Research on the Mechanical Characteristics of a Microalloyed Steel with V in the Agreement with Environmental Trends

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In this paper we studied the behavior of steel 31 VMn12 micronized with V in industrial conditions. In the experiments it was intended to obtain the mechanical characteristics corresponding to the pipe qualities, in the following states of the material: from the heat of rolling; with thermal normalization treatment; with thermal improvement treatment. Experiments have been achieved for two samples made steel and rolled into tubes Φ 219 x 9 mm.

Keywords: mechanical characteristics, microalloyed steel, vanadium

The most used elements in the microalloying of steels are vanadium and niobium. Compared with niobium, vanadium offers steel cost advantages in the continuous casting and hot rolling process. In continuous casting, vanadium reduces the cracking tendency. In hot rolling, the higher the solubility of vanadium carbonates means that lower temperature reheating can be used before rolling or forging, to saving up of energy [24]**.** Higher solubility of vanadium carbonitrides allow control of steel deformation microalloyed with vanadium with more some wear of cylinders [1]. Adding vanadium to steel provides improved strength compared to standard steels, providing all requirements for ductility, weldability and tenacity, without greatly increasing costs and lower energy consumption [10, 17] The main source of vanadium is the recovery of used catalysts in oil refining operations [4,6, 26-34].

These catalysts, together with other vanadium *waste* are subject processing by recycling [14, 29]. Steels microalloyed with V are used for metal structures: containers, bridges, equipment for constructions [15, 16, 18, 19].

Every year, large amounts of vanadium are recycled from catalysts used. This reduces the need to use vanadium extracted from minerals, which reduces energy consumption and pollution generated by mining. Using recycled vanadium also reduces the energy requirement normally associated with ore processing, eliminating or reducing the need for land removal from these *waste* and ensuring the supply of vanadium to steelmakers [1, 3, 5, 7, 9].

When vanadium is used as an alloy in the steel making process, it requires less steel to meet the same structural requirements as for standard C-Mn steel. This reduces the amount of energy required in production [20-23]. So it is possible that the use of V-microalloyed steel will lead to 30-40% less engineering steel reduction to achieve the same goals, resulting in a low environmental impact [1, 11-13].

Experimental part

Materials and methods

In this paper the behavior of 31 VMn12 microalloed V steel under industrial conditions was studied. The composition of the two studied steel batches is presented in table 1.

Experiments realized aiming at establishing the parameters of the thermal treatment with the main objectives: using the steel brand for the production of the pipe quality; insurance limit of flow corresponding to a pipe quality for a number as large a sample of the same steel brand and the same thermal treatment. This is justified by the fact that, depending on the situation of the supply of semi-finished products, the realization of any samples not prejudiced [8, 25].

In the experiments it was intended to obtain the mechanical characteristics corresponding to the pipe qualities, in the following states of the material: from the heat of rolling; with thermal normalization treatment; with thermal improvement treatment. Experiments were performed for two samples made steel and rolled into tubes Φ 219 x 9 mm.

Results and discussions

Mechanical characteristics were determined for the two batches experienced on hot rolled pipes (temperature end rolling is 900 °C).

The structure of the material was analyzed. The analysis was performed in a longitudinal section of the pipes and the structure has the appearance shown in figure 1.

The structure is made of ferrite, perlite and a small amount of bainite. There is a slight orientation of the

Table 1
CHEMICAL COMPOSITION OF THE TWO STEEL BATCHES
31VMn 12

Batch	Chemical composition (%)					
	C	Mn	Si	P	S	V
1	0.33	1.12	0.23	0.019	0.016	0.10
2	0.31	1.20	0.27	0.023	0.020	0.11

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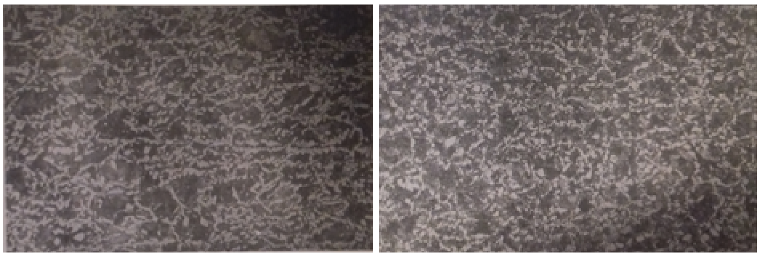
Thermal treatment	Sample	R_c [daN/mm²]	R_m [daN/mm²]	A_5 [%]
Laminated	1	62.2	86.7	19
	2	70	94.3	18
Normalize	1	56.9	77.8	20
	2	59	78.7	26

Where: R_c is the limit flowing of the experimental samples in different laminated and normalized steps [daN/mm²], R_m is the breaking strength of the experimental samples in different stages: laminated and normalized [daN/mm²], A_5 elongation at break [%].

