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STUDY ON THE INFLUENCE OF THE CHEMICAL COMPOSITION IN THE THERMOMECHANICAL PROCESSING OF THE STEEL PRODUCTS

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ABSTRACT

This paper presents the results of industrial scale researches on the influence of the chemical composition on the characteristics of high yield point plates of wieldable fine grain steels. The comparative study of the mechanical characteristics obtained by the classical process and by the controlled rolling process point out the possibility of replacing the classical heat treatment for some steel grades, for plates used metallic structures in railway bridges, high tornage travelling cranes, marine platform bases, high pressure vessels, etc.

KEY WORDS: microalloyed steel, heavy plates, thermomechanical treatment, controlled rolling, chemical composition, mechanical characteristics

1. Introduction

The growing demand of plates characteristics for the manufacture of components for the chemical, oil and naval industries requires sessions consideration on entering new steel grades and new preparation technologies able to improve the structure and mechanical characteristics of the plates, without considerably affecting the factory prices. The development of microalloyed steels, including their alloy design, processing, and application, covers the last four decades. During this period, microalloyed, high-strength, low-alloy steels became an indispensable class of structural steels. Their ability to achieve final engineering properties is as hot- rolled conditions eliminated the need for heat treatments, such as normalizing [1]. Thermomechanical rolling followed by accelerated cooling is the standard production route for steel with high strength and good toughness. This processing route relies on elements microalloying which promotes a finer grain size austenite conditioning. By combining grain refinement and precipitation hardening of elements, microalloying maximizes the strengthening process. Precipitation hardening increases strength but may contribute to brittleness. Grain refinement increases strength also improves toughness. As a result, grain refinement counteracts any embrittling caused by precipitation hardening. In practice, grain refinement can be achieved during hot rolling by the interaction between microalloying elements (niobium, vanadium, or titanium) and hot deformation [2]. Maximum grain refinement can be achieved by increasing the austenite grain-boundary area. This can be accomplished by either producing fine grains of austenite through repeated recrystallization between passes or by flattening non recrystallization austenite grain into pancakes. Grain refinement may be further enhanced by accelerating cooling after the completion of hot rolling [3].

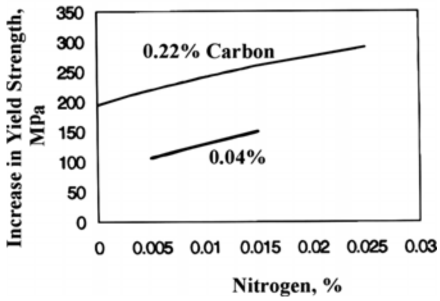

Fig.1. *Increase yield strength in vanadium steels in terms of Nitrogen content*

The undercooling of austenite enhances the rate of ferrite nucleation and slows down the rate of growth. A combination of these two factors contributes to the formation of smaller grains. Significant strengthening is obtained by the precipitation of microalloying elements appearing as carbonitrides (or carbides) in ferrite (fig. 1) [4].

Since their solubility in ferrite is much less than in austenite, there is strong supersaturation which provides the driving force for precipitation. The most desirable are those microalloys, which contribute to both grain refinement and precipitation hardening. The combined effect of these two strengthening mechanisms may provide as much as 70% of the yield strength, accounting for the remarkable cost effectiveness of microalloyed steels (fig.2). Because these two dominant strengthening mechanisms operate in microalloyed steels, their carbon (or CE) may be very low (only 0.04 to 0.06).This low carbon content contributes to excellent weldability [5].

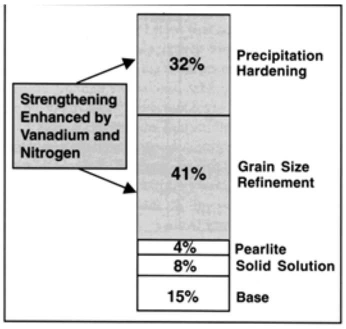

Fig.2 *Strengthening mechanisms in hot-rolled steels*

2. Experimental conditions

For experiments, test specimen of X70 steel grade has been used having chemical composition and mechanical characteristics mentioned in table no.1

The main requirements for steels used for tubes and pipe-lines for gas and oil transportation are regulated by API 5L norm that establishes limits for the chemical composition as well as the minimum values of strength and tenacity (table no.1 presents only PSL2 trades).

a) for each reduction of 0.01 % under the maximum C content specified, a 0.05% increase of specified Mn content is allowed:

- up to 1.5% for X42 to X52 trades
-up to 1.65% for the trades superior to X52 but under X70 and
-up to 2.00% for X70 and above.

