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THE INFLUENCE OF THE TEMPERATURE REGIME ON THE MECHANICAL PROPERTIES OF THE THICK STEEL SHEETS FROM CARBON AND LOW-ALLOY STEELS, LAMINATED TO THICKNESSES LESS THAN 40 MM

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ABSTRACT

Steel remains the most used material in the machinery industry, the construction of oil and gas pipelines, etc. Hot rolling is no longer a simple means of obtaining the final geometry of products in the steel industry, but in some way leading to the lamination process, it is possible to obtain a given structure which gives the rolled products the desired mechanical characteristics.

In this paper we analyzed the technological parameters which influence the properties of the materials, the technological measures for obtaining the appearance and structure of the steels can be deduced.

KEYWORDS: temperature regime, mechanical properties, carbon alloy steel

1. Introduction

The level of mechanical and technological properties of hot rolled flat products is the expression of the combined action of chemical composition factors (including micro-alloying) and structure.

For a given chemical composition, the decisive role in obtaining a certain set of mechanical properties is the structural factor, especially since, depending on the way of conducting the manufacturing process, a wide range of types can be obtained on the finished product structures.

The structure obtained is the result of the cumulative action of all the technological and compositional factors involved in the production of flat products:

- the heating temperature for rolling;
- the degree of reduction applied;
- the cooling rate after rolling;
- final temperature of rolling.

When choosing the technological parameters of lamination, it is taken into account their influence on the structural changes that occur during deformation (dynamic recrystallization, static recrystallization, austenite grain growth, phase transformation).

From the analysis of the sizes that influence the properties of the materials, the technological measures for obtaining the appearance and structure of the steels can be deduced.

Modern molding processes allow the structure and the characteristics of the finished product to be controlled during the deformation processes.

The decrease of the lamination temperature implies, while the other factors (degree of deformation, rolling time) are constant, the reduction of the rate of recrystallization and the obtaining of a fine austenitic granulation and, under certain conditions, of a non-recrystallized austenite upon the background of which cooling forms a ferrite-perlite structure whose fineness will depend on the deformation temperature [1].

It is important to obtain a fine austenitic structure during roughing deformation. The total degree of roughing deformation is generally 60%, decreasing with lower heating temperatures. The last roughing pass must be as large as possible (within acceptable limits) and the rolling temperature should be as low as possible.

Each category of sheet is a particular case in which the chemical composition of the base metal and the lamination scheme must be defined to allow the desired mechanical properties to be obtained without further heat treatment.

Indeed, according to Petch's laws, the limit of elasticity and the transition temperature (resilience) improve when the ferrite grain size decreases.

Numerous papers have specified the optimal configuration of austenite before transformation

$\gamma \rightarrow \alpha$, the grains must be fine, homogeneous and hardened [3].

The lamination at controlled temperature, fixing the conditions of recrystallization and deformation of the austenite, allows obtaining such g grains. At high temperature, the deformations introduced to the lamination of the thick sheets are accompanied by a static recrystallization of the austenite.

In the case of higher temperatures, the grains may increase between each pass. In the case of intermediate temperatures, the grains are refined through successive deformations and recrystallizations. At low temperature the austenite recrystallizes slowly. From a lamination pass to another, the grain does not have time to recrystallize; it progressively prolongs resulting the development of ferrite germination sites (grain boundaries, deformation bands) [4].

The good practice of laminating at controlled temperature therefore requires precise determination of the temperatures at which deformations of the product are to be carried out.

2. Deviations of mechanical characteristics and technological properties

Mechanical characteristics and inappropriate technological properties may in general have the following causes:

- inappropriate chemical composition;
- defects of steel material;
- inappropriate conditions at plastic deformation or chemical treatment;
- inappropriate sample sampling (non-precision dimensions, unfinished surfaces, uninterrupted joints);
- incorrect test execution.

