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DEVELOPMENT OF AN ANALOGICAL MODEL FOR STRAIN MONITORING OF WELDED JOINT REGIONS DURING UNIAXIAL TENSILE TESTING

RAZVIJANJE ANALOGNOG MODELA PRAĆENJA POMERANJA ZONA ZAVARENOG SPOJA TOKOM ISPITIVANJA JEDNOOSNIM ZATEZANJEM

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Abstract

The idea behind the idea of developing this method was to introduce reference points at important locations, such as the fusion line and heat-affected zones, the displacement of which would be monitored during the uniaxial testing, and then measured at key moments. The uniaxial tensile test process was recorded with a high-resolution camera so that changes could be observed during the test. The reason why this approach was chosen was that the crucial zones could be adequately marked and thus allows the allocation of the appropriate frame in order to monitor the strain of each welded joint zone individually.

Rezime

Ideja iza pokušaja razvijanja ove metode se sastoji u tome da se na bitne lokacije kao što su linija stapanja i zone uticaja toplote unesu reperne tačke čije bi se pomeranje tokom ispitivanja pratilo i merilo u ključnim momentima. Proces ispitivanja jedno-osnim zatezanjem je sniman kamerom u visokoj rezoluciji kako bi mogle da se uoče promene tokom ispitivanja. Ovakav pristup je odabran kako bi mogle krucijalne zone da se adekvatno obeleže i na taj način omogućiti izdvajanja odgovarajućeg frejma kako bi se pomeranje svake zone zavrenog spoja ponaosob.

1. Introduction

It is common practice to consider welded joints as a whole, in the case of new joints, and repaired joints alike [1-4]. In reality, a welded joint has at least six regions with different mechanical properties, which is of particular significance in the cases where defects are present which could initiate a crack in the joint [5-8]. It is best to observe displacements and strains for each individual welded joint region, including two areas in the parent material and four area on either side of the heat affected zone – two between the HAZ and the parent material and two at the fusion line, between WM and HAZ. Individual behavior of all of these regions will be shown in this paper. For the purpose of experiments which will be shown here, the upper and lower sides of the weld will be monitored, in accordance with relevant standards, as shown in figure 1 [9].

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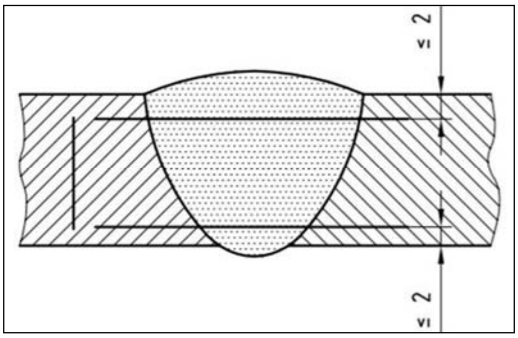

Figure 1: Top and bottom lines of a welded joint, as defined by standard SRPS EN ISO 9015 [9]

Slika 1: Gornja i donja linija zavarenog spoja, kako je definisano standardom SRPS EN ISO 9015 [9]

2. Experiment

Plates were made of carbon steel S275JR [10], welded using filler material VAC 60 [11], with M21 shield gas (18% CO_2 + 82% Ar). After welding, the joint was tested using non-destructive test methods, and no defects were detected. Specimens were tkan out of the plates, according to the cutting plan provided by standard SRPS EN ISO 15614 [12].

Reference points were placed on specimens 5.1 and 5.2, and these specimens were recorded using an HD camera. Displacement recording was performed synchronously with tensile testing, in order to ensure that the start and end time during testing was the same. All specimens were divided into two zones: Top zone (which represents the weld face) and Bottom zone (which corresponds to the root side). Each zone had 6 measuring points: two in the PM, two in the transition area between PM and heat affected zone, and two at the fusion line. Their displacements can provide insight into the general behaviour of each individual welded joint region.

Images which showed the measured displacement of reference points were directly correlated to stress-strain (figures 2 and 3) and time – stress – strain diagrams. Point 0 represents the initial position of the specimen after 2 seconds of tension, i.e. the moment at which equilibrium state is achieved. Time moment for point 2 (6^{th} second) was selected within the elastic region, immediately before plasticity would start to occur. Specimen geometry at initial moment 0 and final point 11 are shown in figures 4 – 7. All points after this one are located in the plastic region of the diagrams. An example of measuring distances is given in figures 4 and 5, whereas graphs with displacement values are shown in figures 8 – 11.

