Analysis of design solutions for galvanizing of small parts of ferrous metals in bulk

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Abstract. In this paper, we present the results of engineering development of a zinc plating plant for small parts of ferrous metals in bulk. The analysis of galvanizing methods for small details of ferrous metals is carried out. The technology of zincing small parts of ferrous metals in bulk is offered, calculations on sizing of the plant’s constructive elements are carried out and an electronic model of the plant is developed. Based on the electronic model and drawings, an experimental sample of the plant is assembled. Testing of the plant on the example of producing a batch of various small parts showed its high efficiency and prospects for its application to the whole class of products made of ferrous metals.

1. Introduction

Currently, galvanizing is the most widely implemented coating for anti-corrosion protection of ferrous metals. This is due to the fact that hot-dip galvanizing and plating have virtually no competitors due to the combination of economic, environmental, technological, physical and chemical factors.

Galvanization (plating) is the process of applying a thin layer of zinc to the surface of metal products in an electrolyte solution. In the process of electrolysis, zinc dissolves and its ions with a positive potential settle on the surface of the base metal to form a layer with the thickness of 4 to 20 microns, highly accurately repeating the contours of the product. The coating created by zinc plating is particularly fine and smooth [1-4].

Zinc plating is performed by electrolysis with a consumable anode. A cathode, as in all electroplating of metals, is a treated work piece, and an anode - plates of pure zinc placed in the plant to ensure smooth flow of anions to the surface. In general, the main reagents in the electrolyte are zinc sulfate and chloride, as well as zinc fluoroborate. To improve the parameters of galvanizing, sodium, potassium and aluminum salts are also introduced into the solution. The deposition rate and the maximum thickness of the zinc layer are regulated by the current density, which depends on the composition of the galvanic solution and its temperature. Based on the method of coating, galvanizing is divided into: hot-dip, cold, gas-thermal and thermal diffusion.
Galvanized parts can be bolts, screws, nuts, washers, threaded inserts, bushings, nails, springs and etc. Covering such small products in bulk is much more convenient and faster than using technological suspensions.

In this regard, this paper examines the issues of design improvements of a galvanizing plant for small parts of ferrous metals in bulk.

2. Engineering development of a galvanizing plant
A plant for galvanizing small parts of ferrous metals in bulk combines a galvanic bath with a built-in rotating drum, ventilation, a retractable tray, a block of electric heaters, temperature and level sensors, an electrical box and a mechanism for lifting the drum for unloading.

Based on the results of works [5 - 7] the authors have developed an electronic model of the plant. A general 3D view of the model is shown in fig.1 - fig.2, and fig.3 - fig.5 show the main nodes.

![Figure 1. 3D rear view of the plant.](image)

2.1. Development of a drum lifting mechanism
In the age of mechanization and automation, manual mechanisms are inferior to the automatic ones, including electric, pneumatic and hydraulic [8-11].

The proposal to change manual lifting of the drum is caused, first of all, by the speed and automation of the process, as well as by the exclusion of physical labor when lifting a fairly heavy structure of a galvanic drum with parts.

When using a pneumatic or hydraulic lifting mechanism, it is necessary to take into account the high cost of devices, as well as availability of compressor units for pneumatics, and oil stations for hydraulics.

The principle of lifting the drum by an electric drive is in winding the transmission belt on the reel at the command of the operator by pressing the "lift" button on the control panel of a stationary unit or in a separate control cabinet.

At the end of the galvanizing process, an operator, gives the command to the drive to raise the drum by pressing the button on the control panel, while not giving the command to stop its rotation inside the plant, which allows the parts inside the drum to shake off the drops of solution while stirring. After some time (2-3 minutes), the operator stops the drum in the overhanging state in order to adjust the tray for unloading parts.
On the side of the plant’s body, there is a rigid metal frame of the drum. Also, a counterweight is installed on the frame to ensure the balance of the drum. This contributes to less belt tension when holding the frame and the drum in the horizontal position. The frame raises and lowers the drum by tightening and loosening the belt, which in turn affects the tension of the material of the side and the wall of the plant. In order to avoid deformation of the plant’s wall when the horizontal position of the drum is reached, the lifting drive must be stopped. In addition to manual stop (pressing the button on the control panel), there are two sensors of "busy positions", which are configured to contact the metal "flags" on the upper and lower control points. When a signal is passed to close the plate with the sensor, a command is given to stop rotation of the lifting drive (see Fig. 3).

After receiving a signal at the intersection of the metal flag and the sensor, the drive stops the tension and stops lifting the drum. The drum is lowered in the reverse order. Upon reaching the horizontal position of the frame, catching the signal from the sensor, the drum’s lifting drive stops rotation of the reel and unwinding of the belt, otherwise the reel will begin winding the belt in the opposite direction, which will lead to further lifting of the drum (see Fig. 4).
2.2. Development of the plant’s main body

The main and supporting structure is the main body of the plant. Engineering development of the galvanic plant’s body for galvanizing of small parts of ferrous metals in bulk was carried out with the design parameters optimal for parts up to 100 mm long and at least 4 mm in diameter.

