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TOPLO CINKOVANJE ČELIČNIH KONSTRUKICJA – MOGUĆNOSTI I OGRANIČENJA

Rezime:

Toplo cinkovanje predstavlja jedan od najčešće primenjivanih sistema zaštite čeličnih konstrukcija od korozije. U slučajevima u kojima nema ograničenja za primenu toplog cinkovanja, ovaj postupak je najekonomičnije rešenje jer se radi o trajnoj zaštiti od korozije koja ne zahteva održavanje u toku eksploatacije objekata. U ovom radu prikazan je sam postupak toplog cinkovana sa akcentom na njegovim specifičnostima, mogućnostima ali i ograničenjima. Posebna pažnja posvećenja je postupku pripreme konstrukcija za toplo cinkovanje kao i opisu prihvatljivog kvaliteta proizvoda nakon samog postupka. U radu su prikazane mogućnosti i kapaciteti svih cinkara u Srbiji i okruženju.

Ključne reči: toplo cinkovanje, čelične konstrukcije, zaštita od korozije

HOT-DIP GALVANIZING OF STEEL STRUCTURES – POSSIBILITIES AND LIMITATIONS

Summary:

Hot-dip galvanizing is one of the most commonly used systems for the corrosion protection of steel structures. In cases where there are no restrictions for the application of hot-dip galvanizing, this procedure is the most economical solution because it offers permanent protection against corrosion that does not require maintenance during the structure's exploitation. In this paper, we present the process of hot-dip galvanizing with an emphasis on its specificities, capabilities and limitations. Particular attention is paid to the process of preparing steel structures for hot-dip galvanizing as well as describing the acceptable quality of the finished product. The paper presents the possibilities and capacities of all hot-dip galvanizing companies in Serbia and in the region.

Key words: hot-dip galvanization, steel structures, corrosion protection

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1. INTRODUCTION

Hot-dip galvanizing is a process in which a zinc coating or a zinc iron alloys coating is applied to steel structural elements. The process is carried out in hot-dip galvanizing baths.

In cases where there are no restrictions for the application of hot-dip galvanizing, this procedure is the most economical solution because it offers permanent protection against corrosion that does not require maintenance during the structure's exploitation.

Hot-dip galvanizing companies must perform their job in accordance with SRPS EN ISO 1461: 2013 [1] standard. It is most important standard about hot-dip galvanizing and it specifies the general properties of coatings and test methods for coatings applied on steel structural elements.

2. TECHNICAL REQUIREMENTS FOR HOT-DIP GALVANIZING OF STEEL STRUCTURES

Before hot-dip galvanization is performed, the customer is obliged to deliver to the contractor certain information related to their request. This information is defined by the standard SRPS EN ISO 1461: 2017 (Annex A) [1]. The information relates to the properties of the basic material that can affect the application of the coating, surface conditions of the interior parts of the construction that are not visible, special requirements related to the coating and other information.

Additionally, prior to beginning the works, the contractor is obliged to submit information related to the methods of applying the coating on uncovered areas. At the end of the process, the contractor should deliver a certificate of conformity and a certificate of job completion in accordance with quality standards, such as ISO 9001.

2.1. TECHNICAL OPENINGS ON STEEL STRUCTURAL ELEMENTS PREPARED FOR HOT-DIP GALVANIZING

Steel structural elements arrive at hot-dip galvanizing companies prepared in a certain way. At the start of the galvanizing process, all delivered elements must be measured on an industrial scale and, subsequently, stored in a proper manner. The minimum sizes of the technical openings (holes) must be in accordance with Table 1. The elements must have drilled holes (wells, cutouts, etc.) in accordance with the EN ISO 14713 [2] standard:

- openings for zinc input and air outlet from closed tubes and angles. They must be located at the bottom of the lower and upper points, as close as possible to the welds. If the structural element has holes that cannot be seen, the customer is obligated to submit a layout of the holes,
- openings for hanging. For simple elements up to 2500 mm in length, there is a single hanging point with a minimum distance of 20 mm from the edge. For elements longer than 8000 mm, more supporting points are necessary and they must be placed at 1500 mm from the end of the steel structural element to avoid its bending,

- irradiation openings, which are also used for closed surfaces between two plates, which are completely welded together (if the welded surface is larger than 2500 mm^2), to prevent explosion during hot-dip galvanizing. The opening can be on one or both plates.

