

LOSS OF CARBON DURING PLASMA-SPRAYING OF
CLAD CARBIDE POWDERS

A. G. Tsidulko, V. M. Rusanov,
G. V. Bobrov, I. A. Dokukina,
I. I. Timofeeva, and
T. I. Shaposhnikova

UDC 621.793.7

Composition of particles upon atomization of unclad and clad powders is studied. It is established that the losses of carbon upon atomization of unclad particles are different for different carbides and increase in the sequence Cr_3C_2 -TiC-WC. Upon atomization of clad powders, we observed the highest carbon losses for the particles of tungsten carbide, somewhat smaller losses for titanium carbide, and almost negligible losses for chromium carbide.

The technical properties of plasma-sprayed coatings of clad powders can be enhanced by changing the conditions of motion and heating of the particles, varying the interphase processes occurring in them, and strengthening the bonding during the formation of such coatings [1]. With regard to clad carbide powders, a positive effect can be produced also by protecting the carbide core from burning out of carbon. However, data are available in the literature on carbon losses during plasma spraying only for tungsten carbide [2]. An analysis of the processes accompanying the heating of particles during plasma spraying indicates that the effectiveness of the protection of carbides from carbon losses depends on their properties, features of interaction with the casing metal, structure of the particles and the casing, and its behavior during the plasma spraying of the particles. Nickel-clad powders of chromium, titanium, and tungsten carbides 40-80 μm in size were investigated by scanning-electron microscopy using an SCh-10 microscope, which had a "Link system-290" attachment for electron-microprobe analysis, as well as by metallographic, x-ray-structural, and chemical analyses. The carbide particles were clad by chemical, carbonyl, and auto-clave methods. The most technologically advanced and simplest in terms of the equipment design turned out to be the chemical method of deposition from aqueous solutions. The particles were sprayed by a mixed argon-hydrogen jet in water at a distance of 140-150 mm.

Carbide powders are industrially produced by various methods for plasma spraying. The method of production substantially affects the structure of the particles and the surface morphology. The powders produced by reduction primarily consist of porous particles with a developed surface, and the powder particles produced by melting and high-temperature self-propagating synthesis (HSS) have a monolithic dense structure with sharp edges.

Electron microscopic investigations showed that, for all the aforementioned forms of cladding, the coating is deposited on the powders in the form of islands, which gradually fill up the whole surface of the particles, whereas, on porous particles, they also fill up the surfaces of the open pores. The amount of the cladding metal necessary to produce casings over the entire surface of the particles depends upon the density of the carbide, the method of its production (structure of the particles), and the size of the powder particles, and is equal to 15-35 wt. %. However, owing to its own island structure, the nickel casing does not form a monolithic layer and does not prevent the contact between the case and the surrounding medium (Fig. 1a). This may result in the oxidation of the particles already in the initial stages of the heating prior to the melting of the casing.

The causes for differences in the behavior of the clad casings prepared by various methods are not clear. Nickel casing is retained on the surface of the particles. It was determined by electron-microprobe analysis that the spheroidized particles of the coating are heated to melting by the nickel layers (Fig. 1b). We did not notice any effect of

