# The Influence of the Temperature Regime on the Mechanical Properties of the Thick Steel Sheets from Carbon and Low alloy Steels, Laminated to Thicknesses More than 40 mm

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*Apparently, defects caused by failures in mechanical characteristics do not have a significant weight, but at a closer analysis it is noted that there are many lamination programs in which the thermal heat treatment is needed. These defects are generally not a reason for rejecting the plates, but annealing leads to increased specific consumption.*

*Keywords: thermal heat treatment, steel, carbon and low alloy steel, thick steel sheets*

The properties of a material are conferred by factors that can be reduced to two terms, which are the chemical composition of the material and its structure.

The manufacturing conditions must be in accordance with the requirements regarding the complexity of characteristics imposed on the finished product.

The next step in obtaining flat products, step which influences the properties of the material, is the hot rolling process. At first, lamination was carried out only for the purpose of deformation, having to reach predetermined dimensions. Modern laminators allow tight tolerances and, in addition, the current rolling technique allows influences on structure development and material properties [1-11].

Modern rolling mills have high rolling forces and high performance measuring and adjustment installations which allow high degree of deformation. The process of *transformation - temperature - time* determines the structure of the laminated steel. During lamination and cooling after lamination, the recrystallization and increase of the austenitic grain as well as the transformation phase process can be carried out in such a way that in the laminated sheet an optimal structure with corresponding properties is obtained.

In the case of conventional lamination, the final deformation temperature is at relatively high values so that, at low deformation resistance, the required reductions are achieved under the conditions of minimum rolling forces. A rough austenitic grain is obtained.

For the mode of action of a deformation, it is necessary to take into account, first, two temperature domains: the domain of transformation $\gamma \rightarrow \alpha$ and the domain in which the austenite does not recrystallize. The shift of the transformation to lower temperature (especially through increased manganese content) and the extension of the austenitic domain which does not recrystallize by microalliation is an important condition, in some variants even necessary.

In the case of annealing lamination (controlled) - for which a microalloying is not mainly necessary - the final lamination temperature is slightly above the austenite recrystallization temperature. There is a polygonal austenitic structure that is similar to a normalization annealing.

The deformed austenite grain can suffer a decrease of resistance before beginning the transformation of the structure $\gamma \rightarrow \alpha$ a by crystallization and recrystallization. In the phase transformation, a secondary structure is formed, comparable to the normalization annealing state.

The austenitic structure can be guided in three phases of the rolling process:

- *during the heating of the brames for lamination*: when the prescribed heating temperature is exceeded, there is an excessive increase in the austenite grains, which influences the structure after rolling;
- *during lamination*: the deformation and temperature over time influence the grain growth and recrystallization processes in such a way that a certain structure can already be prefigured at the end of the lamination;
- *between the end of the lamination and the beginning of the austenitic transformation*: other steps of crystal repair and recrystallization are carried out.

Another very effective measure for influencing the structure is cooling from the final rolling temperature, applying an increased cooling rate. Through accelerated cooling a a finer granulation is obtained, a shift of the structure transformation from ferrite / perlite to ferrite / bainite and to a more uniform structure.

The accelerated cooling process from the lamination temperature creates the possibility that, based on a given chemical composition, laminated plates can be obtained which can present a higher flow limit than after the annealing, or even after the thermomechanical rolling [12-19].

*Considering the defects of thick laminated sheets*

The causes that contribute to defects are varied: the lack of purity of the raw materials, the imperfection of the machinery, the processes and the working conditions involved in the processes of molding, casting and rolling. The human factor, which in many cases is the main cause of product dumping, cannot be neglected.

Establishing measures to prevent defects should be based on the fullest knowledge of the causes that generate or favor their appearance.

Defects produced on laminates can be divided, with regard to the place of appearance in:

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- surface defects, visible to the naked eye and located in a shallow area;
- geometry defects (shape), of size and mass, measurable or visible;
- interior defects, which can be highlighted by appropriate methods and equipment.

