13th Scientific/Research Symposium with International Participation
„METALLIC AND NONMETALLIC MATERIALS“, B&H, 27th May 2021

THE INFLUENCE OF TEST TEMPERATURE ON THE TOTAL ENERGY OF IMPACT

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Key words:total impact energy , Charpy pendulum, impact test, test tubewith a notch

SUMMARY

The paper describes the behavior of welded joints of NN-70 steel in the presence of a cracking error when bending with impact force. The experiment was performed with three groups of test tubes, depending on the cut-off point of the test tube notch with the tip of the crack in BM, in WM and in HAZ. The test method used was conducted on the instrumented Charpy pendulum.

The impact tests were performed in order to detect the value of the total energy of impact depending on the test temperature. Depending on the test temperature, brittle, quasi-brittle or tough fracture can occur. The lowering of the temperature is conducive to the formation of a brittle state and is especially distinctive for the welded joint as well as for the typical heterogeneous structure.

The total impact energy, A_{uk} decreases by lowering test temperature successively from room temperature to -140 ^0C, for all test tubes (BM - WM - HAZ). The influence on the value of the total impact energy, A_{uk}, also has the place from which the tubes were removed, or the place where the V - notch was placed. This means that the heterogeneity of the welded joint structure, which is accompanied by different mechanical properties of the individual welded joint areas (base metal, the weld of the metal, and heat affected zone), has a crucial influence on the impact properties, i.e. the values of the total impact energy.

1. INTRODUCTION

A critical place in a welded structure is a welded joint due to its heterogeneous structure. The safety of the welded structure itself is evaluated by the basis of the welded joint property of the unit and the properties of its components. To evaluate the behaviour of the weld, the properties of the base metal (BM), heat-affected zone (HAZ) and the weld of the metal (WM) are compared, as well as the properties of the welded joint as a whole, which differs from the welded components [1, 2, 3 and 4].The classic test of welded joints provides only reliable information on the maximum strength of fracture and tensile strength, but the elongation data are unreliable because the different areas deform differently depending on the level of tension reached.Therefore, the difficulties in determining the magnitude of the strain occur, which, depending on the ratio of the hardness of the metal weld and the base metal may refer to either of these two regions. V-notch tests on the Charpy pendulum determine impact energy which provides valuable data on the local behaviour of the notch tip area. In today's application, this method has gained new approaches and new views and considerations. When testing the "toughness" according to Charpy, instrumentation emerges as a new approach, and the new views and considerations belong to fracture mechanics. In impact tests, by reducing the test temperature successively from room temperature to -140 ° C in all test tubes (BM - HAZ - WM), the total impact energy, A_{uk}decreases. The influence on the value of the total impact energy, A_{uk}, also has the place from which the tubes were removed, that is the place where the V - notch was placed. This means that the heterogeneous structures of the weld, accompanied by the different mechanical properties of the individual welded joint areas (base metal, weld of the metal, and heat affected zone), have a decisive influence on the impact properties, i.e. the values of the total impact energy.

2. MATERIAL

For the behavior of the welded joint components in the presence of a crack type error under the action of static load, steel NN - 70 was selected. The material was supplied in the form of sheets of 20 mm thickness. The chemical composition of the sheets supplied, is given in Table 1 and the mechanical properties are given in Table 2.

Table 1. Chemical composition od NN-70 steel [5]

Batch	*Chemical composition* % mass.									
	C	Si	Mn	P	S	Cr	Ni	Mo	V	Al
211605	0,10	0,20	0,23	0,009	0,018	1,24	3,10	0,29	0,05	0,08

Table 2. Mechanical properties of NN-70 steel [5]

Batch	Direction of testing	Yield strength $R_{p0,2}$, MPa	Tensile strength, R_m, MPa	Elongation A, %, min.
211605	L - T	710	770	14

The test of procedure and tube geometry is defined according to ASTM E23. The tubes measuring 11x11x55 mm after completing the simulation are handled in standard dimensions 10x10x55 mm with V2 nock, figure 1. The testing has been perfeormed on modern instrumented Charpy pendulum SCHENCK TREBELL 150/300J.

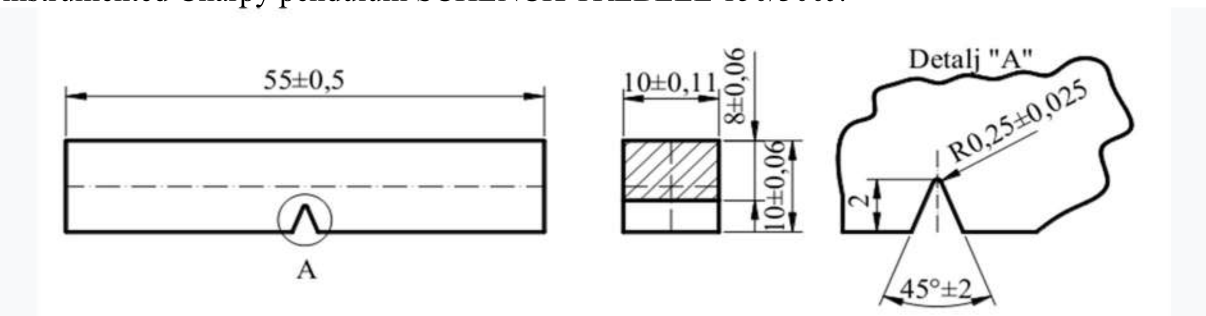


Figure 1. Impact energy test tube [11]

3. IMPACT TESTS

The impact bending test on the tube with a notch can also provide an explanation of the behavior of the material in the case of impeded deformation, i.e. spatial voltage state.

