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THE APPRECIATIONS AND ASPECTS ABOUT HORIZONTAL CENTRIFUGAL CASTING PROCESS OF THE STEEL BRONZE BIMETALLIC BUSHES

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ABSTRACT
The horizontal centrifugal casting process with heating the bimetallic bushes by high frequency current is an ideal method when it must to be applied a non-friction case with high quality on the soft steel support, which could be heated in time of casting process, due to reduce the quantity of expensive material. More that, a soft steel support will be rise significant the mechanical characteristics of bimetallic assembly versus the single block bushes by nonferrous alloy. This proceeding improving the quality process and reduces the cost of manufacturing.
Keywords: bimetallic, centrifugal casting, high frequency current.

1. INTRODUCTION

The proceeding of centrifugal casting process with heating of bimetallic workpiece by high frequency current (HFC) is presented in papers [4,5,6,7], being improved by experimental attempts in Machine-Tools “INFRATIREA”Co. Oradea. At this company has been realized by the horizontal centrifugal casting process the bimetallic bearings with the ratio *L/D = 0.8 - 1.2* (*L* = length and *D* = exterior diameter of bearing), with inner diameter of 14 - 60 mm and the thickness of plating case of 0.8 - 3.5 mm. The material for antifriction case has been used an alloy of copper with tin billet (CuSn10T, CuSn12T, CuSn14T) and the base a steel with less 0.3% carbon [1].
For a good grip of antifriction case on the steel support is required to realize a wetting the steel base, dissolving and diffusing reciprocally a base and liquid alloy at separating limit and alloy crystallization. The crystallization alloy depends of cooling process, after the end of horizontal centrifugal casting of melted alloy at the casting temperature.

2. HEATING AND COOLING PROCESS

For doing the bimetallic bushes by horizontal casting process, with steel base less 0.3% C and the alloy of bronze charge, the melt of bronze done by heating of HFC process to superficial case of sleeve base. Than the heat is transmitted inside of inner surface and than the charge, the compound has been get inside of inductor [6,8], where it’s located after axis device (Fig.1).

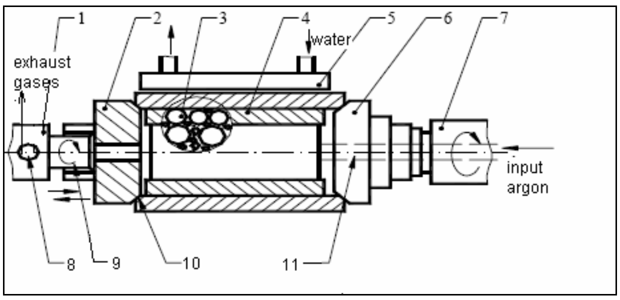

Figure 1. Horizontal centrifugal casting with heat by HFC.

Where: *1* = locating support with hydraulic acting, *2* = cover clamp, *3* = cylindrical steel support, *4* = semi-finished, *5* = inductor, *6* = cover of clamp and action, *7* = device of acting and turning, *8* = holes of exhausted gases, *9* = hole of center, *10* = chamfering, *11*= central channel of input argon gases.
Once with heating the base at melting bronze temperature, the assembly is turning to its symmetrical axis with a continuous rising speed on an optimum speed to ensure a uniform melting distribution on the inner cylindrical surface of base by centrifugal force. The charge temperature growing up in synchronizing with turning speed of assembly since the charge casting temperature become more that 50^0C above the melting temperature, when the heating is stall, going turning of assembly with a decrease speed until a temperature of assembly is at 100-150^0C. After that the turning is stopped and the workpiece is get out from device, the cooling continued in *"silent"* air [6,8].

