Process Design in the Manufacturing of Pipes for Chemical and Petrochemical Industry

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In the present study the influence of vanadium microalloy on kinetics of transformation in medium carbon steel is studied. In order to choose the thermal treatment temperatures at optimal values, the steel transformation points were determined by dilatometric analysis. The bainitic transformation point was obtained under fast cooling conditions. The industrial experiments on the hardening and tempered of steel were performed in five variants of the oil hardening and reversing treatment, with austenitizing temperatures for hardening and the tempered temperature. The steel quality was determined, the influence of the temperature on the microalloyed steel structure with vanadium was highlighted. The mechanical characteristics of the pipes after the thermal hardening and tempering were analyzed after the traction test and the shock break. Electron microscopy analysis on extraction replicas revealed aspects of precipitation, globular constituent after return is finely and uniformly distributed, austenitization at lower temperature, resulted in a finer austenitic grain [20]. The finer structure obtained after hardening resulted in heat treatment to return to precipitation of fine and uniformly distributed carbides. It has been found that the influence on bainitic transformation depends on temperature; the steel structure after the quenching and tempering treatment was analyzed by optical and electronic microscopy. The development of welding consumables is permanently challenged with matching the increasing strength and toughness of thermomechanically treated or hardening and tempered steels.

Keywords: hardening, micro-alloying steel, tempering, mechanical properties, microstructure, microscopy

Using fine-grained steels in manufacturing chemical and petrochemical industry pipes raises a number of issues with technology combining mechanical toughness and corrosion resistance [2].

The main effects of the grain finish of the yield strength is increasing, decreasing the ductile-brittle transition temperature, the impact absorbed energy increases [6]. Ferrite grain size has a predominant role on increasing yield strength and decrease the transition temperature. Ferritic grain finishing is very important which is closely related to the austenite grain size warming heat-treated steel which is achieved by controlled additions of aluminum-nitrogen, niobium, vanadium, titanium. An alternative embodiment of the ultrafine grain size of ferrite is controlled rolling technique [11, 18]. Ferrite grain size depends of developed transformation the size of the austenite of which it is formed, as germs ferrite grain are formed, and the austenitic [5, 15, 19]. Execution pipes have the following requirements according to API - 5 CT, the quality of the finished product: the duty of determining the impact energy absorbed at break values critical to the thickness of the wall of the pipe; the heat treatment requirement; the duty of determining hardenability steel depending on the carbon content of all grades of resistance obtained by quenching and tempering [16]. Steel used in experiments is 31VMn12, fine-grained steel, which currently has a composition technology to decrease the carbon content and an appropriate amount of carbon equivalent (C + Mn / 4), which led by controlling the hot rolling to obtain pipes - plug in the state tempered by quenching and tempering, given that the normalization yielded mechanical characteristics appropriate but the scattering of the absorbed energy at impact was very high (15 J - 90 J) with many values below the minimum prescribed (L - 40 J). The explanation lies in the unevenness large pipe length of how precipitation rolling grain particles small influence on the structure of pearlite in the steel ferritic-perlitic, because of the particularities respective streams - rolling mandrel long particles precipitated that influence the precipitation normalization and specific characteristics of steel micro alloyed with vanadium in those temperatures [2, 6, 11,14]. Solution heat treatment of pipes of this work is by quenching and tempering. The paper characterized the steel in this state [10, 12]. From an environmental perspective, the micro-alloyed steels are durable and 100% recyclable [1, 3, 4]. It is useful to use environment-friendly materials to reduce pollution [7, 9, 10, 17, 18, 25]. It is possible that using vanadium microalloyed steels use 30-40% less steel and achieves the same engineering objectives [23, 24]. On the other hand, global steel production, at current levels, will lead, in a few years, to around two billion tons of steel per year. We reduce waste and, implicitly, protect the environment [4,17]. As a consequence, there is also a lower environmental impact, reduced energy consumption and environmental pollution [1, 4, 7, 17, 20, 22].

Experimental part

Materials and methods

Experiments focused heat treatment manufacture pipes ∅ 88.9 x 12 mm and ∅ 93 x 12.45 mm.

