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THE EFFECT OF COOLING TIME ON THE VALUES OF TOTAL IMPACT ENERGY COMPONENTS

UTICAJ VREMENA HLAĐENJA NA VREDNOSTI KOMPONENTI UKUPNE ENERGIJE UDARA

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- thermal simulation
- construction
- interval
- cooling
- welded joint

Abstract

The microstructure of the base material changes in the area of welded joints during the welding process, to create heat affected zone (HAZ), which can be divided into several areas, in each of which the microstructure depends on the maximum reached temperature of thermal cycle and cooling rate. The cause of change in the microstructure, and hence the properties, is the thermal cycle of welding. The cooling rate in the steel is expressedas time $\Delta t_{8/5}$, and presents the function of the welding energy, thermal properties of the material, joint geometry and joint elements. The efficient assessment of characteristics and microstructure of HAZ critical areas can be obtained by simulating the HAZ. Set parameters, thermal simulation, heating to specific temperature and programmed cooling provide the microstructure that relates to different areas of the HAZ on samples of the size of Charpy specimens. Thermal simulation of HAZ needs to provide conditions as close as possible to real welding conditions. The main objective of this study was to determine the impact energy (impact toughness), which corresponds to the HAZ microstructure - in the steel NN - 70 obtained in welding with several passages in the place where it is expected weakest toughness.

Ključne reči
- termička simulacija
- konstrukcija
- vek trajanja
- hlađenje
- zavareni spoj

Izvod

Mikrostruktura osnovnog materijala se pri zavarivanju menja u oblasti zavarenog spoja, pri čemu nastaje zona uticaja toplote (ZUT) koja se može podeliti na više područja, gdje u svakom području mikrostruktura zavisi od dostignute maksimalne temperature termičkog ciklusa i od brzine hlađenja. Uzrok za promenu mikrostrukture, a time i osobina je termički ciklus zavarivanja.Brzina hlađenja se kod čelika izražava vremenom $\Delta t_{8/5}$, a funkcija je energije zavarivanja, termičkih osobina materijala, te geometrije spoja i spojenih elemenata. Efikasna ocena osobina i mikrostrukture kritičnih područja ZUT može se dobiti simulacijom ZUT. Zadatim parametrima termičke simulacije, zagrijavanjem do određene temperature i programiranim hlađenjem, se dobija mikrostruktura koja odgovara različitim područjima ZUT na uzorcima veličine Šarpi epruvete. Termičkom simulacijom ZUT treba da se obezbede uslovi što bliži realnim uslovima zavarivanja. Osnovni cilj ovih istraživanja je bio da se odredi energija udara (udarna žilavost) mikrostrukture koja odgovara ZUT - u na čeliku NN - 70 dobijenog kod zavarivanja sa više prolaza na onom mestu gdje se očekuje najslabija žilavost.

INTRODUCTION

In the past 30 years there has been significant progress in the development of low and high alloyed steels and high strength. In order to expand the application fields in recent years, particular attention is paid to factors that provide ductility, toughness, ability to design and weldability. It was necessary to develop steels with the lowest carbon content and lower transition temperature, and with good mechanical properties, in order to fully take advantage of improved welding technology.

The required properties are achieved by carefully selected chemical composition and strictly controlled technological process of making. According to the grain size of these are fine grain steels, according to the minimal additions of alloying elements, usually niobium, vanadium and titanium are microalloyed. The advantage of applying high-strength low-alloy steel (HSLA) in structures, particularly for pressure vessels, is to reduced product weight and to economy production . The base material, low alloy high strength steel, NN - 70 [2], is intended to create pressure equipment, and designed to operate at low temperatures.

It is welded good, generally "over matching" where the weld metal has a higher strength than the base metal.

Knowing the conditions under which the pressure vessel has to work, knowing that welding technology, it can be solidly calculated and assumed remaining life of exploitation. That exploitation will be better and more accurately determine if the material of the welded joint is known. It is that sensitivity of welded steel NN - 70 according to the notch effect, cracks and inclusions makes this research even more appropriate [2].

