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RESEARCH ON THE INFLUENCE OF CHEMICAL COMPOSITION AND TECHNOLOGICAL PARAMETERS ON THE MECHANICAL PROPERTIES OF X60M STEEL USED IN THE PRODUCTION OF OIL AND GAS PIPELINES

Beatrice TUDOR, Mirela NOUR
"Dunarea de Jos" University of Galati, Romania
e-mail: beatrice.tudor@ugal.ro

ABSTRACT

The work analyses and determines the mechanical properties of the X60M steel used to make welded pipes for oil and gas transportation. X60M type steels are among the materials most used in the construction of pipelines for the transport of natural gas and oil, due to an advantageous price/performance ratio. Determinations were made of resilience and resistance to breaking, yield strength, elongation and transverse contraction, determined by tensile tests, as well as an analysis of the microstructure.

KEYWORDS: mechanical properties, welded pipes, microstructure

1. Introduction

The steels for constructions and welded structures are carbon and low-alloy steels, intended for the production of metal structures through technological processes of high productivity, satisfying, as the case may be, resistance and tightness conditions.

The main usage characteristics of these steels are:

- Mechanical strength characteristics - yield strength and breaking strength - according to which the steel brands are defined and the allowable design stresses of welded constructions and structures are established.

- The weldability characteristics, considered both in terms of the technological aspect of the facility in execution, and that of safety against brittle breakage by grouping the products into quality classes [1, 3].

The mechanical characteristics are conditioned by the chemical composition and the metallographic structure. At least the following characteristics must be determined:

• breaking strength, yield strength, elongation and transverse contraction, determined by tensile tests;

• breaking energy when bending by shock, at different temperatures;

• the static bending angle without the appearance of cracks.

2. Experimental research

The structural analysis was carried out on X60M steel samples used to make welded pipes for the transportation of oil and gas. 3 7.5 mm V-groove specimens were used to determine resilience and an intermediate sample to determine tensile tests.[4]

General characteristics of X60 M steel, according to API 5L/95 standard, are presented in Table 1 and 2.

***Table 1.** Chemical composition (%)*

C%	Mn%	Si%	P%	S%	Al%	Nb%	V%
0.09-0.12	1.30-1.50	0.20-0.40	max. 0.01	max. 0.01	0.02-0.05	0.02-0.04	0.02-0.04

***Table 2.** Mechanical properties*

R_m [MPa]	$Rp_{0,2}$ [MPa]	A [%]	KV [J]
525-700	425-550	min. 30	min. 45

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The special requirements of the beneficiary are presented in Table 3.

The steel charge with the number 928400 taken in the study, from which the tests were carried out, is according to the requirements of the beneficiary and was developed in the LD converter having the following chemical composition for the liquid, presented in Table 4.

Table 3. *Beneficiary requirements*

Steel	C%	Mn%	Si%	P%	S%	Cu%	Ni%	Cr%	V%	Ti%	Mb%	Nb%	Al%	N%	B%
X60M	max 0.19	max 1.60	max 0.45	max 0.025	max 0.015	max 0.25	max 0.30	max 0.30	max 0.10	max 0.040	max 0.10	max 0.05	0.020-0.060	max 0.012	max 0.001

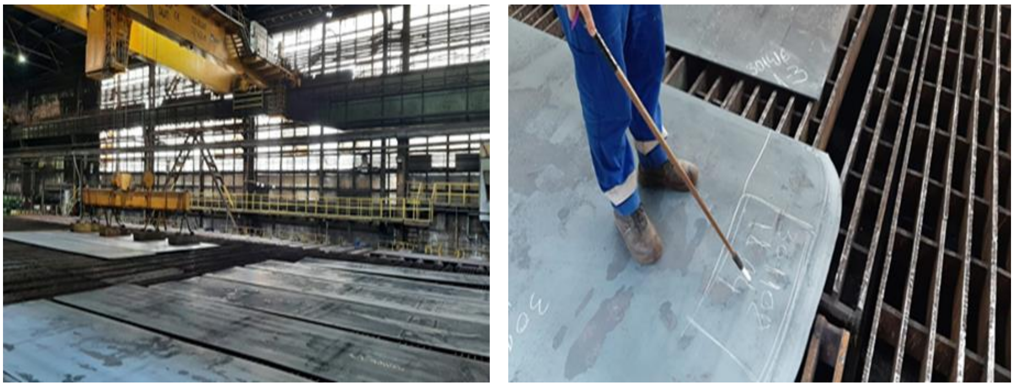
Table 4. *Chemical composition of batch number 928400*

X60M Batch 928400	C	Mn	SI	P	S	Ti	V	Cu	Al	Ni	Cr	Mo	Nb
[%]	0.13	1.47	0.38	0.010	0.004	0.015	0.062	0.04	0.034	0.02	0.03	0.003	0.022

The treatment applied to this type of steel is controlled rolling. Controlled rolling is a thermomechanical treatment that consists of hot rolling in the austenite recrystallization area, cooling to the biphasic area and rolling, followed by the transformation of the austenite to a fine and uniform ferrite-pearlitic structure.

