ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering
Tome XIV [2016] – Fascicule 3 [August]
ISSN: 1584-2665 [print; online]
ISSN: 1584-2673 [CD-Rom; online]
a free-accessmultidisciplinarypublication
of theFaculty of Engineering Hunedoara

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OPTIMISATION OF THE THERMAL TREATMENT TECHNOLOGIES FOR THE CAST HIPEREUTECTOID STEEL ROLLS

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ABSTRACT: Undergo a multi-stages heat-treatment process (double annealing followed by tempering cycles) the exploitation properties of the Adamite steel rolls (hardness, strength and stability at their high temperatures) is obviously improved comparing with hypo-eutectoid and eutectoid steel. There are established several alternatives of thermal treatment improvement of Adamite rolls in order to obtain several rolling tools at higher quality parameters. The secondary thermal treatment of normalization followed by tempering ensures the necessary hardness, the structure stabilization and the stress reduction at minimum as well as physical-mechanical properties of the barrel that are necessary in the rolling process.
Keywords: Adamite steel rolls, heat-treatment process, alternatives

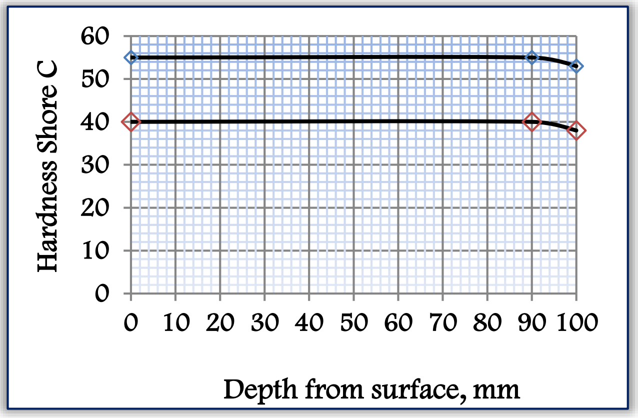
1. INTRODUCTION

Drafting rollers should have high qualities in exploitation mainly determined by hardness, strength and stability at their high temperatures.These qualities determine a high wear resistance as well as resistance to the abrupt temperature variations during the rolling process.Additionally, drafting rollers should ensure a high quality of the rolled product surface as well as the necessary dogging of the metal.From this reason, conditions that material for drafting rollers manufacturing should met, depend on the rolling mill type and the nature of its functions.

Out of various materials being used for working rolls, cast materials on ferrous matrices, due to their tribological properties and costs, have specially good reputation [1-4]. An essential problem constitutes still designing of the microstructure of these materials in such a way as to achieve the required functional properties. Obtaining nearly optimal values of these properties is difficult, however possible.

Adamite steel rolls are classified as ordinary. The Adamite roll is made with a kind of material that is of performances between that of steel that of steel roll and iron roll. Adamite is a material, mechanical, chemical properties and Carbon content of which stands between steel and iron, along-with its alloy elements such as Nickel, Chrome, Molybdenumand/or other alloy elements. Adamite Rolls are basically alloy steel rolls (a kind of high carbon steel) having hardness ranging from 40 degrees Shore C to 55 degrees Shore C with Carbon percentage ranging from 1.35% to 2% (usually between 1.2~2.3%),the extra Carbon and special alloying element giving an extra wear resistance and strength. Adamite rolls are strolled than cast iron rolls and harder than other steel rolls. An outstanding feature of Adamite rolls in that the inner hardness is about the same as that of the surface. Therefore, the Adamite roll's prominent feature is the small variation in hardness of shell, and has a good abrasion resistance and bite performance.