The material of the body is selected based on the aggressiveness of the main environment in the plant. When using a metal structure, it is necessary to protect it in terms of corrosion resistance. To do this, a polymer coating is used on the inside of the main body, in particular PH-2, which, in turn, increases the cost and complicates manufacturing of the main body.

Polypropylene has a number of advantages over metals: processing of body parts, welding method (extrusion, gas welding method); resistance of polypropylene to aggressive environments inside the plant compared to metal; it is easy to clean and it does not accumulate dust and dirt. This reduces the frequency of technical inspections.

On the basis of the above, calculations were done for the strength of the plant’s walls made of polypropylene and reinforced with stiffness belts. The main body of the plant has internal dimensions of 1300*780*700 and the volume of solution - 0.71 m$^3$.

**Initial data**

Internal dimensions of the plant (length * width * height) – 1300*780*700 mm.

Material - polypropylene. Medium - zinc chloride technical concentration 20-80 g/l, aluminum chloride concentration 180-240 g/l, solution density $p = 1.2 \text{ g/cm}^3 = 1,2 \times 10^3 \text{ kg/m}^3$.

Liquid level - $H_l = 0.85 \text{ m}$, $b_{nom}$ - nominal permissible voltage. $b_{nom} = b_T/n_T$. Yield strength for steel 12X18H10T $b_T = 240 \text{ MN/m}^2$. Safety margin $n_T = 1.65$. $b_{nom} = 240 \times 1.65 = 145 \text{ MN/m}^2$.

**Calculation of the wall thickness of the plant’s body.**

P-hydrostatic pressure $P = P_c + g*p*H_l*10^{-6} \text{ MN/m}^2$,

where the overpressure $P_c = 0$; $g = 9.81 \text{ m/s}^2$; liquid level $H_l = 0.85 \text{ m}$.

$P = 9.81*1.2*103*0.55*10^{-6} = 0.007 \text{ MN/m}^2$.

Vertical position of horizontal edges is determined by the formulas:

$H_v = 0.23*H_l = 0.1265 \text{ m}$, taken as 0.125 m.
The calculation of pressure on the wall of the plant’s body is carried out according to the formula:

\[ P_1 = R_1 = p_c + g \cdot p_l \cdot H_l \cdot 10^{-6} = 0.007. \]

The thickness of the wall without strengthening is determined by the formula:

\[ s_1 = S = K \cdot A \cdot \sqrt{\frac{P_1}{\theta}} = 0.0077 \text{ m}. \]

Taking rounding into account, we accept wall thickness \( s = 15 \) mm.

**Determination of the required moment resistance of reinforcing ribs**

\[ W_p = 0.033 \times 10^{-6} \cdot g \cdot p \cdot H_l \cdot (H_l - h_3) \cdot b^2 / b_{nom} = 0.0000018 \text{ m}^3. \]

Selected pipe 60x40x3 GOST 8645-68 with \( W_p = 0.00000686 \).

Fig. 5 shows an image of the plant’s body with stiffening belts.

Engineering design was carried out on the basis of the results of [12-17] using the system of three-dimensional modeling SolidWorks, as well as the drawings. Thus, the design of the plant is made as resource-intensive as possible, due to the fact that compared with other types of galvanizing of small parts of ferrous metals in bulk, it was possible to halve the process time, reduce the cost of manufacturing finished plants by combining many operations of the galvanizing cycle.

All this reduces assembly cost of finished plants compared with those using pneumatic and hydraulic lifts, by approximately 200 thousand rubles per unit compared to a similar plant. This also allows placing these plants in small-sized garage type premises. But most importantly, the proposed design solution reduces the cost of galvanizing operations of small parts of ferrous metals in bulk in comparison with a full galvanizing line, with associated increases in prices for metal structures both for automatic operators and manual control, which also affects the size of premises, energy consumption and operation cost [18 -20].

**3. Results and discussion**

Test operation of the developed plant was carried out at PJSC "TAGAT" named after S.I. Livshits (Russia) at production of a batch containing small details of various forms (see Fig. 6).

**Figure 5.** 3D view of the main body with stiffening belts

**Figure 6.** Photos of the batch of small parts in bulk: a) - before galvanizing; b) - after galvanizing
Tests of the parts with anti-corrosive treatment which was done with the use of the galvanic plant for small details of ferrous metals in bulk including their resistance to various aggressive environments have shown good results.

If galvanizing of small parts is carried out under technological conditions other than optimal, a defect of uneven coating may appear (in the case of slow or very fast rotation of the drum).

In addition, coating in bulk is much more convenient and faster than using technological suspensions for small machined parts (bolts, screws, nuts, washers, bushings, nails, etc.) The quality of coating is more stable within batches made without readjustment of the plant.

4. Conclusion

In this work, the authors have solved the problems of improving the engineering design of the galvanizing plant for small parts of ferrous metals in bulk, in particular: calculations were carried out to determine the structural elements of the plant, engineering development was performed and an experimental sample of the plant was produced. The plant tests on producing of a batch of small parts of various shapes showed its high efficiency and prospects for being used for the whole class of small parts of ferrous metals.

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