Analysis Of Cold Rolling And Annealing On Mechanical Properties Of Steel IS-513 (CRO6)

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ABSTRACT:

Purpose: to examine the impact of cold rolling reduction and annealing on mechanical properties of IS-513 (CRO6) steel.

Design/methodology/approach: Testing the of steel strip of IS-513 was based on a combination of cold rolling, recrystallization annealing using muffle furnace, mechanical properties testing and metallographic analyses.

Findings: It was confirmed that by different reduction percentage and different annealing temperatures there will be change in mechanical properties of same raw material

Research limitations/implications: The experiment should be supplemented by different modes of annealing temperatures, a steel strip with various reductions and a spectrometer.

Practical implications: The results may be utilized for optimization of terms of heat treatment in a cold rolling mill.

Keywords: Mechanical properties; IS-513 (CRO6) steel strip; Cold rolling; Recrystallization annealing

1. Introduction

Cold rolling will affect the structure and material properties of steel because there will be no recrystallization can occur. Gradual extensions of grains in the direction of rolling occur. Due to affect of rolling deformation of other structural phases has been developed, such as attachment, perlitic blocks, etc. A deformation in structural and crystallographic texture arises, which causes change in mechanical properties. As this occurrence is most harmful a heat treatment is done after cold rolling for removal of such of properties. These factors affect the microstructure after annealing and the total reduction in cold rolling, conditions of annealing (temperature, time). In the field of processing of metals more and more new progressive types of material has currently been used. Generally – the high rolling of material before annealing, the less initial temperature of recrystallization. At very low temperatures the time required for finishing of annealing is significantly higher and the required spheroidizing of carbides cannot be attained. Strength properties of material will decrease with increase in temperature of annealing, where as plastic properties also increase. Considerably lowering of strength or hardness values occurs at temperatures which are near to 600 °C. The aim of this work was to investigate impact of three different cold reduction sizes in combination with three modes of recrystallization annealing on mechanical properties of steel IS 513 (CRO6).

2. Research

The initial material is taken after semi-continuous pickling from hot rolled strip with thickness 4.1 mm. Chemical composition of steel was as follows:99.58 Fe – 0.035 C – 0.251 Mn – 0.015 Si – 0.008 P – 0.013 S – 0.034 Al – 0.021 Cr – 0.012 Ni – 0.003 V – 0.001 Ti – 0.006 Nb – 0.006 N (wt. %). Samples in the form of stripes with dimensions 4.1 x 20 x 300 mm were rolled in several passes with total thickness reduction 50 to 80 % by using hydraulically pre stressed mill (a four-high mill with work rolls of diameter ?? mm). Now annealing is done with one of three lower mentioned modes followed. It was carried out in a laboratory muffle furnace in the protective atmosphere. Parameters of particular annealing modes are shown in Table 1. They may be described in a following system: rate of temperature increase up to an intermediate dwell // temperature of the intermediate dwell // time of intermediate dwell.

Table 1.
Description of applied annealing modes
Mode 1 - 160 °C/h // 640 °C // 2 h
Mode 2 - 160 °C/h // 675 °C // 2 h
Mode 3 - 160 °C/h // 710 °C // 2 h

The annealed samples underwent the tensile test at the room temperature and the Brinell hardness test. The gained results – hardness HB, yield stress YS [KN/ mm^2], tensile strength TS [KN/ mm^2] and their ratio, as well as elongation A80 in %, were summarized in graphs in Figs. 1-3 in dependence on cold deformation (i.e. relative thickness reduction) before annealing – Ɛ [%]. The found out points were plotted in a coordinate system and the corresponding curves were constructed.