The final structure depends on the austenite grain size obtained after the different stages of controlled rolling.

After lamination, the sheet of steel was sent to the cooling beds, where the samples were taken (Fig. 1).



a) cooling beds b) sampling

Fig. 1. *Sampling*

a) placing the sample in the INSTRON machine b) obtaining the tested sample

Fig. 2. *Test results on the INSTRON mechanical testing machine*

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The sample presents a sufficient amount of material, for the execution of one or more samples, for the mechanical tests and the samples for achieving resilience.

The determinations were made in the Liberty Galati mechanical testing laboratory, on an X60M steel used in the manufacture of large-diameter welded pipes for the transportation of oil and natural gas products.

As part of the analysis of the structure, analyses were carried out for tensile, shock bending tests.

The tensile test was carried out using the "INSTRON" static testing machine. The stages are shown in Figure 2.

Establishing the breaking strength of the tested material is calculated with the following equations:

$$R_m = F_{max}/S_0 \text{ [MPa]}$$

The elongation at break is calculated using the relationship:

$$A = [(L_u - L_0)/L_0] \times 100 \text{ [\%]}$$

The results obtained for the mechanical tests were centralized in Table 5.

***Table 5.** Mechanical test results*

Steel	Thickness [mm]	Width [mm]	Section [mm²]	FRm [kN]	FRc [kN]	Rm [Mpa]	Rc [Mpa]	A [%]
X60M	10	25	270.71	164.9	136.8	609	505	32

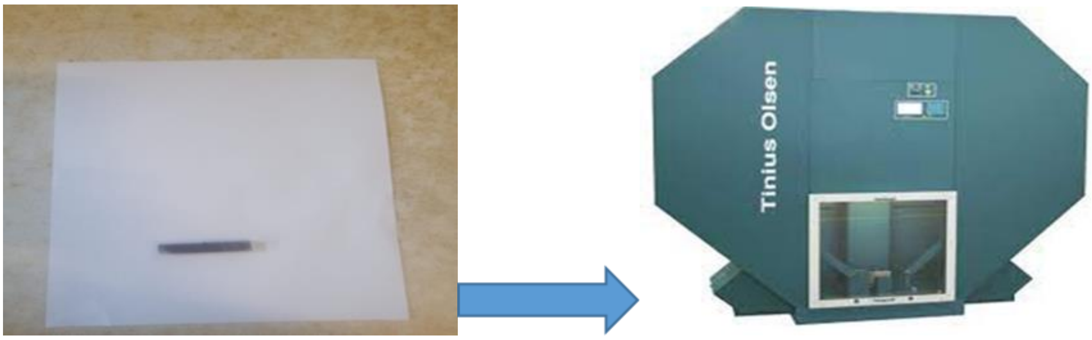
3. Shock bending test (resilience)

The cooling of the samples is carried out at a temperature of – 10 °C using dry ice as a cooling agent. This is done in a heat-insulating cooling container, which has a non-tight lid to prevent explosions due to the pressures of the released gases.

The test piece is inserted into the carbonic snow bath, kept for 5 min, then it is extracted and subjected to shock bending tests.

To carry out the shock bending test, is used the Charpy TINIUS OLSEN pendulum hammer.

The stages of carrying out the testing of the samples are shown in Fig. 3.



