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NEW SOLUTION FOR MANUFACTURING COATING ROLLS USED IN INDUSTRY

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The development of composite materials and related design and their manufacturing technologies is one of the most important advances in the history of materials technology. Composites are multifunctional materials with unprecedented mechanical and physical properties that can be adapted to meet the demands of an increasingly diverse application. Most composite materials have special properties such as high resistance to wear, corrosion, and exposure to high temperatures. The paper presents a technology to improve the mechanical and adhesion properties using ultrasonic deposition in ultrasonic field with a vibration frequency of 28Khz. The resin used for deposition was improved using ZnO nanoparticles to increase corrosion resistance inclusively.

Keywords: materials composite, resin, ultrasonic, coatings, rolls

1. Introduction

One of the successful applications of composite materials consists in the manufacture of cylinders with different applications, such as the brake cylinders used in the brake stands in the Technical Periodic Inspection (TPI) stations, the cylinders used in driving conveyor belts in various industries, but especially in the extractive sector. These cylinders ensure great adhesion of the surfaces that come into contact with them by successively depositing three layers of material.

Specific literature shows that epoxy composites tend to be brittle due to their high crosslinking density, resulting in low resistance to crack initiation and propagation [3]. Epoxy resins are highly versatile and essential in modern materials, offering strong adhesion to a wide range of substrates, including wood, stone, fibers, metals, ceramics, and plastics [1,2,6,8,7,9]. Hyde and Compton [4] discuss

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the role of ultrasound in the electrodeposition of metals. Their findings show that ultrasonic waves can refine microstructures and improve coating uniformity, which has significant implications for improving the quality of metal coatings. The classical techniques used today involve very lengthy manufacturing processes, slowing down the technological flow. To reduce the fabrication time, we propose a new method based on the use of resin enriched with ZnO nanoparticles, deposited in ultrasonic field.

Tudela et al. [5] examine the use of ultrasound in the electrodeposition of composite coatings with embedded particles. Their research demonstrates that ultrasonic-assisted deposition results in better adhesion and a more uniform distribution of particles within the coatings. The characteristics and technology of making these are presented in the present paper.

2. Working methodology

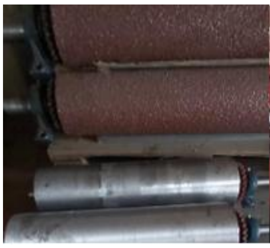
The first layer consists of depositing on the surface of a metal cylinder that was previously processed by turning to a roughness of approximately 100 mm the first layer of resin + hardener mixture over which the first layer of quartos sand granules is placed manually The two containers containing the resin and the hardener are shown in Fig. 1. The thickness of the first mixture layer is approximately 0.4 mm. The resin and the hardener used in the practical execution of the brake cylinders at the manufacturer are of the ***Top epoxy primer*** type, component A and component B produced by ***Europlastic S.R.L.*** The proportion in which the two components are mixed is 2:1.

Fig 1 The resin and the hardener used in the manufacture of brake cylinders are currently used by the manufacturer

Following the research carried out; to improve the mechanical properties, adhesion and corrosion, the resin was enhanced with ZnO nanoparticles, homogenized in ultrasonic field. The uniform incorporation of nanofillers, particularly ZnO, into epoxy resin matrices can greatly improve the mechanical, thermal, and electrical properties of the material. As an alternative mixing technique, ultrasound energy has been shown to be effective in dispersing ZnO fillers throughout the epoxy resin.

In Fig. 2, two metal cylinders on which the composite structure will be made are shown at the bottom. Fig. 2b shows four cylinders on which the first layer of resin + hardener mixture was deposited and then the first layer of quartz sand. Quarto sand has dimensions of 1, 2, and 3 mm. To permanently maintain the cylindrical shape of the composite structure so that there is no leakage of the resin still in a liquid state, the cylinders are rotated continuously for approximately t1 = 8 hours. Precisely this sufficiently long time, as well as sometimes the quality of the final product, constitutes the problems that must be solved by this new method of introducing ultrasonic vibrations into the structure of the composite being made.

As can also be seen in Fig. 2 b, the red light indicates the permanent heating that takes place in the room where the brake cylinders are produced. This heating is necessary to speed up the solidification process, heating which, however, raises the final costs of the obtained product.




a b

c

Fig. 2 Realization of the deposition of the first layer of the composite structure

The second layer of the composite structure begins to be created after approximately t_2 = 8 hours, during which the first layer has solidified. Its realization consists in depositing, manually, the mixture of resin + hardener in the proportion of 2:1, just as in the case of the first layer. This deposition is carried out until the mixture reaches almost the level of the granules deposited in the first layer. At this moment, any gaps that may appear in the first layer are plugged. After this deposition, the second layer of square sand is spread, with the same dimensions of

1, 2, and 3 mm. Fig. 3 shows an image of the construction of the second layer. On the left side of it three cylinders are presented in which the second deposit is made.

Fig. 3 Presentation of the realization of the second layer of the composite structure

At the time, the composite structure made in this way had an average height h = 5...6 mm. Next, the solidification process begins for approximately another time t = 8 hours, during which the cylinders are continuously rotated.

The third deposition of resin + hardener mixture, Fig. 4, is realized after the time t_2 = 8 hours of the previous stage. For this deposition, a dye is also used which will give a red color to the brake cylinders. At this moment the structure is solid, but it is necessary to fill all the gaps between the grains of sand. Thus, in this stage, a third layer of resin mixture + hardener will be deposited up to a height where only the most prominent tips of the quartz grains remain in relief. For this stage, a solidification time of the third layer of resin and hardener is also required, of approximately t_3 = 8 hours.

