RESEARCH ON CHROME PLATING OF STEEL BARS

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***Abstract**: The main objective of this work was to achieve for steel bars according to EN 10083 C45E, a uniform thickness of the layer of chromium deposited on them, after hard chrome plating process. Chrome plating process was occurred by electrochemical and chromium layer deposited. This deposited on the steel bars, must ensure increased corrosion resistance, low friction coefficient, high hardness and high wear resistance. Also following treatment hardening (HI – hardening by induction using medium frequency, induction currents 3400-10.000Hz at a temperature 950^{0}C) on the bars, were determined hardness HV 01 and HRC. Variation of hardness layer with the depth of it, are shown graphs .We can see that the surface induction hardened material has high hardness, and that decrease as we get it chrome plating layer.*

***Keywords**: C45E steel, hardening induction (HI), hard chrome plating, hardness HV 01 and HRC*

1. INTRODUCTION

The chromium electrolytically deposited is silver colored - opaque and is very hard (600-1200 HB). Chromium is deposited generally tough directly without intermediate layers steels with lower hardness value of 56 ... 60 HRC. [1,2] He may settle on surfaces reconditioned parts made from steel, cast iron, copper, brass, aluminum alloys etc. Chromium coatings are used for decorative purposes - protecting to increase wear resistance (hard chrome plating). [1,3]

Chromium rough, abrasion is obtained thicknesses of hundreds of microns and can reach a millimeter. It is used to cover the cylinder, the piston segments with internal combustion engines, cutting tools, molds and dies, the plates stereotypes of rotative presses. [3,4,5]

Chromium layer has high corrosion resistance, low friction coefficient and high hardness and wear resistance. The tensile strength decreases with increasing layer thickness of. With the increase in thickness decreases the resistance to fatigue, which can be reestablished if the workpiece is subject to a recovery heat treatment (at 150-250^{0}C for three hours).

The electrolyte used in the chromium is an aqueous solution of chromic anhydride (CrO_3) with the addition of sulfuric acid (SO_4H_2). Anodes are insoluble and are made of pure lead or lead-antimony alloy.

The voltage applied to the electrodes is 6-10 V. Submission bath of chromium per piece lowers the concentration of chromic anhydride, making it necessary to supplement the systematic electrolyte bath.

The anode is released a large amount of oxygen, which oxidizes lead, the yield decreases chromium layer deposition. In order to prevent such a situation from time to time, the anodes must be cleaned of lead peroxide by means of sulfuric acid solution and sodium hydroxide. For a good chromium plating, it is necessary that the ratio of chromic anhydride and sulfuric acid in the electrolyte is kept constant, most preferably of 90-120. The reduction of this ratio leads to reduced diffusion of the electrolyte, and the yield. Increasing by more than the permissible limit increases the amount of gas released (hydrogen and oxygen) and favors the appearance of cracks in the layer of chromium deposited.

Coating may be defined as a coverage that is applied over the surface of any metal substrate part/object. The purpose of applying coatings is to improve surface properties of a bulk material usually referred to as a substrate. One can improve amongst others appearance, adhesion, wettability, corrosion resistance, wear resistance, scratch resistance, etc. [1,5,6,7]

Chromium coatings are characterized by high corrosion resistance, low coefficient of friction, high hardness and wear resistance. The coatings protect steel in humid atmosphere, in sea water, acidic or alkaline environments oxidizing, ammonia, hydrogen sulfide, gases.[8,9,10]

2. EXPERIMENTAL DETAILS

The technological flow chrome plating steel bars of mark C45E comprises the operations that will be presented. For starters bars are peeling procedure consists of a cutting process to remove the superficial layer of iron oxide using peeler. Follow bars straightening operation which consists of cold plastic deformation resulting from the operation blanks shelling.

After the bars are so prepared, semi hardening takes place, which is performed using medium frequency induction currents (3400-10000 Hz) at a temperature 950^0 C.

Follows degreasing bars, which is performed before surgery to remove chrome plating the emulsion coached the blanks rectified. Degreasing is performed with alkaline solution UNAR 10%.