Due to its consistent hardness and material properties surface to core increase its bite capability, makes it ideal rolls for initial stands (in pre-finishing to polishing stands in structure mills, as work rolls or backup rolls), where wear resistance is important along with considerable strength and toughness, adequate heat treatment is very much necessary to achieve requisite wear resistance along with strength and toughness.

a) 

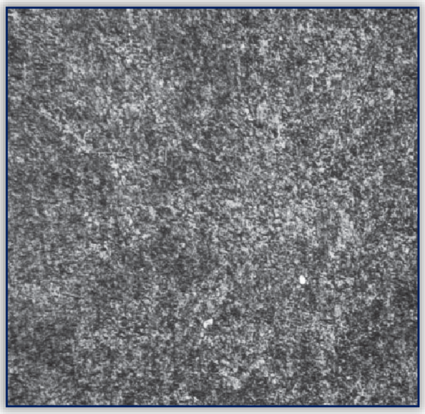
 b)

Figure 1. a) Hardness vs. Depth from surface; b) Microstructure (100x)

These rolls are self-possessed mainly of pearlite with some cementite in the structure, and therefore the wear resistance is obviously improved comparing with hypo-eutectoid and eutectoid steel. Undergo a multi-stages heat-treatment process (double annealing followed by tempering cycles) a micro structure consisting of fine pearlitic matrix with spherodised / broken carbide (dispersed in the matrix) can be gained, which perform well on strength, toughness and hot crack resistance. In fact, after a special heat treatment process, compared with alloy cast steel rolls, it has a good abrasion resistance, and compared with cast iron roll, it has a good strength and toughness.

2. HEAT TREATMENT OF ADAMITE STEEL ROLLS

As raw-cast, the steel rolls are relatively fragile and have lower mechanical properties. In fact, the steel rolls without heat treatment are not appropriate for rolling. Owing to the reasons such as dendritically structure, coarse grain, non-homogeneity and internal stresses these are considered as poor in mechanical properties. Therefore, to give them the good working properties, the cast-steel rolls must be subjected to a heat treatment by which the dendritically structure is destroyed, it eliminates the internal stresses and the mechanical properties, in accordance with the requirements, are improved. Moreover, the application of the heat treatment significantly influenced the cast steel microstructure.

In order to change the morphology of hypereutectoid cementite the cast-steel rolls are heat treated. As a result, these rolls are subjected to precisely calculated and controlled heat treatment.The heat treatment applied to these cast-steel rolls depends on the steels chemical composition, their dimensions and their geometrical form, the size of the grains and the desired mechanical properties. Because of the large variations in size and their shape, the steel rolls heat treatment requires a high technological attention. However cast-steel rolls behave in the heat treatment similar to the forged or laminated products and for all practical purposes the same rules are apply, giving greater attention to their placement in the heating oven in such a way that there is a minimum risk of deformation, contortion or cracking occurs, as to make it unfit for operation.

As applied to hypoeutectoid steel, the heat treatment are usual the followings:

- Annealing – the cast-steel rolls are placed in the oven and heat to a temperature of less than top of point A3, i. e. around 910°C, for carbon steel. The cast-steel rolls shall be maintained at this temperature for about one hour for each 25 mm of thickness of the largest sections and cool slowly in the oven. Such treatment eliminates the internal stresses, refine the graininess and serves to the destruction of the dendritically structure.
- Normalizing – the treatment is similar to annealing, except that the cast-steel rolls should be removed from the heating oven at the end of the maintenance period and cool in the open air. However the internal stresses are not deleted in the same degree as in annealing process. Is often used an double normalization in order to obtain a greater uniformity of grain size. In order to completely eliminate the internal stresses, shall apply in frequently a re-heating to a temperature below the critical curve and slowly cooling in the heating oven. The temperatures of re-heating are between 260 and 690°C
- Hardening and tempering – the use of this treatment will result in an improvement of the mechanical properties, as well as an increase in the level of hardness, producing a tougher, more durable item. Alloys are heated above the critical transformation temperature for the

material, and then cooled rapidly enough to cause the soft initial material to transform to a much harder, stronger structure. Alloys may be air cooled, or cooled by quenching in oil, water, or another liquid, depending upon the amount of alloying elements in the material. Hardened materials are usually tempered or stress relieved to improve their dimensional stability and toughness.The hardening process consists of heating the components above the critical (normalizing) temperature, holding at this temperature for each 25 mm of thickness of the largest sections and cooling at a rate fast enough to allow the material to transform to a much harder, stronger structure, and then tempering. The cast-steel rolls are subsequently tempered to transform the microstructure, achieve the appropriate hardness and eliminate the stresses. The tempering temperature and times are generally controlled to produce the final properties required of the steel. The result is a component with the appropriate combination of hardness, strength and toughness for the intended application.