b) Nb+V cannot be higher than 0.03%
c) Nb,Vor any of their combinations is up to the manufacturer (tab.1).
d) Nb+V+Ti cannot be higher than 0.15% (tab.1)
e) Nb+V can’t be higher than 0.06% (tab.1)

Table 1 *Chemical composition and mechanical characteristics*

Grade Steel	**Chemical composition**					**Obs**	**Rc**		**Rm**	
	[%] max.						[N/mm^2]			
	C	Mn	P	S	Ti		min.	max.	min.	max.
B	0.22	1.20	0.025	0.015	0.040	d, e	241	448	414	758
X42	0.22	1.30	0.025	0.015	0.040	c, d	290	496	414	758
X46	0.22	1.40	0.025	0.015	0.040	c, d	317	524	434	758
X52	0.22	1.40	0.025	0.015	0.040	c, d	359	531	455	758
X56	0.22	1.40	0.025	0.015	0.040	c, d	386	544	490	758
X60	0.22	1.40	0.025	0.015	0.040	c, d	414	565	517	758
X65	0.22	1.45	0.025	0.015	0.040	c, d	448	600	531	758
X70	0.22	1.65	0.025	0.015	0.040	c, d	483	621	565	758
X80	0.22	1.85	0.025	0.015	0.040	c, d	552	690	621	827

The main trend in achieving longitudinally welded large diameter pipes was increasing thickness of the wall which led to the use of steels with low carbon equivalent (under 0.40) with good weldability.

The main technological improvements of the plate with this destination are termomecanical rolling controlled process (TMCP) and accelerated cooling (ACC). According to ASTM A 841 / A 841M-01, the concept of termomecanical rolling with controlled process (TMCP) has developed from the older concept of controlled rolling (CR).[6] Subject to these processes are TMCP steel products with very fine grains in an optimal combination between the chemical composition and the integrated control of the process of heating and until the final cooling after finishing rolling. TMCP incorporates three processes (fig.3) [7].

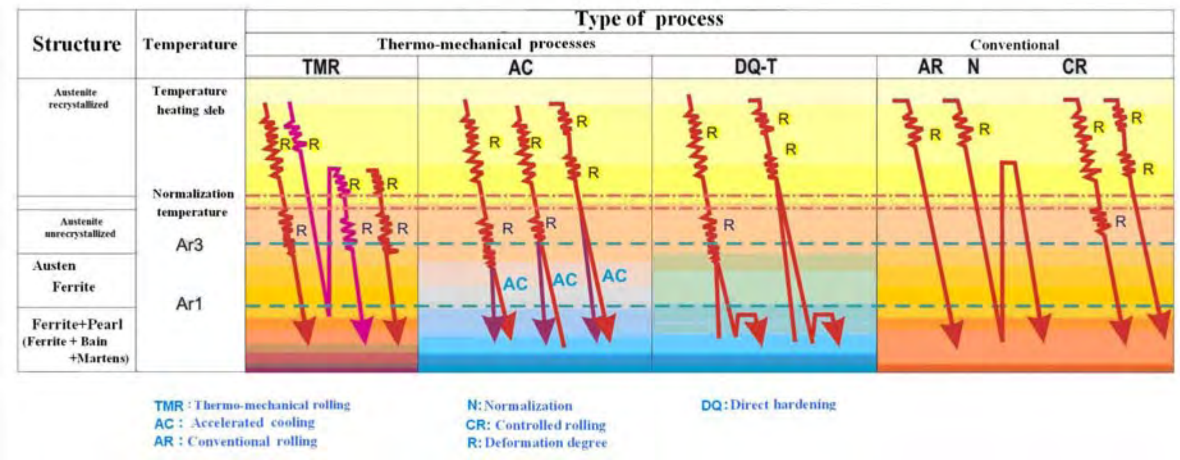

Fig.3. *Schematic diagram of TMCP and conventional rolling (ASTM 841 / A 841M-01)*

a) Termomechanical Rolling (TMR)

Steels with fine grain are produced by rolling in the recrystallized and non-recrystallyzed austenitic domains and sometimes in the biphazic transformation A→F. Final reductions in general are very close or even below the Ar3 temperature.

