cored wires make it difficult to produce arc-sprayed coatings containing more than 50 vol% ceramic particles. Ceramic content should not be increased at the expense of the metal-matrix toughness, because improvements in wear resistance would not result.

This research produced wear-resistant austenitic stainless steel by arc spraying cored wires containing TiB_2. The influence of ceramic content on the abrasion wear resistance of arc-sprayed stainless steel-TiB_2 coatings was assessed. The role of additives that can modify the melting behavior and chemistry of cored stainless wires was also studied. These additives can lower or improve the abrasion wear resistance of arc-sprayed stainless steel coatings.

2. Forming of 316L-TiB_2 Materials

Dense 316L-TiB_2 cermets with a Vickers hardness (10 kgf) of 1800 kg/mm^2 and a toughness (K_{Ic}) of 8.0 $MPa\sqrt{m}$ have been obtained previously by the consolidation of type 316L stainless steel and TiB_2 powders (Ref 7). The densification of powder compacts was ensured by liquid phase sintering. In the Fe-TiB_2 system, the formation of a quasi-binary eutectic at 1250 °C and a ternary eutectic at 1170 °C liberates sufficient liquid phases to wet TiB_2 crystals and infiltrate powder compacts. However, iron and nickel react with TiB_2 to form brittle borides and liberate titanium. To avoid this drawback, different additives have been incorporated in the green compacts. As commercial powders contain carbon, oxygen, and nitrogen, additives are also required to form stable carbides, oxides, and nitrides. These are expected to affect the microstructure and would likely increase the mechanical properties of composites.

Based on the successful fabrication of stainless steel-TiB_2 cermets by means of a liquid phase process, and the fact that these metal-ceramic composites possess hardness and toughness suitable for wear-resistant applications, the deposition of stainless steel-TiB_2 by arc spraying cored wires has been considered.

3. Experimental Procedure

3.1 *Cored Wire Materials and Fabrication*

The cored wires for spraying were produced at the laboratory scale from flat strips of 0.127 mm thick type 304 stainless steel, bent to form a U-shape into which the powder mixtures were introduced. The U-shape was then closed and cold drawn to 1.6 mm diameter. Table 1 shows the chemical analysis of the 304 stainless steel strip used as the cored wire sheath.

The cores were mainly composed of TiB_2 and 316L stainless steel sinterable powders. The chemical analysis of the three types of 316L stainless steel powders used (Pfizer Minerals Pigments and Metals Division, New York, NY; SCM Metal Prod-

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ucts Inc., Research Triangle Park, NC; Anval, Rutherford, NJ) is shown in Table 2 and the particle size distribution in Table 3. Two sinterable TiB_2 powders were used, with a mean particle size of 10 ± 2 μm as certified by the producer (Union Carbide, Cleveland, OH). These powders differed mainly in carbon content (Table 4).

Inorganic materials of C, Al, Sn, Ti, Si, B, W, Mn, CuSn, $TiAl_3$, $ZrSi_2$, MgB_2, and CrB were also added to the main filler powders to modify the chemistry and properties of arc-sprayed stainless steel-TiB_2 composite droplets. Table 5 summarizes the intended uses of these additives. These powders were smaller than 45 μm and at least 99% pure. Prior to their introduction into the metal sheath, all the powder mixes were dry-mixed for 24 h.

Cored wires filled with 10 to 65 wt% TiB_2, 35 to 85 wt% 316L stainless steel, and 1 to 15 wt% inorganic additives were manufactured. Table 6 gives the core composition. It was difficult to fabricate and spray reliable cored wires containing only TiB_2 powder. The cored wire filling percentage was evaluated by separating the sheath from the core and performing weight measurements on these two components. The filling percentage is the mean of four measurements performed in different locations along the wire length. The nominal volume percentage of TiB_2 within sprayed coatings was calculated using the defined wire filling percentage and density data taken from the technical literature and material supplier data sheets.

3.2 *Arc Spraying of Cored Wires*

Cored stainless steel-TiB_2 wires and commercial wires were arc-sprayed using a Miller BP 400 arc spray system (Appleton, MI) with air as the atomizing gas. All the stainless steel-TiB_2 cored wires were sprayed with the following parameters: arc voltage, 26 to 30 V; arc amperage, 100 to 150 A; gas pressure, 600 kPa; and spray distance, 15 cm. Arc stability was the criterion for setting arc voltage. To evaluate wear performance reproducibility, selected cored wires were sprayed with different spray parameters. Commercial wires were also sprayed for comparison purposes using supplier spray parameters. Coatings were deposited on 25 by 78 by 9 mm grit-blasted mild steel pieces. Cooling was not provided on the back face of steel substrates, and no gas was used to cool coatings or sweep away the overspray. Arc-sprayed coatings were diamond ground to obtain flat surfaces and uniform roughness (R_a = 1 μm) prior to wear testing.