MATERIAL

The material is supplied in the form of plates 20 mm thick. The chemical composition of the delivered sheets is given in Table 1 and the mechanical properties are given in Table 2.

Tabela 1: Hemijski sastav čelika NN – 70 [2]
Table 1: Chemical composition of steel NN - 70 [2]

Šarža / Batch	% mas. / % 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

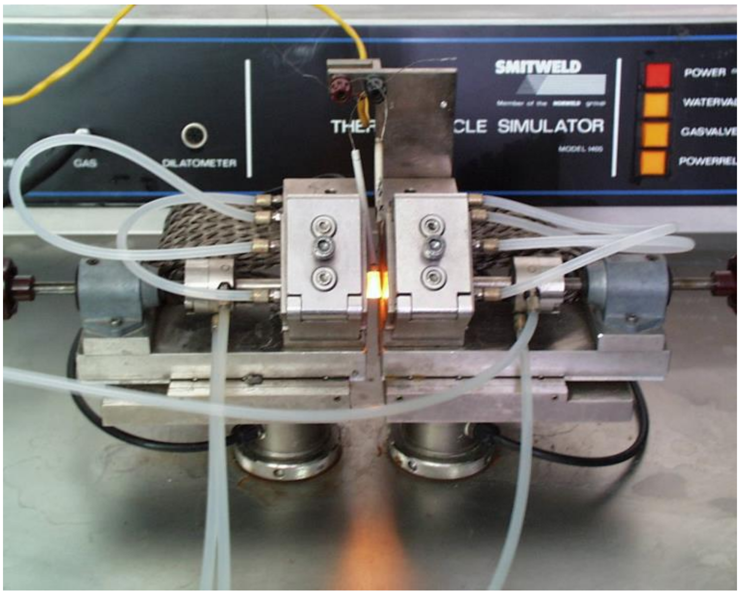
Tabela 2: Mehanička svojstva čelika NN – 70 [2]
Table 2: Mechanical properties of steel NN - 70 [2]

Šarža	Pravac ispitivanja	Napon tečenja $R_{p0,2}$, Mpa	Zatezna čvrstoća, R_m, Mpa	Izduženje A, %, min.
Batch	Direction of testing	Yield strength $R_{p0,2}$, MPa	Tensile strength R_m, MPa	Elongation A, %, min.
211605	L - T	710	770	14

SIMULATION OF HAZ

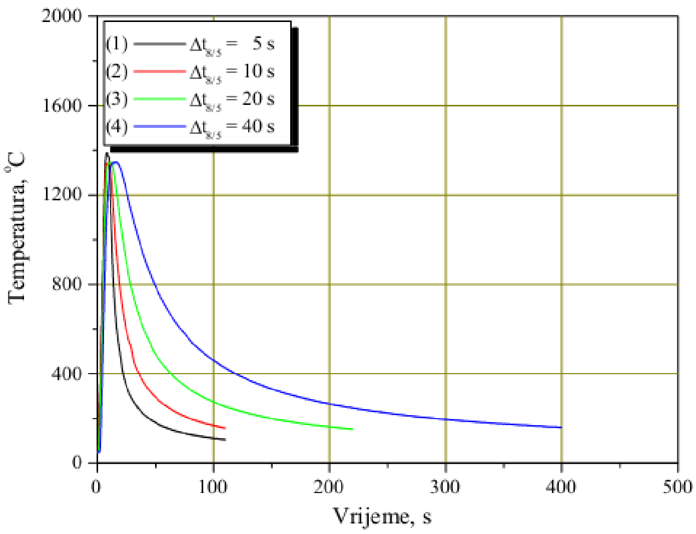
Due to the high speed warming and cooling, welding in general terms, is the imbalance process, so that all structural and phase changes that occur during welding take place under conditions of flow, overheating or hypothermia. How HAZ is a critical spot weld is necessary to determine the actual mechanical properties of all the zones in the heat affected zone. For this purpose, the use of welding simulators, or apparatus that achieves a controlled heating and cooling, similar to welding. In a sample of maximum dimensions 15 x 15 x 60 mm or on its middle part, we get the microstructure width of about 10 mm, which corresponds to the zone of the HAZ, which allows the determination of fundamental mechanical properties [11].

