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THE TORSION MECHANICAL CHARACTERISTICS UNDER LOW TEMPERATURE OF 34MoCrNi16X STEEL

WEBER Francisc

University "Politehnica" Timisoara, Faculty of Engineering Hunedoara, ROMANIA

Abstract

The paper introduces the torsion tests under low temperature for steel grade 34MoCrNi16X, carried out on round test bars, respectively on thin-walled tubular test bars, thus achieving a homogenous bi-axial strain. We described the shape and dimensions of the test bars, the test machine, the cooling room we used and we gave the experimental results we obtained.

Keywords

low temperatures, cooling room, torsion tests.

1. GENERAL NOTIONS

The torsion test is not subject of international norms, although it constitutes a way of examining metal behavior under the force of tangent strains. The results of the test allow considerations on the tenacity of metals [3] by the determination of their torsion resistance and deformability.

The low temperature tests are carried out, methodologically, as in the case of tests at room temperature, the particular characteristic consisting in the fact that the mechanical trial has to be done in the moment the entire mass of the test bar has a certain low temperature, within a certain limit tolerance for the testing temperature [1]; [3].

In the cross-sections of the test bar on which torsion momenta are applied, there appear tangent strains, and the sections twist around their axis at an angle φ which, up to a certain limit is proportional to the distance l between the planes of the charging couples [1]; [2]; [3]. The maximum angular deformation, called specific slide is calculated by means of relation:

$$\gamma_{max} = \frac{r \cdot \varphi}{l} = \frac{d \cdot \varphi}{2 \cdot l} \tag{1}$$

The maximum tangent strain, called torsion resistance is calculated by means of relations:

$$\tau_r = \frac{12M_r}{(\pi d^3)}, \quad \text{for the circular-section test bars;} \tag{2}$$

$$\tau_r = \frac{12M_r}{\pi(D^3 - d^3)}, \text{ for the ring-section test bars.} \tag{3}$$

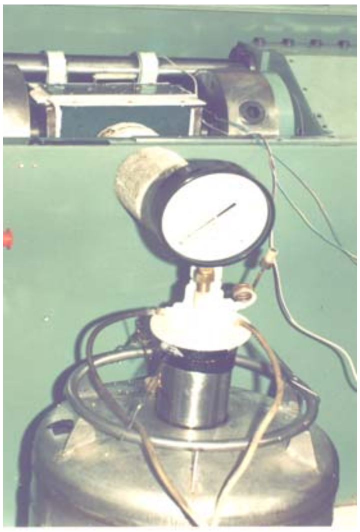
2. EXPERIMENTAL TEST STAND

For the torsion tests under low temperatures, we used test stand made up of:
- the torsion test machine;
- the cooling room;
- Dewar vessel for keeping the solid nitrogen;
- device for the automatic regulation of low temperature.

The torsion tests for the circular, respectively ring-section test bars have been carried out on a machine model MODELL TAD III, available in the laboratory of Material Resistance of the Engineering Faculty of Hunedoara. This machine, described in [4]; [5] and [7] has the following characteristics:

- the loading rate, expressed in rotations/min has four work values (6, 12, 30, respectively 60 rot/min.), button selected;

- the mechanism for measuring the torsion momentum has four work domains (15, 30, 75 and respectively 150 Kf·m), to be obtained by attaching standard weights to its pendulum;
- the torsion test can be carried out clockwise or anticlockwise.



Picture 1. The cooling room mounted on the torsion test machine

For the torsion test under low temperatures we attached a cooling room [4]; [5]; [7] using nitrogen vapors as cooling agent to the test machine.

In order to store the liquid nitrogen we used a 40 l Dewar vessel. In the case of using nitrogen vapors as cooling agent we used a charge resistance immersed in the liquid nitrogen and warmed up so that the vapors at the upper part of the Dewar vessel be exhausted through a transfer pipe connected to the cooling room.

The device of automatic temperature regulation [4]; [6] controls the charge resistance and ensures a flow of nitrogen vapors, at a pre-selected temperature and over the period covering the entire torsion test.

Picture 1 shows the cooling room mounted on the torsion test machine as well as the Dewar vessel with its pressurizing system.

3. THE TEST BARS USED IN THE EXPERIMENT

The aim of the experiment consists in the determination of the torsion characteristic curve of the material, showing the dependency of the tangent strain τ on the specific slide γ. This curve is obtained by processing the diagram drawn by the recording system of the test machine, which represents the dependency between the torsion momentum (M_r) and the torsion angle (φ).