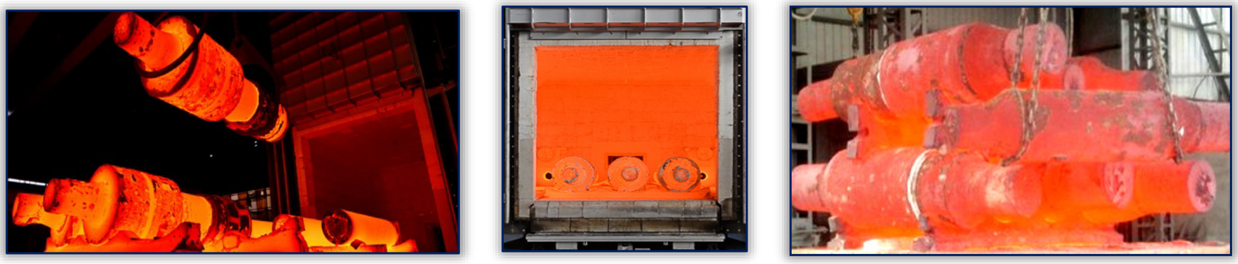


Figure 2. Heat treatments of cast-steel rolls (hypereutectoid steel, Adamite type)

The aim of heat treatments application on the cast-steel rolls (hypereutectoid steel, Adamite type), has a multiple character, respectively:

- eliminate the very high values internal stresses;
- decrease the hardness obtained at casting (~370…400 HB), till the values between the interval 280…300 HB, in view to increase the processing by splinting;
- correction the primary structure by destroying the cementite network, increase of the perlite grains and its fineness in order to assure the proper mechanical properties.

A very important problem related to the cast-steel rolls (hypereutectoid steel, Adamite type) is establishing a corresponding heat treatment which provides the possibility of processing, as well as the obtaining of some final high values of hardness, able to carry out good wear strength.

3. EXPERIMENTAL RESEARCH RESULTS

The chemical composition for the researched steel of Adamite type rolls (statically cast)is presented in Table 1.

Table 1.The chemical composition for the Adamitesteel type rolls

Chemical composition, [%]							
C	Mn	Si	S	P	Cr	Ni	Mo
1.8~2.0	0.7~0.9	0.6~0.8	max.0.02	max.0.04	1.1~1.2	1.5~1.8	0.3~0.5

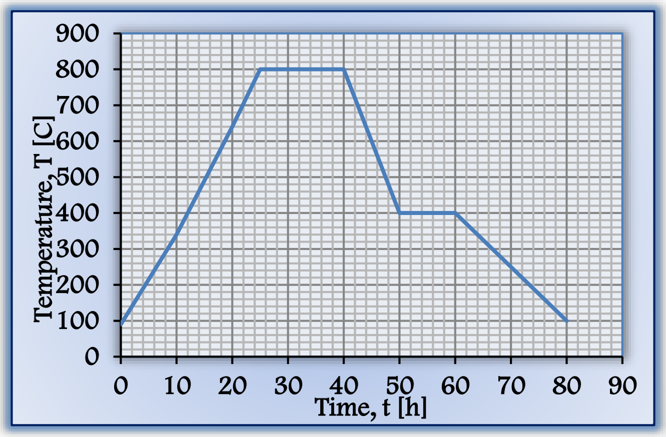


Figure 1. Primary thermal treatment – initial alternative: Heating with 30°C/h – Maintaining at 800°C (17-23 h) – Cooling with 30°C/h – Maintaining at 800°C (14-18 h) – Cooling with 15°C/h – 100°C on furnace hearth

After the thermal treatment the hardness on barrel 360…450 HB have been obtained, that permit this material to be used for rolls manufacturing from many stands.