The HAZ simulation process - is done in a modern simulator thermal cycles "SMITWELD" installed at the Faculty of Mechanical Engineering in Maribor, picture 1. For the used tubes of square cross-sectional dimensions 11x11x 55mm simulation were. Before the heating in the middle of the tube Navarre thermocouple Cr - NiCr, which is accompanied by changes in temperature during the simulation [2].



Slika 1. Simulator termičkog ciklusa "SMITWELD"[2]
Picture 1. The simulator of thermal cycles "SMITWELD" [2]

For the heat cycle when heated during welding data on the maximum temperature and cooling time $\Delta t_{8/5}$ are important. The heat cycle simulator is codcuted with electroresistant heated according to set time schedule. Through the tube is passed pre-set current warming, and when the tube is heated to a maximum temperature, the power supply is interrupted. For the cooling of jaws that hold the sample water is used, and for a sample, a stream of inert gas or CO_2. The budget cycle temperature - time is done by using computer software [2].
Nionikral steel - 70 belongs to the group of micro-alloyed high strength steels. These steels, as recommended by the manufacturer, are welded in plan range of 50s ≤ $\Delta t_{8/5}$≤ 400s, from where it expects the least impact on weakening the impact characteristics of the sample with the microstructure of HAZ -obtained by simulation. Simulation of thermal conditions in welding has made the application of thermal cycles on samples of the base material as a single pass with the impact of the application of one cycle to a temperature of approximately 1350 °C [2].
Speed warming simulations was about 200°C/s . The heating temperature is kept at a maximum (T0) for 5s (to heat the entire cross section of the sample), and the rate of cooling or $\Delta t_{8/5}$ is changed from 5s for the group with 1,10 to 2,20 with the group for group 3 and 40s for the group 4. The schematic diagram of the fourth single pass HAZ thermal cycles is shown in picture 2 [2].

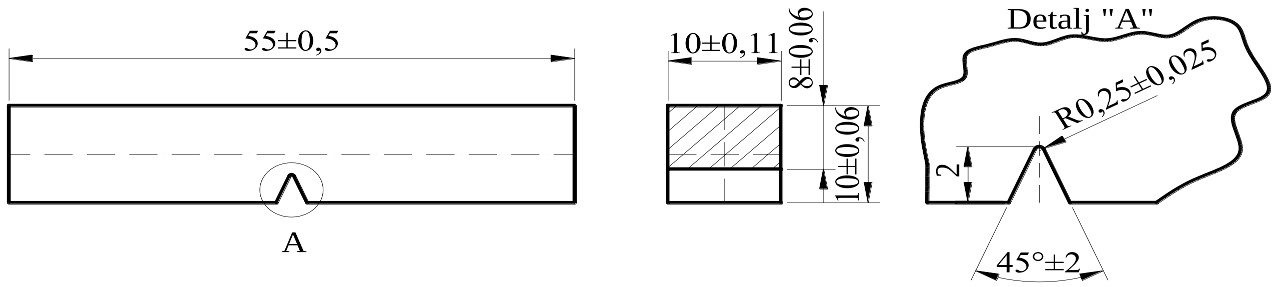


Slika 2. Termički ciklus jednoprolaznog ZUT [2]
Picture 2. Thermal cycle of single pass HAZ [2]