Fig. 4 Depositing the third layer of resin + hardener mixture

As it can be seen, the total time required to obtain a composite structure under the known conditions is approximately T = 24 hours. This time quite long and generally requires the permanent presence of human operators to supervise the entire process, which constitutes another important problem, quite difficult to fulfill in the technological conditions of the producer, at present.

The second and very important problem is that preventing defects that may appear during the operation of the cylinders. As is known, they run in difficult working conditions, with large forces and moments that act throughout their operation. Thus, Fig. 5 shows two types of brake cylinder damage. Fig. 5 a show the damage due to excessive and premature wear, and Fig. 5 b shows the delamination-exfoliation of the composite layers between them as well as from the metal support surface.

a b c

Fig 5. Damage of brake cylinders: a – through excessive wear; b – by delamination-exfoliation; c – the heated chamber for making the brake cylinders

In order to eliminate the deficiencies presented, resulting from the use of the classic technology of obtaining composite structures for the production of brake cylinders, a new technology is proposed that is based on all the technical stages presented previously, but which comes additionally with the introduction of a vibration field in the ultrasonic field and namely 18 KHz.....100 KHz. The problem of creating an ultrasonic system is quite complicated because in this field knowledge is needed from several scientific areas such as materials science and engineering, electrotechnics and the field of vibrations. Since in vibration engineering, it was found that each system has its modes and frequencies of vibration, there is an absolute necessity to design the entire studied assembly so that it works optimally.

For this, almost every application in the field of ultrasound is individualized and follows the design of the ultrasonic system at certain vibration frequencies in order to obtain a high efficiency of functions. If the system does not "work" at certain frequencies, it does not provide enough energy to contribute to the optimization of certain processes.

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Currently, the methodology for making cylinders from the composite structure, deposited on a metallic cylindrical surface, consists of several steps described below. In the first of these, a surface with a roughness of approximately 150 microns will be created on the surface of the metallic cylinder by turning. This fact contributes to a better adhesion between the first layer of resin and the metal surface. However, as it can be seen from Fig. 5, this fact is not enough because many times the layers of composite material exfoliate. In the second stage, the first layer of resin and hardener mixture is deposited, on top of which the particles of quartz sand with sizes between 2...3 mm are placed.

For this first technological step, a cross-linking time of approximately 9 hours corresponds. The ultrasonic activation of the metal support has the main purpose of reducing this rather long solidification time and, very importantly, increasing the adhesion between the resin and the metal surface on the one hand and on the other hand increasing the adhesion between the resin and the sand particles. The reduction of this solidification time is approximately 28%, which means solidification takes place in approximately 6 hours. In the third step of the process of making the brake cylinders, after the solidification of the first deposited layer, the second layer of resin and hardener is deposited, followed by the deposit of quartz sand. As in the case of depositing the first layer, the solidification time is still approximately 9 hours, a long time considering the need to obtain a higher productivity.

To reduce this time, we will intervene, as in the case of the first layer with the ultrasonic activation that takes place every 15 min for a time of approximately 2 minutes. The working time of approximately 2 minutes was determined experimentally considering the fact that after this period the ultrasonic transducer began to heat up excessively. The vibration frequency used in the experiments is f = 20346 Hz, the frequency determined by the FEM method. As can be seen from Fig. 6, the tip of the ultrasonic energy concentrator achieves a maximum vibration amplitude along the OZ axis. Determining the optimal vibration frequency involved the FEM method because it is very difficult to perform multiple tests, different frequencies that correspond to the proposed purpose, namely, to obtain useful vibrations of the tip of the ultrasonic energy concentrator.

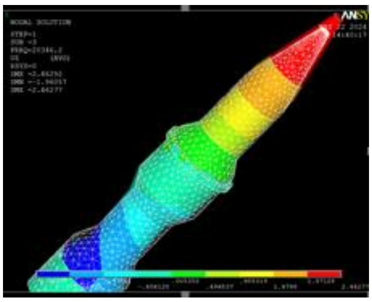

Fig. 6. Determination of the vibration frequency of the ultrasonic system f = 20346 Hz by the finite element method

To validate the deposition method in the ultrasonic field, several bending tests of a specimen made according to the new technology were carried out, where it was possible to observe how this deposition underwent exfoliation only after extremely strong deformation, which in practical reality cannot occur. Fig. 7 shows the result of this bending test.

Fig. 5. Bending test for the validation of the deposition technology in the ultrasonic field

3. Conclusions

Under the same technological conditions, two samples were analyzed: the first sample was solidified naturally, and the second sample was mounted in the ultrasonic system designed and built under the conditions of its application, at the frequency f = 28 Khz and with a current consumption I = 0.8 A. Thus, for the first situation, a solidification was found in approximately 9 hours, while for the sample solidified in the ultrasonic field, the time was approximately 6.5 hours. The manufacturing time reduction for this situation is approximately 28%. If an average is made of the reduction in manufacturing time, a reduction of 27% is found, which for this first series of experiments is very satisfactory.

We used an innovative solution regarding ZnO–epoxy composites with suitable mechanical properties, high adhesion strength, and good corrosion resistance. The final properties of ZnO–epoxy composites depend on several factors, such as the type and contents of nanofillers, the epoxy resin type, curing agent, and preparation methods.

In conclusion, the resin presented above, used in operating conditions, deposited by ultrasound technology has a lifespan 5 times longer than the usual resin deposited by classical methods, in the conditions that the production cost has not increased significantly by 20%.

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