The pipes were processed by hot deformation, deformation under normal last being executed mill extender [18]. Industrial experiments on hardening and tempering of steel were performed in five different treatment of oil hardening and tempering with the parameters listed in table 1, with changing temperatures austenitising tempering and tempering temperature [13].

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Table 1
PARAMETERS VARIANTS OF HEAT TREATMENT

Options	Hardening			Tempering		
	t ,[^{0}C]	Time, min.	Type of cooling	t ,[^{0}C]	Time, min.	Type of cooling
A	920	15	oil	625	40	air
B	920	15	oil	600	40	air
C	920	15	oil	600	30	air
D	880	15	oil	625	30	air
E	880	15	oil	710	30	air

where: t,[^{0}C]- the temperature in Celsius degrees; Time, [min] -the time measured in minutes

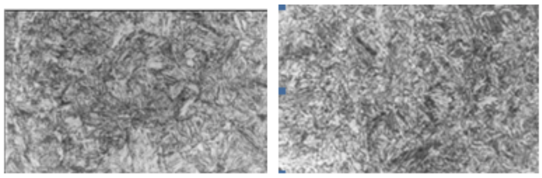
The chemical composition of the material used in the experiments in given in table 2.

Results and discussions

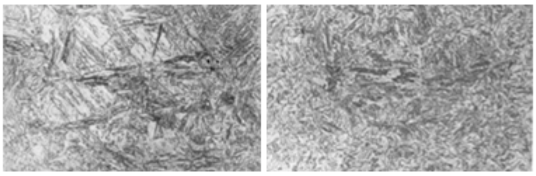
For steel be hardenability to a semimartensitic structure, it must have a hardness of 36HRC after hardening [15].

At a mean composition of the main elements (maximum values for residual elements), 31VMn12 steel can be hardened semimartensitic at a maximum diameter of 80 mm in ideal cooling conditions.

Aspects of the structure obtained after tempering play in figure 1. It is noted that with increasing temperature austenitization, the austenite grain size increases, the needle structure and appearance is coarser (larger needles) [15]. Cooling the oil compared to water quenching leads to a more mixed structure of bainite and lower hardness, both embodiments lead to satisfy the requirement of the API 5CT (min. 38-36) HRC.



a) 880[^{0}C]/water × 1000 b) 880[^{0}C]/oil ×1000



c) 920[^{0}C]/water × 1000 d) 920[^{0}C]/oil × 1000

Fig. 1 a, b, c, d Aspects of the structure after tempering
Variants of heat treatment - industrial experiments

They were carried out at two different quenching and tempering treatment with the parameters listed in table 3.

Steel has good harden ability in oil.

Characteristics mechanical

Pipes treated in two variants, presented after the test in traction and rupture shock (KV) characteristics listed in table 3.

Annealing at 880^{0}C resulted in all three embodiments (A, B) at low levels of energy below the minimum acceptable level or slightly above. So, tempering at 880^{0}C gave satisfactory results, the highest values yielding the highest return 720^{0}C (variant B). In the latter case there is a danger lowering resistance values drop below the minimum allowed.

Table 2
THE CHEMICAL COMPOSITION OF THE MATERIAL USED

Material condition	Elements											
Billet	C	Mn	Si	P	S	Cr	Ni	Mo	Cu	V	N	O_2
Pipe ∅ 88.9x12mm	0.28-0.31	1.22-1.24	0.24-0.28	0.013-0.015	0.014-0.007	0.14-0.14	0.08-0.12	0.01-0.01	0.12-0.14	0.12-0.17	- -	- -
Pipe ∅93x12.5mm	0.31	1.19	0.26	0.019	0.015	indefinite	0.12	0.04	0.20	0.13	0.0083	0.0024
STAS 8185-88	0.31	1.25	0.25	0.021	0.020	0.15	0.12	0.02	0.18	0.14	0.0088	0.0037
API 5CT-1995	0.28-0.34	1.10-1.40	0.17-0.37	max.0.035	max.0.035	max.0.30	max.0.30	max.0.06	max.0.30	0.10-0.20	-	-
	-	-	-	max.0.030	max.0.030	-	-	-	-	-	-	-

Table 3
MECHANICAL TUBE N 80 DEGREE PLUG AFTER QUENCHING AND TEMPERING (VARIANTS A, B)