3.3 *Abrasion Wear Testing of Arc-Sprayed Coatings*

The abrasion wear resistance of arc-sprayed stainless steel-TiB_2 coatings and coatings obtained by spraying commercial wires was measured in accordance with the ASTM G 65 dry sand/rubber wheel abrasion test (Ref 8). This test method consists of abrading a specimen with a grit of controlled size and composition. A force of 130 N maintained the specimen against the rubber-coated wheel. Quartz sand (50 to 70 mesh, 300 to 212 μm) was introduced between the specimen and the wheel at a flow between 4 and 6 g/s. The wheel rotated in the same direction as the flowing sand, and the test ended after 2000 revolutions (ASTM G 65, procedure B).

3.4 *Volume Loss Measurement and Material Characterization*

The volume loss measurements were performed with an optical profilometer (Ref 9). This apparatus, mainly composed of a laser range sensor, allows three-dimensional mapping of worn areas and can evaluate the volume loss on coatings with an accu-

Table 1 Chemical analysis of type 304 stainless steel strip

Element	Weight percent
Chromium	18.54
Nickel	9.52
Manganese	1.41
Silicon	0.53
Copper	0.36
Molybdenum	0.26
Carbon	0.06
Nitrogen	0.04
Phosphorus	0.03
Sulfur	0.001
Iron	bal

Table 2 Chemical composition of type 316L stainless steel powders

	Weight percent		
Element	**SS powder 1**	**SS powder 2**	**SS powder 3**
Chromium	17.65	16.89	17.0
Nickel	11.67	11.06	11.3
Molybdenum	2.32	2.08	2.2
Silicon	0.98	0.76	0.52
Manganese	0.16	0.11	1.48
Carbon	0.018	0.018	0.032
Sulfur	0.016	0.010	0.08
Phosphorus	0.010	...	0.02
Iron	bal	bal	bal

Table 3 Particle size distribution of type 316L stainless steel powders

Tyler mesh	Weight percent		
size	**SS powder 1**	**SS powder 2**	**SS powder 3(a)**
+100	3.4	1.6	...
+150	15.0	9.8	...
+200	30.8	14.7	...
+325	64.4	28.1	...
–325	35.6	45.8	...
–625	...	...	100.0

(a) Stainless steel powder 3 is spherical

Table 4 Chemical analysis of titanium diboride powders

	Weight percent	
Element(a)	**TiB_2 powder 1**	**TiB_2 powder 2**
Titanium	67-69	67-69
Boron	29-32	29-32
Carbon (max)	0.25	0.50
Oxygen (max)	0.50	0.50
Nitrogen (max)	0.15	0.15

(a) Trace metals: iron, 0.02 wt%; zirconium, 0.015 wt%

racy greater than 1%; the accuracy between the wear volume losses performed on different composite coating samples is better than 10%. Polished metallographic cross sections of sprayed coatings and small ingots obtained by melting powder compacts in argon at 1450 °C were examined by optical and scanning electron microscopy. The chemical composition of materials in specific areas was determined using x-ray dispersive energy spectroscopy.

4. Results and Discussion

4.1 *Influence of TiB_2 Volume Content*

The volume loss of arc-sprayed stainless steel-TiB_2 decreased as the volume content of TiB_2 increased from 0 to 33 vol%. Figure 1 indicates that the wear volume loss could be linearly related to the TiB_2 volume fraction within arc-sprayed coatings ($R^2 = 0.79$). This relationship is obtained:

$$W = 155 - 4.73\,V_2 \qquad \text{(Eq 1)}$$

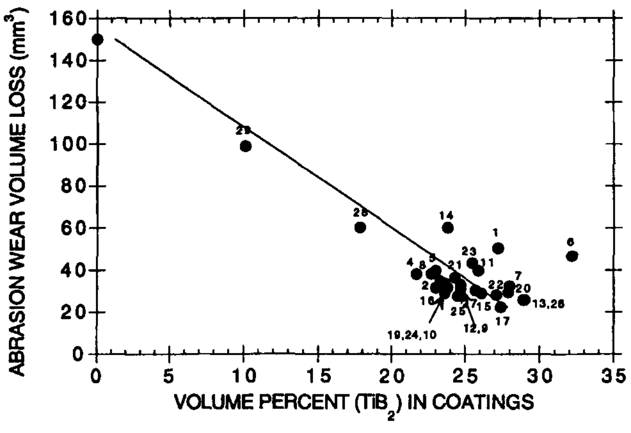

Fig. 1 Abrasion volume loss of arc-sprayed stainless steel-TiB_2 coatings as a function of the nominal TiB_2 volume content

