CHOOSING AND USING RATIONALLY THE THERMIC PROCESSED STEELS

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ABSTRACT

On a global scale one can notice a constant preoccupation for a rational choosing and using of the materials on the whole and, especially of the steels with the main objective the increase of the machines', equipment' and constructions' efficiency and competitiveness. An important issue that contributes, for example, to the choice of the "ideal" brand of steel for a piece, is the availability of a right equipment to produce a thermal processing under control. The research looked for the influence of the carbon content on the one hand, and of the vanadium on the other hand (as a micro alloying element), on the mechanical characteristics and the structure for four series of materials (21VMoCr14, 34 MoCr11, 40 VMoCr11 si 42 MoCr11), which undertook different types of thermal processing.

KEYWORDS: steel, thermal processing, mechanical characteristics, microstructure, efficiency

1. Introduction

The quality of the metallic materials used for producing a product together with the layout design and the manufacturing technology, contributes to the level of the technical, economical performances that it can achieve. Thus, today it is a continuous increase of how to use rationally the materials worldwide as a whole and especially the use of the steels. The main objective is the increase in efficiency and competitiveness of the machines, equipment and constructions.

A rational usage of a metallurgical product for a certain field is a complex issue, and it generally means assigning the steel brand that has the minimum resistance and endurance requirements of the piece for a minimum price. Any tendency to ensure superior materials as to the minimum requirements is harmful from an economic point of view and it does not contribute to increasing the machines' technical performances out of which the respective piece is part of. In our country the steel brands and the products intended to be used in the main fields of the national economy are standardized. Using other materials than those standard is forbidden by law. In order to fulfill with these materials the economy needs' it has grown a relatively wide range of standardized steels, which can sometimes lead to an inefficient marketing of steel brands and products, whose usage is scanty in real life and so they are difficult to buy.

Creating a steel brand in the siderurgical industry is usually made in high capacity plants. Answering to a small quantity request, requires either using from stock-piles, which usually are in a limited range of dimensions and it leads to higher metal consumptions, or waiting until these requests taken to the producer who decides to produce casts with the respective requirements. This can frequently be met in the case of the steels for thermal treated pieces. It is considered to be useful to anticipate, on groups of machines constructions, the limited range of steel brands and recommended products to be used. When choosing these steel brands one has to take also into account the perspective economic materials and, when choosing for a given case the routine should be avoided.

The maximum exploitation of the technological properties of the siderurgical product requires that the steels have adequate technological properties, according to the specific technologies from the machines' construction industry. The most important are: the weldability, the behavior to thermal treatment, the aptitude for plastic deformation, etc. Often enough these proprieties are antagonistic to those of resistance, and so it appears as necessary to establish an optimum compromise.

For instance, any steel is weldable in certain conditions, but it should be avoided welding those steels to which these operations as well as the necessary thermal treatments and the subsequent quality controls are expensive or the quality factor of the welding is relatively low. This is why the steels with a better weldability are to be preferred in these cases and it ensures a welding through efficient procedures. This way, even if the material has lower resistance characteristics, the minimum requirements asked for the respective market are met. An important factor that, for instance, contributes to the choice of the “ideal” steel for a piece, is the availability of the right equipment for thermal treatment. Neglecting this aspect leads most of the time to unnecessary expenses, caused either by the use of an expensive material, or by producing scrap materials due to decarburation, ruptures, excessive deformation, etc.

2. Experimental results

The influence on content of the carbon as well as the vanadium was studied in the research (as an micro alloying element) on the mechanical characteristics and the structure for four series of materials with 0.2%, 0.3%, 0.4%C, on which different types of thermal treatments were applied (classic brands, known according to the STAS rules as steels 21VMoCr14, 34 MoCr11, 40 VMoCr11 and 42 MoCr11). The chemical composition, guaranteed by the producers was confirmed also by the laboratory chemical analysis made on the DV-6 spectrometer.