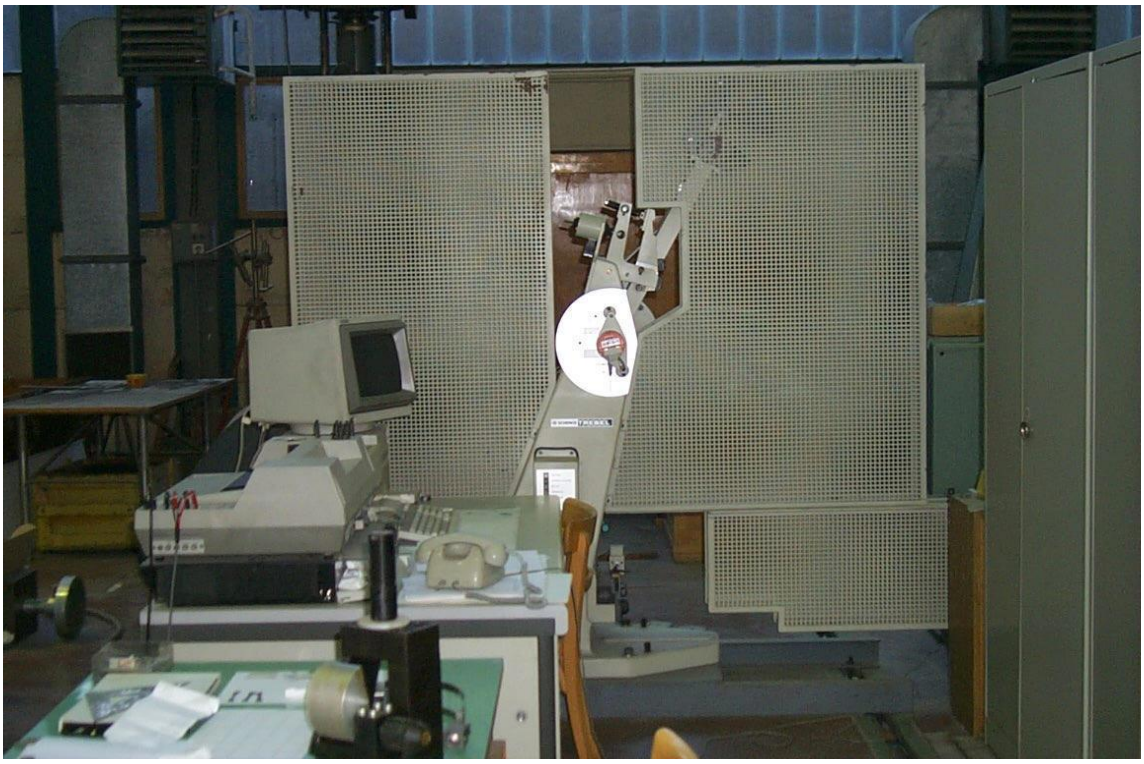
Testing of impact energy on Charpy on simulated samples

The impact test on samples are performed in order to determine the impact energy (impact toughness). 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, picture 3. The testing has been perfeormed on modern instrumented Charpy pendulum SCHENCK TREBELL 150/300J, picture 4.

The main objective of this study was to determine the impact energy (impact toughness), which corresponds to the HAZ microstructure - in the steel NN - 70 obtained in welding with several passages in the place where it is expected weakest toughness. This place is quite close to the connection line, where the steel during was at least once heated to the melting point [2].



Slika 3. Epruveta za određivanje energije udara [12]
Picture 3. The test tube for the detremination of impact energy [12]



Slika 4. Instrumentirano Šarpijevo klatno [2]
Picture 4. Instrumented Charpy pendulum [2]

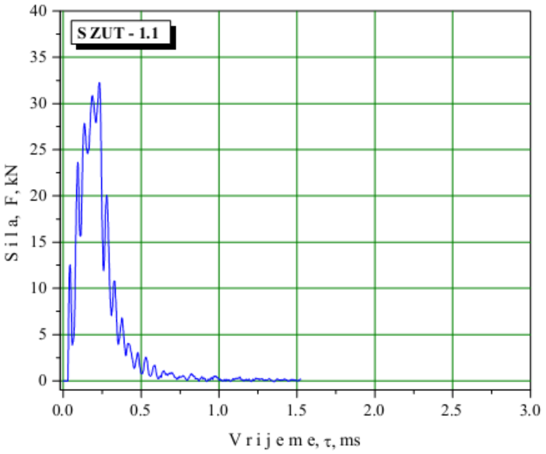
The results of impact tests are given in Table 3. The tubes were examined at room temperature, but at different rates of cooling $\Delta t_{8/5}$.