Chrome plating method blanks is performed by electrochemical deposition of hard chromium in order to enhance wear resistance.

Hard chrome plating electrolyte composition and working regime are: chromic anhydride Cr_2O_3 250-280g / l sulfuric acid H_2SO_4 2.5 to 2.8 g / l chromic acid max. 10 g / l, temperature 55 ^{0}C, current density 40-50 A / dm^2, the voltage 5-6V.

Conditions electrolysis influence the structure, properties and external appearance deposited layer of chromium. If the current density is greater, during operation is reduced and efficiency is increased. At lower densities of 5 A / dm 2 chromium is not deposited the cathode.

Chrome bath temperature varies between 45^0 and 75^{0}C. The decrease temperature favors increasing output current. If working at temperatures too low chromium layer becomes brittle, crack or peel. Increasing the temperature of the electrolyte favors the crystallization of chromium in higher proportion than the hexagonal lattice cubic lattice; this prevents cracks in the coating deposited.

After hard chrome plating operation, the bars are subjected to the grinding and / or cutting and polishing operation. Processing is done according to the requirements of the beneficiaries.

3. EXPERIMENTAL PROCEDURE

From a lot of bars in C45E, was chosen a bar, that was studied in terms of micro chromium layer deposited. Also it has been studied and hardened layer hardness.

From the lot of steel bars C45E mark was chosen the batch number 51034, 45 mm diameter bars. Table 1 presents the chemical composition of the steel C45E according to EN 10083 or OLC 45x according to STAS 800.

Tabel 1. The chemical composition of lots of bars

The brand steel	Chemical composition [%]							
	C	Si	Mn	P max	S	Cr	Ni max	Mo
C45E	0.42 - 0.50	max 0.4	0.50 - 0.8	0.035	max 0.035	max 0.4	0.4	max 0.1
C45E analyzed	0.43	0.23	0.65	0.017	0.015			

Tabel 2. The mechanical properties of the bars before chromium plating process

The brand steel	Rp0.2 [N/mm²]	Rm [N/mm²]	A[%]	Hardness
C45E	Min 305	Min. 580	Min 16	55 - 60 HRC
C45E analyzed	397	680	20	219HB

Mechanical tests from table 2, are carried out before chromium plating process, and they will not influence the subsequent chromium deposits.

We find that the values of mechanical tests of the bar analyzed , fall within the required standards.

The sampling was performed to the rolling direction, according to the way in which they were castings laminate. Cut the sample and incorporates using an epoxy resin by heating to a temperature of ≈ 60 – 61 ^{0}C and then cooled with water.

After embedding thus preparing the sample for examination under a microscope. It uses three types of abrasive grit of 90-100, 300, 600, and then performs polishing with aluminum oxide (1, 3, 6 microns) on the felt.

Sampling was performed in cross section, the attack was carried out with NITAL 5%, achieving microscopic analysis of steel bars in state laminated tempered state. It was subsequently analyzed chromium layer deposited on steel bar C45E.

4. RESULTS AND DISCUSSION

Microstructural analysis shows the specific structure started rolling (ferritic-pearlitic structure) steel bars of mark C45E, according to figure 1.

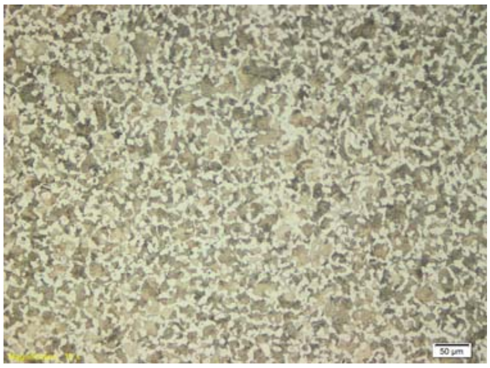

Fig.1 The specific structure of rolled metal (ferrite-pearlite structure) for C45E
Magnification (X200). Attack Nital 5%

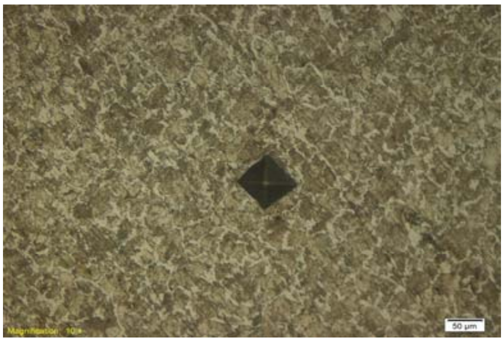

Fig.2 Measurement of microhardness in the steel C45E.
Magnification X 200
Attack Nital 5%.