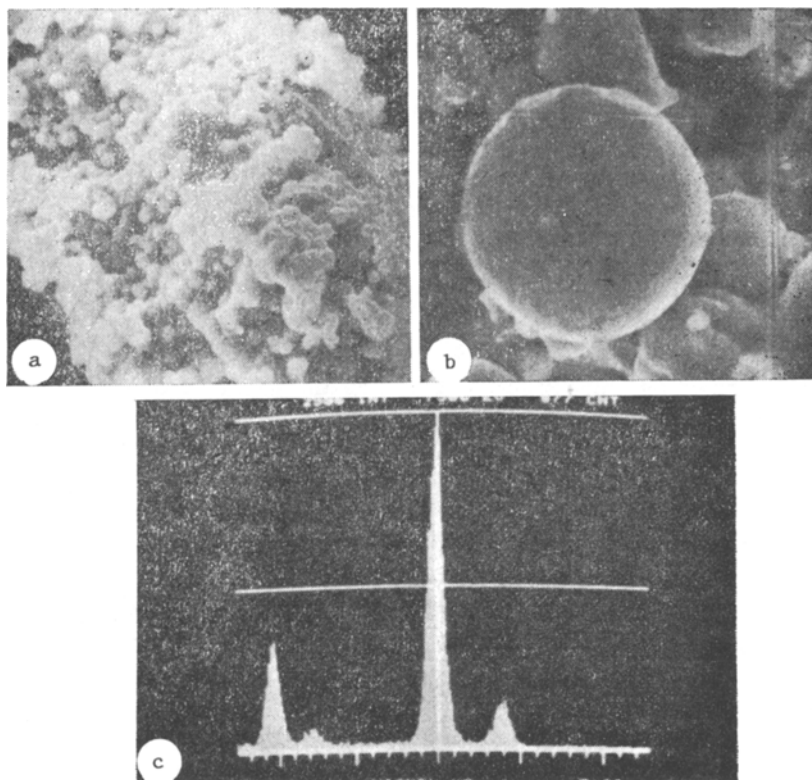


Fig. 1. External shape of the coating of clad particles before plasma spraying (a), the shape of the plasma-sprayed particles (b), and their surface composition (c).

rotation of the nickel casing with the formation of rollers or attachment of large drops of the metal cladding on the surface of the carbide particles.

Electron-microprobe analysis of the surface of all the investigated particles revealed the presence of a carbide core in the metal casing (Fig. 1c) but x-ray structural analysis of the phases in the plasma-sprayed particles revealed that they contained intermetallic phases and complex carbides. Hence, in spite of the short duration ($\sim 10^{-3}$ sec) of their migration to the substrate, the interaction between the clad metal and the core of the particles is sufficient to cause alloying of the matrix. Thus, independently of the cladding method, a molten layer of the casing metal and the carbide-core metal form on the surface of the particles during their heating until the cladding melts.

Carbon losses during the spraying were determined by chemically analyzing the sprayed particles. We compared the total carbon contents in the initial state as well as in the clad particles (Table 1). It was determined that the carbon losses were different upon spraying uncoated particles and increased in the sequence Cr_3C_2 -TiC-WC. The smallest losses were noted to occur in chromium carbide particles, which had a relatively low melting point. The nature of variation in the carbon losses indicates their relation to the barrier properties of the oxides formed on the surface of the particles upon spraying. In the case of cladding of powders, the largest carbon losses were found to occur for spraying of the tungsten carbide particles. These losses were somewhat less for titanium carbide particles and were very small for chromium carbide particles.

During the spraying of the clad particles accompanied by active interaction between the core and the casing, complex nickel-based oxides were formed on the surface. Thus, the effect of cladding upon carbon losses during the spraying of the carbides can be explained by the relation of the barrier properties of the oxides on the surface of the unclad and clad particles. This is supported by the sharp decrease in carbon losses during the spraying of clad chromium carbide powder, the casing of which was saturated with aluminum.

The absence of any substantial difference between the carbon losses during cladding by the various methods is explained by the closeness between the island structures of the

TABLE 1. Carbon Losses upon Plasma Spraying of Carbide Particles

Core material	Cladding method	Nickel content, wt. %	Total carbon content, %		Carbon loss, %	Particle size, μm
			initial value	after spraying		
Chromium carbide	—	—	12,59	10,3	18,2	40—80
	Chemical	30	8,4	6,5	22,6	40—80
	Autoclave	25	11,3	8,4	25,7	40—80
Titanium carbide	Chemical and aluminizing	—	9,9	9,2	7,1	40—80
	—	—	17,1	12,5	26,9	40—80
Tungsten carbide	Chemical	35	12,8	10,7	16,4	40—80
	—	—	3,3*	1,1	67,0	40—50
Tungsten carbide	Chemical	16	5,2	4,1	21,1	40—80
	Carbonyl	25	4,5	2,8	37,8	50

casing of particles in the initial states and its identical behavior during the spraying. The increase in the carbon losses during the cladding of tungsten carbide powder prepared by the carbonyl method may be due to its small particle size.

LITERATURE CITED

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