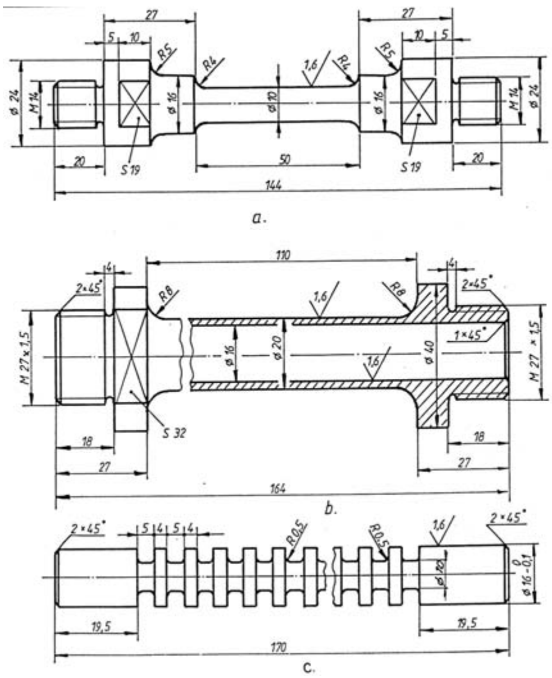


Fig.1.The shape and dimensions of the test bars used for torsion tests at low temperatures

As the torsion test is not nationally standardized, the shape and dimensions of the test bars are not unanimously accepted. Thus, different authors [1]; [2]; [3] recommend different values for the length of the test bars over the calibrated section, the diameter of the test bar (in the case of circular cross-sections), the ratio between the exterior diameter and the thickness of the wall (for the tubular test bars).

Taking into account what we have mentioned above, the author has chosen dimensions which would best rank within these recommendations. The shape of the test bars used for the torsion tests at low temperatures are given in fig.1.

The circular-section test bar (fig.1.a.) have the calibrated area 50 mm long and the diameter of 10mm (L/d = 10), and the joining radius between this zone and the ends is 4 mm.

The tubular test bars with thin walls have the shape and dimensions given in fig.1.b. Thus, the calibrated area is 110 mm long, the exterior diameter of 20 mm and the inner diameter of 16 mm, and the wall is 2 mm thick (L/d = 5,5; D/s = 10). The joining radius between this zone and the ends is 8 mm.

In order that the tubular test tube keep its stability along the torsion test we introduced in it an iron core, having the shape and dimensions given in fig.1.c. It has two cylindrical zones at the ends, while the central area is worked so as to allow the leading of the test tube long ring-shaped portions.

4. THE RESULTS AND CONCLUSIONS OF THE EXPERIMENT

The torsion tests have been done for the steel grade 34MoCrNi16X, which is a highly alloyed steel, worked by plastic deformation and used in machine parts (piston rods, shafts, large toothed wheels, etc.), after thermal treatment. The chemical structure, the mechanic characteristics, the thermal treatment applied, etc. observe STAS 791-88.

Out of the characteristic curves, fig.2 gives the ones obtained for circular-section test-bars for test temperatures of +20°C, -40°C and -80°C and fig.3 those resulting from torsion tests on ring-shaped test bars at test temperatures of +20°C and -40°C. For each level of the test temperature we used two test tubes, the charging rate being 6 rot/min.

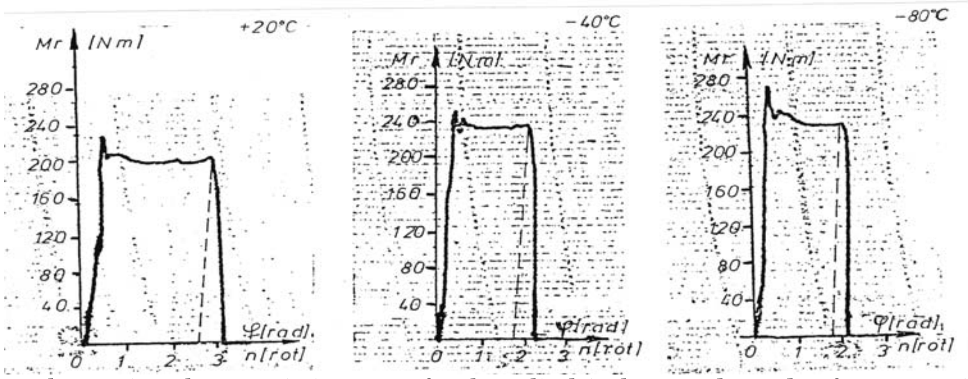


Fig.2.The torsion characteristic curves for the cylindrical test rods made of 34MoCrNi16X

The torsion resistance has been calculated by means of relations (2), respectively (3) and the specific glide by formula (1).

The magnitudes measured and calculated are given in table 1 (for the cylindrical test bars) and in table 2 (for the thin-walled, tubular test bars).