The main mechanical characteristics and technological properties, the more significant and frequent causes (in the hypothesis of a suitable chemical composition) are:

a. Low tensile strength: inappropriate chemical treatment; inappropriate fiber orientation; plastic deformation with a too small cut; discontinuities of the material; internal defects (breaths, cracks, non-metallic inclusions, porosity); steel burning; regional segregation.

b. High tensile strength: inappropriate chemical treatment; too low temperature at the end of plastic deformation; excessive cutting of the laminate section; internal stresses (caused, for example, by uneven cooling of the material).

c. Low resistance: insufficient degassing of steel; gross or non-homogeneous granulation; precipitation at the edge of grains; segregation; structure pronounced in strips; inappropriate fiber orientation; steel burning; material discontinuities; internal defects (breaths, cracks, non-metallic inclusions, porosity); too small ratio of reduction; inappropriate microstructure due to heat treatment; residual internal tensions; fragility on tempering.

d. Insufficient elongation: the causes of these defects are the same as those shown for low resilience, with the observation that the fibrous structure or non-metallic plastic inclusions disposed parallel to the sample axis do not significantly influence the reduction of the elongation and constriction.

e. Shock test: material discontinuity; internal defects (cracks or tears, puffs, traces or porosity); structural defects (trans-crystallization, coarse granulation, grain precipitation, segregation); improper heat treatment, steel burning.

In the case of a suitable chemical composition, the steel structure largely determines the properties of the laminated sheets. Mechanical characteristics and technological properties are strongly influenced by the internal stresses of the laminates, usually caused by non-homogeneous deformations in the section, by inaccurate rolling temperatures and too high cooling speeds, i.e. by non-observance of the technological instructions of the products delivered in laminated state. Mechanical features can be reshaped in these situations by appropriate heat treatments.

Requirements for mechanical and technological properties are particularly important, especially for some steels, such as for example the construction ones. In some cases, the required properties are obtained directly from the plastic processing of steel, or sometimes a thermal treatment is required.

Generally, rejects due to chemical composition are rare, especially when assembling new assortments for which no verified chemical compositions have not yet been established. In order to ensure the prescribed mechanical and technological properties, the steel from which the product is processed must be adequate; badly deoxidized steel and the presence of defects such as: nonmetallic clusters, strong segregation, shrinkages, cracks, may (depending on the defect intensity) reduce the properties to their permissible limit or cause the products reject.

3. Industrial experiments

The industrial experiments aimed at establishing the hot deformation regime of the thick sheets in order to modify the existing rolling technologies to reduce the non-compliance of the mechanical characteristics values within the limits stipulated in the manufacturing norms [13].

For this purpose, different deformation regimes were used for carbon steel and low alloyed sheets with thicknesses less than 40 mm.