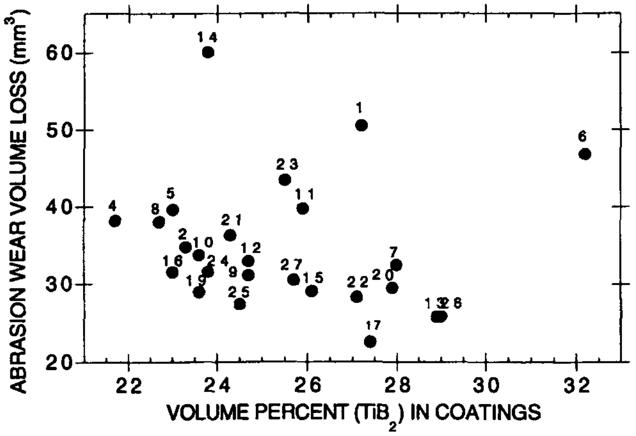

Fig. 2 Abrasion volume loss of arc-sprayed stainless steel-TiB_2 coatings as a function of the nominal TiB_2 volume content for compositions with between 21.7 to 32.2 vol% TiB_2. Coatings 14 and 19 are discussed in the text.

where W (mm^3) designates the abrasion volume loss of sprayed coatings and V_2 the nominal volume percent of TiB_2 within coatings. The origin of the curve (155 mm^3) represents the volume loss of stainless steel.

Though this general trend seems to apply, the volume fraction of hard particles within the sprayed coatings is not the only variable that should be considered to explain the behavior of arc-sprayed stainless steel-TiB_2 coatings. Particularly in the range of 21 to 33 vol% TiB_2, large differences in coating volume losses for the same volume content in TiB_2 are observed (Fig. 2). For instance, the arc-sprayed coating that contains graphite (coating 14) loses twice as much volume as the coating containing tin (coating 19) for about the same TiB_2 volume content (23.8 to 23.6 vol%). Many other examples of such behavior can be drawn from Fig. 2. Therefore, it is inappropriate to relate the wear volume loss to the volume content of TiB_2 by a linear relationship, particularly in the range of 22 to 33 vol% TiB_2. More-

Table 5 Intended uses of additives

Additive	Purpose
Sn, CuSn, Al	Liquid transfer agent
Si, $ZrSi_2$, W	Carbide former
MgB_2, Al, $ZrSi_2$, $TiAl_3$	More stable oxide
Ti, $TiAl_3$	Balance of Ti depletion
CrB, B	Liquid phase former
Mn	Austenite former
C	Ferrite former

Table 6 Composition of cores

Samples are presented in order of increasing wear resistance.

	Core content(a), wt%		
Coating No.	TiB_2	316L SS	Additives
29	10 (2)	84 (2)	4 W, 2 Mn
3	40 (1)	50 (3)	10 Al
28	19 (2)	72 (2), +325 mesh	4 Sn, 5 W
14	34 (1)	64 (1)	2 C
18	33 (1)	61 (3)	6 Sn
1	35 (1)	36 (1), 24 (3)	5 Al
6	50 (1)	42 (1), –325 mesh	8 Al
23	34.6 (2)	52.6 (2)	12.8 Sn
11	33 (1)	61 (1)	6 $ZrSi_2$
5	30	60 (1), –325 mesh	5 Al
4	30	65 (1), –325 mesh	5 $TiAl_3$
8	35 (1)	65 (1), –325 mesh	...
21	29.75 (2)	55.25 (2)	15 Sn
2	30 (1)	60 (3)	5 Al, 5 CrB
10	33 (1)	61 (1)	6 MgB_2
12	33 (1)	61 (1)	6 Si
7	65 (1)	35 (1), –325 mesh	...
16	34 (1)	58 (1)	4 Sn, 4 CrB
24	32 (2)	53 (2)	12 Sn, 3 Ti
9	34 (1)	63 (1), –325 mesh	3 MgB_2
27	38 (2)	49 (2)	7 Sn, 4 Ti, 2 B
20	33 (2)	55 (2)	12 CuSn (50% Cu)
15	34 (1)	58 (1)	6 Sn, 2 Si
19	33 (2)	61 (1), –270 mesh	6 Sn
22	23.79 (2)	57.68 (2)	9.53 Sn
25	38 (2)	49 (2)	10 Sn, 3 Ti
26	38 (2)	49 (2)	10 Sn, 2 Ti, 1 B
13	33 (1)	61 (1)	6 Sn
17	33 (1)	55 (1)	12 Sn

(a) Numbers in parentheses refer to the type of powder; see Tables 2 to 4.

over, this general rule of mixing does not account for additives that modify the wear behavior of sprayed coatings.