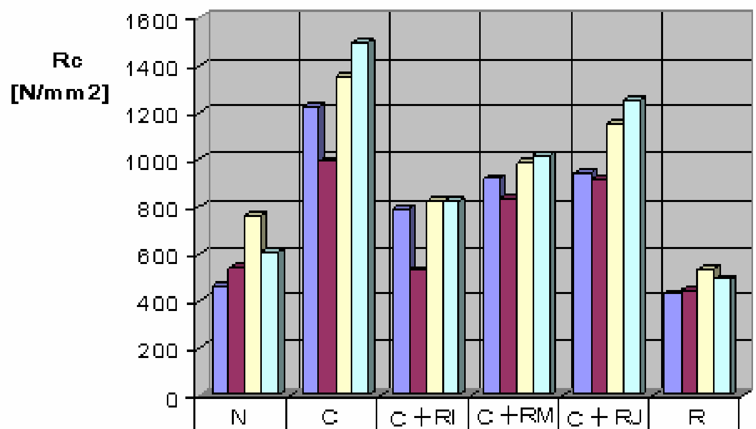
The mechanical proofs were made at the room temperature according to the applicable standards SR EN 10002/1:2002 (traction assay) and SR EN 10045/1:1993 (the bending assay through jolt).

The assay series to be studied were put under the following thermal treatments: normalization (N), quenching (C), quenching + high annealing (C+RI), quenching + medium annealing (C +RM), quenching + low annealing (C+RJ) and annealing (R), after which the metallographic structure was analyzed and the corresponding mechanical characteristics to each quality of material was determined. For this the following assays were made at room temperature: the traction assay, according to SR EN 10002/1 and the bending assay through jolt according to SE EN 10045/1, on samples ISO –V.

We should say that this experimental program was fully kept after each thermal treatment applied to the samples.

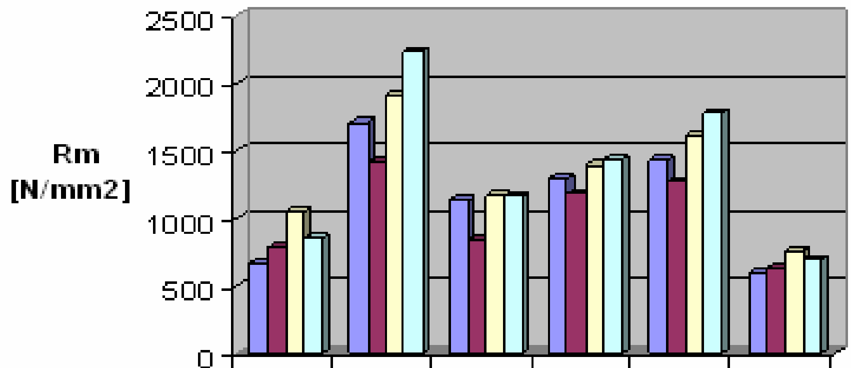
3. Results and Discussion

For all of the four types of steel, depending on the applied thermal treatment, the mechanical characteristic values are comparatively presented for each of the four series of materials in the histograms below (Figures 1-5).



	N	C	C+RI	C+RM	C+RJ	R
21VMoCr14	464	1223	791	920	943	433
34MoCr11	540	992	532	833	914	444
40VMoCr11	761	1352	820	984	1153	533
42MoCr11	607	1495	822	1020	1254	490

Fig. 1. *Variation of the flowing limit depending on the thermal treatment applied for the four steel brands studied*



	N	C	C+RI	C+RM	C+RJ	R
21VMoCr14	673	1711	1133	1295	1430	593
34MoCr11	787	1420	836	1185	1275	633
40VMoCr11	1052	1917	1169	1394	1614	755
42MoCr11	856	2238	1163	1438	1777	697

***Fig. 2.** Variation of the tensile strength depending on the thermal treatment applied for the four steel brands studied*

In order to establish a metallurgical ongoing state in the comparative analysis, all the samples had initially been put under a ***stress-relieving annealing*** thermal treatment. This way the internal tensions, remnant to the rolling process of the semi product, had been tampered down and the potential danger of breaking at mechanical strains was eliminated in order not to affect the determination’s relevance. The four steel brands studied in this paper have a relatively low mechanical resistance combined with satisfying plasticity and tenacity.

The tendency to reduce the tenacity, induced by the chrome presence, is compensated by reducing the fragility with the influence of molybdenum and vanadium.

One can notice a superior plasticity to carbon content comparable (at the brands with vanadium), which is explained by the role of the chemical element in finishing the grains.

After the ***stress-relieving annealing*** thermal treatment applied to the studied samples, if we take into consideration the average value of the impact strength, we notice that this is with over 50% higher at 40VMoCr11, as compared to 42 MoCr11, an observation valid also for the elongation (A), bottlenecking (Z) and flowing (R_c). This gap is also noticed at the comparison between 21VMoCr14 and 34MoCr11, although the comparison is less relevant due to the carbon content difference.

