Morphological analysis of galvanized coating applied under vibrowave process system conditions

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Abstract. The article presents the morphological research results of galvanized coating applied to the metal surface in the course of mechanical and chemical synthesis realized under vibrowave process system conditions. The paper reveals the specifics of the coating morphology, its activating role in free-moving indentors formed under the impact of low-frequency vibrations and its positive influence on the operational performance of the part surface layer. The advantages of this galvanized coating application method are presented in comparison with conventional methods.

1. Introduction

Applying galvanized coating to the metal surface under vibrowave process system conditions is a complicated process; it is a result of the combined influence of a mechanical component and a chemical reaction. Applying coating by a mechanical and chemical method helps to achieve one of the surface quality parameters: absence of the hydrogen-charged layer.

Vast technological possibilities of vibrowave process systems present the most efficient means to obtain quality coatings for different functional use as regards operational performance. The research results show that these properties appear due to the morphological specifics of the galvanized coating applied to the metal surface during activating a vibrowave influence of free-moving indentors in the form of spherical bodies.

2. Research results

The coating was applied using a vibration shaker with a 10 l vibration chamber. Porcelain and glass balls of 5…10 mm in diameter served as a working medium. Processing regimes were changed within the following limits: vibration amplitude of 2 to 5 mm, vibration frequency of 16 to 33 Hz. Samples were made of steel grade 3, 20 and 40 with 20 sq.sm sample surface area subjected to coating. The composition of the galvanized coating was the following: 250 g/l of zinc chloride and 100 g/l of zinc powder.

The galvanized coating density applied to the metal surface was defined by the density of plastic impressions formed on the surface as a result of a shock pulse input by working medium indentors. The area of zinc impressions and the distance between them was measured by the MHM-7 metallographic microscope. For quantity estimation of zinc coating density (N) the following ratio was used:
where \( S_0 \) is a total area of plastic impressions, \( S \) is a sample area under investigation.

It has been found that in case of a 50% load of the work vibrochamber with porcelain indentors of 5 to 10 mm in diameter, the impression area is \( 1 \times 10^5 \) sq. \( \mu \text{m} \), an average distance between the impressions does not exceed 250 \( \mu \text{m} \); in case of an 80% load the impression area is \( 0.225 \times 10^5 \) sq. \( \mu \text{m} \) and an average distance between the impressions is 50 \( \mu \text{m} \). A 30 minute change in processing timing (Figure 1) results in the increased galvanized coating density. Subsequent 30 minutes of processing contribute to the increase of structured bodies dimensions and elimination of sharp interfaces between plastic impressions.

Carbon steel samples were used to study a micro/nanostructure of the zinc coating surface. The given area of the coating was investigated layer by layer from top to bottom, which enabled definition of the crystal dimensions, their form and bond type [1]. The research results are mentioned below. The coating has a chaotically oriented surface structure, where the open areas of the galvanized coating represent \( \approx 100 \mu \text{m} \). (Figure 2a). The scale of 10 \( \mu \text{m} \) (Figure 2b) shows that 2...5 \( \mu \text{m} \) structures are formed at the interference of large surface areas (marked up area). The surface analysis in a 2 \( \mu \text{m} \) scale (Figure 2c) reveals the presence of a transitional area in the structure composed of 1 \( \mu \text{m} \) crystals (marked up by an arrow). An increase of this area to a 1\( \mu \text{m} \) scale displayed the change of morphology and appearance of bonds on top of the crystals in the form of 0.2...0.5 \( \mu \text{m} \) filaments. The further coating surface study in the scale of 200 nm (figure 2d) helped to define the length of intercrystalline bonds and the dimensions of separate crystal elements up to 100 nm. A zinc coating surface morphology illustrated in figure 2f in the scale of 100 nm indicates the type of intercrystalline bonds and separate coating crystals which can be seen on the background in the form of light oval areas.
Figure 2. A zinc coating morphology formed under vibration process system conditions \((T = 60\text{ min}, A = 3\text{ mm})\), for different scales of study:

a) 100 \(\mu\text{m},\) b) 10 \(\mu\text{m},\) c) 2 \(\mu\text{m},\) d) 1 \(\mu\text{m},\) e) 200 nm, f) 100 nm.

In order to clarify the dimensions of zinc coating crystals and intercrystalline bonds between them, the specimen stage with a sample was positioned at an angle of 30°. Figure 3a features coating structural components in the scale of 2 \(\mu\text{m}\) representing a combination of 1 to 2 \(\mu\text{m}\) crystal contrast peaks and dark cavity areas of up to 2 \(\mu\text{m}\) width between them. The biggest crystal is indicated by an arrow in figure 3b in the scale of 1 \(\mu\text{m}\) which has an oval shape (2.3 \(\mu\text{m}\) in a transversal diameter; 2.9 \(\mu\text{m}\) in a horizontal diameter) and represents an upper coating layer. If the scale is enlarged to 200 nm (Figure 3c), the surface morphology can be seen, which was in the background (cavities) in the previous pictures.

The analysis demonstrates that crystal dimensions are within 100 \(\text{nm}\) and 3 \(\mu\text{m};\) the cavities between them are within the same limit. Crystal bond filaments have a dimension of 10 \(\text{nm} \) up to 100 \(\text{nm}\) and are located not only on the crystal surface, but also occupy an intercrystalline space giving additional properties to the coating (corrosion resistance), which implies zinc powder sedimentation in the course of zinc ions reduction.

Figure 3. A zinc coating surface morphology derived along with a sample positioned at an angle of 30° and the following scale of magnification: a) 2 \(\mu\text{m},\) b) 1 \(\mu\text{m},\) c) 200 nm.
The following positioning of zinc crystals in the coating can be acquired only as a result of shock pulse input of free-moving indentors in vibrowave process systems. The morphological research illustrates that the mechanical and chemical synthesis coating contains micro/nanostructured zinc particles in the form of circular shape flakes. A plate-like shape of zinc flakes provides the possibility to decrease the thickness of galvanized coating while preserving the adequate protection. The combination of micro and nanoelements comprising the coating gives high operational surface properties.

3. Conclusion
The performed research, as well as the acquired experience of the galvanized coating practical application allow for the following conclusion:

1. The galvanized coating applied under vibrowave process system conditions possesses a number of advantages, such as the absence of a hydrogen-charged layer, low porosity and high adhesion strength.

2. The coating application technology does not require special equipment, facilities, highly qualified specialists and special waste treatment and recovery facilities.

3. Using this way of the galvanized coating application is appropriate for parts lacking deep openings, as well as for protective and decoration solutions.

References
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