As differences in wear performance could depend on unobserved changes during the deposition process, selected cored wires were arc-sprayed with different electrical parameters. Table 7 shows that the difference observed in volume losses for three cored wires sprayed with different parameters is less than 17%.

To take into account these differences in wear behavior, we can express the volume loss of coatings submitted to abrasion by using the inverse rule of mixing, as defined by:

$$\frac{1}{W} = \frac{f_1}{W_1} + \frac{f_2}{W_2} \tag{Eq 2}$$

where W is the volume loss of a coating containing a volume fraction f_1 of a component that loses a volume W_1 and a volume fraction f_2 of a second component that loses a volume W_2. The term W_1 designates the volume loss by stainless steel, f_1 the volume fraction of stainless steel, f_2 the volume fraction of TiB_2, and W is the volume loss of each of the different arc-sprayed coatings. The inverse rule of mixing as graphically represented in Fig. 3 shows that great improvement in wear can be achieved by adding volume fractions of hard and wear-resistant ceramic particles between 5 and 35 vol%. For volume percentages of hard particles between 0 and 10 vol%, the wear volume loss decreases steeply and almost linearly.

For each sprayed coating, the corresponding volume loss attributed to TiB_2 (W_2) was then calculated according to Eq 2. Table 8 summarizes the results obtained for the different sprayed coatings. As shown, different W_2 volume losses correspond to different arc-sprayed coatings whatever their nominal TiB_2 volume content.

Coatings containing only stainless steel and TiB_2 (coatings 7 and 8) possess an identical W_2 of 10.75 mm^3, even though they contain 28 and 22.7 vol% TiB_2, respectively (Table 7 and Fig. 4). Therefore, the volume loss is determined by the inverse law of mixture and depends only on the volume percentage of TiB_2 (Fig. 4).

4.2 *Influence of Additives*

Additives were used in the cored wire to modify the chemistry and thus the mechanical properties responsible for wear performance. The influence of additives on wear performance can be estimated by considering the W_2 volume loss for the different arc-sprayed coatings. In comparison with sprayed coatings that contain only stainless steel and TiB_2, additives that decrease W_2 are considered to improve wear performance, whereas those that increase W_2 are thought to be detrimental. Therefore, additives that raise W_2 from 10.75 to 24.58 mm^3 are considered detrimental for wear performance, while those that lower W_2 to 6.92 mm^3 are beneficial (Table 8). In this respect, Table 8 contains pertinent information for estimating the role of additives. It should be kept in mind that a variety of stainless steel and TiB_2 powders were used.

4.2.1 Having a Noxious Effect

Regardless of their overall wear volume loss and their TiB_2 volume content, cored wires that contain 5 to 8 wt% Al or 6 wt% $ZrSi_2$ in combination with stainless steel powder No. 1 and TiB_2 powder No. 1, and cored wires containing either 12.8 wt% Sn, 4 wt% Sn and 5 wt% W, or 4 wt% W and 2 wt% Mn in combination with stainless steel powder No. 2 and TiB_2 powder No. 2, did not result in sprayed coatings with W_2 volume losses lower than coatings obtained with cored wires containing only stainless steel and TiB_2. These additives in combination with the specific

Table 7 Volume loss of selected coatings as a function of spraying parameters

Coating No.	Arc voltage, V	Arc amperage, A	Wear volume loss, mm^3 (±10%)
1	30	150	49.5
	26	150	49.1
12	27	100	35.5
	28.5	110	30.5
20	26.5	100	31.9
	27.5	100	27.1

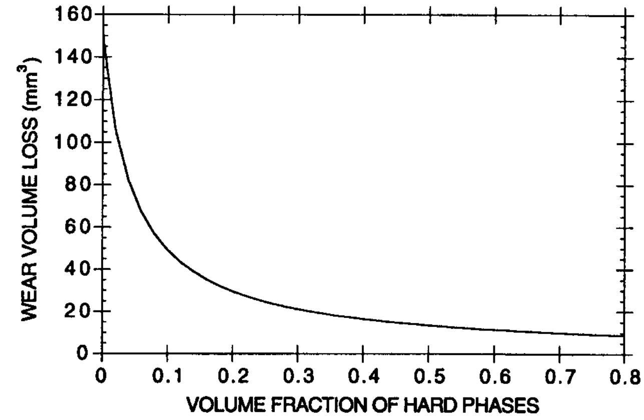

Fig. 3 Influence of the volume content of hard phases on the wear volume loss using the inverse rule of mixing, with $W_1 = 150$ mm^3 and $W_2 = 7$ mm^3

