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EXPERIMENTAL DETERMINATION OF THE HARDNESS CURVES IN DEEP CARBURIZING HEAT TREATMENT

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Abstract. Was achieved an experimental research of influence of carburizing time on hardness and depth. The variation of the carbon content depth, which determines the appearance of the curve of the carbon content (carbon profiles) is revealed for SAE 3310. Determining hardness curves allows setting optimal parameters for carburizing process, eliminating hyper-carburization of the outer layer, and allows a carburizing depth up to 10 mm. After quenching, was necessary to find a solution to reduce the amount of carbon in the normal. This was done by applying an annealing diffusion treatment after carburizing into the atmosphere of carbon potential decreased. The hardness curve demonstrates the necessity of the proposed solution.

Keywords: hardness curves, carburizing treatment, carbon potential

1. Introduction

Research has been done to highlight the fact that the carburizing thermo-chemical treatment made to the bearing elements in general and to the hollow roller in particular, can attain great depths (8-10mm) with excellent results in the increase the life of bearings. Thus, attempts have been made by two types of materials used in the construction of large bearing that is SAE 3310 and SAE 4320.

Transport and transfer of carbon in the metal matrix is made in two steps, the first with a high carbon potential for acceleration of the reactions, the second having the carbon potential at a level close of the concentration to eutectoid for diffusion. Have in view two aims: the carbon concentration and the depth of the carburization. For the construction of the theoretical model it was selected: temperature T = 950 °C, time t_I = 60h and t_{II} = 20h, the coefficient transferring of mass $\beta_I = 2.5\cdot10^{-5}$ respectively $\beta_{II} = 3\cdot10^{-5}$ [5, 6]. In obtained diagram, the calculation of curve II is performed to use as initial parameters the values resulted in calculation of the curve I (Figure 1) [1].

The maximum carburization rate is obtained when the carbon transfer from the atmosphere is greater than the carbon diffusion rate in the carburized layer. The carbon transfer is proportional to the difference between the carbon potential in the atmosphere and the steel surface concentration.

The researches lead to the possibility of making easy the achievement of the date banks. The influence of material parameters and of the process quality establishes the designing of thermo-chemical treatment and can do an analysis with amount of data which may predict the comportment of different steels in time of carburization.

The entry data are: chemical composition of steel, carbon potential, mass transfer coefficient of steel, the roller radius, time of maintaining in controlled atmosphere and the temperature of this space. For optimal results, is imposed to obtain a controlled percentage of carbon to a certain depth, making allowances for rectification processes so that the hollow rollers must be resistant to the load stresses end to the heat treatment [6].

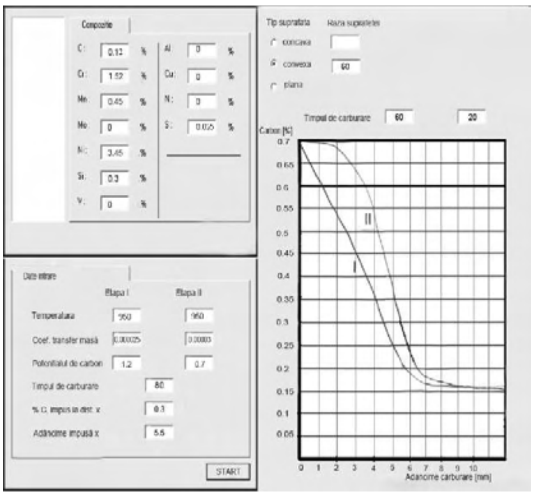

Figure 1. Carburizing optimization for SAE 3310 [1]

2. Theoretical considerations on deep carburizing heat treatment

The relational model applied is based on mass transfer law for convex surfaces (1, 2) and the diffusion equation the second Fick's law at limit conditions (3).

$$\frac{\partial c}{\partial t}=\frac{\partial}{\partial x}\left(D_C\cdot\frac{\partial C}{\partial x}\right)-\frac{D_C\cdot\partial C}{r-x\cdot\partial x} \qquad (1)$$

$$D_C=-\frac{1}{\left(-\frac{1}{x^2}+\frac{1}{x\cdot(r-x)}\right)\cdot t} \qquad (2)$$

where D_C is diffusion coefficient of carbon, r is hollow roller radius and x is deep of measurement to surface carburized.