a) Cooled specimen

b) Charpy Tinius Olsen hammer

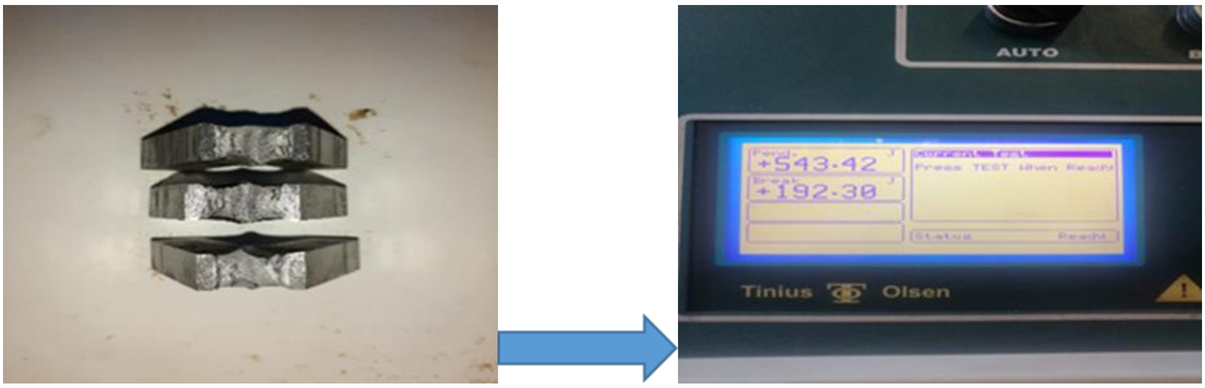


***Fig. 3.** Breaking of the specimens by the shock bending test*

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Results obtained from shock bending tests are presented in Table 6.

Table 6. *Shock bending test results*

Steel	Energie KV [J]	Test type [mm]	Tempure [°C]
X60M	61 – 60 – 58	KV 7.5	-10

4. Microscopic analysis

For the microscopic analysis, the sample was prepared by polishing the surfaces with the help of an automatic metallographic sample processing machine type LS2 – Remet (Fig. 4).

Fig. 4. *Automatic machine for processing metallographic samples type LS2 – Remet*

The polishing operation was performed mechanically and the metallographic attack was done with nital 2%.

The samples were analysed with the OLYMPUS PMG 3 microscope (Fig. 5).

By heating during thermal processing processes (heat treatments, plastic deformation, welding) a series of microstructural changes similar to those in non-alloyed steels can occur, which involve the change of pearlite morphology (from lamellar to semi-globalized pearlite). The extent of these phenomena depends on the value of the temperature and the holding time at that temperature [2, 5].

Fig. 5. *OLYMPUS PMG 3 metallographic optical microscope*

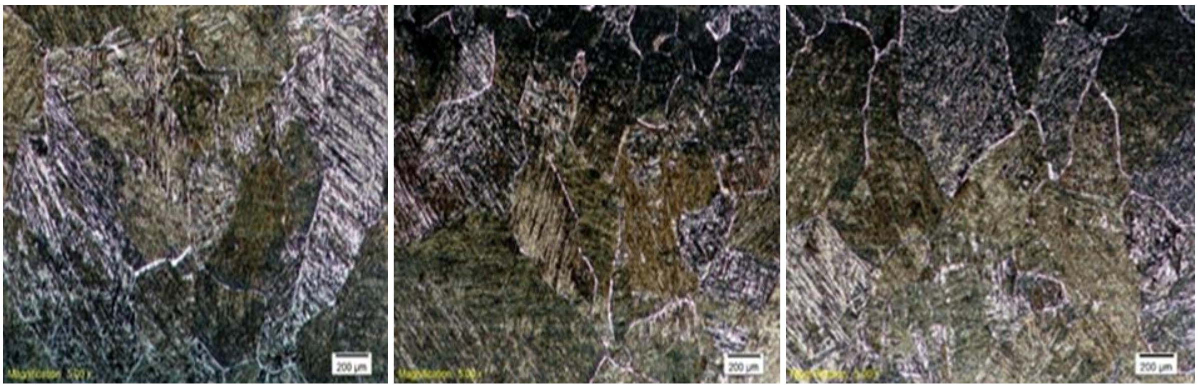

Fig. 6. *Magnified images: 200X*

5. Conclusions

The micro-alloyed steels used in the manufacture of longitudinally welded pipes under flux can be obtained by a combination between an appropriate chemical composition and a thermomechanical lamination at certain parameters of section reduction and temperature.

X60M steel, intended for the construction of pipes for the transport of gas and oil products, has very good resistance and plasticity.

X60M steels are among the materials most used in the construction of pipelines for the transport of natural gas and oil, due to an advantageous price/performance ratio.

The role of the micro-alloy elements is to confer special properties of resistance and tenacity.

Microalloying only with niobium cannot ensure satisfactory tenacity properties for all pipe sizes and thicknesses, therefore microalloying with Ti is also done for a positive effect.

The improvement of the shock fracture energy depends on the purity of the steel and requires a low content of P and S, avoiding the formation and segregation of iron phosphide which gives a lot of brittleness to the steel.

The studied steel, X60M, intended for the construction of pipes for the transport of gas and petroleum products, has a very good resistance and plasticity.

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