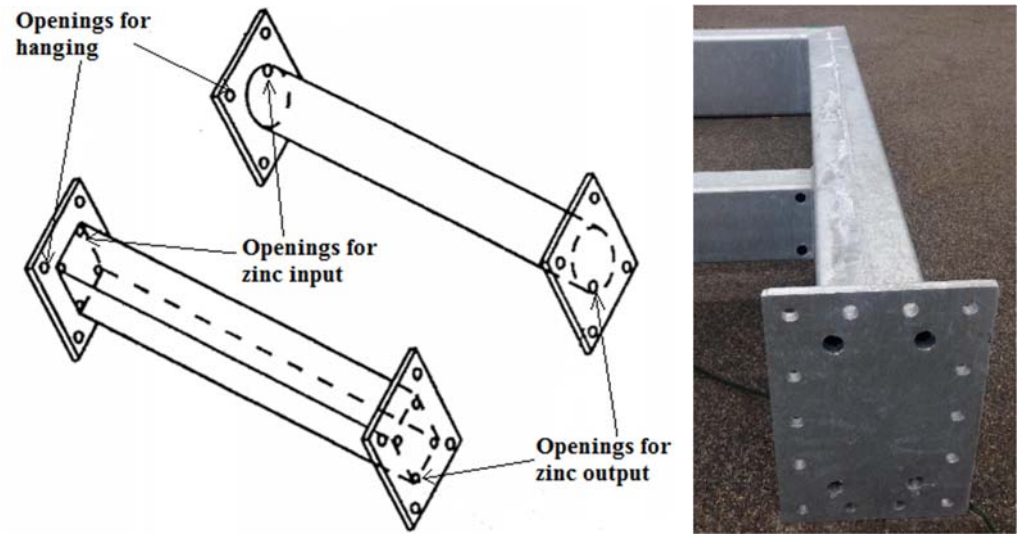

Figure 1 – Technical openings on steel structural elements [3]

The plates and stiffeners must be cut into critical areas where zinc accumulation would cause an explosion.

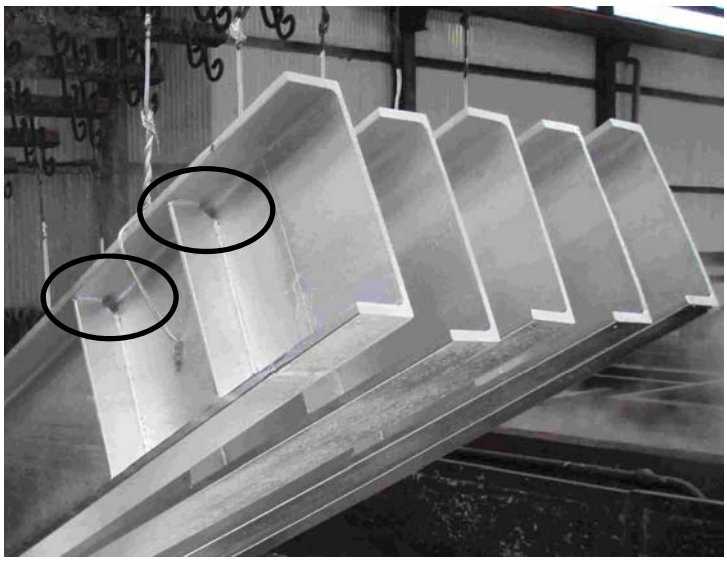

Figure 2 – Stiffeners cut in the critical areas [4]

Table 1 – Minimal diameter of technical openings [5]

Steel hollow sections – dimensions [mm]			Minimal diameter of the opening $Ø_{min}$ [mm]		
			Number of openings		
○	□	▭	1	2	4
15	15	20x10	6	-	-
20	20	30x15	8	-	-
30	30	40x20	10	8	-
40	40	50x30	12	10	-
50	50	60x40	16	12	10
60	60	80x40	20	12	10
80	80	100x60	20	16	12
100	100	120x80	25	20	12
120	120	160x80	25	20	16
160	160	200x120	32	20	16
200	200	260x140	32	20	16

2.2. PREPARATION OF STEEL SURFACES PRIOR TO HOT-DIP GALVANIZING

Applying effective corrosion protection is conditioned by the preparation of the steel surface, as the zinc reaction occurs only on a chemically clean surface. The chemical composition and condition of the surface of the base material (final appearance and roughness), the mass of the parts and the conditions during the application of the zinc coating can affect the thickness, texture, physical and mechanical properties of the coating [3].

