FORMATION OF DETONATION-DEPOSITED TUNGSTEN CARBIDE-BASE COATINGS

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Detonation-deposited VNm-15 coatings from mechanical mixtures of tungsten carbide and nickel have quite satisfactory operating characteristics, including fairly high wear resistance. However, long-time contact wear tests have shown the operating life of these coatings to be relatively short, apparently as a result of appreciable losses of tungsten carbide suffered by them during deposition. A chemical analysis of a VNm-15 coating applied by spray-deposition revealed that its nickel content had risen to 30-35 wt.%, i.e., that it had lost 15-20 wt.% of its tungsten carbide.

It would appear that the useful life of such a coating could be prolonged by decreasing its loss of tungsten carbide during deposition. In this connection, to discover the causes of the loss of tungsten carbide and find a method of decreasing it, an investigation was carried out into the mechanism of formation of these coatings, consisting of a series of experiments on the deposition, into water and onto glass, of nickel particles, a mechanical mixture of tungsten carbide and nickel (VNm-15), and tungsten carbide particles clad with nickel (VNc-15).

Examination of the condition of nickel particles sprayed into water revealed the presence of occasional spheroidized particles of size less than 6 μm. Nickel particles more than 6 μm in size had not undergone any noticeable changes. During the deposition of the VNm-15 mechanical mixture into water the same results were obtained with the nickel particles of the mixture. No spheroidized tungsten carbide particles were detected, but the tungsten carbide particle size had decreased considerably. Examinations of VNc-15 particles before and after spray-deposition into water (Fig. 1) showed that the nickel layers on the particles had not changed during the process.

Under the action of the detonation wave, clad tungsten carbide particles cracked, but their nickel shell prevented them from disintegrating. During the deposition of the mechanical mixture of tungsten carbide and nickel, the tungsten carbide particles, having no protective shells, apparently broke up.

Next, experiments were carried out on the deposition of the materials investigated onto glass. Deposition was performed under conditions ensuring minimum powder feed in one or two cycles. During deposition nickel particles were found to melt and spread on the glass surface (Fig. 2). Some drops were in the form of metal which had spread freely, while others had disintegrated on hitting the surface. Evidently, this was a result of differences in size between different particles and hence in the amounts of kinetic energy which they possessed. Now it is known that nickel experience practically no melting in the barrel of a detonation unit, and it can therefore be concluded that the nickel particles melted on hitting the base plate. The kinetic energy of some of the particles was so large that the resultant drops disintegrated on glass, forming splashes.

The deposition of the VNm-15 mechanical mixture onto glass was accompanied by slight chipping of the glass, which was not observed during the deposition of nickel. Examinations established that the chipping of glass was produced by the tungsten carbide particles, which did not melt during impact and did not take part in coating formation. In this case x-ray structural analysis revealed only traces of tungsten carbide on the glass surface. A similar situation arose during the deposition of VNc-15 particles onto glass, but the amount of tungsten carbide detected was much greater.

On the basis of these experiments calculations were made of particle temperatures and velocities at the instants of impact against the surface being coated. The assumption was made that at the instant of impact the whole kinetic energy of a particle is converted into heat. Nickel particles reaching the surface being coated melted, which was confirmed by results of metallographic examinations. From the equality of the kinetic energy of a nickel particle
Fig. 1. VNc-15 particles: a) starting; b) after spray-deposition into water.

Fig. 2. Fused nickel particles on glass surface.

Fig. 3. Variation of temperature of particles with their size.

Fig. 4. Microstructures of tungsten carbide-base coatings: a) VNm-15; b) VNc-15.

and the amount of heat required for melting it, we can find the velocity attained by particle as a result of the action of detonation products in the barrel of the unit on the batch of powder,

\[ v = \sqrt{\frac{2}{c} \left( t_m - t_{im} \right) + \lambda} \]

where \( c \) is the specific heat of nickel (J/kg·deg C); \( t_m \), melting point of nickel (deg C); \( t_{im} \), temperature of a nickel particle at the instant of impact against the base surface being coated (deg C); and \( \lambda \), latent heat of melting of nickel (J/kg).

To find the velocity of the particle, it is necessary first of all to determine in Eq. (1) its temperature at the instant of impact against the surface being coated. A calculation was therefore made of the thermal state of the particles, making the assumption that all the particles, irrespective of their size, remained in the detonation products for the same length of time.

Since in the experiments on the deposition of nickel into water the maximum diameter of the spheroidized particles was 6 \( \mu \)m, the amount of heat necessary for melting these particles can be found from the expression

\[ Q = m \left[ c \left( t_m - t_0 \right) + \lambda \right]. \]