Determining the work required for fracture under specified test conditions is most commonly used for the ongoing control of the quality and homogeneity of the material as well as its processing.This test procedure can determine the tendency to brittle fracture, i.e. the tendency to increase brittleness during exploitation(aging). Impact tests oftubes with notches in the base metal (BM), in the weld metal (WM) and the heat affected zone (HAZ) were performed to determine the total impact energy as well as the components, crack creation energy and crack propagation energy.The test procedure, as well as the shape and dimensions of the test tubes, Figure 1, is defined by EN 10045-1 - Destructive tests on welds in metallic materials - Charpy impact test - Part 1: Test method [11], or ASTM E23-02 - Standard Method for Notched Bar Impact Testing of Metallic Materials [7].The notch position with respect to the welded joint is defined by the standard ***EN 875 - Destructive tests on welds in metallic materials - Impact tests - Test specimen location, notch orientation and examination*** [10]**,** figure 2. The notch is usually made by milling so that the material does not change during processing. No machining marks should be visible at the base of the notch.

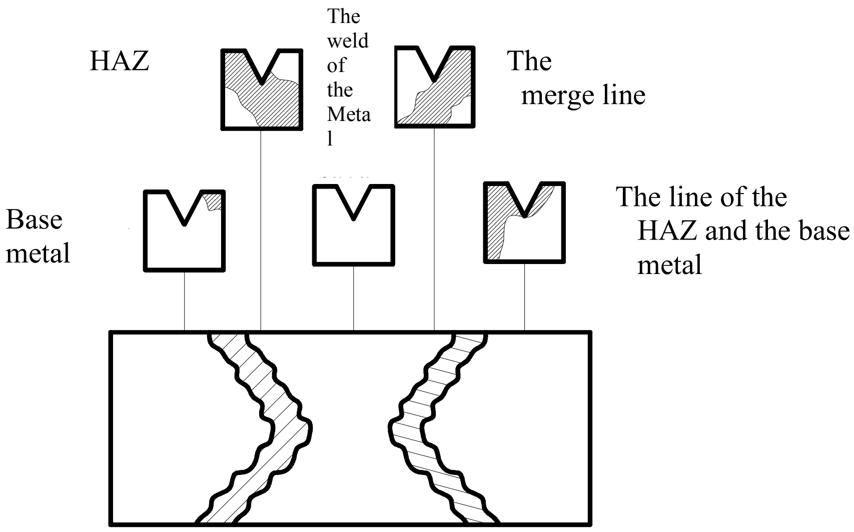
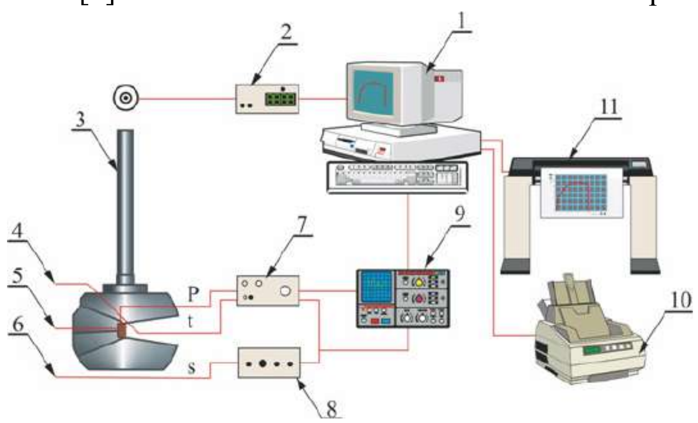


Figure 2. Notch position in relations to welded joint [10]

In impact bending tests, the fracture energy is determined as the integral size. Such determined fracture energydoes not give the possibility of separating the resistance of the material to the formation or expantion of the crack. To achieve this, the impact force and time should be continuously recorded during testing, which can be performed by instrumentation of the pendulum [5].The scheme of the modern instrumented pendulum is given in Figure 3.



1. Computer
2. Counter
3.Pendulum
4.The time detector
5.Force meter
6. Deformation meter
7. Amplifier
8. Amplifier
9.Oscilloscope
10. Printer
11. Plotter

Figure 3. Schematic representation of a modern instrumented pendulum [9]

The attached schematic representation shows that the instrumentation of the pendulum includes the connection of a force measuring instrument, which is installed in the pendulum hammer, a fracture time detector and a deformation measuring instrument via an amplifier with an oscilloscope. As the test tube fracture is short-lived (0.5 - 12 ms), it is the role of the

oscilloscope to make the registered signals visible.Testing on an instrumented oscilloscope pendulum gave the diagrams of forces-time and energy-time, which enabled the analysis of test results, first of all, the assessment of the influence of the V - 2 notch location and the test temperature (determination of the transition temperature) on the total impact energy A_{uk}, and its components, the $A_I$crack generation energy, and the A_P crack propagation energy.
Liquid nitrogen in alcohol, ie. petroleum ether, was used as the coolant to achieve low temperatures. The test itself was performed on the SCHENCK TREBEL 150 J instrumented Charpy pendulum.Three groups of tubes were made, depending on the location of the notch V - 2 notches, as follow:

- I group – test tube with V - 2 notch in base metal (BM),
- II group – test tube with V - 2 notch in the weld of metal (WM) and
- III group – test tube with V - 2 notch in the heat affected zone (HAZ).

The results of impact tests are given in Table 3 for the test tubes with a notch in BM, Table 4 for the test tubes with a notch in the WM and Table 5 for the test tubes with a notch in the HAZ.Characteristic diagrams obtained by examining the test tubes with a notch in BM at different temperatures shown in Figures 5 to 9, for test tubes with a notch in WM at different temperatures in Figures 9 to 13, and for test tubes with a notch in HAZ in Figures 14 to 18. Other diagrams are not shown because they indicate a similar character behaviour of the samples examined [5].