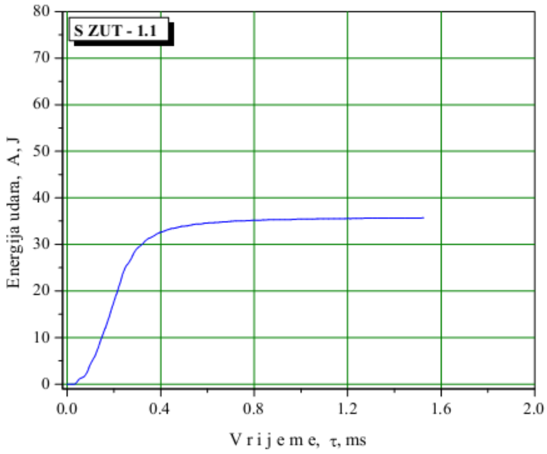
Tabela 3: Rezultati udarnih ispitivanja epruveta jednoprolazno simuliranim ZUT [2]
Table 3: The results of impact tests of test tubes in single pass simulated HAZ [2]

Oznaka Uzorka	**Temperatura ispitivanja, °C**	**Vrijeme hlađenja $\Delta t_{8/5}$, s**	**Ukupna energija udara, A_{uk}, J**	**Energija stvaranja prsline, A_I, J**	**Energija širenja prsline, A_P ,J**
Sample label	**Test temperature, °C**	**Time of cooling, $\Delta t_{8/5}$, s**	**Total energy of impact, A_{uk}, J**	**Energy of crack creation, A_I, J**	**Energy of crack extension, A_P ,J**
S ZUT - 1.1	20	5	33	24	9
S ZUT - 1.2			31	23	8
S ZUT - 1.3			30	23	7
S ZUT - 2.1	20	10	36	22	14
S ZUT - 2.2			35	21	14
S ZUT - 2.3			38	22	16
S ZUT - 3.1	20	20	50	22	28
S ZUT - 3.2			48	22	26
S ZUT - 3.3			51	23	28
S ZUT - 4.1	20	40	63	24	39
S ZUT - 4.2			67	25	42
S ZUT - 4.3			65	24	41

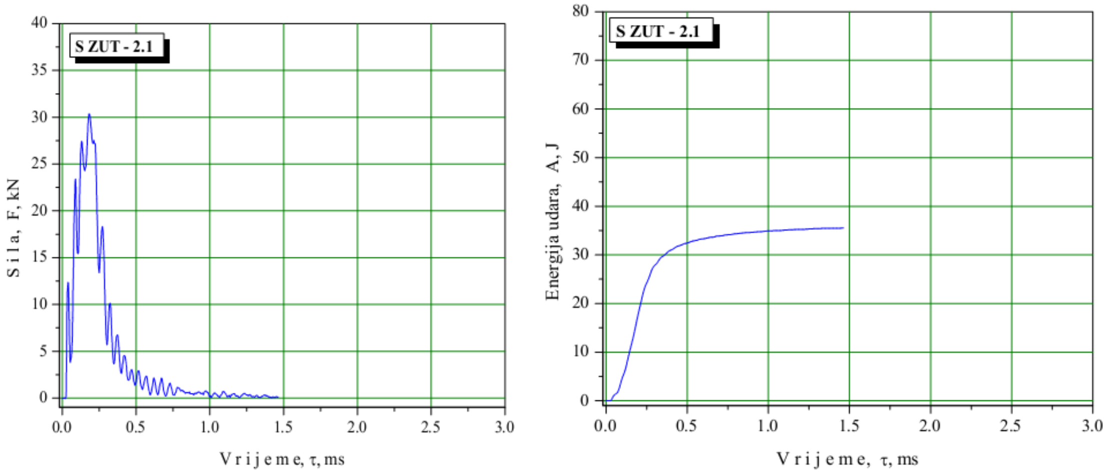
How the testing is done on instrumented Charpy pendulum with an oscilloscope it was possible to evaluate how impact (impulse) activity affects the impact characteristics, and evaluation of the plasticity of the test material. The study obtained depending on the force - time and energy-time. Characteristic diagrams for specimens at room temperature, but at different times cooling $\Delta t_{8/5}$ shown in the pictures 5 to 8.