In figure 2, is shown footprint C45E material hardness for using your device Affric hardness tester.
After it was presented specific microstructure of rolling, the bar was subject to tempering by induction . After this treatment were obtained following on experimental data in table 3.

Tabel 3. The hardness HV 01 and HRC

The depth of induction hardened coating [mm]	Induction hardened layer hardness	
	HV 01	HRC
0.2	654.80	57.8
0.4	641.33	57.3
1.0	622.92	56.3
1.2	562.61	55.2
1.5	562.61	53.0
1.7	470.37	46.9
2.0	446.43	45.3

Induction hardening depth of 1.0 mm, is carried out at a heating time of 2.5 seconds the bars, requiring a specific energy of 2.25 kWs/cm^2, while the depth of 2.0 mm is obtained at a heating lasting 9.0 seconds being required specific energy dual 4.5 kWs / cm^2.

Table 3 shows the hardness HV 01 and HRC, hardness obtained after treatment of induction hardening of the bar. Microhardness measurements hardened coating between 0.2-2.0 mm are made using your device Affri hardness tester, and results are shown graphically in figures 3 and 4.

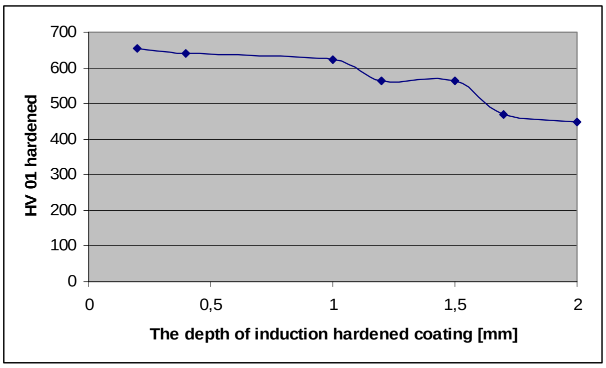

Fig 3. The variation hardness HV 01, hardened layer of depth measurement function

According to Figure 3, we find that the microhardness measured by unit AFFRI, decreases as the depth of penetration of camera settings hardened layer increases.

The micro-hardness reaches a maximum value of 0.2 mm, the value of 654.80 HV microhardness being 01 and 57.8 HRC, and a minimum point to a value of 2 mm hardened coating depth value being 446.43 HV 01 and 45.3 HRC, as shown in Figures 3 and 4.

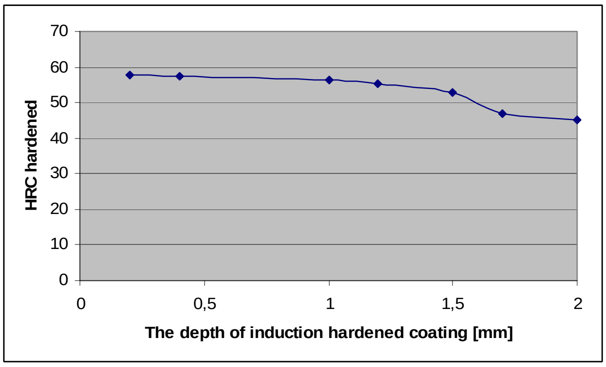

Fig 4. The variation hardness HRC hardened layer of depth measurement function

Fig. 5 Measuring the induction hardened coating microhardness and depth of Magnification (X50)

On the surface induction hardened material has high hardness, as we get it drops layer. The first prick (as shown in figure 5) which is performed using 0.2 mm

Vickers microhardenss surface basically when the bar passes through the inductor, speed time a well established time it takes the high hardness.