The significant expressions, which represent horizontal centrifugal casting process of bimetallic bushes, are [9]:

- The raising warm body temperature by induction:

$$\frac{dT}{dt} = K\frac{m(d/\delta)\sqrt{F}}{d} \tag{1}$$

Where: T – workpiece temperature [^{0}C]; K – coefficient of variation a rise speed of temperature; F – frequency of induction current [Hz]; m – mass of workpiece [kg]; d – exterior diameter of base cm]; δ – coefficient of penetration [cm], which it has calculated with relation:

$$\delta = 50.3\sqrt{\rho/\mu F} \tag{2}$$

Where: ρ - resistive of base [$\Omega mm^2/m$], and μ - magnetic permeability.

- The ratio of temperatures for determination of heating time:

$$\frac{T_0}{T_e} = \frac{1}{1+S(0,t)} = F(t) \tag{3}$$

Where: T_0 – temperature at exterior surface of base [^{0}C]; T_e – temperature at inner surface of base [^{0}C], that is the same with the casting temperature of melting alloy; S – surface base heating by high frequency current [m^2]; t – time for heating [s].

- The Arhimede's Law for turning systems:

$$F_c = \frac{V\omega^2 r}{g}\left(Y_i - Y_m\right) \tag{4}$$

Where: V – volume of inclusions [cm^3]; ω – angular speed of turning [s^{-1}]; r – center radius of inertial force [cm]; Y_i – density of inclusions [g/cm^3]; Y_m – density of alloy [g/cm^3].
The following ratio could be note:

$$K_g = \frac{\omega^2 r}{g} \tag{5}$$

- The optima turning speed of assembly after Constantinov [6]:

$$n = 300\sqrt{K_g / r_i} \tag{6}$$

Where: n – optima turning speed [rev/min]; r_i – inner radius of base [cm]; K_g – coefficient of gravitation, and it taken empiric: $K_g = 340/Y_m$.

In fig.2 is depicted the diagram of cooling curve of steel base with less 0.3%C, used jet of water, where it could see the distinguish phase of cooling, being important an adequate choosing of start cooling temperature, the cooling time and the end cooling temperature [1,6].

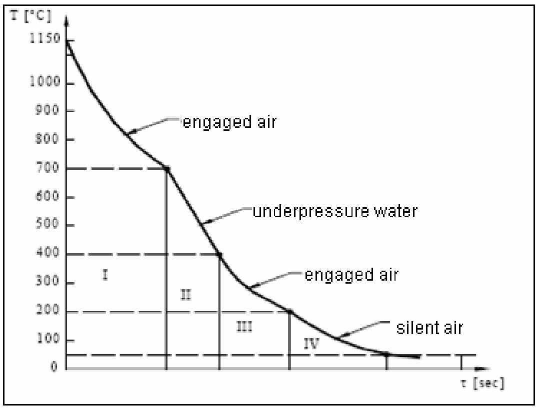

Figure 2. The diagram of steel cooling with air and water.

At the end of casting cycle, it has stopped the heat by HFC of base steel, going ahead with assembly turning with a descendent speed. The assembly being in rotation engaged the environmental air due a cooling in turbulence air (1st phase of cooling) and the workpiece temperature is down at 700^0C in several seconds. In this moment is started the cooling with jet water (under pressure of 2 – 3 atmospheres, and 20^0C). At start the contact between the piece and water due to quick water evaporation and fast down the temperature of workpiece at 600^0C (2nd phase cooling). This phase realized a slowly cooling due to decrease of workpiece temperature at 400^0C, when it stall of cooling with water and beginning the 3td phase of cooling by engaged air with speed of turning assembly. When the exterior surface of base is down at 200^0C it stopped the turning assembly and than it's pull out of device going ahead with cooling in silent air (4th phase cooling) until at room temperature.

3. THE PRACTICAL ASPECTS OF COOLING

After many attempts and by economic reasons is taken the decision in choosing pipes carbon steel which compound is presented in Tab.1., being a hypoeutectoid steel (less 0.3%C) [1,8] with of non-homogeneous microstructure (feritte + pearlite). For avoided the internal stresses and achieved of homogeneous microstructure with a good machinability, is required a homogenized annealing applied to steel base. The heat by HCF of steel is done at complete austenitizing process above A_{C3} between (1100 - 1150^0C), with a short keeping and than following a slowly cooling (fig.3).