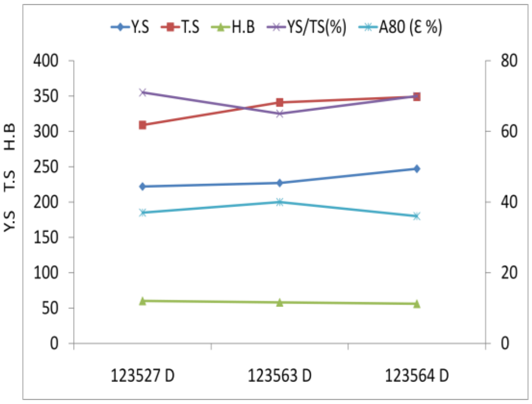

Fig.1.Mechanical properties of samples annealed by mode 1

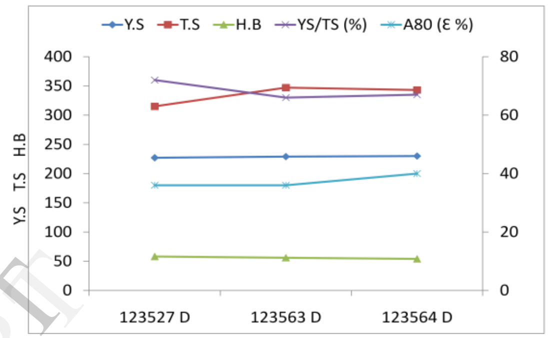

Fig.2.Mechanical properties of samples annealed by mode 2

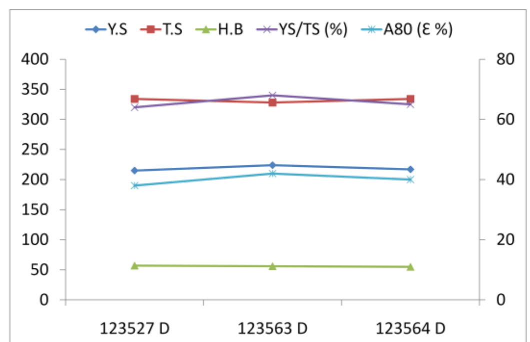

Fig.3. Mechanical properties of samples annealed by mode 3

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3. Metallographic analysis

Samples for micro structure by metrological microscope were taken from middle parts of rolled coils (in a perpendicular section, i.e. in rolling direction). Now the structure was evaluated with selected samples after annealing. The microstructure was created absolutely by ferrite, with a negligible existence of pearlite and very fine grains after cold rolling from 4 HI mill. Nevertheless, not all ferrite grains were approximately equal in all dimensions.

The adjacent Figs [4-6] are the microstructure of rolled samples; Figs [7-9] are the microstructure of the selected annealed samples. All samples have fundamentally structured by ferrite and very low content of pearlite, a character of which (extent of spheroidizing) and region of occurrence depend on parameters of deformation and annealing. The results of the experiment are seen in graphs & structures.

