THEORETICAL AND PRACTICAL CONSIDERATIONS ON SOME OF THE DIFFUSION ASPECTS IN THE PRESENCE OF MECHANICAL VIBRATIONS

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Abstract

This paper presents some considerations regarding the diffusion processes which occur during the sulphocyanurizing of high speed steels in vibratory field. The mechanical vibrations which are introduced into the metallic material contribute to a increase of the thermochemical treatment efficiency due to the elastic deformations of the basic crystalline grid. Therefore, there are obtained harder layers and the treatment duration is significantly shortened.

Keywords: Vibratory field, diffusion, termochemical treatment

Introduction:

The thermochemical processes are generally characterized by relatively long periods of maintenance compared to the conventional heat treatments. In order to increase their efficiency the efforts are outstanding, along with the use of new technologies and materials.

Due to a series of experimental tests it was found that subjecting pieces to mechanical vibrations has as first effect the increasing of the diffusion speed. The hardness, the layer compactness and the fatigue resistance of tools and pieces also increase

Besides the effects on the active environment of the thermochemical treatment, the vibrations also have a stimulating effect on the crystalline grid of the metal. Below are highlighted some aspects of this problem.

Theoretical considerations

The cc iron has in its unit cell two types of vacancies that can be occupied by diffusion atoms in order to form interstitial solid solutions.

These were the coordinates (0, 1/2, 0) and (1/2, 1/2, 0), shown in Figure 1 and indicated with a_1 and a_2.

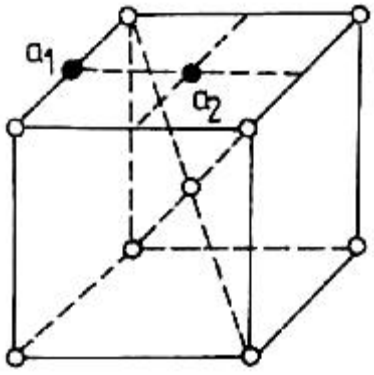

Fig. 1. possible positions to be occupied by foreign atoms in the unit cell of α iron

Taking into consideration the unit cell dimensions of iron, it was calculated that the radius of the sphere that can be introduced into the a_1-type interstices is r_1, and of the one that can be introduced in the a_2-type interstices is r_2.

Table 1. Shows the values of these sizes and the atomic radiuses of the diffusion elements, carbon and nitrogen.

Table 1.The values of these sizes and the atomic radiuses of the diffusion element

r_1 [Å]	r_2 [Å]	Atomic radiuses		Ionic radiuses	
		Rc [Å]	R_N[Å]	Rc4+ [Å]	R_{N5}+ [Å]
0,19	0,36	0,80	0,70	0,18	0,13

Comparing the values from the table above it is shown that the penetration of the carbon or nitrogen atoms in the unit cell of the iron is accompanied by a deformation of the crystalline grid. In a crystal which is under no tension the foreign atoms can evenly occupy the places of type ai and a2. Through the diffusion process, these atoms jump from one interstitial position to another with the time of standing in position which is equal in all cases.

If the crystalline grid is subjected to a tensile stress (in the elastic field) on one direction ie x, the distribution of foreign atoms is disturbed because the the interstices increase on the direction x and on directions y and z decrease. Therefore, the time of standing changes on each of the 3 directions.

Submitting the crystalline grid to a variable stress of sinusoidal type, with period T, there can be imagined the following situations:

1) τ »T: the oscillations period is small compared to the time of standing %, thus the foreign atoms cannot jump in a position favored by the variable stress as these positions become non-favored before being occupied through diffusion;
2) τ «T: oscillations period is large compared to the time of standing, the atoms can pass through the favored places.

Between these two extremes, there is an optimal value for T, when the vast majority of foreign atoms succed to jump from positions which become non-favored to the new favored ones.