Table 3. Results of impact tests with a notch in the BM [5]

Sample mark	Test temperature °C	Total impact energy, A_{uk}, J	The energy of crack formation, A_I, J	The energy of crack propagation, A_P, J
BM-1	20	176	61	115
BM-2		188	64	124
BM-3		183	63	120
BM-4	-20	143	57	86
BM-5		157	59	98
BM-6		152	57	95
BM-7	-60	82	55	27
BM-8		103	59	44
BM-9		91	57	34
BM-10	-100	45	14	31
BM-11		50	16	34
BM-12		41	14	27
BM-13	-140	31	22	9
BM-14		28	21	7
BM-15		33	22	11

Table 4. The results of impact test with a notch in WM[5]

Sample mark	The test temperature °C	The total impact energy, A_{uk}, J	The energy of crack formation, A_I, J	The energy of crack propagation, A_P, J
WM-1	20	152	58	94
WM-2		168	59	109
WM-3		161	59	102
WM-4	-20	130	60	70
WM-5		102	58	54

WM-6		96	57	39
WM-7	-60	68	32	36
WM-8		75	34	41
WM-9		71	33	38
WM-10	-100	32	21	11
WM-11		35	22	13
WM-12		29	20	9

Table 5. The results of impact tests with a notch in HAZ[5]

Sample mark	**Testing tempearture °C**	**Total impact energy, A_{uk}, J**	**The energy of crack formation, A_I, J**	**The energy of crack propagation, A_P, J**
HAZ-1	20	179	61	118
HAZ-2		185	63	122
HAZ-3		190	65	125
HAZ-1	-20	135	55	80
HAZ-2		142	55	87
HAZ-3		153	56	97
HAZ-1	-60	97	53	44
HAZ-2		85	51	34
HAZ-3		93	52	41
HAZ-1	-100	54	25	29
HAZ-2		60	27	33
HAZ-3		63	28	35
HAZ-1	-140	44	25	19
HAZ-2		38	23	15
HAZ-3		48	27	21

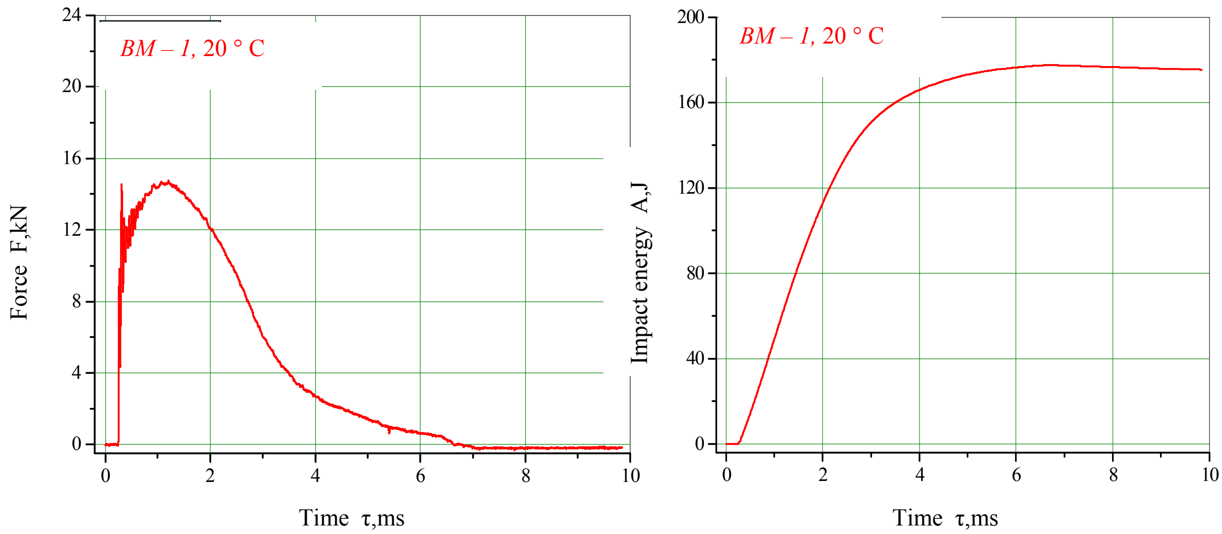


Figure 4. Diagrams obtained by the impact testing of the test tubein BM - 1 tested at 20 ° C [5]

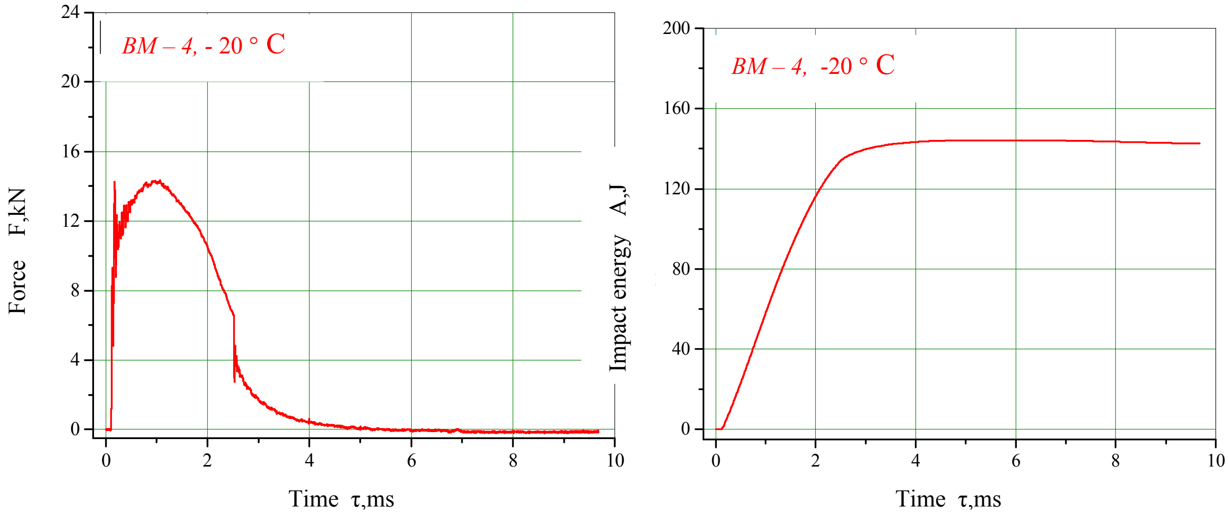


Figure 5. Diagrams obtained by the impact testing of the test tube in BM - 4 tested at–20℃[5]