***Table 1.** Moments during which stresses and strains were measured/determined, specimen 5.1*

***Tabela 1.** Trenuci tokom kojih su mereni/određeni naponi i deformacije, uzorak 5.1*

Point	Stress [MPa]	Strain [%]	Time [s]
0	/	/	2
1	275	1	12
2	341	2	17
3	401	4	26
4	431	6	35
5	451	8	46
6	461	10	54
7	466	12	62
8	467	13	68
9	466	14	73
10	457	16	82
11	409	20	100

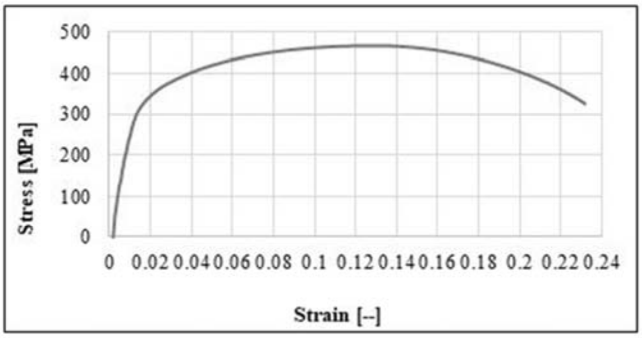

Figure 2. *Stress-strain diagram, specimen 5.1*

Slika 2. *Dijagram napon-deformacija, uzorak 5.1*

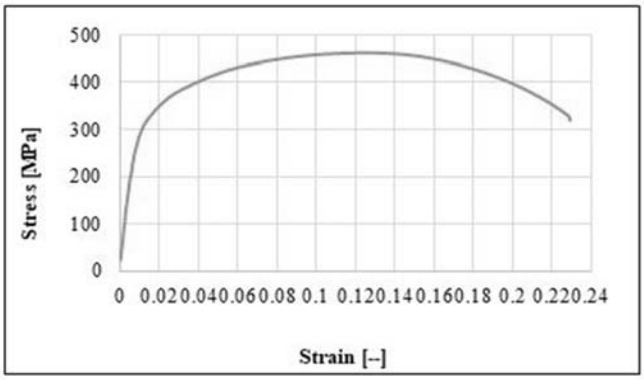

Figure 3. *Stress-strain diagram, specimen 5.2*

Slika 3. *Dijagram napon-deformacija, uzorak 5.2*

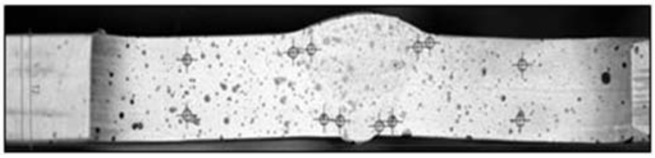

Figure 4. *Specimen 5.1: time point 0 (2s)*

Slika 4. *Uzorak 5.1: vremenska tačka 0 (2s)*

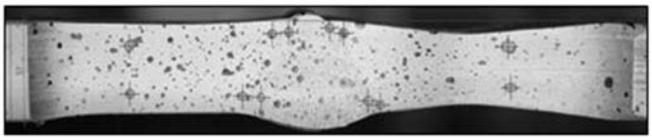

Figure 5. *Specimen 5.1: time point 11 (100s)*

Slika 5. *Uzorak 5.1: vremenska tačka 11 (100s)*

Table 2. *Moments during which stresses and strains were measured/determined, specimen 5.2*

Tabela 2. *Trenuci tokom kojih su mereni/određeni naponi i deformacije, uzorak 5.2*

Points	Stress [MPa]	Strain [%]	Time [s]
0	/	/	2
1	250	0.7	7
2	344	2	12
3	398	4	22
4	429	6	32
5	447	8	41
6	456	10	50
7	461	12	60
8	462	13	63
9	460	14	69
10	451	16	78
11	395	20	99