The flow limit for the four steels studied is comparatively presented in the graph in Fig. 1. It can be noticed that the highest values of the flow limit is recorded in the case of ***quenching and quenching followed by low annealing***.

The tensile strength records values significantly higher when quenching, according to the thermal treatment applied to the studied steels for the four types of steel.

Elongation has the highest values at high annealing. All four steels have the best values compared to the other treatments in the case of high annealing. So, high annealing is the most efficient treatment for the studied steels, when it is required as the main property elongation.

The impact strength has significant values when high annealing is applied, the highest value obtained is 82.7 Joule, for the steel 34MoCr11. When quenching we have the lowest impact strength values, for all the types of the studied steels.

Bottlenecking depending on the thermal treatment has the highest values for high annealing for all the steel types in question.

Applying ***the normalization treatment*** had as a notable result an increase of the mechanical resistance (Fig. 2) without important changes of the plasticity or tenacity. The brands with a higher content of carbon presented the highest variations of the tensile strength and the flow limit, while the role of the alloying elements had a similar behavior just like the annealing. It is to be noticed the increase of 40% of the mechanical resistance for the brand 40VMoCr11, while keeping an average value of 32 Joule for the breaking energy, value that means it has a satisfying tenacity. It can also be noticed that the influence of the carbon content on the increase of the mechanical resistance is higher for steels with vanadium, where this element acted as a strong agent of forming the carbides.

The quenching thermal treatment applied on the four series of material lead to doubling the mechanical resistance (Fig. 2), associated with a drastic diminishing of the plasticity and tenacity, with but one exception (34MoCr11), where it was a diminishing of the elongation of three times and of the bottlenecking of half (Figures 3-5).

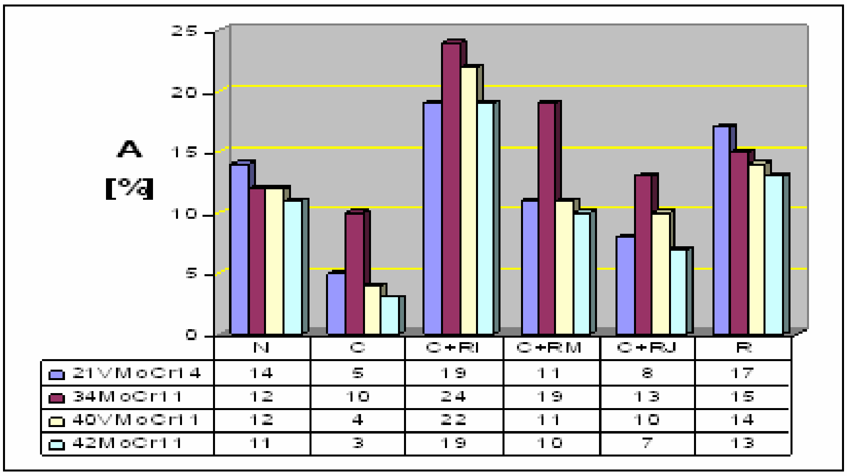
The average value of the breaking energy dropped under the value of 27 Joule in all cases, a value that is considered as a limit under which the breaking becomes fragile. The hardness value increased with a similar proportion to the mechanical resistance, with a higher effect at the brands with high content of carbon.

The presence of chrome increased the fragility tendency in all cases, with a higher effect at the brands with a high carbon content.

The double thermal treatment of quenching and annealing made that the mechanical resistances to decrease while the units characterizing plasticity (A, Z) and tenacity (KV) to increase significantly.

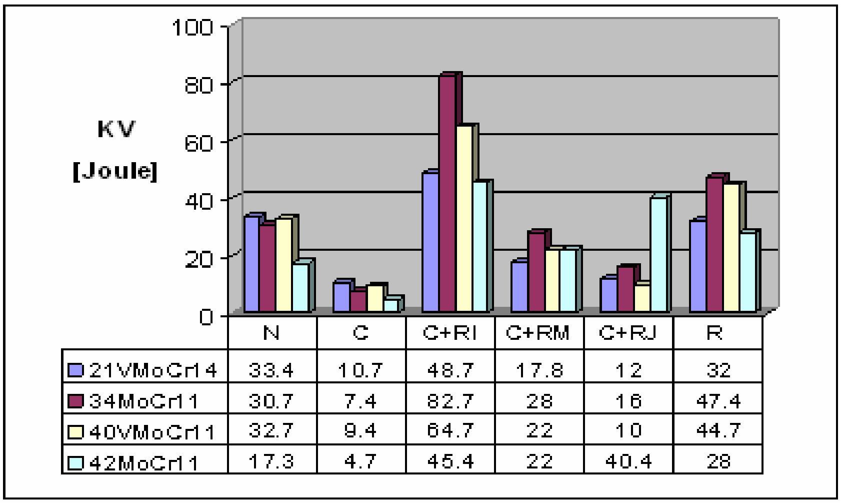
These evolutions are the more obvious as the annealing temperature rises. Please notice the highly different proportion where the mechanical resistance changes as compared to the tenacity.