Table 2
MECHANICAL CHARACTERISTICS OBTAINED ON PIPES MADE FROM LAMINATED AND NORMALIZED Φ 219 x 9 mm THE STEEL 31VMn12 219 x 9 mm



x 100 sample 1 x 100 sample 2

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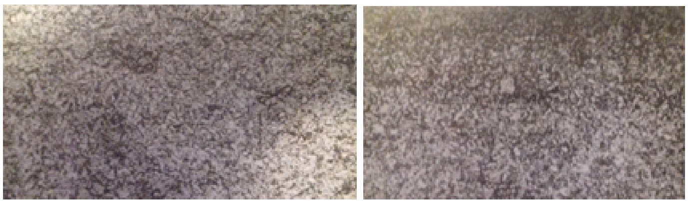
Fig. 1 Appearance of the structure of the material in the laminated state, steel 31 VMn12 pipes Φ 219 x 9 mm



x 100 sample 1 x 100 sample 2

Fig. 2 Aspect of the structure of the material after normalization, steel grade 31 VMn12 pipes Φ 219 x 9 mm

Thermal treatment	Sample	R_c [daN/mm²]	R_m [daN/mm²]	A_5 [%]
Laminated	1	60.8	86.5	25
	2	65.2	91.7	20
Normalize	1	53.3	71	24
	2	55.9	75.7	38.5

R_c is the limit flowing of the experimental samples in different laminated and normalized steps [daN/mm²], R_m is the breaking strength of the experimental samples in different stages: laminated and normalized [daN/mm²], A_5 elongation at break [%].

Table 3
MECHANICAL CHARACTERISTICS OBTAINED ON ROLLED AND NORMALIZED STEEL PIPES 31VMn 12

structure in the strings. Due to its mechanical properties, this steel can not be used in the heat of rolling.

Mechanical characteristics obtained in the normalized state

The pipes were normalized at 900°C, 30 min in the tunnel furnace. The values of the mechanical characteristics after normalization are shown in table 3.

There is a decrease in the limit flow and tear strength with 10-15 daN / mm² after normalization over the rolling values.

The properties obtained after normalization are within the 100% API 5 prescriptions [2].

Metallographic analysis of samples after normalization put it in evidence a fine-grained ferrite-perlite structure (fig. 2).

The mechanical characteristics obtained after quenching and tempering

Semi-industrial experiments were conducted to establish the potential of this mark over a wide range of return temperatures. Laminated pipes were sampled and then recovered from 20 to 20 °C in the range 520-660°C. From each batch, one sample was taken for each tempering temperature, determining the mechanical characteristics: flow limit, breaking strength and elongation. The values obtained are presented in tables 4 and 5 and the minimum, mean and maximum values in table 6.

It can be observe that between the two analyzed samples there are no very large differences in the flow limit values and there is a small dispersion of the values of the analyzed parameter at lower values of the return temperature. This dispersion variation is due to differences in chemical chemical composition between the two samples.

The metallographic analysis carried out after the improvement treatment revealed the existence of rebound structures with the coalescence of the carbide particles as the return temperature increased. The characteristic aspects of the structure are shown in figures 3 and 4.

Table 4

MECHANICAL CHARACTERISTICS OBTAINED ON PIPES Φ 219 X 9 mm HEAT TREATED (IMPROVEMENT) DEPENDING ON THE TEMPERING TEMPERATURE MADE FROM THE STEEL 31VMn12, SAMPLE 1

T_r °C	R_c daN/mm²	R_m daN/mm²	A_5 [%]
520	104.7	111.9	13.1
540	95.1	103.8	16.5
560	97.8	105.5	18.0
580	94.3	102.2	16.9
600	92.4	99.5	18.9
620	87.6	95.3	15.4
640	83.7	93.7	18.3
660	69.9	79.8	19.2

Table 5

MECHANICAL CHARACTERISTICS OBTAINED ON PIPES Φ 219 X 9 mm THERMAL TREATMENT (IMPROVEMENT) DEPENDING ON THE TEMPERING TEMPERATURE PRODUCED BY THE STEEL 31VMn12, SAMPLE 2

T_r °C	R_c daN/mm²	R_m daN/mm²	A5 [%]
520	109.9	117.0	14.1
540	107.3	116.5	16.7
560	111.7	120.1	17.5
580	104.4	111.7	19.2
600	92.5	99.7	19.8
620	96.7	107.1	18.2
640	83.7	93.6	21.8
660	76.4	83.4	20.6

Table 6

MINIMUM, MEDIUM AND MAXIMUM MECHANICAL CHARACTERISTICS OF PIPE SAMPLES Φ 219 x 9 mm DIFFERENTIATED THERMAL TREATMENTS. STEEL 31VMn12, SAMPLE 1 and 2