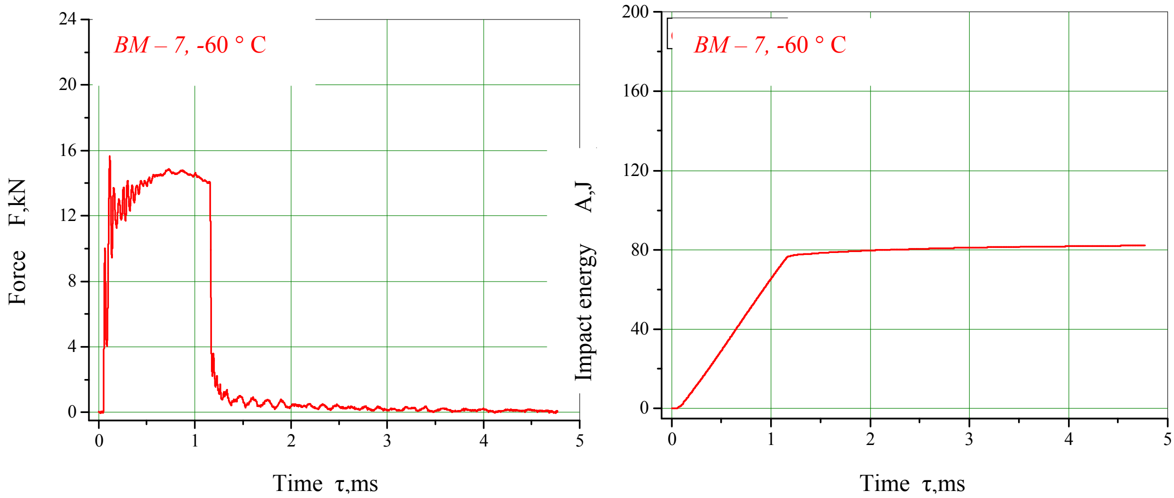


Figure 6. Diagrams obtained by the impact testing of the test tube in BM - 7 tested at–60℃[5]

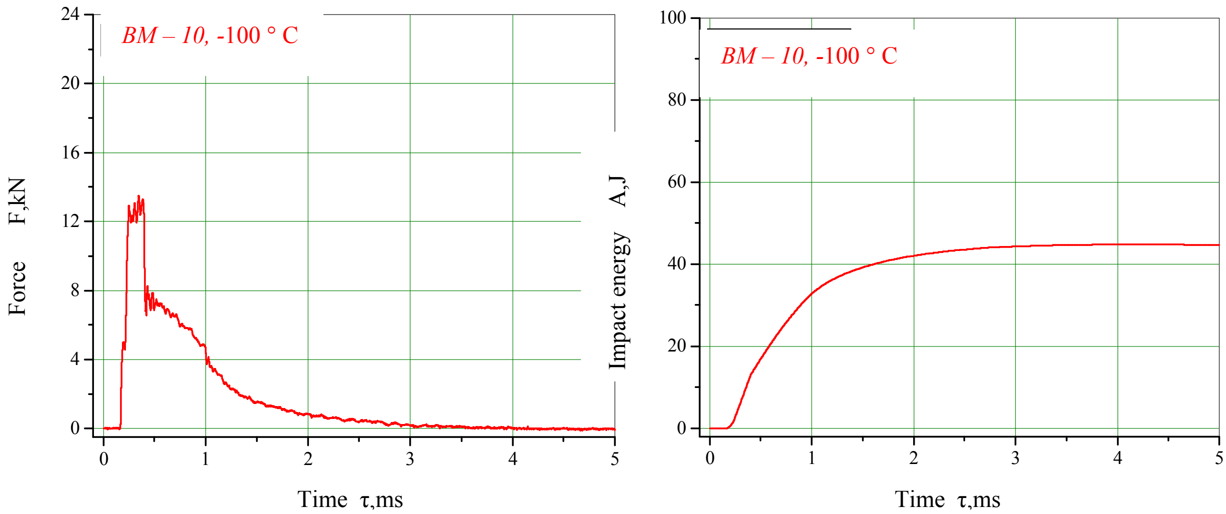


Figure 7. Diagrams obtained by the impact testing of the test tube in BM - 10 tested at–100℃[5]

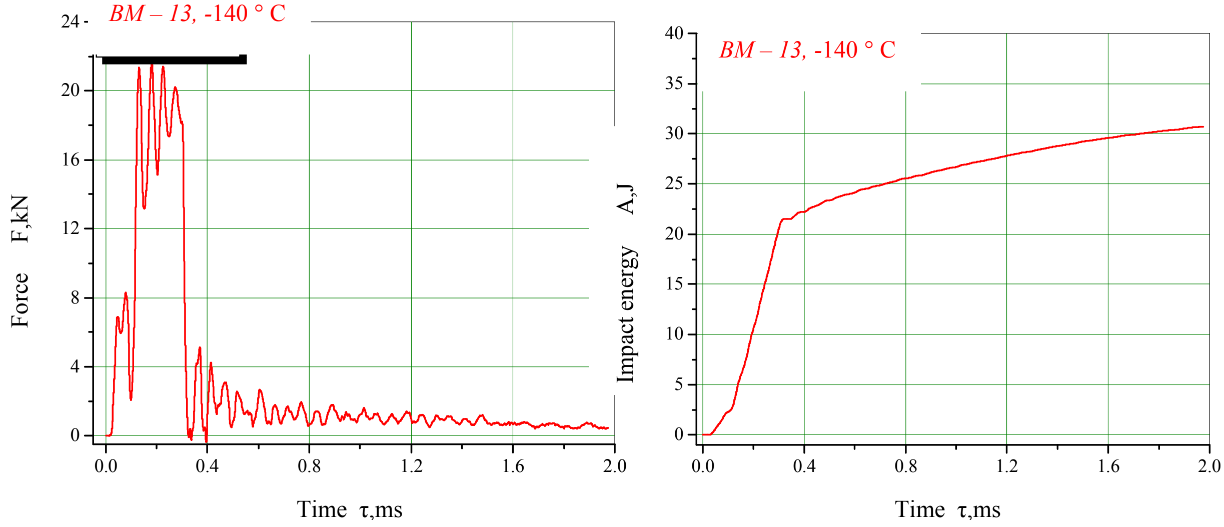


Figure 8. Diagrams obtained by the impact testing of the test tube in BM - 13 tested at–140 ℃[5]