The high annealing at 42MoCr11 lead to the decrease of the mechanical resistance with approximately 50%, while the breaking energy increased ten times. As the studied steels are made for the construction of machine components, this evolution confirms the usage aptitude that requires high mechanical resistance combined with a very good tenacity (durable without affecting the capacity of jolt taking).



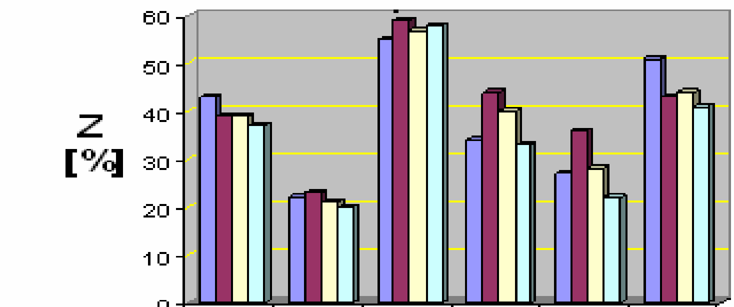
	N	C	C+RI	C+RM	C+RJ	R
21VMoCr14	14	5	19	11	8	17
34MoCr11	12	10	24	19	13	15
40VMoCr11	12	4	22	11	10	14
42MoCr11	11	3	19	10	7	13

Fig. 3. *Elongation variation depending on the thermal treatment applied to the four steel brands studied*



	N	C	C+RI	C+RM	C+RJ	R
21VMoCr14	33.4	10.7	48.7	17.8	12	32
34MoCr11	30.7	7.4	82.7	28	16	47.4
40VMoCr11	32.7	9.4	64.7	22	10	44.7
42MoCr11	17.3	4.7	45.4	22	40.4	28

Fig. 4. *Impact strength variation depending on the thermal treatment applied to the four steel brands studied*



	N	C	C+RI	C+RM	C+RJ	R
21VMoCr14	43	22	55	34	27	51
34MoCr11	39	23	59	44	36	43
40VMoCr11	39	21	57	40	28	44
42MoCr11	37	20	58	33	22	41

Fig. 5. *Bottleneck variation depending on the thermal treatment applied to the four steel brands studied*

Fig. 6. *Microstructure obtained after the normalisation treatment for the steel 40VMoCr11-ferite+fine perlite (x100)*

Fig. 7. *Microstructure obtained after the normalisation treatment for the steel 42MoCr11-ferite+perlite (X100)*

Fig. 8. *Microstructure obtained after the normalisation treatment for the steel 40VMoCr11-ferite+very fine perlite+ troostite (x500)*

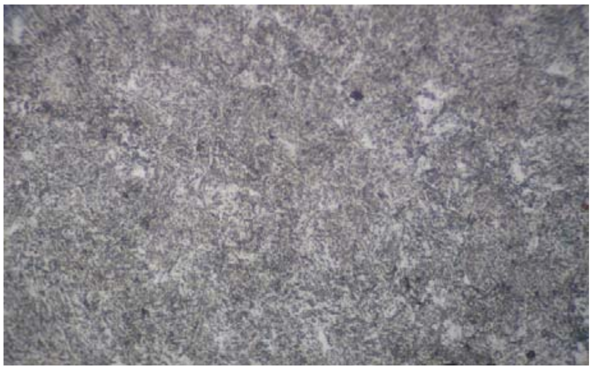


Fig. 9. *Microstructure obtained after the normalisation treatment for the steel 42MoCr11 -ferite+perlite (X500)*

The mechanical characteristics are confirmed by the quantity, size, shape of the structural constituents resulted after the phase transformations at thermal processing.

The structural morphology depends both on the carbon content as well as the presence of the other elements from the chemical composition of the steel brands analyzed in this paper. In figures 6-15, there are several examples of microstructures (at different zooms in order to be more suggestive) that should show the acute change of the structural constituents as well as the size of the crystalline grains. This is a result of the increase of the carbon content or of vanadium alloying.