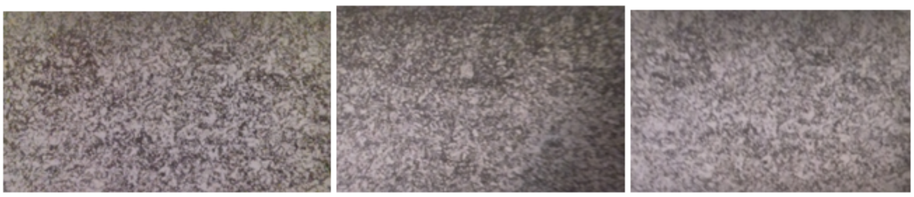
Sampl e	Chemical composition			T_r °C	Characteristics mechanical								
	C	Mn	V		R_c daN/mm²			R_m daN/mm²			A_5 %		
1	**0.33**	**1.12**	**0.10**		min.	med.	max	min.	med.	max	min.	med.	max
				520	103.9	106.9	109.6	111.7	113.6	116.4	11.0	13.6	17.7
				540	85.3	93.0	95.9	96.7	101.3	104.2	12.0	15.7	18.7
				560	90.6	98.3	106.9	98.8	105.1	112.0	14.1	15.9	18.8
				580	91.3	97.3	101.5	98.6	104.2	109.4	12.2	15.5	17.5
				600	83.2	91.2	98.6	92.5	99.1	107.7	15.1	16.9	20.0
				620	81.5	85.7	89.1	91.5	93.5	97.3	15.3	17.1	19.6
				640	72.5	81.3	89.3	85.5	91.1	95.0	16.7	18.8	21.6
				660	62.5	70.9	83.1	76.3	82.7	90.2	17.9	20.4	23.4
				L	59.8	62.7	66.8	86.5	88.6	92.0	18.0	19.7	25.0
				N	52.9	55.4	57.4	70.1	73.4	77.8	18.0	22.0	25.0
2	0.31	1.20	0.11	520	106.2	112.8	120.6	116.5	120.0	127.0	13.5	15.1	17.3
				540	95.9	102.9	107.3	102.4	109.5	116.5	14.3	15.9	18.5
				560	101.5	105.5	111.7	108.5	113.6	125.9	15.3	17.4	20.0
				580	96.1	100.4	104.4	103.2	107.3	111.7	14.9	17.8	20.8
				600	88.8	94.1	100.1	96.9	101.7	108.3	16.3	19.1	21.2
				620	82.3	91.6	96.7	97.9	102.0	107.1	17.7	19.4	21.0
				640	72.9	79.9	84.6	85.1	90.4	93.9	17.7	21.6	24.4
				66	67.4	75.8	80.3	80.3	85.5	91.2	18.3	22.8	26.7
				L	61.8	67.9	76.4	91.2	93.8	96.5	18.0	19.8	24.0
				N	54.8	56.6	61.0	73.9	75.8	80.8	21.0	25.0	27.0

T_r - tmpering temperature, °C, L - mechanical characteristics of the rolling heat, N - mechanical characteristics on normalized specimens T_N =900° C, T_N - normalization temperature

Table 7

MECHANICAL CHARACTERISTICS MINIMUM, AVERAGE AND MAXIMUM VALUES OBTAINED ON TWO STEEL SAMPLES (1 AND 2) 31VMn 12

T_r °C	R_c daN/mm²			R_m daN/mm²			A_5		
	min.	med	max	min.	med	max	min.	med	max
520	103.9	109.90	120.6	111.7	116.85	127.2	11.0	14.40	17.7
540	85.3	98	107.3	96.7	105.43	116.5	12.0	16.14	18.7
560	90.6	10.90	111.7	98.8	108.73	125.9	14.1	16.70	20.0
580	91.3	98.98	101.5	98.6	105.80	111.7	12.2	16.70	20.8
600	83.2	92.69	100.1	92.5	100.71	107.7	15.1	18.07	21.2
620	81.5	88.68	96.7	91.5	97.78	107.1	15.3	18.28	21.0
640	72.5	80.60	84.6	85.1	91.33	95	16.7	20.23	24.4
660	62.5	73.40	83.1	76.3	84.14	91.2	20.4	21.61	26.7



x 500 T_r = 520°C x 500 T_r = 580° C x 500 T_r = 640 ° C

Fig. 3 Aspects of the structure of the material after improvement, steel 31VMn 12 sample 1

Fig. 4 Aspects of the structure of the material after improvement, steel 31VMn 12 sample 2

x 500 $T_r = 520^0C$ x 500 $T_r = 580^0$ C x 500 $T_r = 640^{\ 0}$ C

Conclusions

Experiments realized they followed establishing the parameters of the thermal treatment with the main objectives: using the steel brand for the production of the pipe quality; insurance limit of flow corresponding to a pipe quality for the largest number of samples within the same steel brand and the same thermal treatment. This is justified by the fact that, depending on the circumstances of the supply of semi-finished products, the realization of any assortment is not prejudiced. It was intended to obtain the mechanical characteristics corresponding to the qualities of the pipe in the following states of the material: from the heat of rolling; with thermal normalization treatment; with thermal improvement.

A decrease in the yield limit and breaking strength of 10-15 daN/mm^2 after normalization over the rolling values is observed.

Metallographic analysis performed after the improvement treatment highlighted the existence tempering structures with the coalescence of the carbide particles as the tempering temperature increases.

The steel brand 31VMn 12 corresponds to the manufacture a wide range of qualities of oil pipes, which can be obtained by heat treatment of normalization, quenching plus tempering.

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