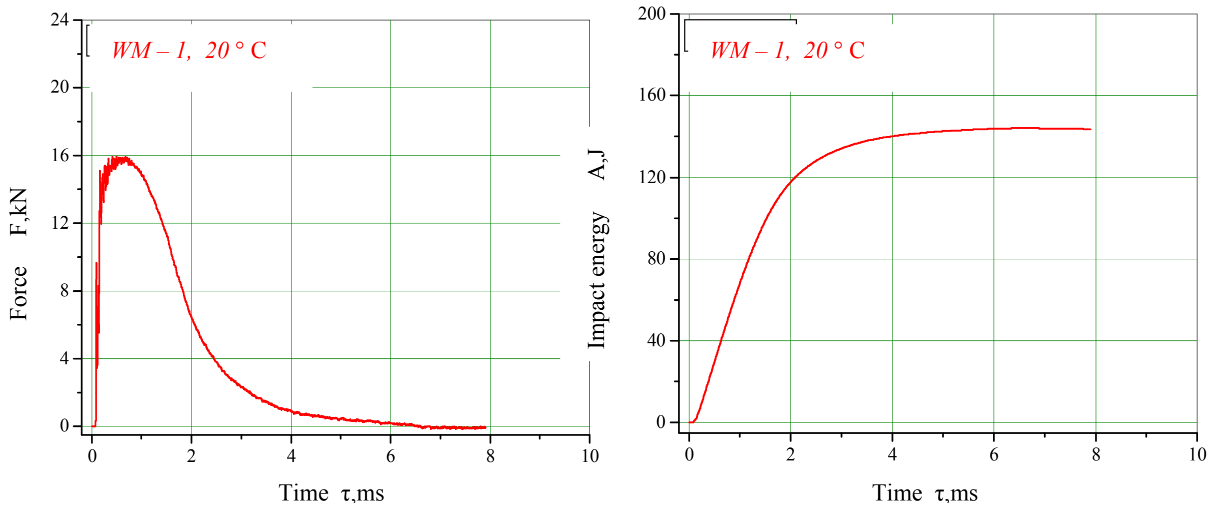


Figure 9. Diagrams obtained by the impact testing of the test tube in WM - 1 tested at 20 ℃[5]

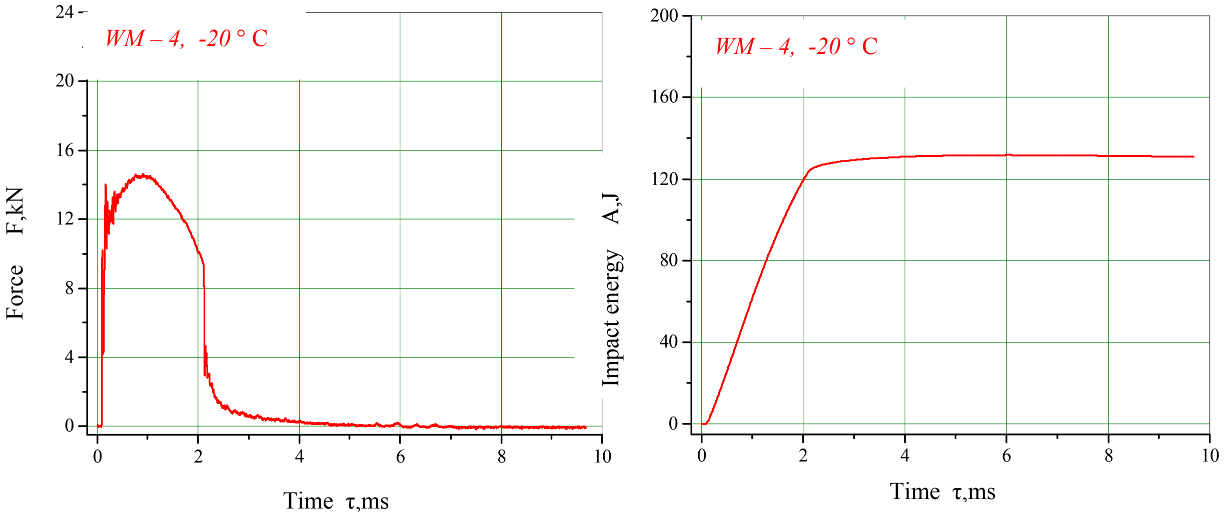


Figure 10. Diagrams obtained by the impact testing of the test tube in WM - 4 tested at -20 ℃[5]

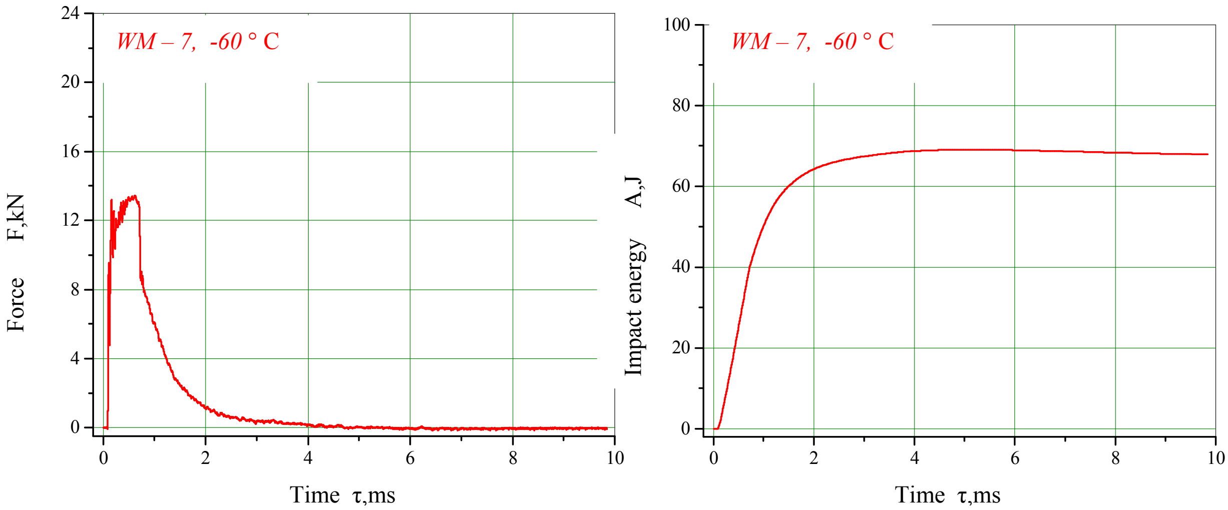


Figure 11. Diagrams obtained by the impact testing of the test tube in WM -7 tested at–60℃ [5]

