Properties of Metal-Sprayed Coating Produced by Electric-Arc-Spraying Process

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The recent development in the field of metallizing (or metal-spraying) is the rapid use of arc pistols for spraying metals onto various surfaces both as a protection against corrosion and formation of scale as well as for rebuilding and repair work. The conventional gas-fired wire guns are progressively being substituted by arc spray guns, because there are intrinsic advantages in the arc spray process, and the qualities of deposits formed by it. The observations in this paper will be confined to sprayed deposits produced by wire type arc spray process only, and plasma-arc-spray techniques are not considered at this stage.

There are various parameters which affect the quality of arc sprayed layers, the important being the amperage, voltage, compressed air pressure and volume and nozzle distance. Before evaluating the deposits, it is necessary that these parameters are set optimum as per the recommendation of the manufacturer of the equipment.

Adherence

The most important characteristic of arc sprayed deposit is its firm adherence to the base material. The metallizing process is not welding or brazing, hence 100 percent metallurgical bond can not be expected. In metallizing literature, the bond between spray particles and the substrate as well as the bond between particle and particle has been referred to as a 'Physico-chemical' bond, and sometimes purely as a 'Mechanical Bond'. Either of the expressions does not give the true nature of spraying bond but it has, however, been recognized that the bond effected by arc metallizing is far stronger than that of gas metallizing. The main reasons for the better bond and layer strength are :—

(a) In arc spraying the metal is fused at high temperature—over 4000°C.

(b) There is higher air pressure which blasts the spray particles with a greater force.

(c) Apart from force, the particles travel to the surface more rapidly because high air pressure shortens the time required for the transportation of the particles from nozzle to the substrate. Laboratory tests have confirmed that the particles in the arc are projected at three times the velocity of gas sprayed ones.

Oxides

The oxide content in the arc sprayed deposit is also very low since there is no direct oxygen in the flame as in gas spraying. By using nitrogen gas the oxidation could be reduced still further. This is an important point as there are some engineering surface applications where oxidation has to be the minimum. In Germany, efforts have been made to arc spray in vacuum chambers to have coatings free of oxide. The oxidation is not disadvantageous from the point of view of strength of coating, since it is possible for the

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oxides to be even stronger than the material itself. It has, however, to be taken into account in protective coatings in liquid reagents.

Coating Strength

The tensile strength of arc sprayed coatings differs from metal to metal, the highest being in the case of aluminium where it is about two times greater than the corresponding value in gas sprayed coating. Dr. Ing. Steffens has found the adhesion of arc sprayed aluminium coatings to steel surface to be 190 kg/cm^2 against 95 kg/cm^2 for gas sprayed aluminium. The arc sprayed aluminium over steel substrate could be bent and pressed without risk of peeling off. This quality is progressively now exploited in as much as automatic production line plants have been set up in Czechoslovakia at Vitkovice Steel Works to apply aluminium spray coating of 200 to 300 micron thickness over a surface of 324000 sq. metres per year. The aluminium sprayed metal sheets are pressed and welded to form boxes of mine tubs. It is a great achievement and it could be predicted that in future more and more aluminium will be sprayed by arc guns and this material will be used in preference to zinc and other metals wherever such substitution could be possible.

The high strength of arc sprayed deposit is particularly advantageous when very heavy layers (10 to 15 mm) of steels are to be made, because here there is risk of cracking due to overheating, stress formation and shrinkage of sprayed material. On a sugar mill crusher roller, steel has been applied to the tune of 15 to 18 mm thickness and that too also by 0.1% carbon steel which is a high shrinkage metal. The weight of the crusher roller was 2 tons, length 15 ft. and diameter from 1 ft. to $2\frac{1}{2}$ ft. The metallizing of steel on the bearing area (2ft. $\times$ $1\frac{1}{2}$ft.) of this roller was completed in a remarkably short time i.e. one hour and ten minutes. One other metallizer reports having completed metallizing of 1000 crankshafts successfully by arc spray using high carbon steel wire. In gas spraying process, special precaution has to be taken while selecting the particular wire, because of shrinkage values. In arc spraying, elaborate caution may not be necessary and carbon steel wires have been used in place of 13% chrome steel (low shrink) in many a case without deterioration of quality of sprayed coatings.