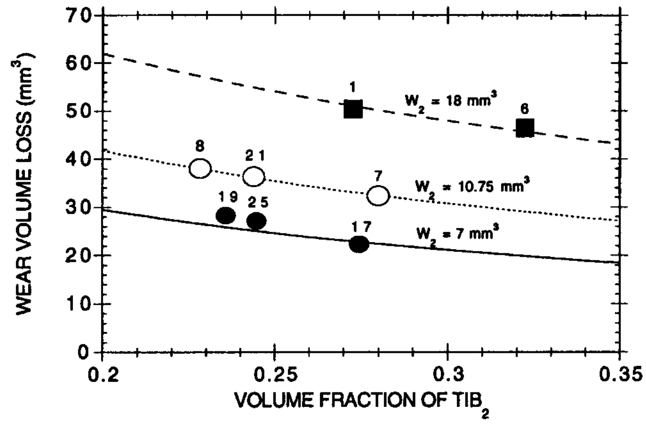

Fig. 4 Wear volume loss of selected arc-sprayed coatings as a function of volume content of TiB_2. Continuous lines are drawn according to the inverse rule of mixing (Eq 2) for different W_2 volume losses.

stainless steel and TiB_2 powders used in cored wires are considered harmful.

4.2.2 Additives Having a Beneficial Effect

On the other hand, cored wires containing other additives used in combination with different stainless steel and TiB_2 powders produce sprayed coatings with W_2 volume losses lower than those obtained with cored wires containing only stainless steel and TiB_2 powders. These additives considerably improve the wear resistance of arc-sprayed coatings regardless of their nominal TiB_2 volume content, as shown in Table 8. Without discussing the specific influence of all these additives, it should be mentioned that their effect depends on the type of stainless steel and TiB_2 powders used. Tin, tin-copper, titanium, silicon, CrB, MgB_2, and $TiAl_3$ were found to be effective in lowering the volume loss. Nevertheless, the effectiveness of additives seems to depend on the purity and relative proportion of major constituents filling cored wires (Tables 6 and 8).

Improvement in wear performance most likely results from microstructure modifications due to additives. Air-arc-sprayed coatings typically exhibit complex microstructures consisting of overlapping lamellae of different sizes, often with protruding stringers composed mostly of oxides (Fig. 5). These large features contain very fine (below 0.5 μm) crystals (Fig. 6) of a chemical composition that is difficult to determine accurately without analytical transmission electron microscopy. X-ray dispersive energy spectroscopy analysis performed on coating lamellae and oxide stringers revealed no significant differences among the coatings, except that stringers are composed mainly of titanium dioxide associated with the oxide corresponding to the element added.

4.2.3 Influence of Tin

Among all the additives tested alone or in combination, tin was the most powerful in reducing wear loss for a given TiB_2 volume fraction. Wear volume losses of arc-sprayed coatings containing 27.1-27.4 vol% TiB_2 (coatings 1, 22, and 17) are reduced from 50.54 mm^3 to 28.32 and 22.5 mm^3 after replacing 5 wt% Al by 9.53 and 12 wt% Sn. To explain the effect of tin on the wear performance improvement, microscopic analysis was carried out on small ingots melted in argon at 1450 °C. Core compositions containing 0, 6, and 12 wt% Sn, corresponding to the cores of wires 8, 17, and 19, respectively, were considered.

As shown in Fig. 7 to 9, increasing additions of tin cause TiB_2 to become more dispersed within the metal matrix. The fall in melting temperatures following the addition of tin would certainly promote the homogeneity of composites. However, the chemical analysis of dark clusters containing large amounts of light elements present in these composites is particularly revealing. Indeed, as shown in Fig. 10, the silicon concentration increases and the titanium percentage decreases as the tin content increases.

Major changes were not observed in the other composite constituents, except that the concentration of tin reaches 2.5 wt% within the metal matrix for composites that originally contain 12 wt%. As little tin was also observed in arc-sprayed coatings, this metallic element was obviously vaporized during melting.