From the origin point of view, the defects within the different groups of laminated products are classified into:
- defects in material produced during steel metallurgical steel casting and casting operations;
- processing defects caused by how the raw material was prepared, steel heating, rolling, cooling, heat treatment, product adjustment.

Generally, a defect is the result of the interaction of complex causes, depending on a variable number of parameters. Similar defects as an external appearance may have one or more different causes, as apparently different defects may have common causes.

In many cases, the causes of the defects have not yet been elucidated yet, the proposed assumptions only partially explaining the implications of the phenomena. Particular circumstances and local working conditions can explain partially this situation and justify the initiation and development of own research in this field [20-33].

## Experimental part

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.

For this purpose, different deformation regimes were used for carbon steel and low alloyed sheets with thicknesses from 40 to 100 mm.

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.

## Results and discussions

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 sheets with thicknesses greater than 40 mm:

*a) the influence of the thermal deformation regime:*

- achieving a higher final temperature in the higher roughing stand (1000-1030°C) results in increased strength characteristics;
- the start of lamination in finishing stand at temperatures above 880°C affects the values of mechanical characteristics in the negative sense; It results that a waiting period for lowering the temperature of the material is required between the rouging and the finishing stand;
- guaranteed mechanical characteristics are obtained at lamination final temperatures of 800-840°C;
- the lower the value of the final temperature towards the inferior value of this interval is, the higher the resilience values are.

b) Influence of deformation degree:

- at reductions of over 70% of the total reduction in the bumper, the mechanical characteristics decrease, only the resilience being positively influenced;