In addition to the foregoing, the "elastic hysteresis" should be taken into account. It consists of the fact that after the stress cancellation the object keeps some residual deformation for a period of time even if the stress was applied in the elastic field, hence at low amplitudes of the deformation. The elastic hysteresis is due to an internal regrouping phenomena which propagates with a certain speed. If the hysteresis frequency is low, the deformations are considered instantaneous. Thus, at the diffusion stimulation in the crystalline grid of the iron the oscillations frequency has a low influence. Higher amplitudes can be used at low frequencies and require a lower energy consumption compared to the those at high frequencies. The oscillator power, at the frequency of 50Hz is effectively used both to activate the bath and stimulate the diffusion in the crystalline grid of steels.

Experimental attempts and results

Samples of Rp5 speed steel were subjected to sulphocyanurizing thermochemical treatment after hardening and two consecutive annealings. The sulphocyanurizing treatment took place concurrently with a third annealing at its temperature according to Table 2. A series of samples was treated in the absence of the energetic field, and the second one in its presence. The mechanical vibrations were directly transmitted to the samples which were to be treated.

Table 2. Aplied treatments

Material type	Heat treatment		Thermochemical treatment	
	Hardening	Annealing	Usual	Simulated
Rp5	1190 [°C], oil	560[°C], 2xlh	560[°C] 20, 40 and 60min	560[°C]; 50Hz; 20, 40 and 60 min

The samples obtained according to the diagram above were processed in order to measure the hardness, the diffusion layer thickness and for the microstructure study (Table 3).

Table 3. Microhardness

Treatment type	Usual thermochemical treatment			Simulated thermochemical treatment		
	20 min	40min	60min	20min	40min	60min
Layer thickness [mm]	0,0150	0,0244	0,0330	0,0280	0,0415	0,0522
Microhardness [$HV_{0,1}$]	940	921	933	987	974	972

At the sulphocyanurizing treatment in vibrator field were obtained hardness values higher by 20 ... 40 units Vickers [HV0, i] in the diffusion area. Of course, under the influence of the vibrations, by the increase of the diffusion atoms penetration, there is a stronger stress of the crystalline grid. This leads to the increase of both the hardness and the fatigue resistance. Due to these effects, the wear resistance and the durability of the cutting tools increase considerably.

As for the diffusion proces, the thicknesses of the layers which were obtained in vibratory field increased considerably, compared to those obtained by usual procedure, with a equal maintaining duration.

In addition to the vibrations effects on the crystalline grid and facilitation of the addition atoms diffusion, they also stimulate the thermochemical process by:

- Homogenizating the salts bath;
- Activating the area situated close to the metallic surface;
- Preventing the deposits formation;
- Increasing the dissociation, etc..

The figures 2...7 present the microstructures of the samples which were obtained in diffrent conditions of thermochemical treatment.

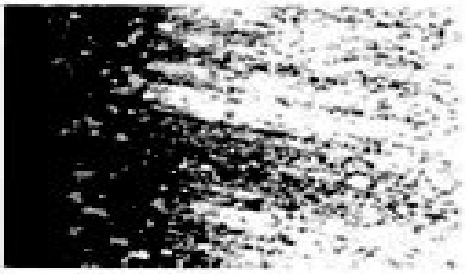

Fig.2 Rp5 steel after the usual sulphocyanurizing treatment, 20 min. Nital attack 1000:1

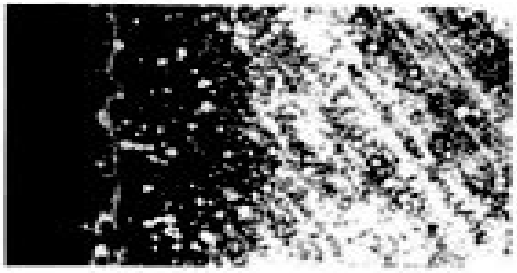

Fig.3 Rp5 steel after the sulphocyanurizing treatment in vibratory field, 20 min. Nital attack 1000:1