Table 1. The mechanic torsion characteristics of 34MoCrNi16X steel determined on cylindrical test bars

No.	Test	$(M_r)_{max}$		n	φ_{max}	τ_r	γ_{max}
	temperature [°C]	[kgf·m]*	[N·m]	[rot]	[rad]	[N/mm²]	[rad]
1		22,51	220,823	2,53	15,88	843,909	1,588
2	+20	21,78	213,661	2,41	15,13	816,538	1,513
Media		22,14	217,193	2,47	15,51	830,223	1,551
1		22,82	223,864	2,24	14,06	855,531	1,406
2	-20	22,61	221,804	2,18	13,69	847,658	1,369
Media		22,71	222,834	2,21	13,87	851,594	1,387
1		24,75	242,797	1,73	10,86	927,886	1,086
2	-40	23,94	234,851	1,68	10,55	897,519	1,055
Media		24,34	238,824	1,70	10,70	912,703	1,070
1		25,32	248,389	1,65	10,36	949,257	1,036
2	-60	24,95	244,759	1,59	9,98	935,384	0,998
Media		25,13	246,574	1,62	10,17	942,321	1,017
1		27,22	267,028	1,62	10,17	1020,489	1,017
2	-80	28,12	275,857	1,58	9,92	1054,230	0,992
Media		27,67	271,442	1,60	10,05	1037,359	1,005

* The scales of the test machine are standardized in kgf.m

Table 2. The mechanic torsion characteristics of 34MoCrNi16X steel determined on tubular test bars

No.	Test	$(M_r)_{max}$		n	φ_{max}	τ_r	γ_{max}
	temperature [°C]	[kgf·m]*	[N·m]	[rot]	[rad]	[N/mm²]	[rad]
1		53,25	522,382	1,98	12,43	511,934	1,11
2	-+20	54,12	530,917	1,90	11,93	520,298	1,07
Media		53,68	526,649	1,94	12,18	516,116	1,09
1		68,25	669,532	1,62	10,17	656,141	0,91
2	-40	67,52	662,371	1,71	10,73	649,123	0,96
Media		67,88	665,951	1,66	10,45	652,631	0,94

* The scales of the test machine are standardized in kgf.m

The characteristic curves of the cylindrical test bars differ from those obtained for steel grade 10Ni35R, [4] inasmuch as after the maximum value for the torsion momentum has been reached, at the end of the linear variation zone, it decreases and then stays approximately constant up to the breakpoint (see fig.2).

The explanation consists in the fact that, as steel possesses a relatively high resistance to torsion, in the zone in which it passes from the elastic behavior to the elasto-plastic, respectively plastic one, there arises a heating which is only partially compensated by the low temperature.

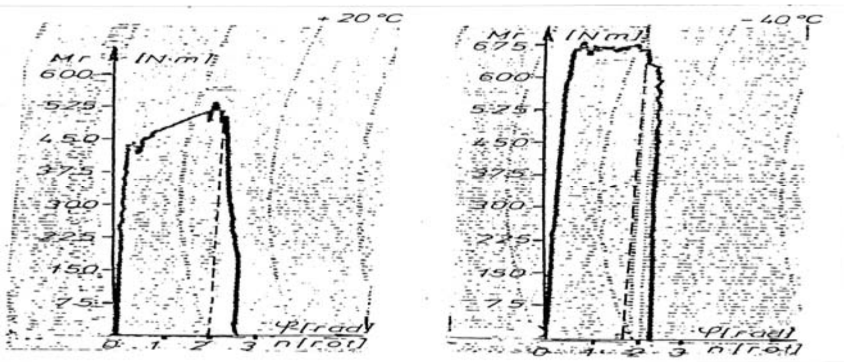


Fig.3 The torsion characteristic curves for tubular test bars made of 34MoCrNi16X

Fig.4 gives the variation curves of characteristics τ_r and γ_{max} with respect to the test temperature for the circular-section test bars.

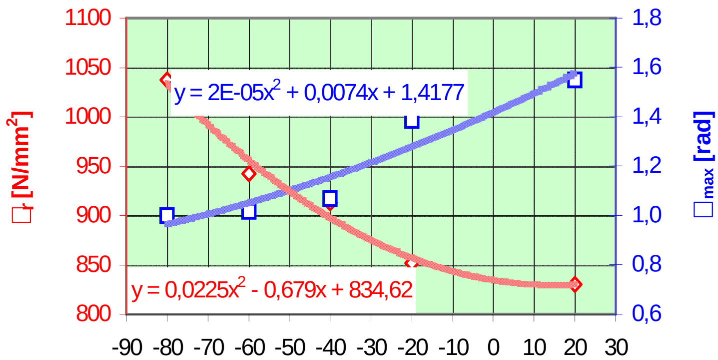


Fig. 4.The variation of the mechanical torsion characteristics with respect to the test temperature

We noticed an increase of the resistance to torsion, respectively a diminishing of the specific glide as the test temperature decreased. At -80°C the resistance to torsion is approximately 25% higher than the one obtained for +20°C.

For the ring-cross section test bars, the resistance to torsion at -40°C is 26% higher than at +20°C.

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