THE SPRAYING OF COATINGS BY SUPERSONIC METALLIZATION

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Abstract

A technology and a specialized equipment complex based on a supersonic arc spraying gun, where a supersonic stream of combustion products of hydrocarbon-gas (HC-gas)[1] with air is used as an atomizing gas, have been developed. Durable and safe work of coated parts functioning under conditions of intensive loading is determined (except general requirements to coatings: wear resistance, hardness, adhesion to a large extent by the fatigue strength and the stability of the properties of coatings. New possibilities for satisfying all the requirements to coatings on parts type arc opened up by a high speed spraying of wire. This is provided at the expanse of raising the kinetic energy of particles under spray, increase of their concentration in a metal stream, lowering of the spread of parameters (velocity, temperature, sizes) in the vicinity of a substrate. This, in its turn, determines the increase of adhesive and cohesive strength of a coating, the decrease of oxidizability, the improvement of stability and reproducibility of its properties. The results of the investigations of the influence of the variable parameters of the process on the listed above properties of coatings are presented. A procedure of computer evaluation of the degree of the rcproducibilily of structural peculiarities of sprayed coatings is worked out. An industrial installation and examples of its use for the strengthening of automobile parts are described.

LIMITATIONS OF METALLIZATION PROCESS are mainly, due to low strength and inadequate reproducibility of coating properties. Successful development of modern problems of new materials developments are connected with increase of velocity of particles sprayed.

Improvement of Quality and Oxidizability Reduction of Coatings as a Result of Equipment Advancement

Higher particles velocity is obtained with the use of supersonic flow. Formation of the flow with optimum parameters in supersonic stream has its features. The most important features in respect to the installations.

Slightly expanded supersonic stream of hot product of HC-gases and air combustion flowing out from the sound nozzle is used for spraying wires melted by electric arc. Gas dynamics analysis found that the side wire produces most of the flow disturbance. The area of wind shadow is formed down the flow behind the wire. Radial changes of dynamic head in the stream cross-section at the distances 2, 7, 12, 22 22 mm from the point, where the central and lateral wires meet each other are presented It can be seen by comparing that the flow process in the supersonic stream having wires as obstacles changes depending on burner gun operation mode. At $\alpha = 0.9$ in contrast to $\alpha = 1, 2$ the flow converges behind the lateral wire.

Dispersed particles scattering in high velocity flow depends on direction of averaged velocity" vector along the particles trajectory and turbulence parameters. direction of the averaged velocity vector provides compression of the metal particles flow and the level of turbulent pulsations is reduced at transonic velocity resulting in the flow laminarization. These two factors are critical for dispersion phase reduction, lower angle of opening of metal particles flow and straggling of particles velocity.

High degree of oxidization is one of the features of coatings obtained with the use of electric arc metallization This fact is often considered as a negative one. Coatings which are formed with particles being oxidized also feature high level of porosity and low adhesion of coating with substrate. The main reason of particles oxidization is their interaction with oxygen in the area of electric arcing between two

electrode wires.

Nitrogen and argon arc used as atomizing gas in order to reduce oxygen amount in the area of material melting, but this procedure didn't prove to be applicable in industry. There arc, mainly, two reasons of this. First, the gases are expensive, which makes spray coaling process much more expensive taking into consideration high amounts of the gases required for spraying. Secondly, smooth spraying can be performed only with increase of arc voltage.

Another method to lessen the effect of oxygen on melted metal is to make it bonded with HC-gases (preferably with methane). To this end, combustible gases should be blended to the spraying air. The promising use of this sort of gas-air mixture as a spraying gas can be estimated with the use of analysis of material oxidizabilily in the area of its dispersion. The most active metal-gases interaction takes place in the dispersion area due to high temperatures.