No residual oil, grease, dirt or slag are allowed to remain on the surface; therefore, a series of procedures are used. At first, elements are degreased by immersion in an alkaline or acid solution, after which they are washed in water (rinsing). The second step is to immerse the elements in hydrochloric acid (which is at room temperature), which removes rust and slag from the rolling mill (pickling). Afterwards, the elements must be rinsed in water again. It is very important to note that the pickling process lasts between 20 and 90 min, which represents a bottleneck of the hot-dip galvanizing process, and the capacity of the plant depends on the number of baths with hydrochloric acid. The third and final step of the surface preparation in the galvanizing process (fluxing), consists of the elements' immersion in a 30% zinc ammonium chloride solution at 65–80 °C (flux solution). This removes any remaining oxides, welding slag, paint and heavy grease from the surface of the elements and provides better adhesion of zinc and base material and deposits a protective layer on the steel to prevent any further oxides from forming on the surface prior to immersion in the molten zinc. The cleaning process is shown schematically in Figure 3.

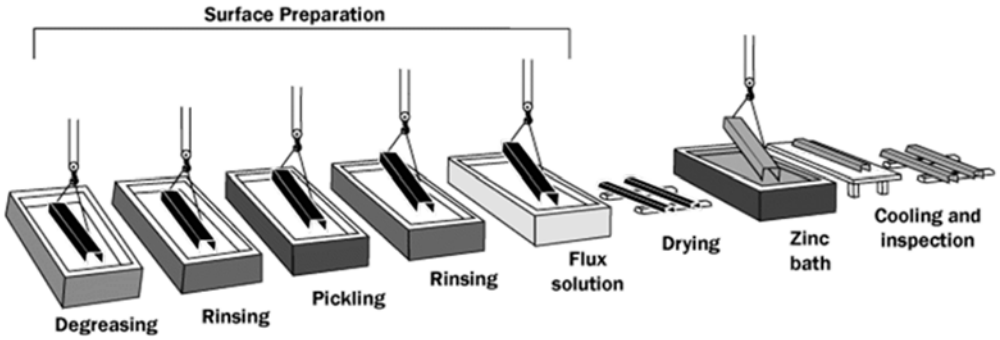

Figure 3 – Hot-dip galvanizing process [6]

3. HOT-DIP GALVANIZING TECHNOLOGY

After cleaning and rinsing of steel structural elements (which are hanging from bearing beams during the entire process) they are immersed in the bath with molten zinc. The molted zinc is at a temperature of around 450 °C because that is the temperature at which the metallurgical reaction between iron and zinc occurs. During the reaction, more ferro-zinc layers are formed. The initial reaction is very fast and the main protective layer is formed during this period, with the appearance of a large quantity of water vapour (Figure 4). After that, the reaction slows down and the thickness of the coating does not increase significantly any further, but the element is still immersed for a certain period. The process usually lasts about 4–5 min, but can take longer, e.g. for some elements in which zinc should penetrate into the interior.

Figure 4 – Hot-dip galvanizing process

When extracting from the tub, the bearing beam is raised at a certain angle due to zinc plating, and the workers remove excess zinc and slag from the surface of the melt. The galvanized element can be cooled either with water or air, after which a clear, luminous shine appears.

Additionally, this is an efficient way to inhibit undesirable reactions of the newly formed coating with the atmosphere.

3.1. DETERMINATION OF ZINC COATING THICKNESS

The length of effective corrosion protection is approximately proportional to the thickness of the coating. The thickness of the coating is usually determined by the thickness of the steel and can be determined according to Tables 2 and 3, given in EN ISO 1461:2013 [1], for centrifuged or non-centrifuged samples.

Table 2 – Minimum coating thickness and mass on samples that are not centrifuged [1]

Article and its thickness	Local coating thickness (minimum)[a] µm	Local coating mass (minimum)[b] g/m²	Mean coating thickness (minimum)[c] µm	Mean coating mass (minimum)[b] g/m²
Steel > 6 mm	70	505	85	610
Steel > 3 mm to ⩽ 6 mm	55	395	70	505
Steel ⩾ 1,5 mm to ⩽ 3 mm	45	325	55	395
Steel < 1,5 mm	35	250	45	325
Castings ⩾ 6 mm	70	505	80	575
Castings < 6 mm	60	430	70	505

Table 3 – Minimum coating thickness and mass on samples that are centrifuged [1]

Article and its thickness	Local coating thickness (minimum)[a] µm	Local coating mass (minimum)[b] g/m²	Mean coating thickness (minimum)[c] µm	Mean coating mass (minimum)[b] g/m²
Articles with threads:				
> 6 mm diameter	40	285	50	360
⩽ 6 mm diameter	20	145	25	180
Other articles (including castings):				
⩾ 3 mm	45	325	55	395
< 3 mm	35	250	45	325

Centrifugal zinc plating represents the immersion of elements in a prefabricated vessel, which, after forming the coating, rotates at a high speed and in this way removes excess zinc. It is used for hot-dip galvanizing elements with threads and other small parts.

