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MECHANICAL TESTING BY SHOCK BENDING UNDER HIGH TEMPERATURE

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Abstract: The paper introduces the shock bending test for steel grade OLT 45K carried out on Mesnager-type test rods (the groove depth h = 2 mm) under high temperatures. The test rods were longitudinal, respectively cross-sectional samples of semi-finished ingots. We introduced the results of the experiments and the analysis of the influence that the type of test rod sampled longitudinally or cross-sectionally with respect to the rolling direction, has upon the values of resilience.

1.GENERAL CONSIDERATIONS

The dynamic shock trials are being used in order to study material behavior under high charging rates, in order to point out their deforming capacity under high deformation rates, and the dependency on the strain state and trial temperature. On principle, these dynamic trials can be carried out for all simple strains: traction, compression, bending and torsion. Out of these, it is only shock bending that is norm-regulated (***SR EN 10045-1:1993- The shock bending trial on Charpy test rods,*** that replaces STAS 1400-75; STAS 1511-81 and STAS 6833-79), the other trials being object of research works.

In order to carry out the shock bending test under high temperatures, the following elements are needed: test rods, having well-determined shapes and dimensions; an oven for heating up the test rods to the desired temperature and a scale pendulum hammer (Charpy hammer).

Test rod heating up to high temperatures can be done in ovens that, on principle, consist in a thermally insulated room, in which the set of test rods can be placed on a stand, so as to ensure their contact on all surfaces with the heating means. The ovens are either delivered as annexes of the trial equipment, or are built in the industrial labs mean for mechanical trials. After the rod reaches the desired temperature, it is being kept for a time at this temperature and removed from the heating oven and placed on the trial device of machine, in view of performing the trial.

The time elapsed while handling the test rod between the oven and the trial device must be short enough in order to basically keep the trial temperature of the test rod.

Once the *trial temperature has increased* the character of the break is influenced by a series of factors such as: the content in alloy elements, the content in impurifying elements (sulphur, phosphorus, oxygen, hydrogen, etc,); the strain focusers, and also the surface flaws; microstructure; hardness.

2.THE TEST RODS USED IN SHOCK BENDING TRIALS

The shock bending trial under high temperatures shall be carried out similarly to the one done at room temperature and the length and cross section of the test rods used in the shock bending trials must be chosen according to the capacity of the pendulum-hammer.

Norm [1] points out that “in case of trials carried out under temperatures other than room temperature, the test rod should be introduced into a heating means for a sufficient time span, so as the entire test rod reach the respective temperature (for example 10 minutes into a liquid or at least 30 minutes into a gaseous medium). The test rod must be broken within 5 seconds from the moment it has been removed from the heating device.

The principle of shock bending trial consist in breaking at a single blow, by means of a pendulum hammer, under determined conditions, a test rod having a U or V-groove in the middle, seated on two supports. The determined characteristic is called **absorbed energy** [J] and it is specific for the shock resistance of materials (also called “resilience”).

The sampling procedure, the type of test rod used, the number of test rods, the thermal treatment applied (as the case may be) and their orientation are mentioned in the product standards.

The cropping and working of the test rods shall be done only by cutting procedures. The **U** groove shall be obtained by drilling, making use of an adequate device, and the **V** groove shall be done by means of a properly shaped milling machine.

The shape and dimensions of the test rods to be used in the experiments are given in figure 1 and the principle of shock bending in fig.2.