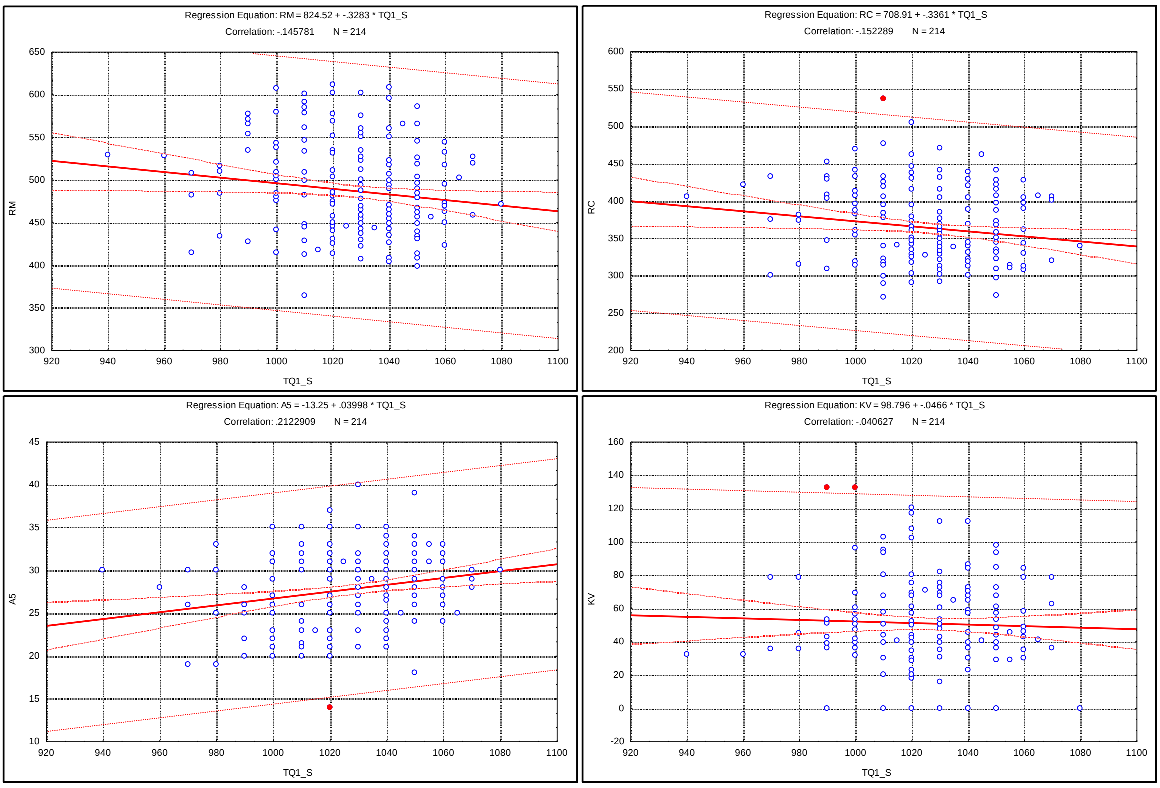

Fig. 1. *Results of the laboratory tests according to the final temperature of rolling in the roughing stand (TQ1-S)*

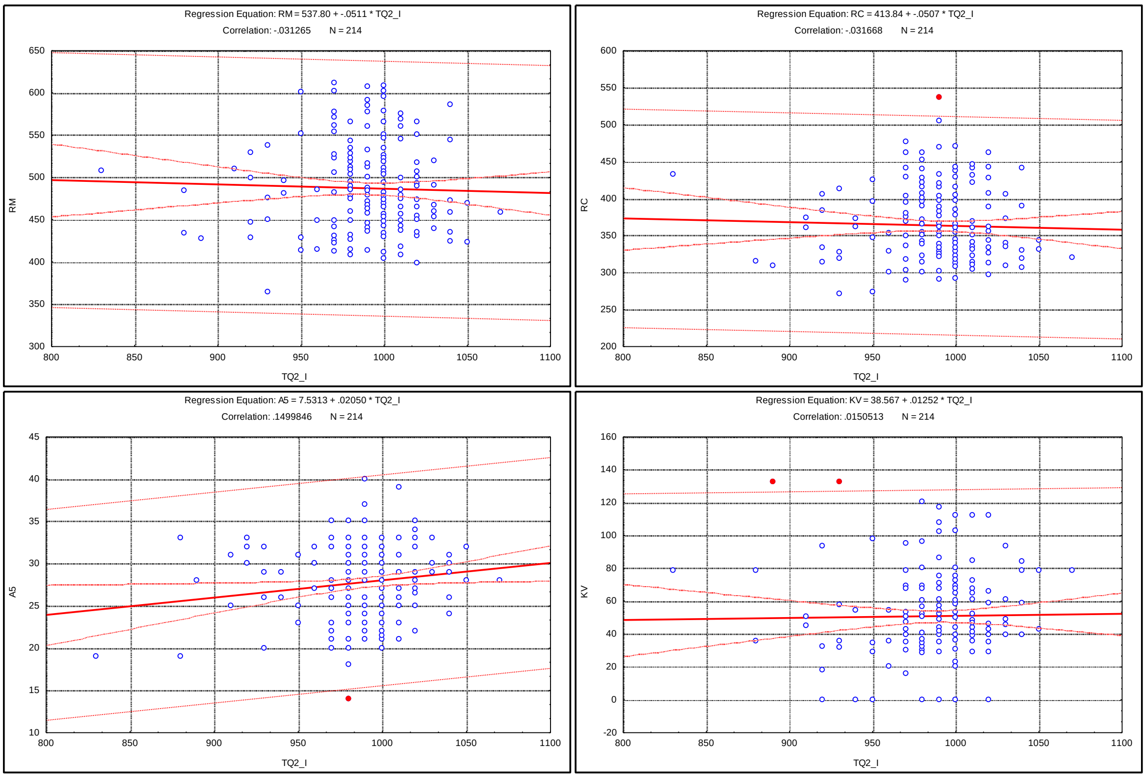

Fig. 2. *Results of the laboratory tests according to the starting temperature in the finishing stand (TQ2-I)*