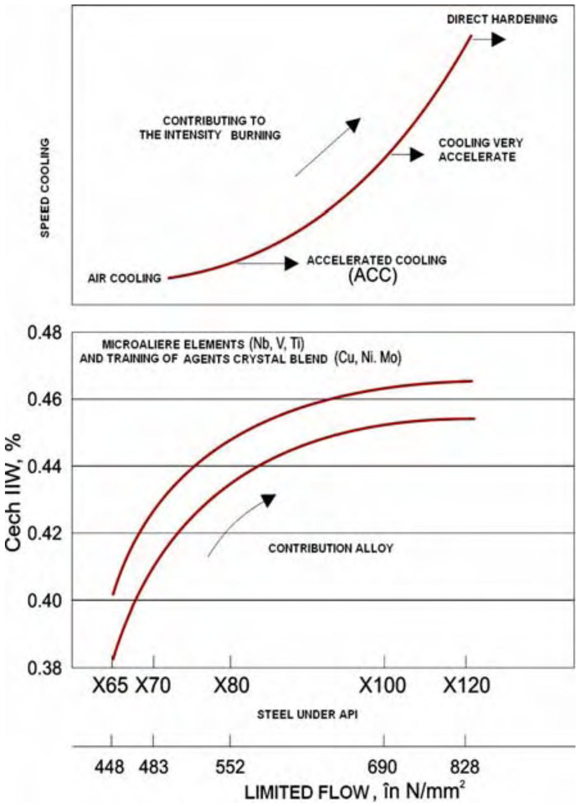

Fig.4. *Dependence of flow limit on the cooling intensity and the level of steel microalloying.*

Steels guaranteeing superior strength and tenacity have a very fine grain structure and an optimal structures (F + P, F + P + B, acicular ferrite + B, F + M + B) obtained by accelerated cooling with water immediately after finishing controlled rolling (CR) or termomechanical rolling (TMR).

c) Direct Quenching and Tempering (DQT)

If for the quality of X65 or X70, we have an API limit flow of 448 N/mm2 and 483 N/mm2, for moderate content of carbon equivalent, on the conditions of a TM process followed by cooling in air to produce safe quality X80 with a limit of minimum flow of 552 N/mm^2, accelerated cooling is used, despite a higher content of carbon equivalent (fig. 4) [8].

In experiments we have used the mark of X70 steel with two microalloying variants (fig.5): NbVTi (classic), NbCrTi (steel HTP), the adaptation of rolling scheme and use of accelerated cooling, as follows:

- small power 2.5 x final thickness (steel a.) 6-8 passes in finisher
- high power 3.5 x final thickness (steel b.) 9 - 11 passages in finisher
- final rolling temperature (ERT: Ar3 + 20-40 ° C and the following the heat treatment in ACC (accelerated cooling facility)
- input temperature ACC: Ar3 + 10 ÷ 20 ° C
- temperature drop in ACC: 80 ÷ 160 ° C
- cooling rate: 6 ÷ 12 ° C / sec.

In fig 6, 7, 8, Rm, Rc and KV variation is presented according to Cech., sheet thickness and cooling water flow.