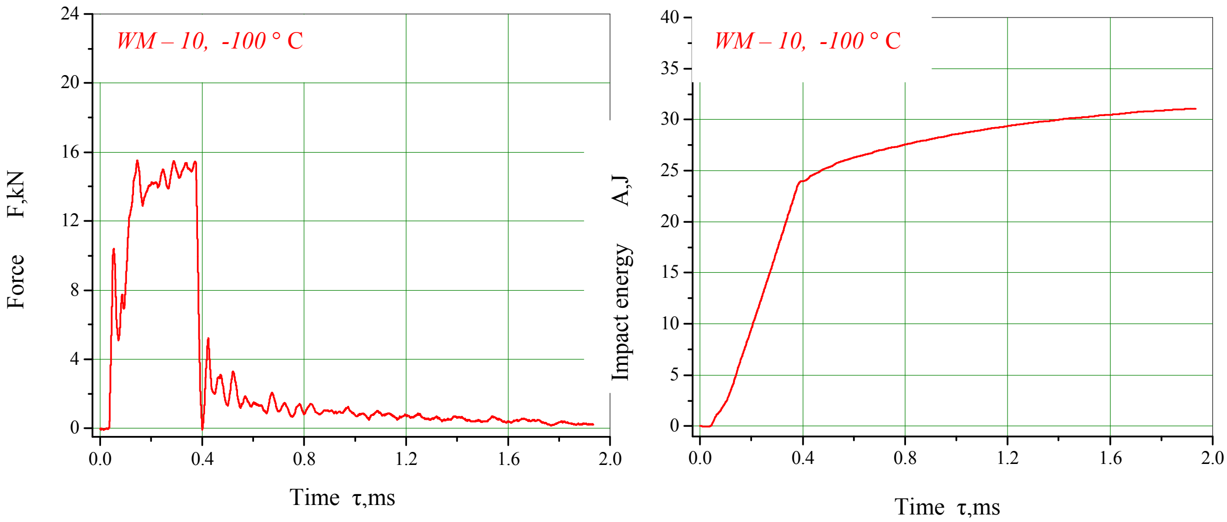


Figure 12:Diagrams obtained by the impact testing of the test tube in WM - 10 tested at –100℃ [5]

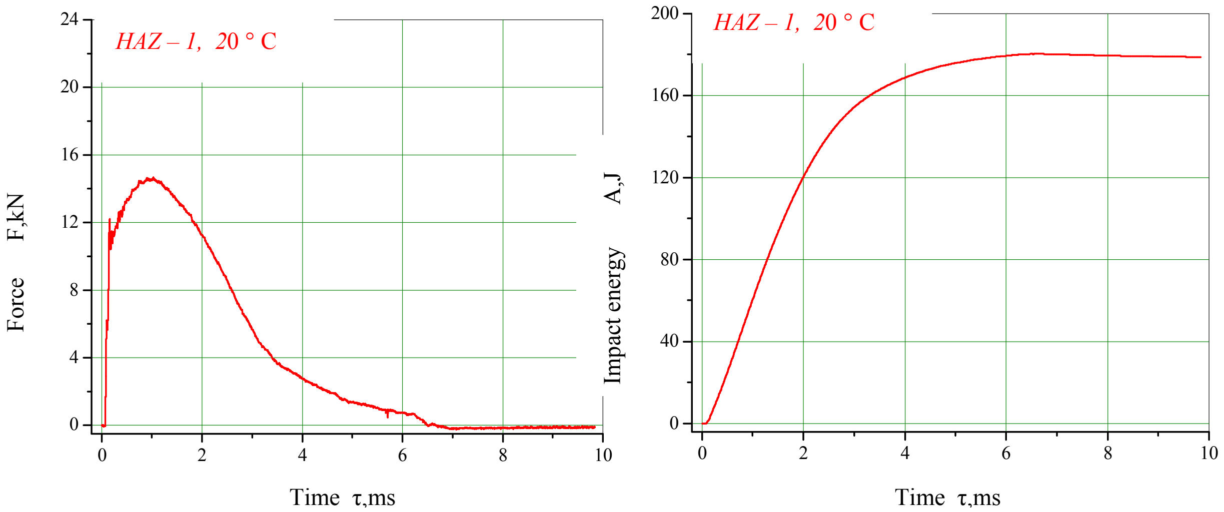


Figure 13. Diagrams obtained by the impact testing of the test tube in HAZ - 1 tested at 20℃[5]

