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THE INFLUENCE OF ELABORATION CONDITIONS UPON THE TENACITY OF SOME ALL PURPOSE STEELS

Doina Elena Petre
Adrian Claudiu Gavanescu **Erika Monika Popa**

Faculty of Engineering Hunedoara
Str.Revolutiei nr.5 Hunedoara
Romania

ABSTRACT

The paper introduces the relationships established between the elaboration conditions (e.i. the chemical composition and the quieting degree) and the level of cold plastic deformation the one part, and the tenacity of some all-purpose steels. The conclusions define the maximum admitted level of deformation in order to preserve an acceptable tenacity of steel, as well as the compulsory content in aluminum left in the steel which can guarantee a minimum level of tenacity

Keywords: steel, aluminium, tenacity

1. FOREWORD

Since all-purpose steels may be looked for in certain fields and be subject to particular conditions of mechanical shock strains, we did some experiments meant to establish correlations between the chemical composition and the degree of deformation on the one part, and the shock break energy on the other part.

2. EXPERIMENTS

The shock break energy can only be determined on 10mm-side test bars, according to the standards in use. In order to place the notch of the test bar in the least favorable part of the rolled section, respectively in the center, we decided to carry on the experiments on test bars 25 mm long. We considered it important to have the root of the notch in the center of the rolled section, as the central part is most influenced by hardening in the case of round samples deformed between parallel plane surfaces. Structurally, too, the central part is the most segregated one.

In order to establish the influence of the chemical composition and the quieting degree upon tenacity, for steels having a carbon content of up to 0.35%, we tested rolled sections from six steel charges, all of them quieted with silicon, three of them being alloyed with Al (0.027 - 0.05%).

Rolled sections of 35 to 40 mm were turned into samples 25mm diameter, which were subjected to cold plastic deformations.

The tests aimed at determining the dynamic characteristics by shock-bending of U and V-notched test bars.

Since the reference literature mentions as a basic influential factor for steel tenacity the size of the real and inherited austenitic grain, the annealing temperature was 925^{o}C, corresponding to the standard temperature for determining the hereditary austenitic granulation.

After annealing and turning, the samples were kept at room temperature for 72 hours, in order to eliminate all the remnant strains.

The test bars used for determining the shock-break energy were processed to a diameter of 25mm and a length of 60mm, then cold plastic deformed by pressing on 30 kN, 50 kN, 60 kN and 70 kN force generators.

The samples used for shock bending tests were made both of deformed test bars and the blank assay, so that the notch root correspond to the central area of the rolled section, deformed or not deformed.

The test was performed with a Charpy pendulum hammer, with a direct reading of the break energy in J.

For the identification of the samples and test rods, we established, before the thermal treatment, a marking code based on the steel chemical composition, which was preserved during all tests and which corresponds to a charge and a bar out of which all the samples and test bars with the respective mark have been made. Although the number of tests is reduced by using this procedure, for research purposes it is very efficient, as it eliminates the influence, of temperature, hot deformation, cooling rate after rolling, of area segregation in the ingot, etc.

Table 1 presents the chemical compositions of the charges under analysis.

Table 1. The chemical composition of the charges under analysis

Steel grade	*Sample mark*	*Chemical composition, %*								
		C	*Mn*	*Si*	*P*	*S*	*Cr*	*Ni*	*Cu*	*Al*
OL321k	*1*	*0.10*	*0.40*	*0.25*	*0.017*	*0.015*	*0.05*	*0.05*	*0.08*	*0.005*
OL341k	*2*	*0.13*	*0.34*	*0.25*	*0.045*	*0.014*	*0.07*	*0.15*	*0.30*	*0.006*
OL371k	*3*	*0.17*	*0.58*	*0.23*	*0.042*	*0.023*	*0.10*	*0.07*	*0.13*	*0.005*
OLC20	*4*	*0.20*	*0.58*	*0.34*	*0.045*	*0,020*	*0.16*	*0.12*	*0.21*	*0.030*
OLC25	*5*	*0.25*	*0.70*	*0.27*	*0.027*	*0.016*	*0.07*	*0.06*	*0.09*	*0.050*
OLC30	*6*	*0.33*	*0.73*	*0.26*	*0.040*	*0.020*	*0.08*	*0.06*	*0.09*	*0.027*

The analysis of the data under question leads to the conclusion that the steels we used belong to the carbon quieted steels, with different contents in aluminum, charges 1-3 with a low aluminum content, which determined a rough austenitic granulation (under 5), and charges 4-6, with a content in aluminum higher than 0.02 %, ensuring a fine austenitic granulation (5-8).

Before the shock break test, we underwent Vickers HV_5 hardness tests, the values obtained on both the blank assay and the deformed samples being given in Table 2.

Table 2. The (HV_5) hardnesses of test rods for shock break tests

Sample mark	*% C*	*HV_5 hardness*				
		Deforming force, x 10^4 N				
		0	*30*	*50*	*60*	*70*
1	*0,10*	*144*	*155*	*151*	*162*	*152*
2	*0,13*	*146*	*152*	*167*	*-*	*-*
3	*0,17*	*150*	*158*	*167*	*180*	*174*
4	*0,20*	*144*	*150*	*165*	*-*	*-*
5	*0,25*	*152*	*140*	*160*	*178*	*-*
6	*0,33*	*156*	*158*	*168*	*168*	*-*

The table given above presents the results obtained under different deforming forces, for test bars having the same dimensions, namely 25 mm diameter and 60 mm length.