Fig. 10. *Microstructure obtained after the quenching treatment for the steel 40VMoCr11– martensite +rezidual austenite +troostite (x100)*

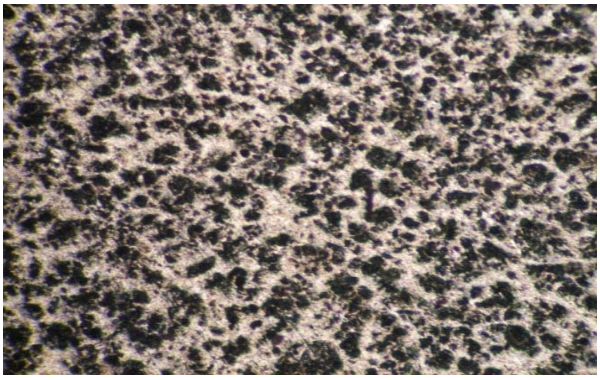


Fig. 11. *Microstructure obtained after the quenching treatment for the steel 42MoCr11- white martensite + rezidual austenite + troostite (X100)*

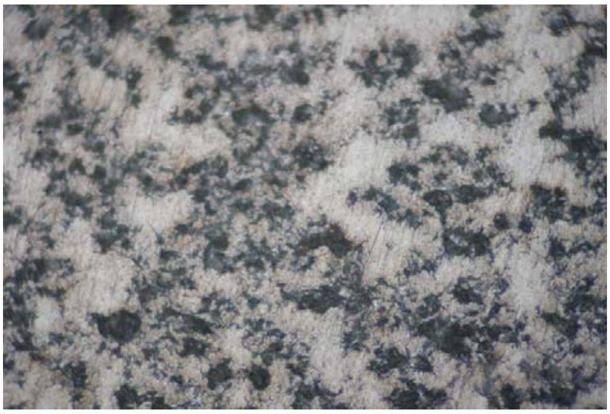


Fig. 12. *Microstructure obtained after the quenching treatment for the steel 40VMoCr11 – martensite +rezidual austenite +troostite (X500)*

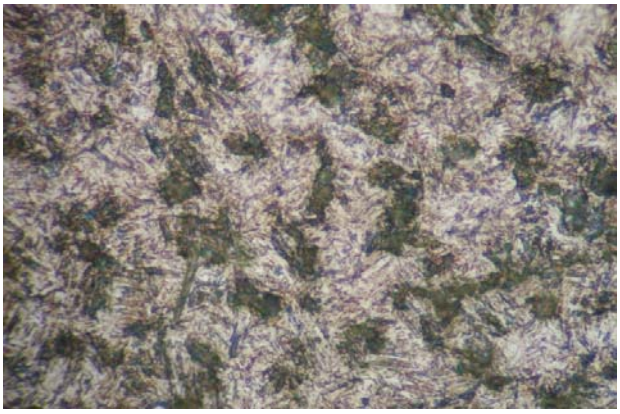


Fig. 13. *Microstructure obtained after the quenching treatment for the steel 42MoCr11- white martensite + rezidual austenite + troostite (X500)*

Fig. 14. *Microstructure obtained after the quenching + high annealing treatment (improvement) for the steel 40VMoCr11- sorbite (X100)*

Fig. 15. *Microstructure obtained after the quenching + high annealing treatment (improvement) for the steel 42MoCr11 - sorbite (X100)*

4. Conclusions

Applying the normalization treatment had as a notable result the increase of the mechanical resistance, without important changes of plasticity and tenacity.

The quenching behaviour of the studied brands can be summarized by doubling the mechanical resistance, associated with a drastic decrease of the plasticity and tenacity, which requires for a second annealing thermal treatment so that it takes the structure to phases closer to equilibrium.

Comparing the values after normalisation, and after annealing, we notice that the high annealing lead in all cases to mechanical properties of resistance, ductility and tenacity superior to those obtained after normalization.

One can also notice the influence of the content of alloying of the elements on the mechanical characteristics when we compare the brand 40VMoCr14 to the 42MoCr11.

Under the same treatment (high annealing), the mechanical resistance is superior to 40VMoCr14, with a lower carbon content, the result being obtained without a significant weighing factor of plasticity or tenacity.

As the studied steels are meant for the construction of machine components, this evolution confirms the usage aptitude that requires a high mechanical resistance combined with a very good tenacity (durability, without affecting the capacity of jolt taking).

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