The high resistance in exploitation of Adamite rolls is ensured during forming condition of a structure with development of a uniform distributed carbide phase.

By the old technology of primary thermal treatment has been realized the spherical matter of perlite's basis obtaining a good processing on cutting machines.

The advantage of this treatment is the short time, a lower annealing temperature that lead to savings of time and fuel. The disadvantage of this thermal treatment is that it couldn´t be realized the fracturing of carbide lattice that leads to rolls embrittlement. In order to solve this problem there have been analyzed the following alternatives of primary thermal treatment.

The tempering afterglow has been done at the same temperature as other alternatives so that has been realized a better fracture of the cementite lattice and the high tempering from the Alternative II has been replaced with the globulization tempering that improves the cutting machine processing.

The tempering afterglow has been done at the same temperature as other alternatives so that has been realized a better fracture of the cementite lattice and the high tempering from the Alternative II has been replaced with the globulization tempering that improves the cutting machine processing.

To the secondary thermal treatment have been researched two alternatives of thermal treatment.

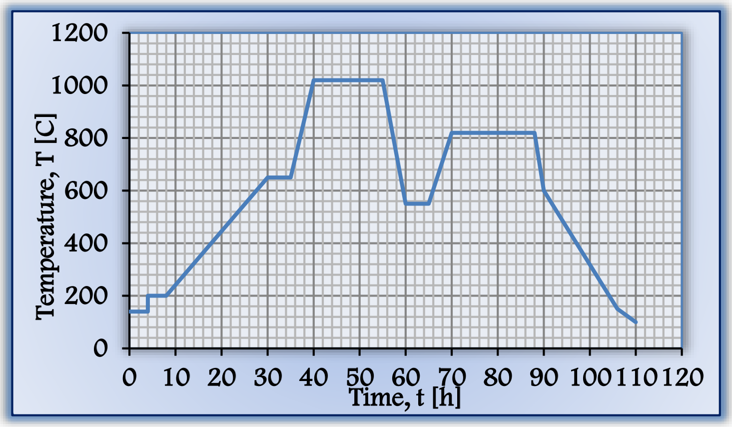


Figure 2. Primary thermal treatment – researchedalternative: Pre-heating and maintaining at 120°C (4 h) – Heating and maintaining at 200°C (4 h) – Heating with 30°C/h and maintaining at 650°C (5 h) – Heating at 1020°C and maintaining (20 h) – Air Cooling until 550°C and maintaining (3 h) – Heating at 820°C and maintaining (20 h) – Combined cooling with 30°C/h until 600°C and with 20°C/h until 150°C – 100°C on furnace hearth