The diagrams obtained by testing on instrumented pendulum with an oscilloscope enabled the assessment of the influence of cooling time on the total impact energy and its components, the energy for crack A_I and energy of crack A_P [2].

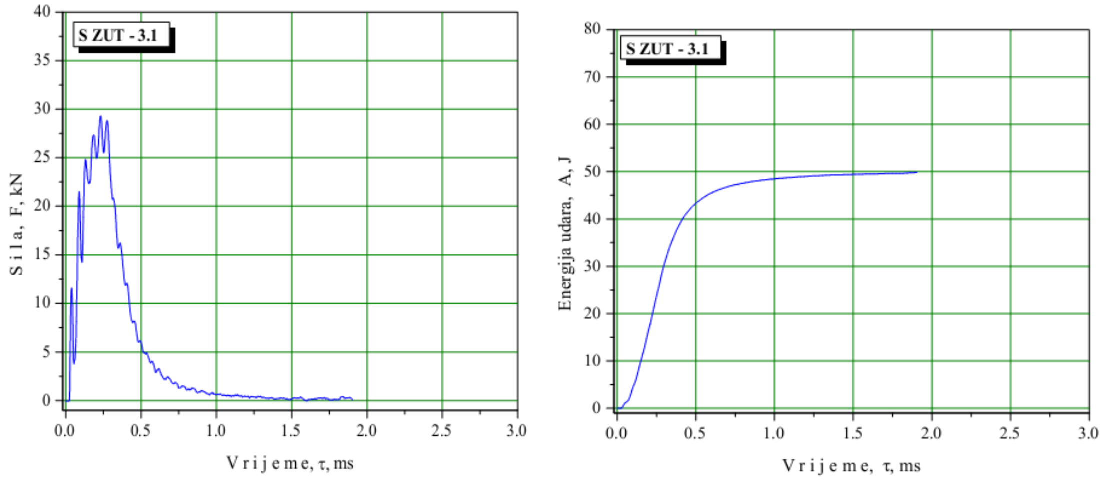




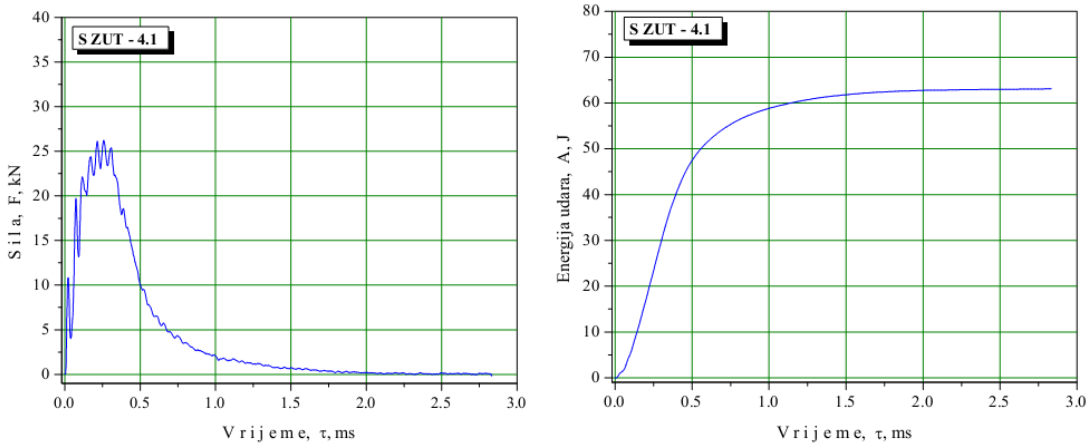
Slika 5 Dijagrami dobijeni udarnim ispitivanjem epruvete S ZUT – 1.1 [2]
Picture 5 Diagrams obtained by impact testing of test tube S HAZ – 1.1 [2]