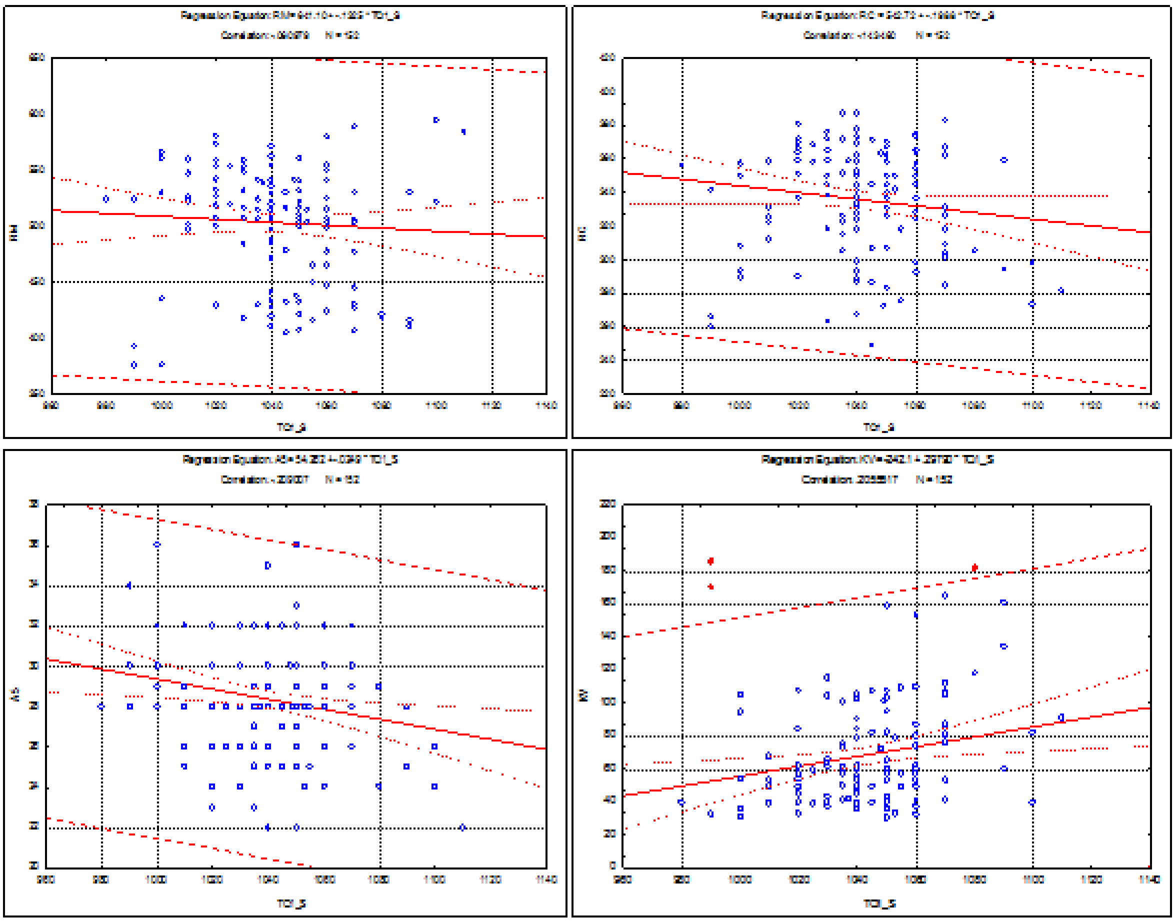

Fig. 1. Results of the Rm, Rc, A5, KV according to the final temperature of rolling in the roughing stand (TQ1-S)

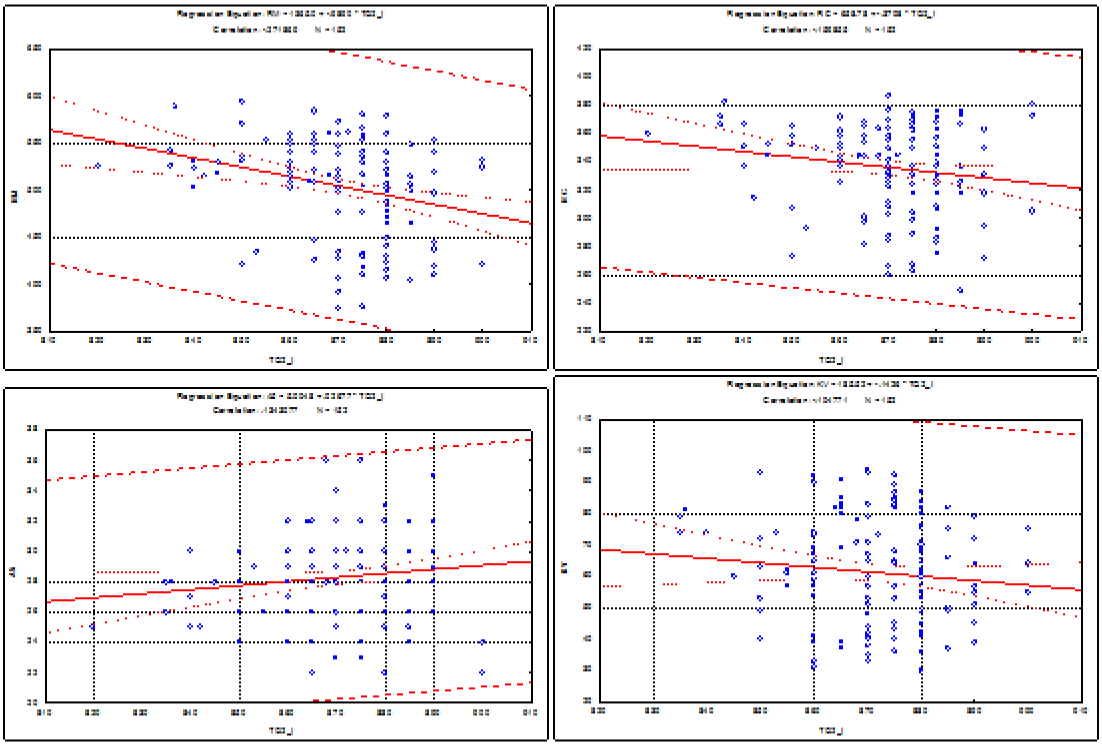

Fig. 2. Results of the Rm, Rc, A5, KV according to the starting temperature in the finishing stand (TQ2-I)