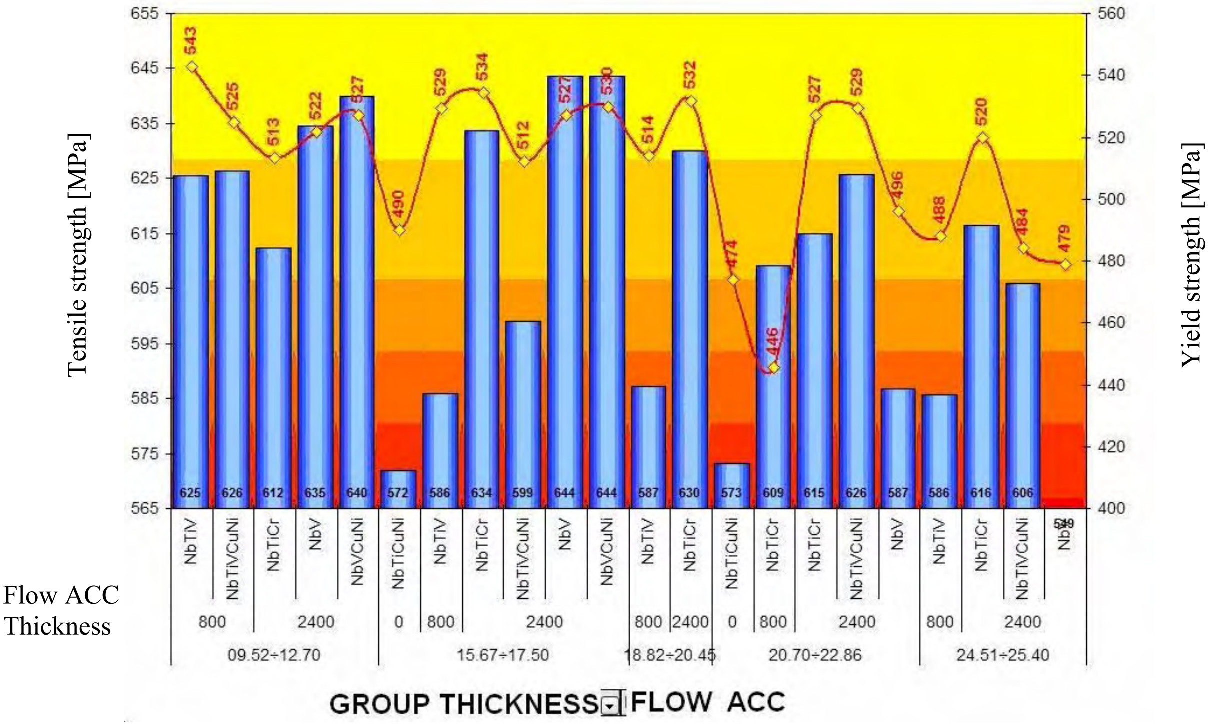

Fig.5. *Rc and Rm distribution in groups of thickness, cooling intensity and type of steel*

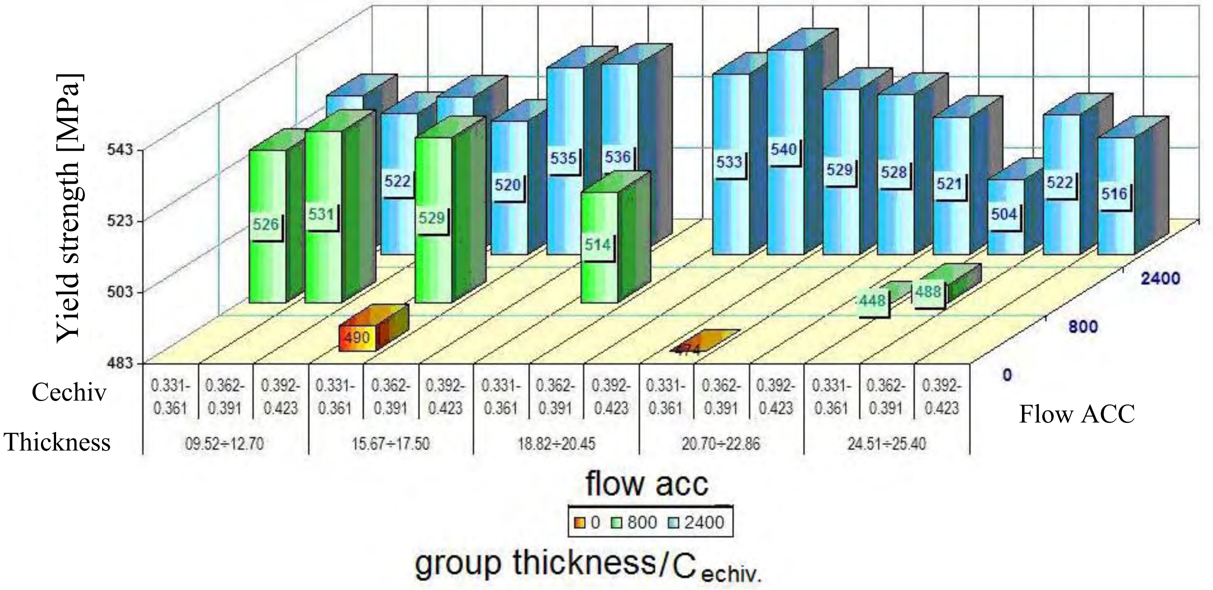

Fig.6*. Distribution of yield strength for groups of thicknesses,*
C_{ech} and ACC flow rates [weighted average]