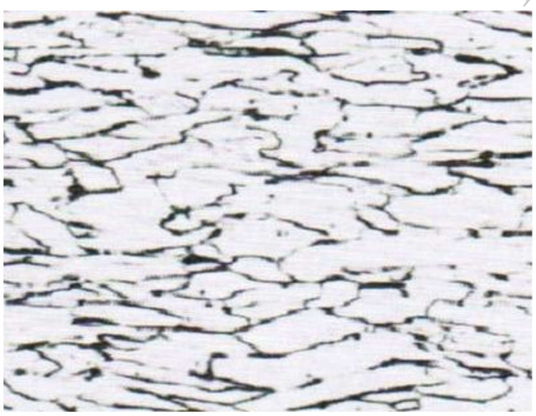

Fig.4. Microstructure after 50% reduction

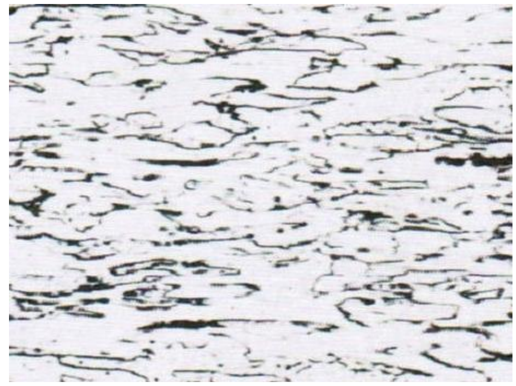

Fig.5. Microstructure after 60% reduction

Fig.6. Microstructure after 80% reduction

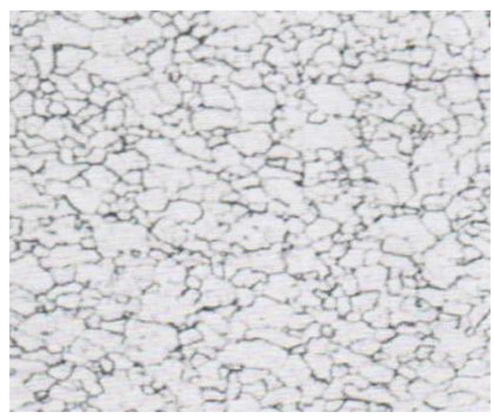

Fig.7. Microstructure after annealing mode 1, reduction 50%

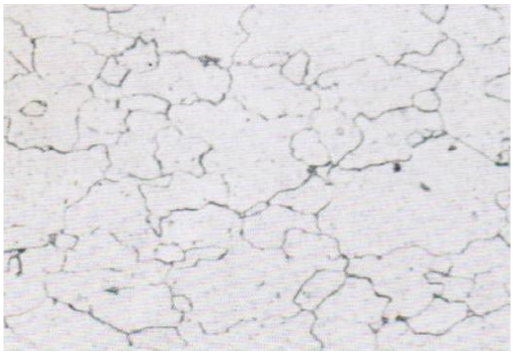

Fig.8. Microstructure after annealing mode 2, reduction 60%

Fig.9. Microstructure after annealing mode 3, reduction 80%

4. Discussion of results

Annealing mode 1 is featured by a gentle increase of strength properties with rising strain up to the value of Ɛ = 37 %; after reaching the value a comparative abrupt drop follows, which is caused by the sequence of recrystallization. Plastic properties (Ɛ % and YS/TS ratio) were comparatively less influenced by the deformation and they are worse than in case of other annealing modes. Annealing mode 2 exhibits the most convoluted course of mechanical properties because a slow rise of YS and TS is followed by these properties after previous strains 50 % to 60 %. The reason is uneven coarsening of recrystallized grains. For strains above 60 % a rise of described properties occurs again. The trend of plastic properties is not so problematical. In the case of annealing mode 3 a prominent minimum of YS and ratio YS/TS is visible, together with maximum of elongation after deformation 60 % to 80 %, which is due to abnormal coarsening of the recrystallized structure. Remarkable is a prominent abrupt drop and rise of YS in compared to TS, which is clear documented by the YS/TS ratio of these variables in the graph. Strength properties achieved by this mode of annealing are the lowermost ones and, on the divergent, plastic properties (mainly after deformations around 50 %) the best ones, which is not astonishing with regard to a high annealing temperature. particular curves in all graphs replicate the relation between plastic and strength properties. Formability rises and vice versa strength and plastic properties fall with increase in temperature of recrystallization annealing.

5. Conclusion

By the described way it is possible to regulate microstructure of strip and gain a major share of ferrite grains equal dimensions in all directions, but an average size of resulting grains is by no means drastically smaller than that one after hot rolled. It was confirmed that by an apposite combination of size of previous cold deformation and limits of the following recrystallization annealing. It is possible to stimulus a complex of mechanical properties of precise strips. Strength properties of material were comparatively declining with the rise in annealing temperature; where as plastic properties were increasing. With repute to the fact that mechanical properties can vary a lot on demand of the client. It is not possible to set up a general-purpose annealing mode that would be the most appropriate. Specific tendencies of strength and plastic properties resemble to each other and they may be employed for optimization of terms of heat treatment of the examined CRO6 steel in a cold rolling mill, exactly in compliance with specific requirements for a relative between plastic and strength properties of the given material.

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