DEFECTS IN METAL DURING PLASMA AND TIG SURFACING (REVIEW)

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Abstract. In the process of exploitation, such property of articles as working capacity most often depends on the quality and condition of the surface layer. Therefore, a complex approach that includes a multifactorial effect on phase formation and structure formation in metal systems with the use of modern equipment is of particular relevance. The quality of products, determined by a number of its mechanical properties, can be significantly reduced by the occurrence and spreading of defects in products in surfacing, welding and additive technologies that are associated with the use of highly concentrated energy sources, which is a significant problem. Preventing the occurrence of defects during surfacing is a priority and urgent task in modern machine-building production. The solution to this problem can be the selection of optimal deposition modes in accordance with the requirements for the quality of the welded layer, the mechanical properties of the material of the parts and the quality of the products as a whole.

1. The influence technologies of surfacing on the properties of materials and on the quality of products.

At present, the development of machine building is closely connected with the development of new materials, the introduction of innovative technologies, including additive technologies for obtaining new products, technologies for applying functional coatings and restoring products [1].

The quality of products, determined by a number of its mechanical properties, can be significantly reduced by the occurrence and spreading of defects in products when surfacing, welding and additive technologies that are associated with the use of highly concentrated energy sources, which is a significant problem [2-4].

Only if the requirements for welds are observed, regulating their mechanical characteristics, and with the optimal welding conditions, it can be ensured that the metal structure will last as long and efficiently as required.

Surfacing is one of the methods for producing laminates with changing properties and allows the creation of high-strength products of sufficiently low cost while ensuring a high durability under operating conditions. When depositing dissimilar materials, they tend to reduce the share of the main material in the deposited layer. The weight of the weld metal at the same time is 2-6% of the mass of the part as a whole, but the performance of such a part increases many times. The wide use of bimetallic structures obtained by surfacing is explained not only by technological advantages, but also by economic ones [3, 4].
The need to obtain bimetallic materials arises in the manufacture of a wide variety of products: chemical engineering vessels, aircraft industry, in the construction industry, in electrical engineering and instrument making, in the production of consumer goods.

The main defects that arise during surfacing include cracks in the welded layer and in the fusion zone with the base metal of the part, pores and shells, slag inclusions and others [5].

Defects can be either external, which come to the surface of surfacing, and internal, which are located inside the deposited layer. External defects can be detected relatively easily by examining the surfacing, using magnetic flaw detection, etc. Detection of internal defects is a complex and not always solvable problem. In this case, X-ray or gamma rays are used for transmission, by magnetic and ultrasonic flaw detection, metallographic studies of macro- and microsections, etc.

Cracks are the most dangerous defect of surfacing, because under the influence of rapidly changing loads or thermal vibrations they can develop, i.e., increase in size, which can lead to premature failure of the part. Therefore, control over the detection of cracks should be given very serious attention.

When depositing dissimilar materials, the boundary layer is of greatest interest from the standpoint of structural strength. The presence of such a layer with increased hardness and, obviously, a lower relaxation capacity in the structure can serve as a prerequisite for the appearance of cracks already in the process of crystallization. When surfacing is characterized by a sharp increase in microhardness in the boundary layer (Figures 1, 2). For example, with a plasma surfacing of a nickel alloy, the microhardness increases to 440-450 HV, which is practically a twofold increase in comparison with the basic microhardness of the material. With argon-arc surfacing, the increase in microhardness is lower - up to 400HV [6,7].

![Figure 1. Distribution of microhardness in the depth of metal during plasma surfacing on nickel alloy EP 648 with wire EP 609, x300 [6,7]](image-url)
The formation of a transition layer with an increased microhardness up to 1.5 - 2 times in comparison with the base can lead to the formation of hot cracks (Figure 3).

The change in microhardness can be observed when surfacing a layer based on copper. In Figure 4 shows the microhardness of the deposited layer. On average, the microhardness of the deposited layer is 140 HV 0.050, which is much higher than the hardness of copper (55-60 HB) and slightly lower
than the microhardness of Fe-Ni alloy (190-200 HV 0.050). In general, a slight decrease in microhardness is observed in the depth of the deposited layer [8].

![Graph showing distribution of microhardness over the depth of the copper-based deposited layer](image)

**Figure 4.** Distribution of microhardness over the depth of the copper-based deposited layer [8]

### 2. Defects arising from argon-arc and plasma surfacing

Wear resistance and strength of the weld metal reduce pores, which are less dangerous defect than cracks, but their presence makes the metal leaky and permeable to gases and liquids, which reduces the quality of the product.

At plasma surfacing of steel 30CrMnSiN, there is a probability of appearance of pores with a size of 5-10 microns, which is shown by metallographic studies (Figure 5).

![Microsections with pores](image)

**Figure 5.** Fragments of microsections with pores (plasma surfacing, steel 30CrMnSiN), × 300
The formation of such defects can be associated with a large gas saturation and rapid solidification of the molten metal. When the weld metal is cooled, the solubility of the gases in it decreases, as a result of which some of the gases remain in the weld metal in the form of pores. For example, an elevated carbon content in the base metal or welding material may cause pores to appear, since carbon is burned out during the surfacing process and pores filled with carbon dioxide and carbon monoxide appear in the weld metal.

Single pores do not reduce the vibrational strength of the welded part. With an increase in the number of pores, the endurance limit drops insignificantly, however, in the presence of a chain of pores, its decrease is already significant.

Slag inclusions are more often observed with multilayer surfacing. They are the result of surfacing by undeleted or poorly removed slag crust from the previous layers. In this case, the slag does not have time to melt and float to the surface of the metal, as a result of which it remains in the metal in the form of slag inclusions. With multi-layer plasma surfacing of steel 04Cr19Ni9 on the currents of direct and reverse polarity, the appearance of slag inclusions at the boundaries of layers was noted (Figure 6).

![Figure 6. Non-metallic inclusions for multilayer plasma surfacing of steel 04Cr19Ni9: a - direct polarity of current, b - reverse polarity of current, × 300](image)

However, it is established that the plasma effect leads to an increase in the purity of the surfacing for nonmetallic inclusions of the oxide and sulphide groups. Figure 7 shows a typical distribution of inclusions in size groups in the fusion zones for plasma and argon-arc surfacing. It was revealed that with argon-arc surfacing the share of large inclusions of 9-10 size groups (20 μm and higher) grows, the largest accumulation of inclusions is in the overheating zone. On average, the level of metal contamination with argon-arc surfacing is higher by 20-30% compared to the metal of the plasma surfacing, regardless of the current intensity and polarity [6, 9].
Preventing the occurrence of defects in surfacing is a priority and urgent task in modern machine-building production, using innovative technologies and equipment in the production of new products and the restoration of parts. The solution to this problem can be the selection of optimal deposition modes in accordance with the requirements for the quality of the welded layer, the mechanical properties of the material of the parts and the quality of the products as a whole.

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