$$\beta\cdot(C_P-C_S)=-D_C\cdot\frac{\partial C}{\partial x} \qquad (3)$$

where β represent mass transfer coefficient, C_P is carbon potential, C_S is the carbon concentration on surface of roller and C is the carbon concentration on x, in mm, from surface.

$$\beta=\frac{\Phi}{C_a-C_s} \qquad (4)$$

where C_a is the carbon potential of the furnace atmosphere, in g/cm^3, and Φ is unit mass flow, in g/(cm^2·s).

Mass transfer on the furnace atmosphere to the metallic surface occurs due to the difference between the average concentration C_a and metal surface C_s, Eqs. (4) and (5) [2, 7].

$$\beta=\sqrt{\frac{D}{3t}}\cdot\frac{C_a-C_s}{C_P-C_S} \qquad (5)$$

During heating from ambient temperature, the carbon potential of atmosphere is constant (C_P =1.1÷1.4) and is provided by enrichment with propane. The time of carburizing process is 60 hours and the time of diffusion process is 20 hours. Cooling is done by heat treatment furnace. Electrostatic forces leading to the formation of ions or ionic complex by the process of ionization of the environment caused by the emission of electron transfer from the metal surface by the thermal power of the gas molecules acting on the excited gas molecules causing their adsorption onto the metal surface [3].

The ionic complexes dissociate adsorbed state, thus forming the active carbon atoms, which then diffuse into the metal mass. Diffusion occurs in the metallic material as a result of occurrence of a carbon excess on the surface layer in the gas adsorption mechanisms. Carbon atoms from the metal surface will diffuse into the surface layer to the C_s concentration inside the solid body strength C_i, which results in the formation of carbide layer [4, 5].

Formation of a quantity of residual austenite is almost inevitable in microstructures of carburized layers containing high levels of carbon, who, in quantities of more than 50%, causing a significant decrease in the level of hardness and reduced fatigue. The main cause of excess residual austenite is the existence of higher carbon content in the surface layer. In Figure 2 [8] is show the system of providing the atmosphere for carburizing heat treatment in furnace with gas having the following composition: 20% CO, 40% H_2, 40% N_2. Enrichment in carbon is done with propane.

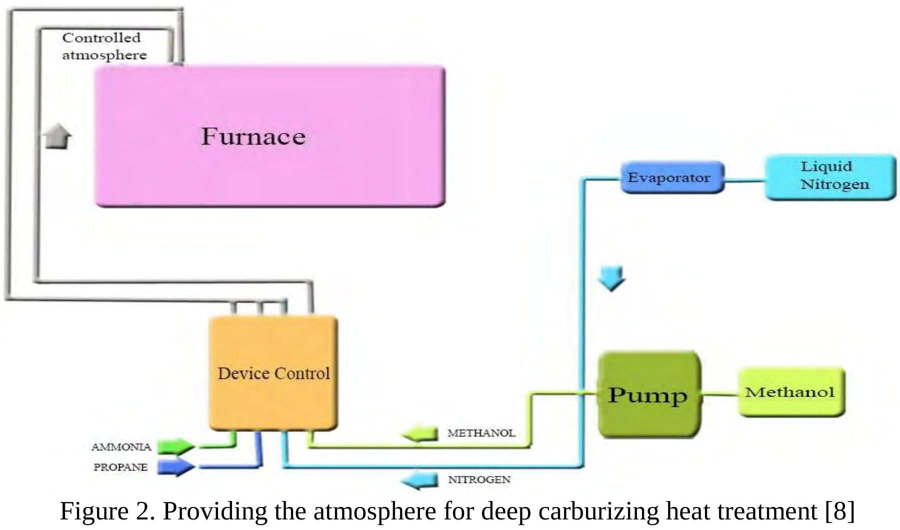

Figure 2. Providing the atmosphere for deep carburizing heat treatment [8]

3. The results of researches

The material of control sample is SAE 3310 and SAE 4320. In Figure 3a is show a control sample carburized for 25 hours in an atmosphere with C_P = 1.4. Carbon potential was measured every six hours and brought to the prescribed value by adding propane.