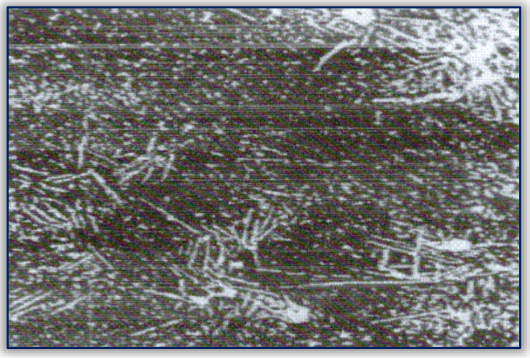


Figure 3. Primary thermal treatment – initial alternative: Hardness HB = 355

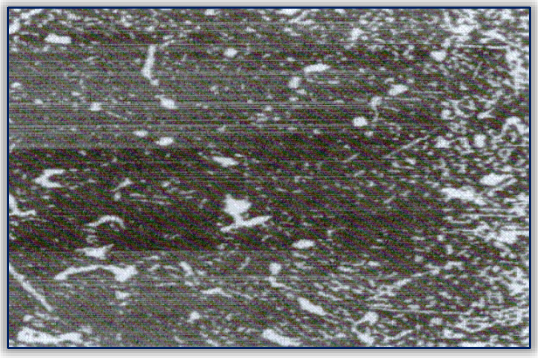


Figure 4. Primary thermal treatment – researched alternative: Hardness HB = 325

4. ALTERNATIVE I

The normalization temperature of 920°C ensures a good hardness but the disadvantage consists of the tempering temperature that is too high and the hardness that is under the lowest limit.

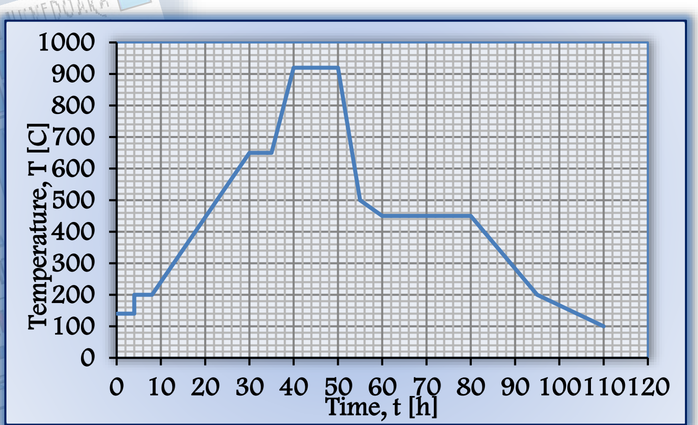


Figure 5. Secondary thermal treatment–initial alternative (I). Pre-heating and maintaining at 100°C (3 h) – Heating and maintaining at 200°C (3 h) – Heating with 20°C/h and maintaining at 650°C (6 h) – Heating with 50°C/h at 920°C and maintaining (15 h) – Air cooling until 500°C – Air cooling until 450°C – Maintaining at 450°C (24 h) – Cooling with 15°C/h until 200°C – Cooling until 100°C in furnace – 100°C on furnace hearth

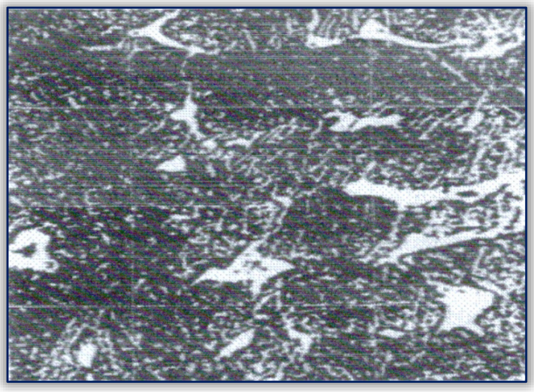


Figure 6. Secondary thermal treatment – initial alternative (I): Hardness on necks HB = 320…330, Hardness on body HB = 360…370

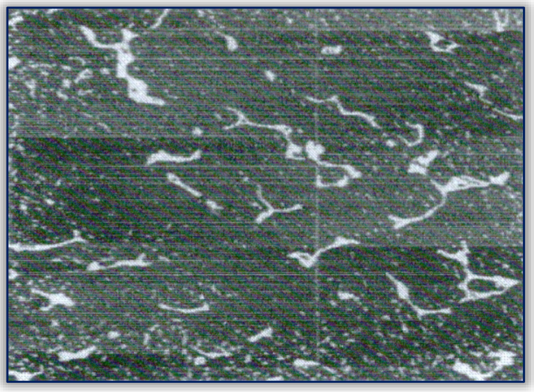


Figure 8. Secondary thermal treatment – researched alternative (II): Hardness on necks HB = 290…300, Hardness on body HB = 400…420

5. ALTERNATIVE II

The normalization temperature of 920⁰C ensures a good hardness but the tempering temperature is too high and the hardness is close to the lowest limit.