Table 8 Calculated W_2 volume losses with respect to coating volume losses, TiB_2 volume contents, types of powders, and additives within cores

Coating No.	W_2, mm^3	Volume loss, mm^3	TiB_2(a), vol%	Type of stainless steel(a)	Additives in the core, wt%
17	6.92	22.50	27.4 (1)	(1)	12 Sn
25	7.79	27.40	24.5 (2)	(2)	10 Sn, 3 Ti
19	8.00	28.91	23.6 (2)	(1)	6 Sn
13	8.52	25.80	29.0 (1)	(1)	6 Sn
16	8.64	31.49	23.0 (1)	(1)	4 Sn, 4 CrB
26	8.50	25.80	28.9 (2)	(2)	10 Sn, 2 Ti, 1 B
15	8.86	29.09	26.1 (1)	(1)	6 Sn, 2 Si
22	8.90	28.32	27.1 (2)	(2)	9.53 Sn
24	8.94	31.55	23.8 (2)	(2)	12 Sn, 3 Ti
9	9.10	31.10	24.7 (1)	(1)	3 MgB_2
27	9.23	30.49	25.7 (2)	(2)	7 Sn, 4 Ti, 2 B
10	9.60	33.69	23.6 (1)	(1)	6 MgB_2
20	9.59	29.50	27.9 (2)	(2)	12 CuSn
2	9.84	34.74	23.3 (1)	(3)	5 Al, 5 CrB
12	9.75	32.94	24.7 (1)	(1)	6 Si
4	10.35	38.19	23.0 (1)	(1)	5 $TiAl_3$
7	10.75	32.44	28.0 (1)	(1)	...
8	10.74	38.05	22.7 (1)	(1)	...
21	10.80	36.31	24.3 (2)	(2)	15 Sn
5	11.43	39.60	23.0 (1)	(1)	5 Al
11	12.82	39.78	25.9 (1)	(1)	6 $ZrSi_2$
23	14.13	43.45	25.5 (2)	(2)	12.8 Sn
28	15.98	60.18	17.8 (2)	(2)	4 Sn, 5 W
1	18.21	50.54	27.2 (1)	(1, 3)	5 Al
6	19.12	46.82	32.2 (1)	(1)	8 Al
14	20.56	60.03	23.8 (1)	(1)	2 C
29	24.58	98.99	10.1 (2)	(2)	4 W, 2 Mn

(a) Numbers in parentheses refer to the type of powder; see Tables 2 to 4.

Therefore, perhaps tin acts as a liquid agent to collect and transfer preferentially certain elements. Based on previous work carried out on the formation of carbide coatings on graphite by the liquid metal transfer agent method (Ref 10, 11), silicon is dissolved in tin and reacts thereafter with light elements (carbon, nitrogen, and oxygen) to form ceramic compounds. The isolation of light elements by tin would improve mechanical and wear properties.

With a titanium diboride powder (No. 2) that contains more carbon than powder No. 1, reactive elements must be added with tin to avoid the formation of brittle complex borides due to titanium depletion within the melt. Titanium or silicon in combination with tin is required to maintain good wear properties (coatings 24 to 27 in Tables 6 and 8). Addition of tin should be limited to 12 wt% unless too much residual tin is present in the sprayed coatings. Higher percentages of tin result in soft sprayed coatings with inferior wear properties (coatings 21 and 23 in Tables 6 and 8). Titanium and silicon are preferred reactive elements to use with tin as the liquid transfer agent. Aluminum or copper-tin were not found efficient as liquid transfer agents. Being less fugitive than tin, these elements remained in the coatings. Tungsten deteriorated the wear properties of coatings (Tables 6 and 8) and thus cannot be used as a reactive element.

4.3 *Abrasion Wear Resistance of Stainless Steel-TiB$_2$ Coating Versus Commercial Arc-Sprayed Coatings*

All the arc-sprayed coatings of stainless steel and TiB$_2$ performed better than those obtained by spraying conventional austenitic stainless steel wires. The volume loss of the stainless steel-TiB$_2$ coating containing 10 vol% TiB$_2$ is 98.99 mm^3, whereas that of austenitic stainless steel reaches 145 mm^3. As shown in Table 8 , arc-sprayed stainless steel coatings that con-

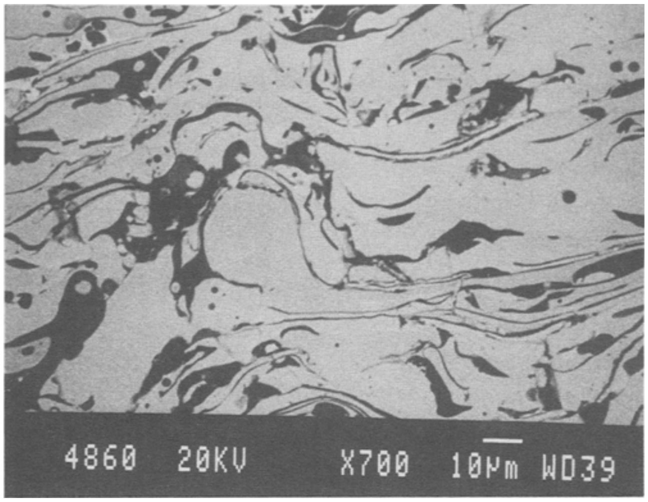

Fig. 5 Typical backscattered electron micrograph of an arc-sprayed stainless steel-TiB$_2$ coating (coating 17)