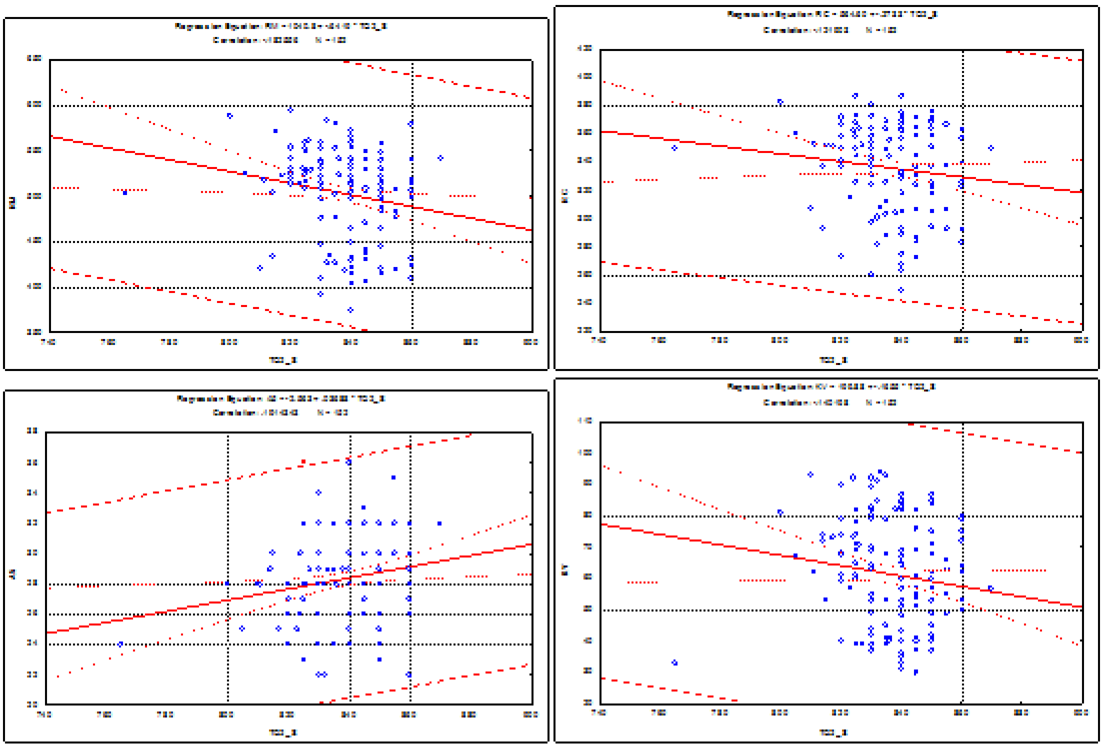

Fig. 3. Results of the Rm, Rc, A5, KV according to the final temperature of rolling in the finishing stand (TQ2-S)

- by increasing the degree of deformation to 30% of the total reduction in finishing cage, the mechanical characteristics values increase.

## Conclusions

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

In order to increase the level of mechanical properties of carbon steel for general use it is necessary to improve the technology of laminate production and to systematically analyze its quality according to thickness, assortment, steel grade.

For hot-rolled flat products greater than 40mm thick, it is possible to improve the resistance properties by laminating at lower temperatures followed by accelerated cooling.

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

-the application of a reduction degree of about 70% in the rouging stand;

-the beginning of rolling in the finishing does not exceed 860-880°C;

-the final temperature is in the range 800-820°C;

-during rolling in the finishing, the board will cool intensively on each pass.

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