Pipe size Øxg [mm]	Treatment type	Mechanical properties			The absorbed energy[J/ ^{0}C]			
		$R_{t0.5}$ [N/mm^2]	R_m [N/mm^2]	A[%]	1	2	3	average
88.9x12	A	654	815	27.1	35	35	28	33
93x12.5	E	609	773	25.0	140	145	119	135
API5CT 1995 Grad N80		552-758	min.689	min.17	min.40			

where: $R_{t0.5}$ [N/mm^2]- Conventional extension limit; R_m [N/mm^2]- tensile strength; A[%]-elongation

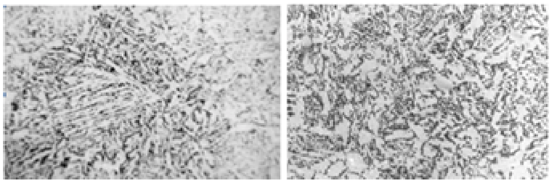
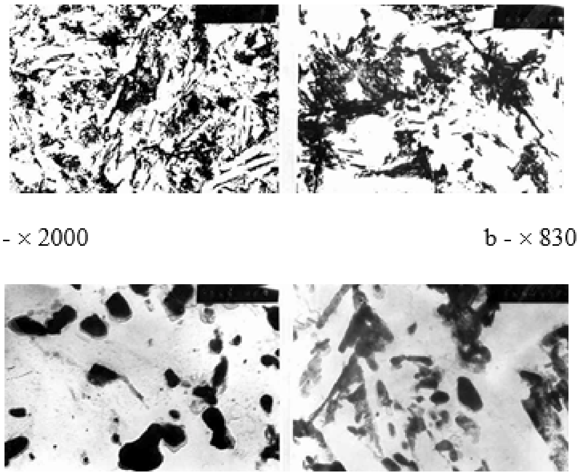

variant A × 100 variant B

Fig. 2 a, b Aspects of the structure obtained after hardening and tempering in the variants A, B


a - × 2000 b - × 8300

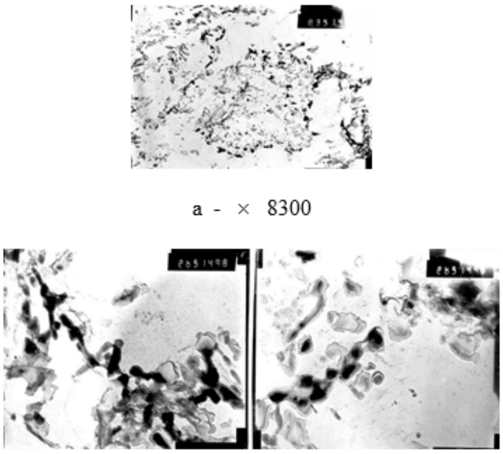
c - × 2600 d - × 26000

Fig. 3 a, b, c, d Electron Microscopy - reply extraction
Variant A – 920 [^{0}C]/ water – 625 [^{0}C] / 40 min, KV = 34 J
a - structure as a whole; b - detail of structure
c and d - areas with different size distribution and carbides early

Analysis of the structure after quenching and tempering variants A, B.

Aspects of the structure of the material obtained after recovery is shown in figure 3, where A, (annealing at 920^{0}C) due to the austenitic grain size is maintained after the return of the needle aspect hardening constituent. B version, return of the high temperature phase has begun and recrystallization of ferritic structure after annealing is ferrite of sorbitol separation, which explains the decrease of the yield strength.

Electron microscopy analysis on extraction replicas highlighted aspects related to five variants of precipitation year. Variant A, shows clusters of carbides with varying magnitude (0.04-0.4μ). Which direction hardening needle structure from which they originated due to high grain austenitic (fig. 3). In some cases agglomeration is strong; there are even protected areas without precipitation (fig. 4) likely due to small segregation chemical and steel.


a - × 8300

b - × 13000 c - × 26000

Fig. 4 a, b, c Electron Microscopy - reply extraction
Variant B – 880 [^{0}C] / water – 625 [^{0}C] / 40 min. - KV = 96 J
a - whole - carbides evenly distributed; b - detail
c - diffraction image

This has resulted in reduced values of impact energy absorbed at break.