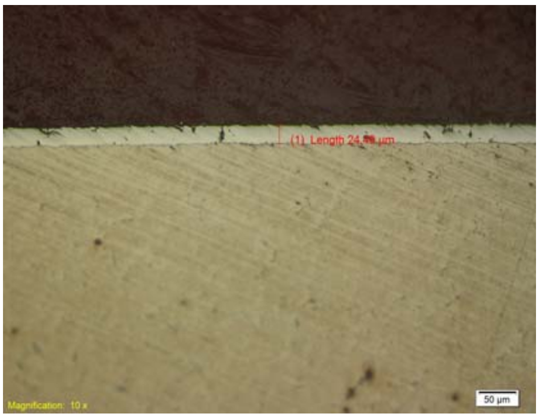

Fig. 6 Chromium layer measured Magnification (X200)

Note that chromium layer deposited is a uniform layer without porosity, as shown in figure 6.

Fig. 7 Measurement of microhardness on the outside surface of C45E chrome bar Magnification (X200)

Hardness of chromium coating obtained is 977.77 HV 01, shown in figure 7, and hardness of the base material before hardening and chromium plating treatments is 219 HB.

For bars analyzed was obtained 24.49 µm (see figure 6) a layer of chromium which is in accordance with the literature, as for bars with diameter greater than 20 mm, deposited of chromium layer must be at least 20 µm and double chrome plating, must achieve a Cr layer of min 50 µm.

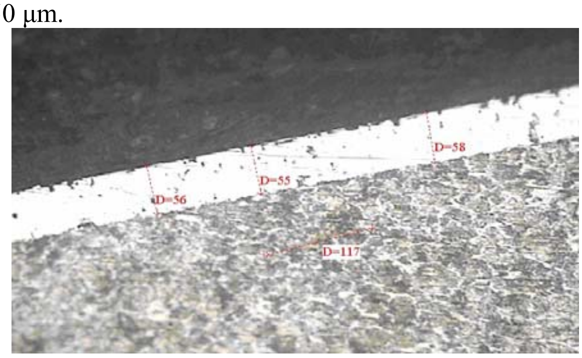

Fig. 8. Hard chrome plating (double) on a steel C45E

The thickness of chromium is between 56 -58µm, as shown in Figure 8. On a distance of 117 µm is noted minor irregularities layer of chromium, which can be considered slight defects. They can occur as compared CrO_3 / H_2SO_4 is above 200 and therefore always must be strictly adhered electrolyte concentration of chromium plating.
The thickness of the double chrome deposited on a C45 steel is between 55 -58µm, and if the same bar, but subjected to a hardening heat treatment (Induction hardened), later chromium plating layer thickness does not exceed 24.49 µm as shown in figure 6.

Chrome deposits are composed of crystals as face-centered cubic crystal and variable proportion of hexagonal shape.

5. CONCLUSIONS

Corrosion is the main element involved in determining the lifetime of a product for which this paper tries to somehow extend the life bars are used to intense and high temperatures by creating a layer of chromium uniform and high hardness.

From the point of view of the metallographic analysis, we find that the sample correspond to conditions imposed by the client, ie specific structure of rolled metal (ferritic-perlitic), chromium deposit is constant, and the layer hardness comply with quality standards required of beneficiaries. On the surface, the material hardened has high hardness, as we move forward in this layer decreases.
We find that the microhardness measured by the device Affric, decreases as the depth of penetration of camera settings hardened layer (hard) increases.
The hardness of chromium layer is 977.77HV01 and its thickness is 55 -58µm micrometres for the bar analyzed, C45E steel
It notes that the thickness of chromium deposited is uniform and shows no irregularities, leading to the conclusion that throughout the process of chrome plating were fully respected by the technological conditions.
The hard chrome surface of the bars confers corrosion and wear resistance, reduces friction, improves durability and through abrasion tolerance ensures good oil holding as well.
Commonly used for non aggressive, indoor applications, for rods not exposed to mechanical strokes or blows.
The smooth appearance of the hard chrome surface is conferred by attentive preparation of the steel bars before plating.

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