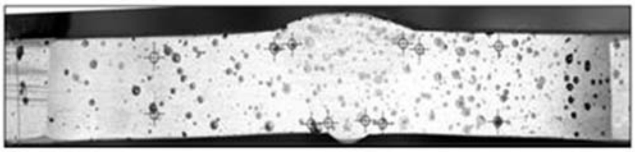

Figure 6. *Specimen 5.2: time point 0 (2s)*

Slika 6. *Uzorak 5.2: vremenska tačka 0 (2s)*

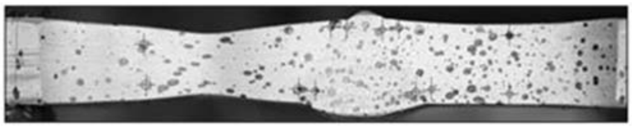

Figure 7. *Specimen 5.2: time point 11 (99s)*

Slika 7. *Uzorak 5.2: vremenska tačka 11 (99s)*

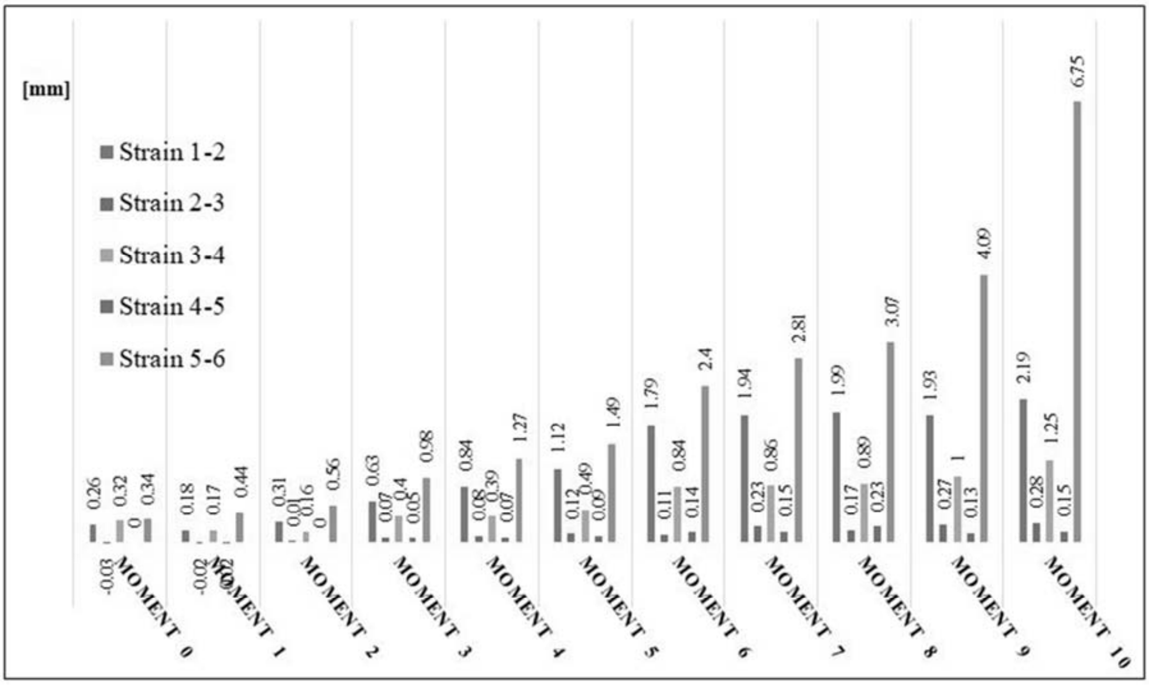

Figure 8. *Weld face point displacements specimen 5.1*

Slika 8. *Pomeranja tačke sa lica zavara za uzorak 5.1*

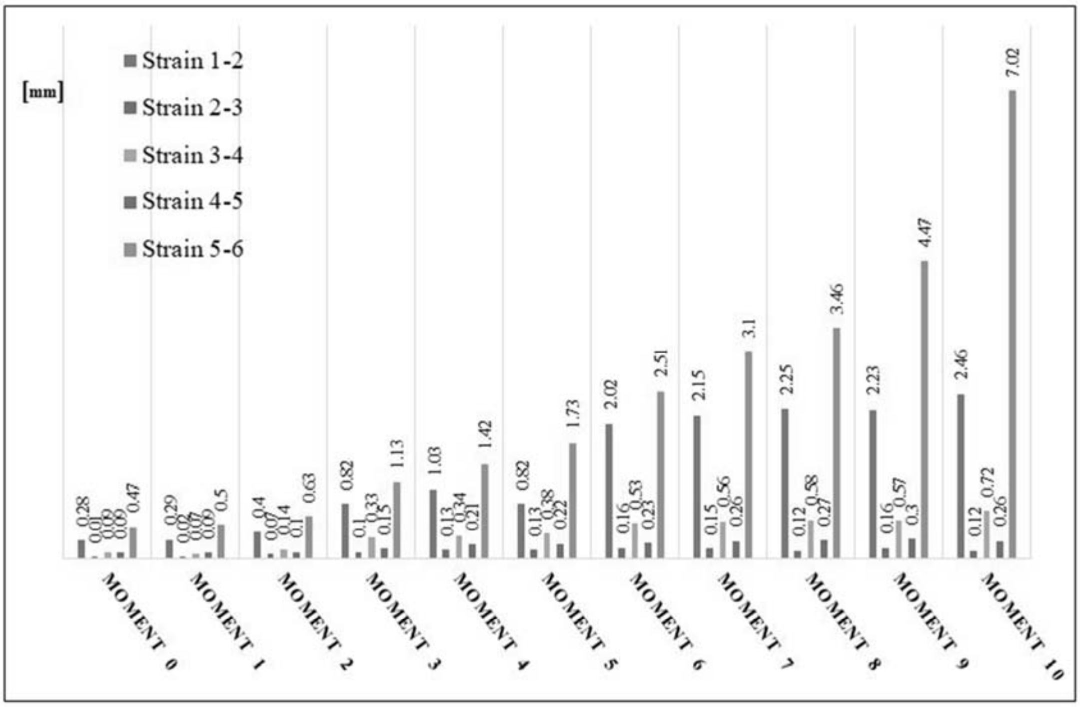

Figure 9. *Weld root point displacements specimen 5-1*

Slika 9. *Pomeranja tačke u korenu zavara za uzorak 5.1*

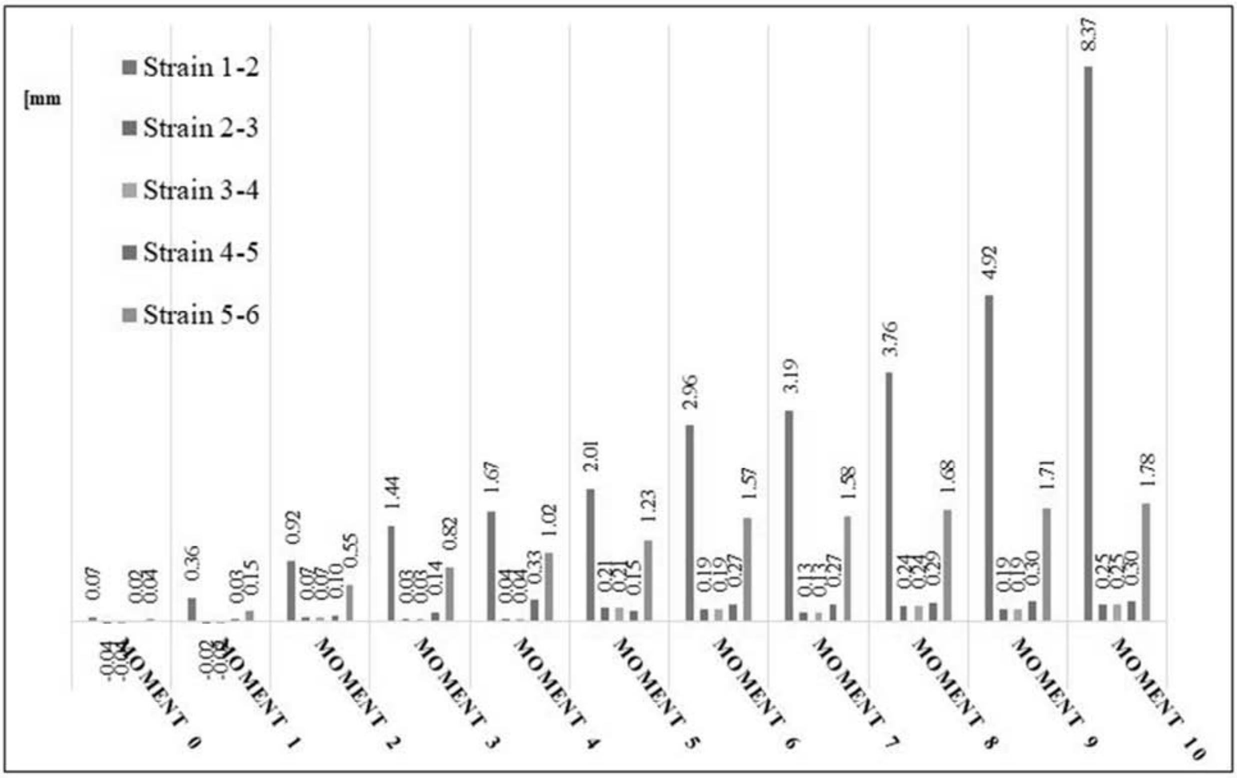

Figure 11. *Root face point displacements, specimen 5-2*

Slika 11. *Pomeranja tačke u korenu zavara za uzorak 5-2*

3. Discussion and conclusions

Strain at failure for both specimens (5.1 and 5.2) was around 23%, at force magnitude of 77 kN (corresponding to a stress of around 300 MPa), and both specimens entered the plastic strain stage at this point, whereas failure occurred in the parent material for both specimens. Largest displacement was measured in point 5-6 in the case of specimen 5.1, in the weld root area. This displacement was 7.02 mm, whereas the highest displacement in the case of specimen 5.2 was measured in the weld face area – 8.37 mm in points 1-2. Smallest displacement values were recorded in the heat affected zone, weld face side, in points 4-5 and it had a magnitude of 0.15 mm. For the second specimen, displacement was lowest in the heat affected zone between points 2-3. Hence, lowest displacement (and strain) occurred in the heat affected zones for both specimens, whereas the highest values were in the parent material, on the side where the tensile force was applied. This was expected due to the considerable