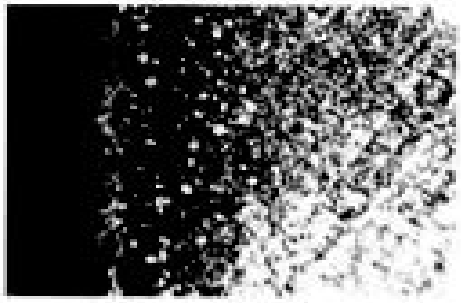

Fig.4 Rp5 steel after the usual sulphocyanurizing treatment, 30 min. Nital attack 1000:1

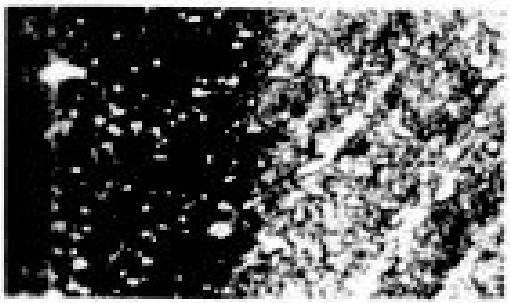

Fig.5 Rp5 steel after the sulphocyanurizing treatment in vibratory field, 30 min. Nital attack 1000:1

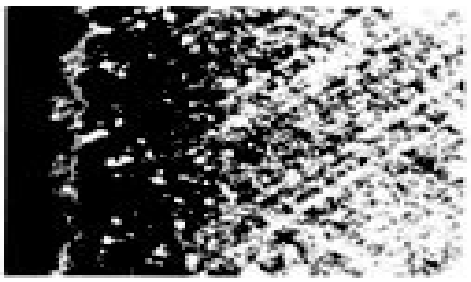

Fig.6 Rp5 steel after the usual sulphocyanurizing treatment, 40 min. Nital attack 1000:1

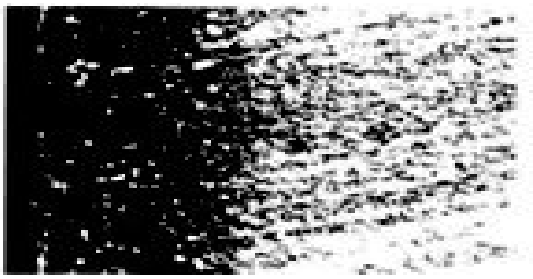

Fig.7 Rp5 steel after the sulphocyanurizing treatment in vibratory field, 40 min. Nital attack 1000:1

From the micrographs it is found that the core structure consists of martensite with inclusions of primary and secondary carbides.

The diffusion layer consists of a dark mass of nitrogen martensite with inclusions of and primary and secondary carbides, as well as inclusions of carbonitrides and uniformly distributed fine sulfides. Sometimes, on the surface is found the appearance of the white layer (the combinations area) made by a agglomeration of defined compounds (sulfides, carbonitrides).

Conclusion:

The diffusion processes of the thermochemical treatments can be substantially accelerated by applying energetic fields. Mechanical vibrations can be applied on the active (liquid) environment or the metallic material. It was proved that the most effective application was directly on the pieces which were to be treated. In this case, the active medium is also stimulated, particularly the one close to the pieces surface.

In addition to the increasing of the diffusion coefficient value, there is also obtained the increasing of the layers hardnesses, with effects on the wear and fatigue resistances

References:

Giacomelli, Ioan, Şerban, Cornel: Thermic and thermochemical heat treatment nonconventional methods. EVIEC VIII Ben Gurion University, Israel, 1997.

Giacomelli, Ioan, Druga, Leontin, Samoila, Cornel, Bot, Dumitru: Unconventional technologies with solid state phase transformations. Editura Lux- Libris, 2000.

Vermesan Gheorghe, and col. - Special heat treatment processes. Cluj - Napoca, 1990

Pogodina-Alekseeva, K.M.,Biront,V.S.,Slavin,L.D.: Effect of ultrasonic vibration on the mechanical properties of R18 steel, Metal Science and Heat Treatment, ISSN: 0026-0673

K. J. L. Iyer: Enhanced activity of austenite resulting from ultrasonic vibration in a low alloy case-hardened steel: Journal of Materials Science, ISSN: 0022-2461