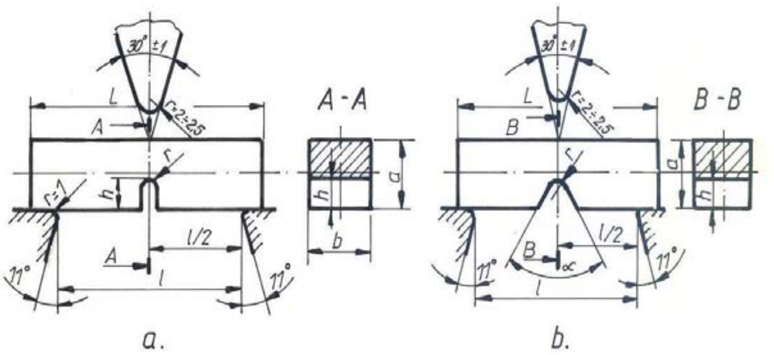

Fig.1 ***The shape and dimensions of the test rods used in the trials***

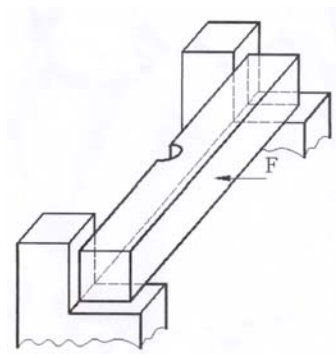

Fig.2.***The principle of shock bending.***

For steels with special destination, working under high temperatures, we used U-grooved test rods. The U shape of the groove brings into relief the capacity of a steel to resist initial cracking and the V shape points out to the capacity of a steel to resist the propagation of an existing crack.

During the experiments, the heating of the test rods meant for bend shock under high temperatures was being done in an oven built by the author on this particular purpose. We also had in view the estimation of the shock bending characteristic of cross-sectionally sampled test rods with respect to that determined for longitudinally sampled ones, for a certain trial temperature.

3.THE TRIALS

In order to demonstrate the tough character of the steel under study at high temperatures we carried out chock bending tests on test rods longitudinally, respectively cross-sectionally sampled with respect to the rolling direction.

We used test rods having the width b = 10 mm, with the **U** groove of depth h = 2mm, as mentioned in the product norms given for steel OLT 45K, at room temperature.

The shock bending trial was done on lot of three test rods, for each temperature level between + 20^{0}C and +500^{0}C.

The test rods used in the experiment were sampled from a OLT 45K steel charge, elaborated in an electric arc oven, having a chemical composition that complies with the product standard. The surface working of the test rods was made by cutting and the groove by drilling by means of a proper machine.

Table 1.*Chemical composition of steel OLT 45K*

Material	C	Mn	Si	S	P	Cr	Ni	Cu	Mo
	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
OLT 45K	0,21	0,46	0,27	0,005	-	0,17	0,14	0,20	0,28
STAS 8184-87	Max. 0,23	Min. 0,45	0,15… 0,35	Max. 0,045	Max. 0,040	Max. 0,30	Max. 0,30	Max. 0,30	-

4. EXPERIMENTAL RESULTS

The experimental values obtained as a result of the trials are given in table 2.

The test rods were heated up in an oven and kept at the respective temperature for about 10 minutes, so as temperature deviations in the last 5 minutes ranged within the accepted limit deviations [1].

The temperature of the test rods was measured by means of a Cr-Al thermo-coupling.

Test rod handling was done by means of some pliers of special construction, whose active part was heated up to the same temperature and that allowed setting and centering the test rod on the stand of the pendulum-hammer, which was ready for the trial. The test rods were broken within 5 seconds from the moment they were removed from the oven.

Table 2. The resilience values – for the OLT 45K steel test rods longitudinally and cross-sectionally sampled

Temp.	KCU2 resilience for the longitudinally sampled test rods [J/cm^2]			Mean	Temp.	KCU resilience for the cross-sectionally sampled test rods [J/cm^2]			Mean
+20^{0}C	65	62	63,5	63,5	**+20^{0}C**	63	64,5	62,75	63,41
+100^{0}C	170	160	165	165,00	**+100^{0}C**	95	97,5	96,5	96,33
+200^{0}C	147,5	127,5	132,5	135,83	**+200^{0}C**	87,5	75	82,5	81,66
+300^{0}C	97,5	105	101,5	101,33	**+300^{0}C**	58,75	60	62,25	60,33
+400^{0}C	115	117,5	117	116,50	**+400^{0}C**	66,25	77,5	70,75	71,5
+500^{0}C	95	96,25	95,75	95,66	**+500^{0}C**	72,5	52,5	67,5	64,16

As a result of the trials, we could determine the KCU2 resiliencies for the test rods that were longitudinally, respectively cross-sectionally sampled as to the rolling direction.

Fig.3 shows a lot of test rods after their trial under high temperatures.

The resilience variation with temperature is given in fig.4.