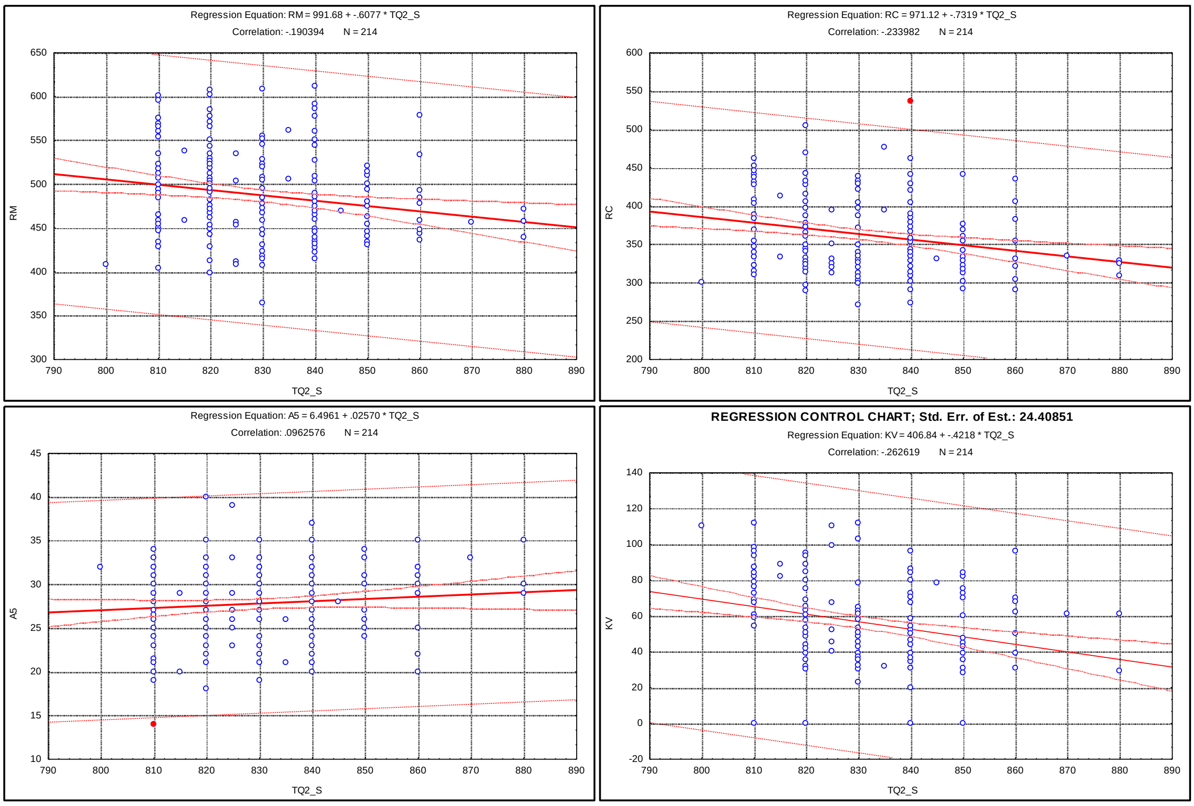

***Fig. 3.** Results of the laboratory tests according to the final temperature of rolling in the finishing stand (TQ2-S)*

The parameters values recorded of the flow and the mechanical characteristics resulting from the laboratory tests have been recorded and processed.

With the results of the laboratory tests, the regression curves were plotted according to:

- the final temperature of rolling in the roughing stand (TQ1-S);
- the starting temperature in the finishing stand (TQ2-I);
- the final temperature of rolling in the finishing stand (TQ2-S);
- the degree of deformation in the roughing stand (DH-Q1) and;
- the degree of deformation in the finishing stand (DH-Q2) (as a percentage of the total reduction).

The graphical representation of the regression equations thus obtained is shown in Figures 1-3.

4. Conclusions and measures

4.1. Conclusions resulting from the processing of recorded data

From the analysis of the mechanical test values and the shape of the regression curves, the following conclusions are reached regarding the carbon and low alloy steel plates with thicknesses less than 40 mm:

a) the influence of the thermal deformation regime:

- the tensile strength and flow limit decreases with the increase of the end lamination temperature;
- elongation and resilience increase with the end lamination temperature increasing;
- deformation in the finishing stand provides values corresponding to the mechanical characteristics if it is in the range 980 - 820 ºC;
- the final temperature of rolling is in the range 820-840 ºC.

b) Influence of the deformation degree:

- by increasing the degree of reduction in the roughing stand over 75%, the values of the tensile strength, the flow limit and the resilience decrease while the elongation increases;
- by increasing the reduction in finishing stand, the values of the mechanical characteristics are higher than the minimum admissible limits and it is recommended that the reduction should be approx. 30% from the total reduction;

4.2. Measures to improve rolling technologies

We presented the dependence of the mechanical characteristics of the plate products on the manufacturing process parameters. Therefore, the mechanical characteristics can be varied within wide limits by choosing suitable manufacturing conditions within the three phases: elaboration, lamination, heat treatment.