Austenitising at a lower temperature, leading to a finer austenitic grain in the process interfering particles probably is unnoticeable to expanding the power of the microscope resolution (max. 26.000). Finer structure obtained after quenching led to precipitation of carbides return to a fine and uniformly distributed. It is observed both in the austenitization higher undissolved particles (0.1μ) and smaller particles or precipitates grown likely to rebound (0.1μ) (fig. 4). This distribution carbide led to elevated energy KV.

Analysis of the diffraction image indicates that the network precipitate is cubic. The distance between planes resulting from the calculation of the value of vanadium carbide, results confirmed the type of network - cubic (fig. 3 and 4).

Returning over 700^{0}C, under a fine and evenly distributed precipitation has led to intensification of poligonization with the creation of sub-limits. It is clearly observed on the sub-limits the local existence of grains new large particles of precipitate, as compared to the smaller size of carbides in the ferrite table (fig. 3, b and 3, c). Beginning with the emergence of sub-limits recrystallization produced growth more value KV, but the decrease in yield strength by the appearance of new phase grains- ferrite.

So steel 31VMn 12 heat treated by quenching in oil and tempering, must be heated to austenitising below 900^{0}C to avoid increasing grain by solubilizing particles which reduces graininess and over 850^{0}C for complete conversion and then returned at temperatures between 600 - 700^{0}C for precipitating fine and uniform training sublime grains in small proportion (recrystallized volume growth mitigates the yield strength).

The formation of sub-limits should not be withheld (but the amount of recrystallized grains to be controlled) because their existence alongside precipitated particles are barriers in the movement of dislocations and all increasing the yield strength of steel.

With the advent of recrystallization sub-limits happened gain greater value KV, but it produces the decrease in yield strength by grain appearance the new phase – ferrite.

Conclusions

The steel mark 31 VMn 12 can be used in the manufacture of both extraction pipes (with the setting of a technological chemical composition for controlled rolling) and the corresponding heat-treated jacks, thus simplifying the manufacturing technology. Steel is appropriate from the point of view of the hardenability according to the requirement of API 5 CT standard in 1995, the hardenability calculated according to ASTM A 255-89 is comparable to 35Mn16 carbon steel.

Given the particularities of the vanadium microalloy for finishing the granulation, ie the precipitation and solubilization of the particles in heating and cooling, the thermal treatment parameters must be well controlled to use the steel microalloying potential in order to obtain the set of required characteristics.

The dilatometric analysis indicated that the steel austenitic transformation point of the steel is 800^{0}C, so heating for quenching is indicated to be carried out at a temperature of 870 ... 890^{0}C. Exceeding this temperature leads to advanced solubilization of finishing particles and increased austenitic granulation, and heating below this level leads to the insolubilization of a sufficient amount of carbides and thus decreases the calorific value of the steel. After hardening, in the mass of steel there are a number of precipitated particles located on the limits of the former austenite grains. On heat treatment tempering, these particles on the boundaries increase, thus evidencing the precipitated carbons in this phase of heat treatment.

By electronic microscopy, the analysis of the diffraction pattern revealed the existence of cubic mesh vanadium carbide. The distribution of carbons (uniformly distributed or agglomerated) as well as their size along with the degree of polygolization has an influence on the value of the energy absorbed by the shock break. At temperatures above 700^{0}C, the recrystallization of the ferrite phase takes place, which leads to the decrease of the flow limit, through the polygonization process.

As a result of these conclusions from laboratory experiments and analyzes that were correlated with the level of the mechanical characteristics, it was proposed it is being suggested as industrial heat treatment for N 80 pipe fittings - hardening and tempering with the following parameters: austenitization hardening at 880^{0}C - holding 20 min and cooling in water, tempering to 650 ° C - holding 35 min and cooling in air.

So the 31VMn 12 heat-treated steel by heating in oil and returning must be heated to austenitize below 900^{0}C to avoid granulation growth by solubilizing the finishing particles and over 850^{0}C for complete transformation and then returned to temperatures between 600-700^{0}C for fine and uniform precipitation and formation of grain sublimation in small proportion (increasing the recrystallized volume leads to the decrease of the flow limit).

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