Slika 6 Dijagrami dobijeni udarnim ispitivanjem epruvete S ZUT – 2.1 [2]
Picture 6 Diagrams obtained by impact testing of test tube S HAZ – 2.1 [2]

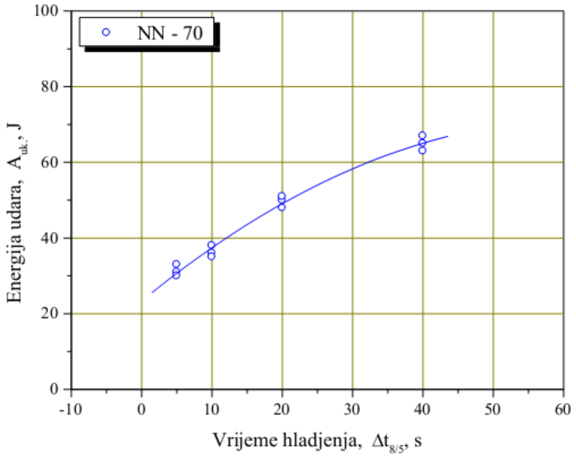


Slika 7 Dijagrami dobijeni udarnim ispitivanjem epruvete S ZUT – 3.1 [2]
Picture 7 Diagrams obtained by impact testing of test tube S HAZ – 3.1 [2]



Slika 8 Dijagrami dobijeni udarnim ispitivanjem epruvete S ZUT – 4.1 [2]
Picture 8 Diagrams obtained by impact testing of test tube S HAZ – 4.1 [2]

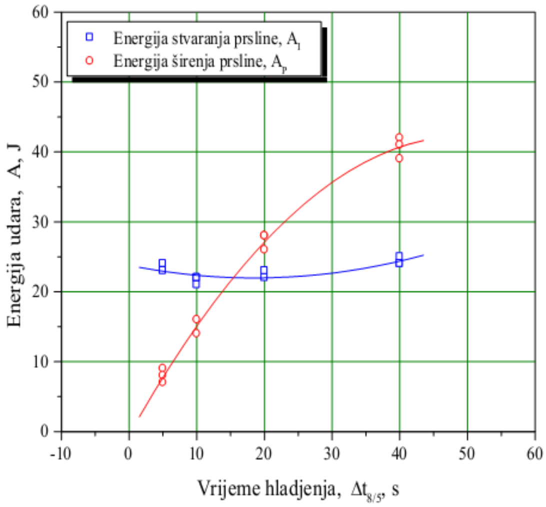
Picture 9 shows the change in total energy shock HAZ single pass - and the cooling rate. We see that the heating temperature 1350 °C the best overall value of impact energy have samples in which the longest cooling time (40s). The total impact energy decreases to the cooling time of 5s [2].



Slika 9 Zavisnost A_{uk} – vrijeme hlađenja [2]

Picture 9 Dependence A_{uk} – cooling time [2]

The effect of cooling time on the value of the components of the total impact energy, the energy for crack, A_I, and the energy of crack A_P, is shown in Picture 10.



Slika 10 Zavisnost A_I i A_P – vrijeme hlađenja [2]
Picture 10 Dependence of A_I and A_P – cooling time [2]

CONCLUSIONS

When welding alloyed steels such as the NN - 70 most important is to choose the correct welding thermal cycle which will not have a negative effect on the properties of the steel. At the weld thermal cycle affects a number of factors, Contained energy, Thickness of the material, The temperature of the base material (preheat temperature), Weldment shape and dimensions and number of layers.

We see that with increasing cooling time $\Delta t_{8/5}$, increases the energy of crack extension, meaning the growing component of ductile fracture. This is very important to define the optimal welding parameters, i.e. welding parameters which should provide the best characteristics of the HAZ zone - as the most critical part of the welded joint [2]. Thermal simulation of heating to a certain temperature and programmed cooling yielded cooling time between 800°C and 500°C, $\Delta t_{8/5}$ of 40s, based on these characteristics optimal welding parameters are defined [2].

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