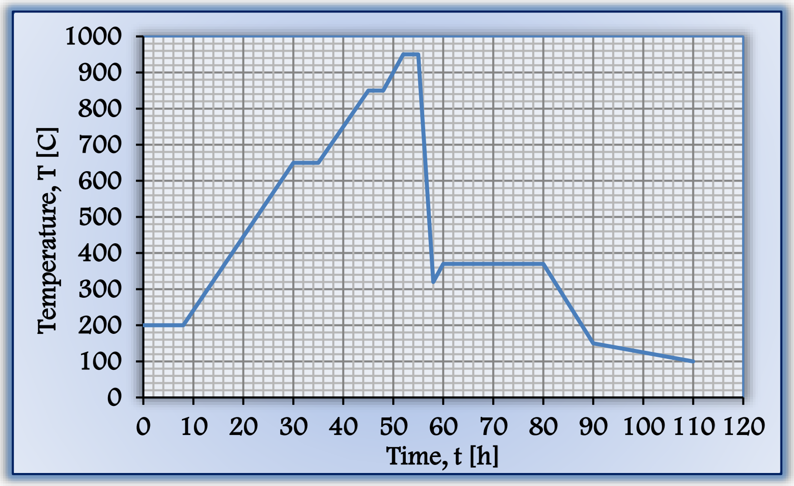


Figure 7. Secondary thermal treatment–researched alternative (II)
Pre-heating and maintaining at 200⁰C (6 h) – Heating with 20⁰C/h and maintaining at 650⁰C (6 h) – Heating with 50⁰C/h (6 h) and maintaining at 850⁰C (4 h) – Heating (6 h) and maintaining at max. 950⁰C (4 h) – Air cooling until 320⁰C – Short re-heating at 370⁰C and maintaining (24 h) – Cooling with 15⁰C/h until 150⁰C – Cooling until 100⁰C in air

In order to obtain a high hardness has been reduced the tempering temperature at 370⁰C.
Analyzing the results obtained from the three alternatives, the final conclusion was that Alternative II is the optimal one.
Before the secondary thermal treatment the roll pins are protected and the heating for normalization is performed very slowly to avoid the thermal stress that leads to rolls breaking.
In order to deeply equalize the temperature is performed the keeping of temperature at 850⁰C followed by another one at 950⁰C. The keeping time at 950⁰C has been reduced because at temperature exceeding 850⁰C occurs the solving of cementite lattice from the grains limit that leads to a low yield point.
As a consequence of this phenomena at longer keeping times appear deformations over the admitted limit by processing allowances. After the keeping period follows the air cooling and then a medium tempering at 370⁰C the structure stabilization and reduction at minimum of the stress are realized. The cooling after the tempering is slowly together with the furnace to reduce at minimum the remanent stress level of the roll.

6. CONCLUSIONS

The research of thermal fatigue of the cylinders for hot-roll, constitute a novelty, and the study of its breakage and rupturing, represents one of the most important issues from the theoretic point of view, and practice, as well.In rolls's choosing, it is necessary to take in consideration the rolling mill type, the efficiency, the stands, which the rolls are adjusting for, the value of reductions, the steel mark which is rolling, the minimum and maximum diameter of rolls, working temperature in rolling process and the cooling way of rolls in rolling time.

Researches performed establish three improved alternatives of thermal treatment for drafting rolls of Adamite type. These consisted of heating and cooling at speeds as low as possible and to increase the normalization temperature has been succeeded the merging of cementite lattice in austenite in order to obtain, after air cooling, a structure as homogenous is possible with a fractured cementite lattice at short dimensions.

The secondary thermal treatment of normalization followed by tempering ensures the necessary hardness, structure stabilization and stress reduction at minimum as well as the physical-mechanical properties of the barrel that are necessary in the rolling process.

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