Blank is cylindrical and has dimensions D =120 mm and L = 300 mm. Cooling water was made. For comparison it was chosen hardness of

550 HV measured on a device Zvick, measurements performed at a distance of 0.5 mm step. In Figures 3, b, c and d, time of heat treatment is 35, 50 and 60 hours.

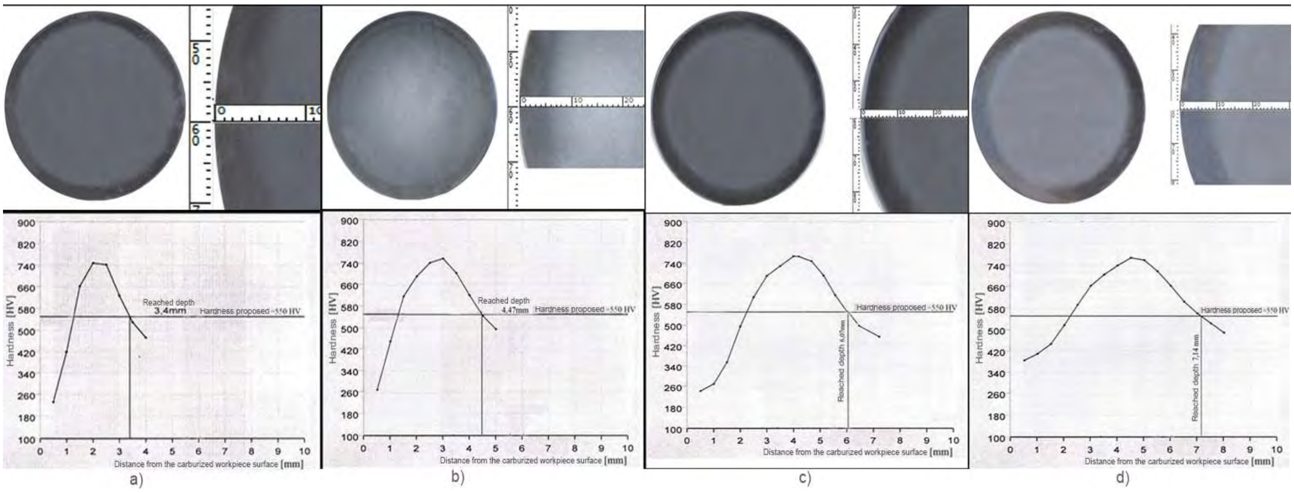

Figure 3. Carburized samples and hardness graph of carburized layer a) 25h, b) 35h, c) 50h, d) 60h

Carbide samples have a distance of 1÷3 mm a large amount of residual austenite, which reduces the hardness of the outer layer. The highest hardness is obtained at 3÷5 mm from the surface layer. As it advances to the core, the hardness decrease to the required value (550 HV).

The main cause of excess residual austenite is the existence of higher carbon content in the surface layer. Most common areas of the surface carbon concentration are edges and corner of the parts because they are areas where austenite saturated carbon in the first stage of the cycle of carburizing.

Carbon potential is strictly controlled by sensors, when its decline was again filled with propane atmosphere.

Gas mixture that provides the potential of carbon for the duration of treatment is made after the scheme of Figure 2. Initially, the furnace is prepared by purging with nitrogen and methanol non-active gas. Carburizing speed is: a) 0.136 mm/h, b) 0.127 mm/h, c) 0.122 mm/h, d) 0.119 mm/h.

The measurement of hardness is shown in Table 1.

In Figure 3 and in Table 1 is revealed low hardness of the outer layer due to residual austenite who decreases the toughness of steel.

Formation of hardening martensite leads to maximum hardness. In salt bath, products are maintained for 20 hours for processing of hardening martensite to tempering martensite and reduce residual austenite content.

Duration of tempering is relatively high for relaxation and redistribution of residual stresses.