difference in mechanical properties between the HAZ and the PM. Due to a noticeably lower yield stress and tensile strength in the parent material, it started to deform much earlier compared to the HAZ. These results have, among other things, confirmed that the welding technology was properly selected, since the failure did not occur in the weld or the

3. Diskusija i zaključci

Deformacija pri lomu za oba uzorka (5.1 i 5.2) iznosila je oko 23%, pri sili od 77 kN (što odgovara naponu od oko 300 MPa), i oba uzorka su u ovom trenutku ušla u fazu plastične deformacije, dok je do loma došlo u osnovnom materijalu kod oba uzorka. ajveći pomak je izmeren u tački 5-6 u slučaju uzorka 5.1, u oblasti korena šava. vaj pomak je iznosio 7,02 mm, dok je najveći pomak u slučaju uzorka 5,2 izmjeren u području lica šava – 8,37 mm u tačkama 1-2. ajmanje vrednosti pomaka zabeležene su u zoni uticaja toplote, na strani lica šava, u tačkama 4-5 i imale su veličinu od 0,15 mm. Za drugi uzorak, pomeranje je bilo najmanje u zoni uticaja toplote između tačaka 2-3. Dakle, najmanji pomeraj (i deformacija) nastao je u zonama uticaja toplotote za oba uzorka, dok su najveće vrednosti bile u osnovnom materijalu, na strani gde je primenjena sila zatezanja. vo je bilo očekivano zbog značajne razlike u mehaničkim svojstvima između zone uticaja toplote i osnovnog materijala. bog primetno nižeg napona tečenja i zatezne čvrstoće osnovnog materijala, on je počeo da se deformiše mnogo ranije u odnosu na zonu uticaja toplote. vi rezultati su, između ostalog, potvrdili da je tehnologija zavarivanja bila pravilno odabrana, jer nije došlo do loma u metalu šava ili zoni uticaja toplote, što je problem koji se često sreće u praksi. Rezultati prikazani u ovom radu heat affected