The next table presents the deformation degrees obtained by applying different deforming forces, expressed both by the deformation degree of the section ε_s and by the unitary deformation degree ε_u.

Table 3. The deformation degree of samples undergoing the shock break test

Sample mark	%C	Deforming force, x 10^4 N							
		30		50		60		70	
		ε_s	ε_u	ε_s	ε_u	ε_s	ε_u	ε_s	ε_u
1	0,10	3.6	10.5	11.2	21.5	14.5	25.5	18.4	30.0
2	0,13	3.0	9.0	9.7	19.0	-	-	-	-
3	0,17	2.5	7.5	7.9	17.0	11.3	21.6	14.9	26.0
4	0,20	2.6	8.0	7.6	16.5	-	-	-	-
5	0,25	1.4	5.5	6.5	15.1	10.0	20.0	-	-
6	0,33	1.5	5.7	5.5	13.3	9.2	18.7	-	-

The break energy obtained on Charpy V test rods under the pendulum hammer having the energy of 30 daJ is given in table 4.

Table 4. The break energy for the shock bending test

Sample mark	%C	%Al	Compression force, x 10^4 N				
			0	30	50	60	70
1	0,10	0,005	183	22	17	7	10
2	0,13	0,006	138	46	11	-	-
3	0,17	0,005	118	11	9	9	6
4	0,20	0,030	125	135	101	-	-
5	0,25	0,050	127	122	97	97	-
6	0,33	0,027	96	50	98	94	-

It is to be noticed that with shock bending, there is a grouping of the values of the break energy, with respect to the contents in aluminum. Thus:

- with charges 1 - 3 , where the Al content is 0.005 - 0.006%, the break energy is much below the one in charges 4 - 6 where the Al content is above 0.027%. With charges 1 - 3, the break energy diminishes at a rapid rate even for slight deformation degrees, of 2.5 - 3.0 %, the 15 J brittleness level (accepted for semi-quieted steels) being attained only by the steel with 0.10%C for a deformation of 11%. For the steel with 0.17%C, the brittle fracture is attained even for deformation degrees of 2.5% and for the 0.13%C steel, the deformation should be over 3%;
- for fine-grained quieted steels, the brittleness level admitted in the reference literature is 29 J and in the case of the steels from charges 4 - 6 , even for deformation degrees of 10 % and contents in carbon of 0.33 % the break energy is above 90 J. With these steels, the decrease in the break energy values is less influenced by the degree of deformation when the content in carbon increases, than in the case of rough austenitic granulation steels.

In order to bring into relief the influence of the connection radius of the notch upon the break energy, we made Charpy U and V test rods out of charge 4. Table 5 presents the comparative results of these tests.

Table 5. Comparative data regarding the values obtained in testing U Charpy and V Charpy tests of the same steel grade

Deformation degree %	Break energy			
	KV J	KU J	KCU J/cm^2	KCU' J/cm^2
0	125	136	170	139
2,6	135	130	163	146
7,6	101	130	163	120

KCU' - determined according to STAS R 10025-75

As charge 4 is a steel with fine austenitic granulation, it belongs to the group of high tenacity steels, the values obtained for the break energy ranging within 100 - 136 J, for both the plastic deformed samples and for the non-deformed one.
The break energy of the Charpy V samples show a decrease for the deformation degrees of 7.6 % as compared to the value corresponding to a 2.6% deformation degree, while for the Charpy U samples tenacity is practically maintained at the same level. By comparing the resilience values determined experimentally to those of standard STAS R 10025 - 75 we will find higher real values than those given in table 2 of the above-mentioned standards.
Thus, in order to obtain high tenacities for deformation degrees above 10%, with steels having a carbon content of up to 0.35%, it is compulsory to have an aluminum addition during steel elaboration, so that the rolled sections should preserve an aluminum level of at least 0.025%. In the case of steels with a content in aluminum of about 0.005%, the steel is brittle even for low deformation forces, in the range of 3 - 5 %.

3. CONCLUSIONS

- the break energy for quieted all-purpose construction steels decreases abruptly while cold plastic deforming, the decrease being more accented when the content in carbon is higher. Practically, the quieted steels grade OL 32, OL 34, OL 37 k can not guarantee the tenacity expressed by the break energy of 27J at environment temperature;
- with steels OL 37 kf, OL 42 kf and OLC 20, OLC 25, OLC 35, with a content in aluminum per product of at least 0.020% the break energy of at least 27J can be guaranteed even for deformation degrees of up to 20 %.

As a conclusion, we suggest as a method of increasing the resistance characteristics by about 30%, the cold plastic deformation by compressing (rolling) to a deformation degree of up to 15%, and if a minimum tenacity level is requested, the steels have to be quieted suplimentarily, by addition of aluminum, ensuring a minimum aluminium level per product of 0.020 %.

4. REFERENCES

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