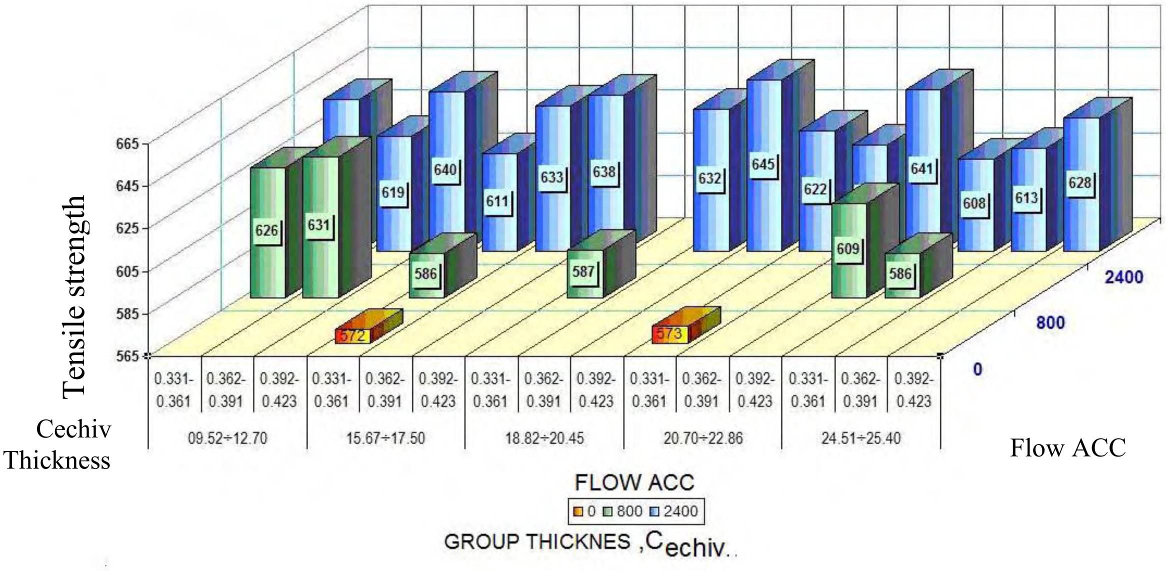

Fig.7. *Distribution Rm limit for groups of thicknesses, carbon equivalent and ACC water flow [weighted average]*

Obs. It highlights the cumulative influences of carbon equivalent, the cooling intensity and thickness of the final level of resistance (Rc and Rm).

The condition still requires a minimum intensity of cooling water flow.

Obs. Generally the level of tenacity in terms of fracture energy KV is excellent, with values above the minimum level (about 3 times and even more).

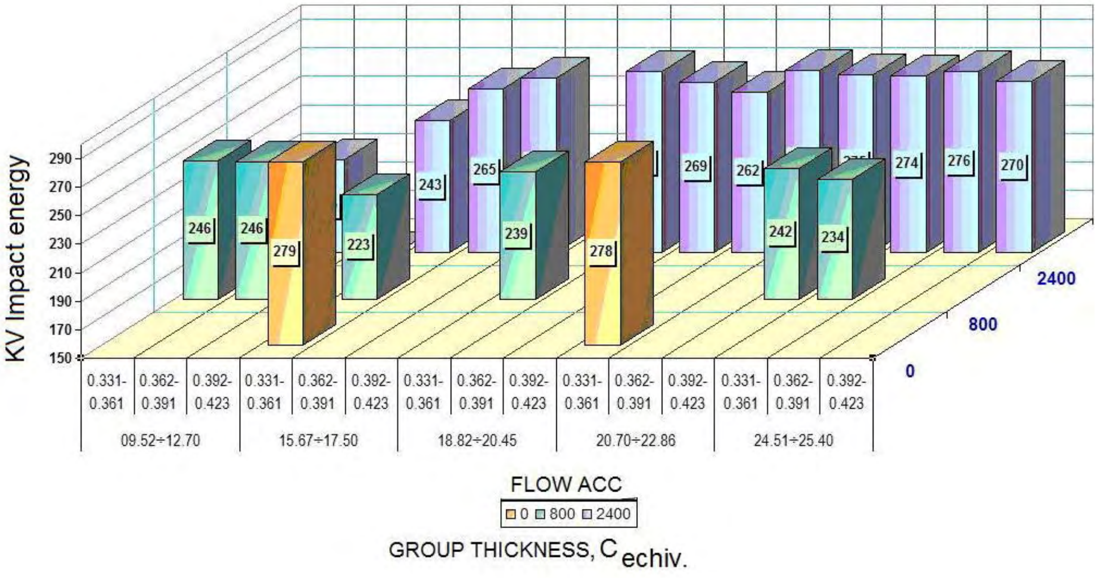

Fig.8. *KV Energy distribution for groups of thicknesses, carbon equivalent and ACC water flow [weighted average]*

4. Conclusions

A statistical overview for the 2 families of steels for trade X70 is as follows:

1. Steel matrix NbCrTi called HTP (High Temperature steel) presents a lower cost than those NbVTi and it is feasible to produce heavy plates X70 mark to with max. 25.4 mm thickness when using a minimum of 2400 m^3 of water in the ACC.

2. To get a good tenacity and mechanical strength depends on the following factors:

- carbon equivalent

- Temperature at the end of rolling,
- fall in temperature in ACC,
- water flow rate and coolig rate in the ACC board.

3. To increase the thickness of the sheet is necessary the correlation with the content of carbon equivalent.

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