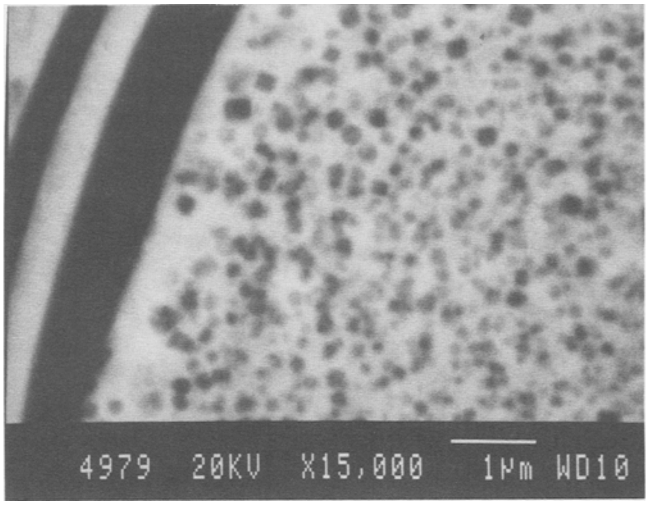

Fig. 6 Backscattered electron micrograph of an arc-sprayed stainless steel-TiB$_2$ showing the fineness of crystals (coating 17)

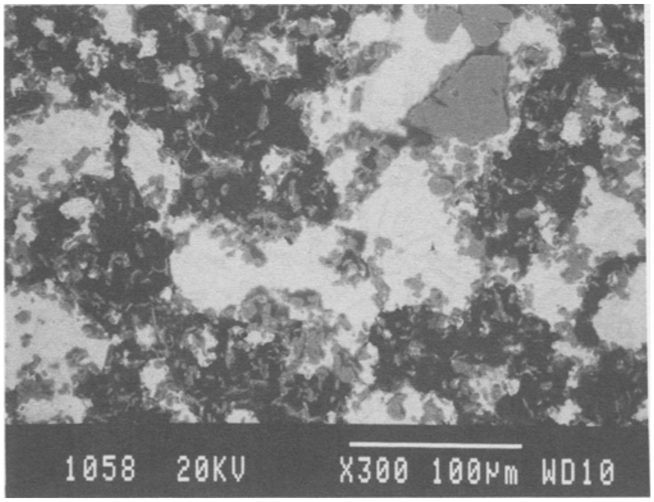

Fig. 7 Backscattered electron micrograph of a composite containing 65 wt% 316L stainless steel and 35 wt% TiB$_2$ melted in a furnace at 1450 °C. The composition corresponds to coating core 8.

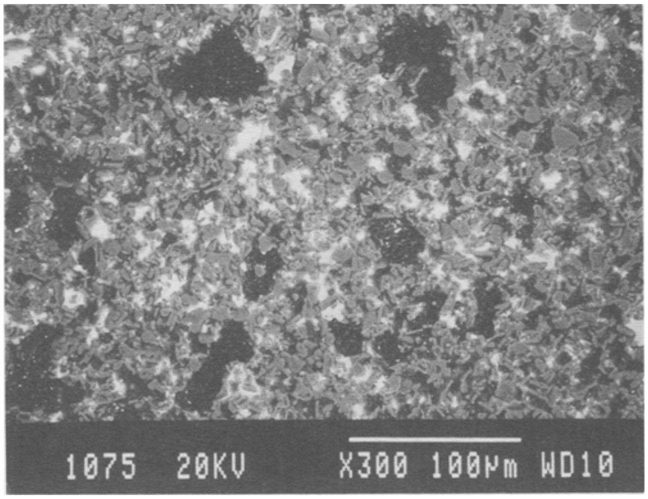

Fig. 8 Backscattered electron micrograph of a composite containing 61 wt% 316L stainless steel, 33 wt% TiB$_2$, and 6 wt% Sn melted in a furnace at 1450 °C. The composition corresponds to the coating core 19.