Table 1. The chemical composition of carbon steels used for a base of bushes.

Steel	% C	% Mn	%Si	% P	% S	[N/mm^2] σ_{tr}
T 35	0.09-0.16	0.30	0.10-0.35	0.04	0.045	35
T 45	max 0.23	0.40	0.010	0.04	0.045	45

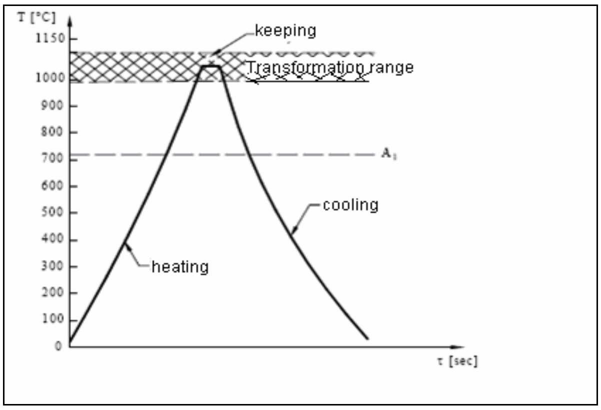

Figure 3. The short phases diagram of homogeneous annealing for steel base of bushes.

The keeping time is very short (fractions of second) ensured the whole mass of workpiece to get the desire temperature. Near line A_1 the cooling is done more quickly, because in this range (600 - 750^{0}C) the feritte grain exhibit tendency of grown, which required using water for cooling.
The main reason which has been resolved in this paper is that thermal cycles of annealing for homogeneous of steel base of bushes concurred with the thermal cycles of horizontal centrifugal casting of bimetallic bushes of steel-bronze [1,8]. This means that at casting temperature (950^{0}C+50^{0}C) to the end cycle concurred with internal surface temperature of steel base located in austenitizing field having the same pattern for heat and cooling process. In range of 700 – 400^{0}C is used water to ensure raising cooling speed, after that it must decrease this speed used turbulence air for cooling, and at 200^{0}C the assembly is stopped and getting off from device going ahead with a slow cooling in silent air at room temperature.
After passing all horizontal centrifugal casting cycles of bimetallic bushes is required to get some measures for avoidance internal stresses and inter-dendrides structures of copper-tin alloy with 10 - 14%Sn by applying the workpieces a annealing process at 250 – 300^{0}C time two hours and than a slow cooling rate inside of furnace. Thus the bi-phase eutectoid $(\alpha + \beta)$, which is harder and brittle will be transform in mono-phase structure of solid solution α, improving mechanical properties of bronze casting. In fig.4 is depicted a bimetallic steel-bronze bush and in fig.5 the microstructure of bush at steel-bronze boundary (magnified 200X) [1].

Figure 4. Bimetallic steel-bronze bush.

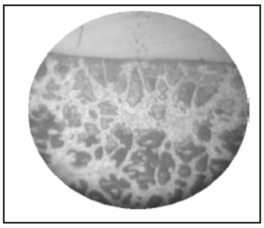

Figure 5. Microstructure (Magnified 200X).

4. CONCLUSIONS

At the end of this paper can be getting some conclusion about horizontal centrifugal casting of bimetallic bushes:

- At horizontal centrifugal casting with high HFC bimetallic steel-bronze bushes, for realized a good adherence of bronze case on steel support it must respected all the thermal cycles at asting and heat treatment in correspondence with compound of materials.
- The cooling of steel-bronze assembly in range of 700-400^{0}C temperature done with higher speed for obtained a fine structure feritte-pearlite of steel base.
- For avoidance the cracks of steel case, which can occurs in cooling at range of 400 - 200^{0}C the cooling speed is decrease used turbulence air.
- For enhance the copper-tin alloy structure $\alpha + (\alpha + \delta)$ and avoided intern stresses the bimetallic bushes will be heated at 250^{0}C inside of furnace, keeping two hours and than slow cooling in furnace.

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