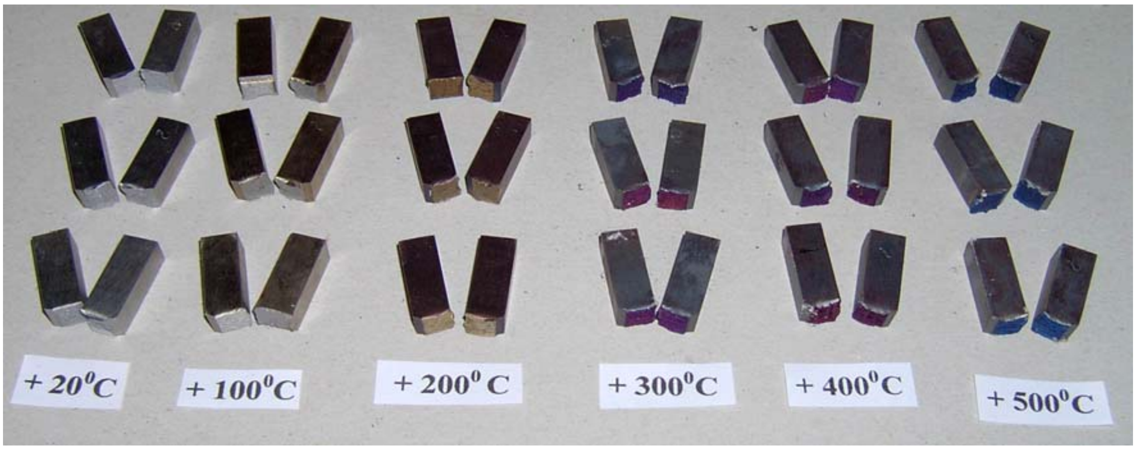

Fig. 3. Lot of test rods tried under high temperatures

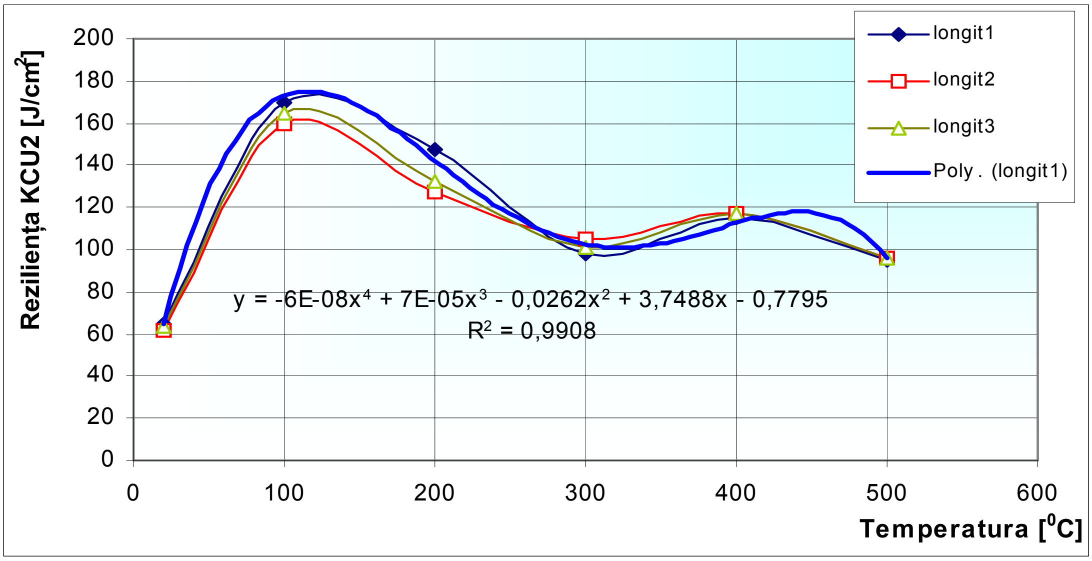

Fig. 4. The KCU2 resilience variation with respect to trial temperature, for test rods longitudinally sampled as to the rolling direction