The chemical tests of sprayed arc deposits have revealed that there is substantial burn off of some of the ingredients, specially carbon, silicon and manganese between 25% to 40%. This is why special metallizing wires are required to compensate for these losses ; otherwise the coatings will not be hard. Those steel wires which have given 60 RC hardness in gas spray could give only 50 RC in arc spray due to burn off of carbon and other elements. Low oxidation also tends to lower the hardness values.

Porosity

All sprayed coatings contain pores, some isolated and some interconnected. It is dependent upon nozzle distance, atomising air pressure, spraying angle and the diameter of the wire. In arc spray, the spraying particles are invariably bigger and coarser than those in gas spraying which, while increasing strength and bond properties of deposits, gives a surface finish more porous than that in gas metallized surface. In case of special service requirement of some jobs, such as hydraulic rams, it is advisable to apply gas spray coating above the arc sprayed deposits to obtain fine and very smooth finish. Some sealers have also been developed to fill up the porous structure of the sprayed deposits. At present, the manufacturers are giving much attention to this problem of porosity and it can be expected that shortly such arc spray guns will be designed which will make possible a surface finish comparable to that obtained by gas spray. It should, however, be noted that porosity is different to permeability—the latter depends upon the permeating agent such as the liquid or gas which may permeate the coating. A sufficiently thick sprayed coating will become practically impermeable to liquids or gases.

Pseudoalloys

Pseudoalloys can also be made by arc spraying by using two different metal wires ; both fuse at the point of their contact and produce an alloy of two metals. For production of bearing bushings, steel and bronze were arc sprayed to obtain the combination of hardness (due to steel) and sliding qualities (due to bronze). There are many other applications of this characteristic of arc spray but limited experiments have been made hitherto. S. Kumanov of Bulgaria has made some study on formation of pseudoalloys by changing the feed of wires, amperes, volts, nozzle tube angle and air supply. He concludes that such alloys could be produced to a limited extent as, after a point, there occurs deterioration of the melting condition and droplet formation of both wires.

Wear Resistance

The wear resistance qualities of sprayed coatings have been of interest to engineers. The modern view is that wear is a function of friction which is mainly influenced by whether the surface remains under lubrication or not. Resistance to wear is, therefore, a function of the retention of the oil film, rather than of the hardness properties of the metals themselves. A very hard, perfectly smooth surface will not retain the necessary oil film. In the case of a metal sprayed surface, as stated earlier, there is a face containing minute pores which hold oil very tenaciously and such a surface should wear even better than a new metal face. Tests have been carried out on sprayed steel shaft running in white metal bearings. Unlike the hardened steel shaft, which seized in about three hours after the oil supply had been cut off, the sprayed steel shaft ran for 22½ hours before seizure took place, and then it was much more gradual. Moreover, after one hour's rest, it ran again for another three hours before seizing.

The economics of arc sprayed deposits need mention. First, there is no need of expensive bonding coats of Molybdenum or Nickel-Aluminide. Fuel cost is also drastically lower in comparison to gas spraying. Thirdly heavier coatings are made possible. Again the spraying rate is also very high. 10 to 18 kg. of steels and 50 to 80 kg. of zinc could be sprayed per hour. The comparative cost of arc spraying installation is, of course, high—about Rs. 32,000/- and dust extraction system also costs additionally Rs. 5,000 to Rs. 10,000. Part of the arc spraying equipment can also be used for welding, as the power source is either a rectifier or welding motor generator. The low costs of arc sprayed deposits and their superior qualities are attracting the attention of engineers. It can be predicted that the development of spraying technology will follow the same path as from gas to arc welding.

References

1. 'METAL SPRAYING AND FLAME DEPOSITION OF CERAMICS & PLASTICS' BY W. E. BALLARD.

2. 'WEAR RESISTANCE AND INTERNAL STRESS EVALUATION IN GAS AND ARC SPRAYED DEPOSITS' by Stanton—A paper presented in the 6th International Metal Spraying Conference 1970.

3. 'ARC SPRAYING OF PSEUDOALLOYS' by S. Kumanov—(6th International Metal Spraying Conference 1970).

4. 'ELECTRIC ARC METALLIZATION—RECENT DEVELOPMENTS AND EXPERIENCE'—by Gunter Hessler (3rd International Metal Spraying Conference 1963).