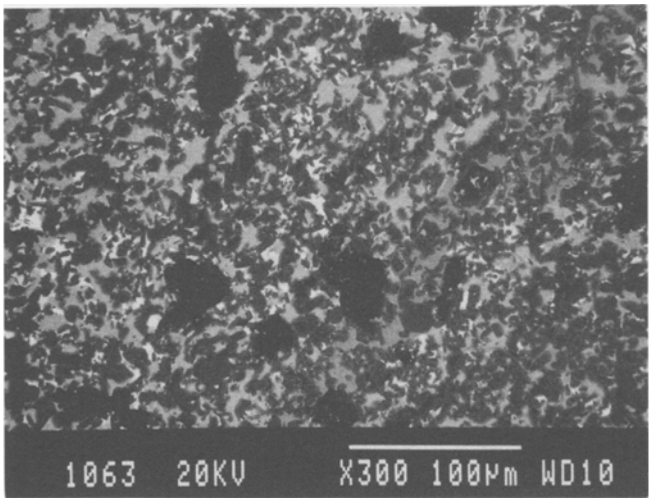

Fig. 9 Backscattered electron micrograph of a composite containing 55 wt% 316L stainless steel, 33 wt% TiB_2, and 12 wt% Sn melted in a furnace at 1450 °C. The composition corresponds to the coating core 17.

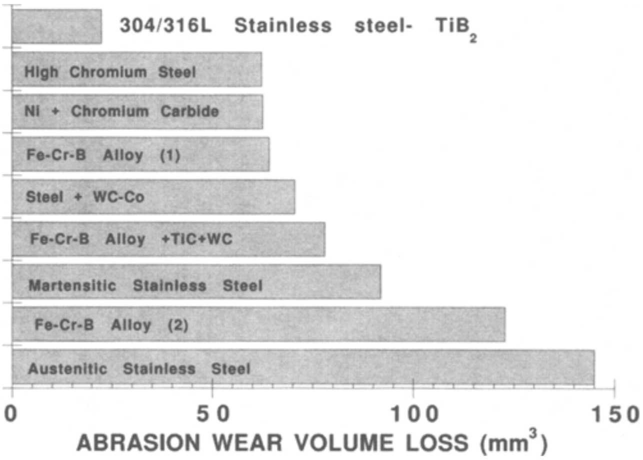

Fig. 11 Wear volume losses of coatings obtained by arc spraying stainless steel-TiB_2 cored wires and commercial wires. Austenitic and martensitic stainless steel coatings were fabricated with conventional wires.

tain more than 18 vol% TiB_2 experienced less volume loss than coatings obtained with commercial wires. The lowest volume loss measured for a coating obtained with a commercial cored wire was 62 mm^3. Moreover, as shown in Fig. 11, the best stainless steel-TiB_2 coating exhibited about 6.5 times less volume loss than an austenitic stainless steel coating and 3 times less than coatings obtained with the best commercial cored wire tested.

5. Conclusions

Cored wires containing 316L stainless steel and TiB_2 can be arc-sprayed with air for forming abrasion-wear-resistant coatings. The wear resistance of arc-sprayed stainless steel-TiB_2 coatings depends on the proportion of TiB_2 within the cored wire as well as various additives. The inverse rule of mixing was found appropriate to take into account the ceramic content as well as the influence of additives on wear performance. Tin, used as a fugitive liquid transfer agent, was found to be the most powerful of all the additives tested for improving the abrasion wear resistance of arc-sprayed stainless steel-TiB_2 coatings. These advanced coatings are more abrasion wear-resistant than those obtained by spraying some commercial cored and conventional wires.

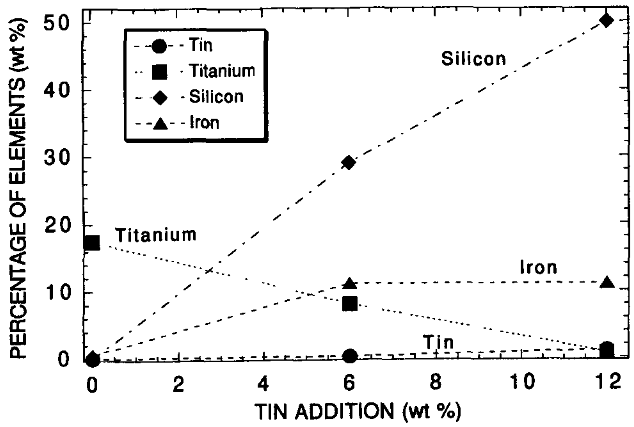

Fig. 10 Evolution of the main metallic elements within dark clusters present in stainless steel-TiB_2 composites with the percentage of tin added

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