Table 1. Hardness values [HV] for SAE 3310

Depth measure [mm]	Carb 60h Dif 20h	Carb 60h	Carb 58h	Carb 50h	Carb 35h	Carb 25h
0.5	701	385	395	245	272	232
1.0	710	410	308	273	450	420
1.5	719	446	367	358	618	662
2.0	721	516	472	494	694	748
2.5	716	593	560	608	744	742
3.0	708	665	657	690	760	627
3.5	701	706	716	729	706	530
4.0	686	740	744	767	623	473
4.5	673	769	765	750	545	-
5.0	652	760	756	699	496	-
5.5	630	719	714	627	-	-
6.0	602	665	647	567	-	-
6.5	575	605	591	517	-	-
7.0	544	560	547	450	-	-
7.5	512	523	505	-	-	-
8.0	486	489	475	-	-	-

4. Conclusions

Hardness curves were obtained depending on the time of carburizing and carbide layer depth, drawing diagrams that can be used in choosing the carburizing parameters for plain and hollow rollers. It is noted the relationship between the average carburizing rate and holding time, noting the decrease of that, with increasing of carburizing time (Figure 4). Considering, in the case of deep carburizing, that occurs inevitably, a hyper-carburization on depth 1÷3 mm, with the effect of obtaining an unacceptable concentration of residual austenite (60-70%), after quenching, was necessary to find a solution to reduce the amount of carbon in the normal. This was done by applying an annealing diffusion treatment after carburizing into the atmosphere of carbon potential decreased. While maintaining the temperature at 950 °C, for 20 hours into an atmosphere with C_P = 1.1 was done redistribution of carbon atoms in the layer, on 7÷10 mm from surface. From the study of the diffusion and carburizing treatments can be observed decrease in residual austenite content located on the surface of the piece after diffusion, which leads to increased hardness in the area.

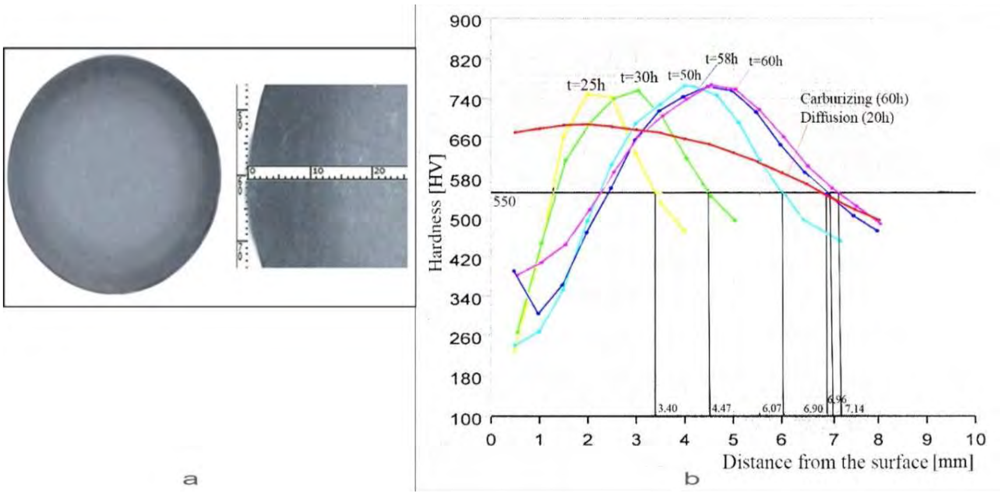

Figure 4. Graph of hardness based on depth and time-keeping of carburizing heat treatment

Carbon enrichment in the surface layer is characterized by:

- The carbon content of the outer layer (C_S);
- Depth of carburizing (A_S);
- The variation of the carbon content with depth carburizing which determines the appearance of the curve of the carbon content (carbon profiles);
- The carbon content of the core (C_i);
- The carbon potential (C_P).

The factors that determine the distribution of carbon in the layer are carburizing temperature, maintaining time in furnace, carburizing environment features, characteristics of the steel subjected to carburizing can be established after determination of hardness curves from materials.

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