zone, which is a problem that is commonly encountered in practice. Results shown in this paper indicate that each individual welded joint region had shown different tensile behaviour, in terms of strain and displacements. This is, for example, reflected in the 20% difference in displacement values for HAZ between the two specimens, even though they were taken from the same welded plate. Hence, this methodology confirmed the initial assumption that the welded joint should not be viewed as whole, but rather as a combination of individual regions. This approach could be further improved by dividing the heat affected zone into subregions with different microstructures. The main disadvantage of this method is that is has lower accuracy compared to other conventional measuring method, and therefore it is recommended to be used in combination with these methods (such as digital image correlation) in order to obtain better results.

pokazuju da je svaka pojedinačna oblast zavarenog spoja pokazala različito zatezno ponašanje, u smislu deformacije i pomaka. vo se, na primer, ogleda u razlici od 20% u vrednostima pomaka u zoni uticaja toplote između dva uzorka, iako su uzeti iz iste zavarene ploče. akle, ova metodologija je potvrdila početnu pretpostavku da zavareni spoj ne treba posmatrati kao celinu, već kao kombinaciju pojedinačnih regiona. vaj pristup bi se mogao dalje poboljšati podelom zone uticaja toplote na podoblast sa različitim mikrostrukturama. Glavni nedostatak ove metode je što ima manju tačnost u odnosu na druge konvencionalne metode merenja, pa se stoga preporučuje da se koristi u kombinaciji sa ovim metodama (kao što je korelacija digitalne slike) kako bi se dobili bolji rezultati.

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