1. For hot rolled flat products made of low carbon or low alloy steels up to 40 mm thick, it is possible the improvement of the strength properties by rolling at lower temperatures followed by accelerated cooling.

2. Achievement of high mechanical characteristics is ensured by the proper choice of steel and by strict observance of the specific technological parameters of the process: austenitic temperature, temperature and deformation degree, number of passes, duration of breaks between passes, final cooling conditions, etc.

3. It is proposed to supplement the manufacturing process instructions as follows:

- the application of a reduction degree of about 75% in the roughing stand;
- the final temperature of rolling in the finishing stand is between 820 and 840 °C.

References

[1]. Antonio Augusto Gorni, *Steel Forming and Heat Treating Handbook*, São Vicente SP Brazil, 20 February 2014.

[2]. Bordei M., Drăgulin I, Tănase D., Vasiliu A., *Tehnologii, agregate şi utilaje pentru deformare plastică la cald*, Ed. Ştiinţifică Fundaţia Metalurgia Română, ISBN 973-8151-26-0, Bucureşti, 2004.

[3]. Cazimirovici E., *Bazele teoretice ale deformării plastice*, Ed. Bren, Bucureşti, 1999.

[4]. Cananau Nicolae, Tanase Dinel, *Bazele teoretice ale deformărilor plastice - Rezistenţa la deformare a materialelor metalice*, Galati University Press, 2011.

[5]. Chen C. Y., Yen H. W., Kao F. H., Li W. C., Huang C. Y., Yang J. R., Wang S. H., *Precipitation hardening of high-strength low-alloy steels by nanometer-sized carbides*, Materials Science and Engineering, 499(1), p. 162-166, 2009.

[6]. Mihoc G., *Matematici aplicate în statistică*, Ed. Academiei, Bucureşti, 1988.

[7]. Moretto Christian, *Making Heavy Plate - plate mill rolling process*, ArcelorMittal University 2014;

[8]. Ginzburg Vladimir B., Ballas Robert, *Fundamentals of Flat Rolling Manufacturing Engineering and Materials Processing*, Publisher CRC Press, 2000.

[9]. Potecaşu Florentina, Potecaşu Octavian, Drugescu Elena, Alexandru Petrică, *The Influence of Cold Rolling on the Microsucture for Drawing Steels*, The Annals of ‘Dunărea de Jos’ University of Galaţi, Fascicle IX Metallurgy and Material Science, no. 2, p. 40-46, 2007.

[10]. Potecasu Octavian, Potecasu Florentina, Alexandru Petrica, Radu Tamara, *The Influence of Cold Rolling on the Mechanical Characteristics for Drawing Steels*, The Annals of ‘Dunărea de Jos’ University of Galaţi, Fascicle IX Metallurgy and Material Science, no. 1, p. 55-61, 2008.

[11]. Sakaia Taku, Belyakovb Andrey, Kaibyshevb Rustam, Miuraa Hiromi, Jonasc John J., *Dynamic and postdynamic recrystallization under hot, cold and severe plastic deformation conditions*, Progress in Materials Science, vol. 60, p. 130-207, March 2014.

[12]. Stănescu C., *Studii şi cercetări de modelare matematică a procesului de laminare la caje reversibile*, Teză doctorat, Universitatea-Politehnica Bucuresti 1996.

[13]. Wang X. D., Huang B. X., Wang L., Rong Y. H., *Microstructure and mechanical properties of microalloyed highstrength transformation-induced plasticity steels*, Metallurgical and Materials Transactions A., 39(1), p. 1-7, 2008.

[14]. Charles Romberger, *Studiu tehnico economic LTG2 - 1979 - Procedura de fabricaţie a tablelor groase/ Making Heavy Plate - Slab prepapration*, ArcelorMittal University, 2014.