If there are uncoated areas, they must not exceed 0,5 % of the total surface of the element and each uncoated area for renovation shall not exceed 10 cm^2. If uncoated areas are larger, the article containing such areas shall be re-galvanized, unless otherwise agreed between the customer and contractor. The coating thickness on the renovated areas shall be a minimum of 100 µm unless the customer purchaser advises the contractor otherwise, for example, when the galvanized surface is to be over-coated and the thickness for renovated areas is to be the same as

for the hot-dip galvanized coating. The coating on the renovated areas shall be capable of giving corrosion protection to the steel to which it is applied [1].

The first purpose of zinc coating is to protect steel from corrosion, while the outer appearance and aesthetics should be secondary. Roughness and smoothness are relative terms and are different when the elements are protected by zinc coating or mechanically purified, such as wires, tubes and sheets. In practice, it is not possible to determine the definition of appearance and finishing. However, appearance should be controlled from a distance of at least 1 m and the surface must be free of clumps, bubbles, rough and sharp places and uncoated surfaces.

The acceptance control may be performed by the customer or it will be performed on their behalf, before the product leaves the hot-dip galvanizing company. This control represents an assessment of the appearance of the coating on the product and measurement of the thickness of the zinc coating. Testing of zinc coating adhesion is usually not performed, unless otherwise agreed. The control sample for measuring the zinc layer thickness should be taken from the article or group of articles from a lot that is selected for sampling. The minimum number of articles from each inspection lot that forms the control sample shall be in accordance with Table 4 [1].

Table 4 – Minimum coating thickness and mass on samples that are not centrifuged [1]

Category	Size of significant surface area	Number of reference areas to be taken per article
a	$> 2\ m^2$	$\geqslant 3$
b	$> 100\ cm^2$ to $\leqslant 2\ m^2$	$\geqslant 1$
c	$> 10\ cm^2$ to $\leqslant 100\ cm^2$	1
d	$\leqslant 10\ cm^2$	1 on each of N articles
NOTE $2\ m^2 = 200\ cm \times 100\ cm$; $100\ cm^2 = 10\ cm \times 10\ cm$.		

4. CONCLUSIONS

The most important limitation for using hot-dip galvanizing as corrosion protection of steel structures are the dimensions of galvanizing baths. Very often, dimensions of steel structural elements are not limited by transport possibilities, but by galvanizing bath dimensions, so it is very important that the designers have good information about galvanizing possibilities in their country and region (Table 5). Sometimes, the limiting parameter are bearing beams and crane capacity (in cases of massive girders – welded or hot rolled) which can be up to 10 t (in MetalCinkara, Inđija) or number of baths with hydrochloric acid (e.g. in MetalCinkara there are 8 baths with hydrochloric acid).

Hot dip galvanized steel structural elements are not influenced by operating conditions (temperature, humidity, air quality, etc.), which is contrary to painted elements. The upper layer of steel consists only of zinc, but there is no demarcation line between the steel and zinc; rather, a gradual transition through a series of zinc-iron alloys. The protective coating is fused into the metal and can therefore provide much better protection than other coatings such as paint. While protection by paint may have to be re-processed every 5 or 6 years, protection by galvanizing should last in excess of 30 years, even with exterior usage in coastal environments [7].

Table 5 – Bath dimensions in galvanizing companies in Serbia and region

Country	Company	Bath dimensions		
		Length [mm]	Width [mm]	Depth [mm]
Serbia	MetalCinkara, Inđija	13750	1700	3200
Serbia	Cinkara, Kruševac	9300	1400	3200
Serbia	Unipromet, Čačak	9500	1400	2800
Serbia-Kosovo	Galvazink, Prizren	8800	1300	2600
BIH	Ibra, Tuzla	6000	700	2000
BIH	Fabrika za pocinčavanje, Srebrenica	7000	1200	1800
BIH	SurTec Eurosjaj, Konjic	9000	1100	2900
Croatia	Italikacink, Gospić	9200	1600	3000
Croatia	Kotlar, Đurđevac	3500	1400	2000
Croatia	Cinčaona Helena, Donja Zelina	6200	1200	2500
Croatia	Adriacink, Split	7500	1400	2800
Croatia	Dalekovod proizvodnja, Dugo Selo	12500	1700	2800
Slovenia	Pocinkovalnica, Celje	12600	1700	2900

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