Qualitative analysis of particles oxidizability can be obtained from thermodynamics equilibrium calculations of material-gaseous atmosphere systems. The results of calculations of non-ferrous metal — H—0—N—C systems, where H, 0, N, C are components of air and combustible gas, indicate that particles oxidizability is not observed when sprayed by air-gas mixture with ratio "natural gas : air mixture with the ratio "natural gas : air" - 1: 8. When performing spray coating procedure, a group of iron-based materials are preferably used. This makes the analysis of the materials oxidizabilily of special interest. The calculations of thermodynamics equilibrium condition of the "FeC – H – N – O - C" system were computed with the natural gas content of the gas-air mixture at the range of 0—30 %. Further increase of methane amount used in the spraying is not reasonable economically. The analysis of the calculations indicated that actually is not possible to provide total protection of metal against oxidization shows changes of iron oxides content of the system being analyzed depending on natural 'gas content or the gas air mixture.

Process of mixing should be taken into consideration when electric-arc spraying. The tests indicated that change pattern or oxides content of coaling is similar to the one shown in the figure for the case of the mixture pre burning and further spraying with the combustion products. Moreover, mechanical mixing of gas and air even gives a rise in the amount of oxidized sprayed particles by 9—10 %. Spray coating with combustion products of gas—air mixture having 14—15 % of natural gas may be considered acceptable economically. Under these conditions the particles oxidizability reduces by 35--40 % as compared with the traditional spraying with compressed air. The second factor promoting decrease of spray coated material oxidization in supersonic flow is to lower the contact time of melted particles with atmosphere by increasing their velocity

Computer Evaluation at Structural Features of Coatings

Qualitative analysis of structural features of coatings has been carried out. The objective of the analysis is to provide optimum conditions for spray coaling onto the desired coating structure, estimate homogeneity of coaling on various areas of a piece, and degree of a structure rcproducibiHty of a coating. As an example, the given are the analysis data of 8 micro-sections of iron based flux-cored electrode coatings, which were obtained with the use of supersonic electric-arc metallization process.

Mathematical processing of spray coatings microseclions with numbers assigned by 0—15 brightness scale was to obtain binary, two interval (0—7, 8—15) histograms, where the value of 15 corresponded to metal phase. The number of the values obtained is a total, averaged throughout the whole pattern characteristic of coating, which determines the degree of change of phase composition and porosity.

Development of Industrial Installation

The system which provides blowing process of a stabilized electric arc with hot combustion products is taken as a basis when developing a new installation for spray coaling using electric arc metallization. The electric arc is located along the gas flow between two melting wires. The speed of blowing exceeds sound velocity. This system provides high stability of arc burning (due to its orientation along the gas flow) and, consequently, heat transfer to melting electrodes: high rate of acceleration and fragmentation of particles of melted metal, protection of the particles in flight against oxidization, reduction of the amount of evaporated material (owning to formation of two-phase flow by high speed stream of combustion products). The installation consists of: arc spray gun with a built — in supersonic burner gun operated on a mixture of air and natural gas, gas chamber, wire feeder with D. C. actuator , arc power supply.

Performances:

Operating voltage of arc (V)	36—38
Arc electric current (A)	150—400
Steel spraying rate (kg/h)	8—20
Diameter of wire sprayed (mm)	1. 2—2. 0
Gas pressure at burner inlet (mpa)	0. 5—0. 6
Total gases consumption (nm3/h)	35—40
Natural gas content of gas air mixture (%)	7—15
Pressure of cooling water (MPa)	0. 2—0. 3

The level of electric current is set by speed of delivery of the central electrode with the given arc voltage. With equal currents, the speed depends on polarity of applied voltage, under direct polarity the speed is higher

The speed of lateral electrode melting does not depend on polarity, and it is always higher than that of the central electrode.

The angle of opening is 6—10 when supersonic burner operates to spray wire without any additional steps for focusing two-phase flow.

Conclusion

The procedure of qualitative classification of spray coating structures based on computer processing of patterns, has been developed.

The new installation designed to obtain qualitative coaling, better adhesion strength and reduced porosity has been developed. Thus, another easily adjustable parameter — combustible gas and air ratio - as compared with the traditional one has been found. This extends technological potentialities of electric arc metallizing process and provides target control of coating structure.