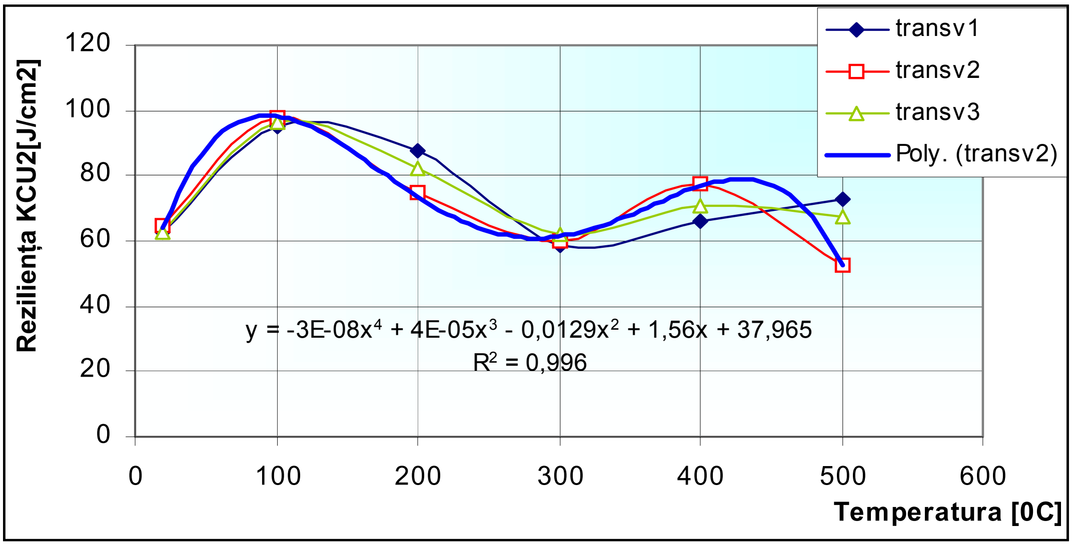

Fig. 5. The KCU2 resilience variation with respect to trial temperature, for test rods cross-sectionally sampled as to the rolling direction

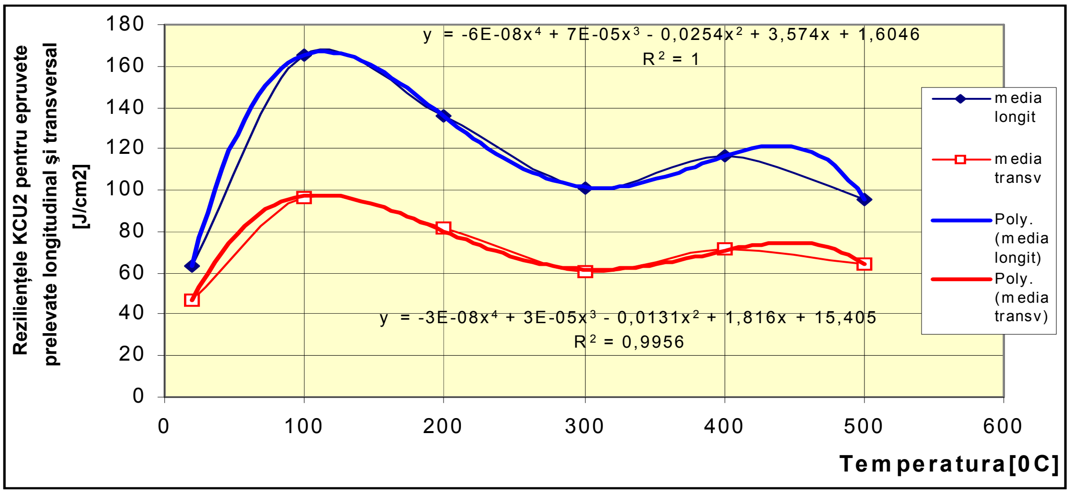

Fig.6. The KCU2 resilience variation with respect to trial temperature, for test rods longitudinally and cross-sectionally sampled made of OLT 45K steel

The steel under study, OLT 45K is used in making pipes for steam boilers, and is subject to thermal shocks when functioning, particularly when the boiler starts or stops functioning. The results show that the material has good tenacity qualities for temperature between 20^0C and 500^0C, which makes it fit for being used at these temperatures.

In order to study the tenacity of this steel grade according to the test rot type of sampling (longitudinal or cross-sectional) we drew the graph given in fig. 5, which clearly shows that on high temperatures, the breaking energy for the longitudinally sampled test rods we obtained a correlation coefficient R^2 = 1, by approximating the resilience variation with a 4^{th} degree polynomial function, while for the cross-sectionally sampled ones, R^2 = 0.9956. By analyzing figure 5 one can notice that KCU2 resilience increases up to temperatures of 100^0C and then decreases until temperature is 300^0C, increasing again up to a temperature of 450^0C, later to decrease again.

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