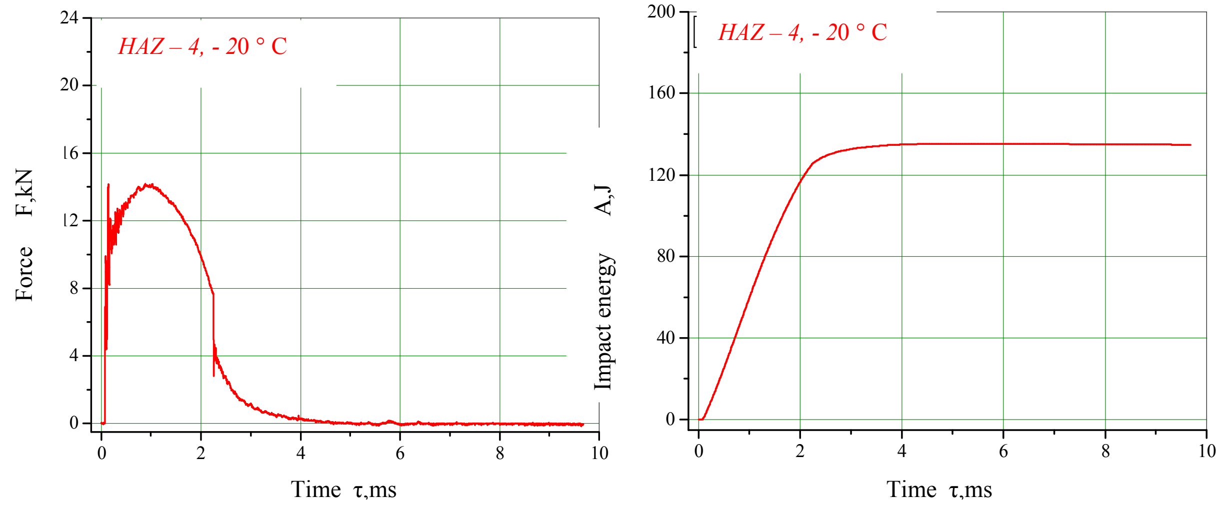


Figure 14. Diagrams obtained by the impact testing of the test tube in HAZ - 4 tested at–20℃[5]

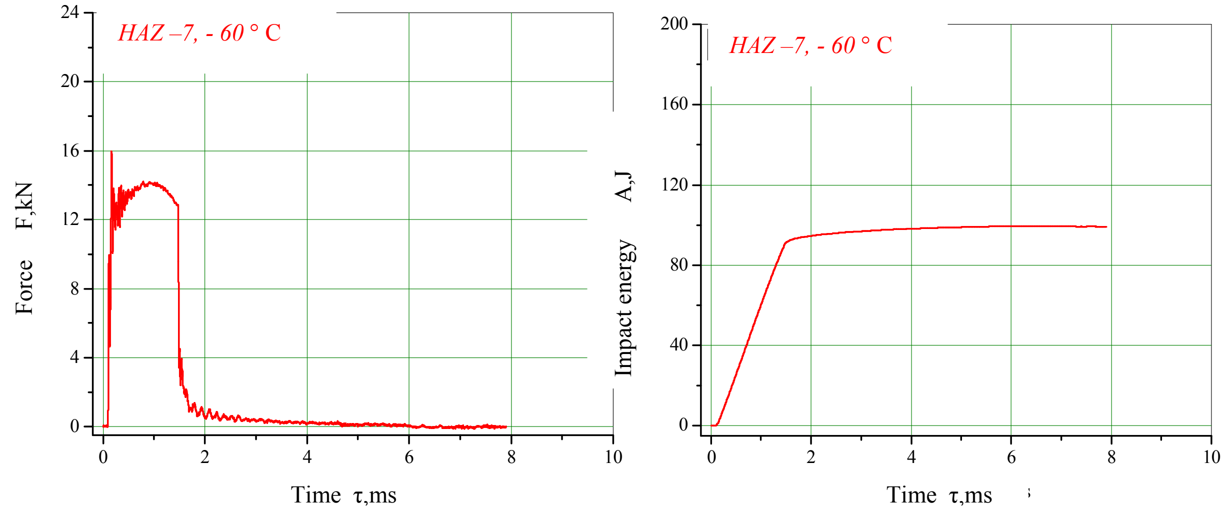


Figure 15. Diagrams obtained by the impact testing of the test tube in HAZ - 7 tested at–60℃ [5]

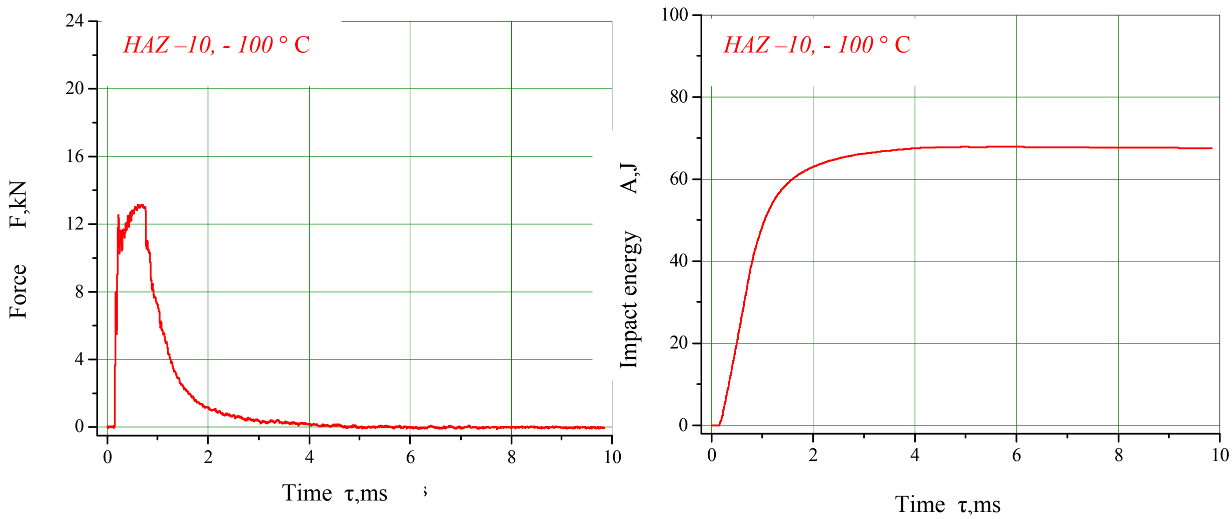


Figure 16. Diagrams obtained by the impact testing of the test tube in HAZ - 10 tested at–100℃ [5]

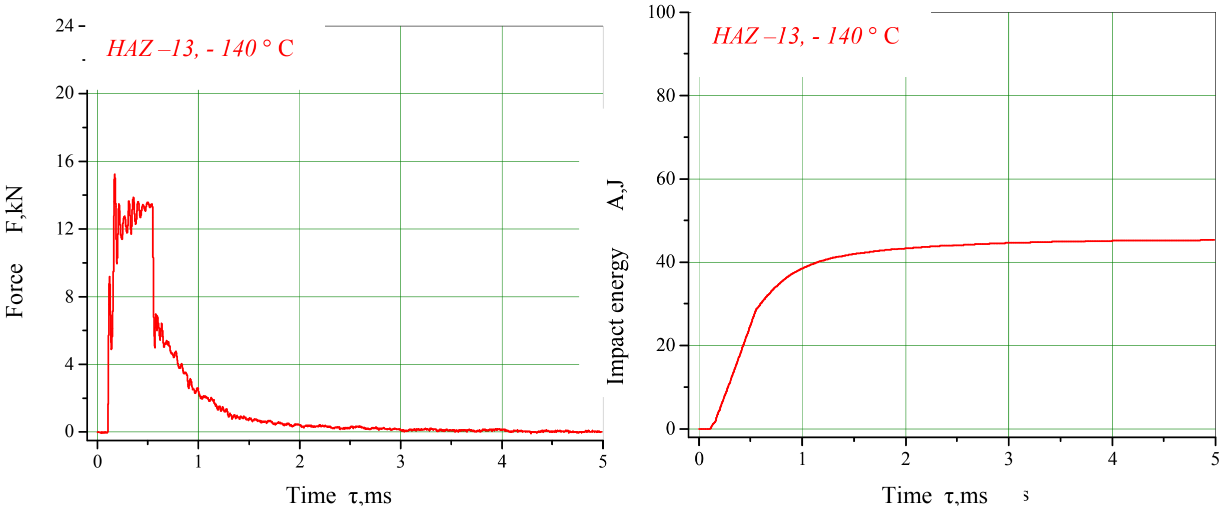


Figure 17. Diagrams obtained by the impact testing of the test tube in HAZ - 13 tested at–140 ℃[5]

The dependence of the total impact energy, A_{uk}, on the test temperature and the location of the V-notch was also shown diagrammatic in Figures 17 and 18 for all three groups of tested tubes [5].

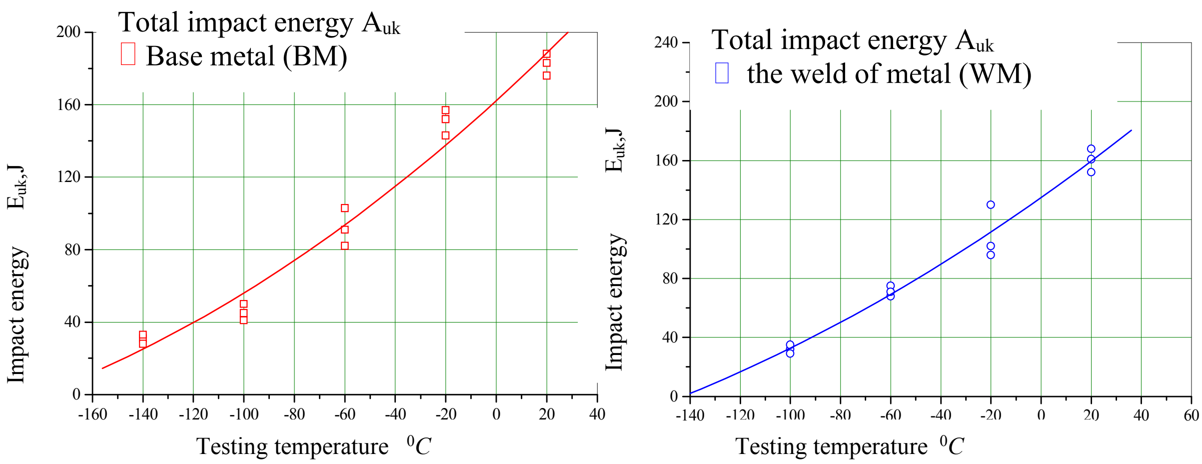


Figure 18. The influence of testing temperature on A_{uk}test tube with a V - notch in BM and in WM[5]

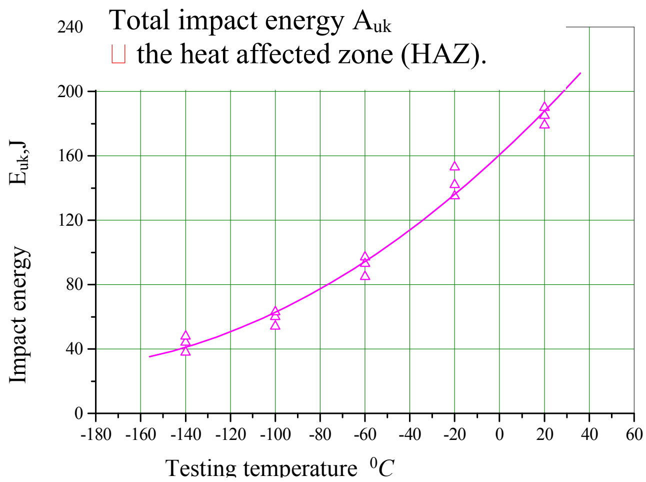


Figure 19. The influence of the testing temperature on A_{uk}test tubes with a V – notch in the HAZ[5]

4. CONCLUSION

Based on the results obtained by the impact tests and the measured values of the total impact energy, A_{uk},itshould be pointed out that the following phenomena are clearly observed:

- The values of the total impact energy, ie. the fracture mechanism and the appearance of the fracture surfaces, depend significantly on the test temperature, since it is closely related to the plastic properties of the test material. The decrease in temperature favours the formation of a brittle state and is especially expressed for a welded joint as a typical heterogeneous structure. The total impact energy, A_{uk}, decreases by decreasing testing temperature successively from room temperature to-140°C in all groups of the test tubes (WM - HAZ - BM).
- The impact on the total impact energy, A_{uk}, also has a place from which the tubes were removed, that is, where the V - notch was placed. This means that the heterogeneity of the welded joint structure, which is accompanied by different mechanical properties of the individual welded joint areas (base metal, weld metal, and heat affected zone), has a decisive influence on the impact properties, i.e. the value of the total impact energy.
- The highest value of total impact energy is presented in test tubes with V - notch in BM, while the lowest value of total impact energy is present in test tubes with V - notch in WM. The total impact energy for the case when the notch is set in the HAZ is close to the values obtained from the BM testing, which confirms the well-defined and selected welding technology [5].

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