Emhamed Omar Argoub [1]
Aleksandar Sedmak [1]
Mohamed Ali Essamei [2]

PROCENA INTEGRITETA ZAVARENE KONSTRUKCIJE OBLIKA PLOČE SA PRSLINOM
STRUCTURAL INTEGRITY ASSESSMENT OF WELDED PLATE WITH A CRACK

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Adresa autora / Author's address:
1) Mašinski fakultet Univerziteta u Beogradu / Faculty of Mechanical Engineering, University of Belgrade
2) R & D Centre, Tripolis, Lybia

Ključne reči
- zavareni spoj
- overmečing
- metoda konačnih elemenata
- zavareni spoj
- porvšinska prslina
- integritet konstrukcija

Izvod

Analiziran je uticaj geometrije (položaj prsline, dimenzije i oblik zavarenog spoja, dimenzija uzorka) i heterogenosti materijala na ponašanje i ocenu integriteta zavarenih ploča. Eksperimentalnom analizom obuhvaćene su ploče sa malom i velikom površinskom prslinom, koja se nalaze na različitim mestima u zavarenom spoju. Za rešavanje ovog problema primenjene su analize trodimenzionalnim konačnim elementima, a dobijeni rezultati su upoređeni sa eksperimentom, čime je omogućen detaljniji uvid u ponašanje zavarene ploče kao i mogućnost procene integriteta.

UVOD

Opšte je poznato da se u različitim oblastima zavarenog spoja javljaju različiti nivoi čvrstoće, na pr. “mismečing” ponašanje. Ova nepodudarnost u čvrstoći, tj. *mismečing*, često se javlja kao *overmečing* zavarenog spoja (tj. metal šava je veće čvrstoće od osnovnog materijala) u slučaju zavarenih spojeva čelika srednje čvrstoće. Tada, pojava grešaka ili kratkih prslina nije zanemarljiva, pa je ocena integriteta konstrukcije od velikog značaja za siguran rad. Osim toga, prisustvo mikro- i makro-heterogenosti u zavarenim spojevima, koje nastaje usled različitih mikrostruktura i mehaničkih osobina osnovnog materijala, metala šava i zone uticaja toplote (ZUT), dovodi do neravnomerne raspodele plastičnih deformacija u realnim konstrukcijama. Kombinovani uticaji geometrije i heterogenosti materijala zavarenog spoja sa prslinom, uključujući opšte tečenje (GSY), tečenje neto preseka (NSY) i tečenje ligamenta (LY), dodatno otežavaju procenu integriteta konstrukcije. Osnovni cilj rada je analiza ovih uticaja i uspostavljenog stanja deformacija. .

Keywords
- welded joint
- overmatching
- finite element method
- weldment
- surface crack
- structural integrity

Abstract

This paper analyzes the geometry (crack position, welded joint size and shape, size of specimen) and material heterogeneity effects on the behaviour and integrity assessment of welded plates. The experimental analysis includes plates with small and large surface crack, positioned at different locations in the welded joint. Three-dimensional finite element analyses were applied in solving this problem, and the obtained results were compared with the experiment, thus providing detailed insight in welded plate behaviour and enabling its integrity assessment.

INTRODUCTION

In general, different regions of a welded joint exhibit different strength levels, i.e. mismatching behaviour. This strength mismatching often occurs as an overmatching weld (i.e. the weld metal is of higher strength than the base metal) in medium–strength steel weldments. In this case, the occurrence of defects or short cracks cannot be neglecting, and therefore, structural integrity assessment is essential for their safe exploitation. Yet the presence of micro and macro-heterogeneities of welded joints, caused by different microstructures and mechanical properties of the base metal, weld metal, and heat-affected-zone (HAZ), leads to a non-uniform plastic strain distribution in real structures. The combined effect of geometry and material heterogeneity of a cracked welded joint, including gross-scale-yielding (GSY), net-section-yielding (NSY) and ligament yielding (LY), additionally complicated its structural integrity assessment. The main aim of the paper is the analysis of these effects and established strain states.

ESKPERIMENTI I REZULTATI

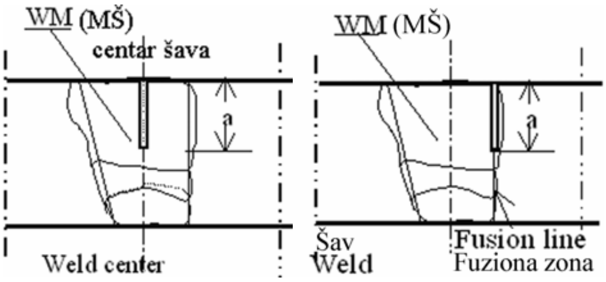
Niskolegirani čelik povišene čvrstoće Nb/Ti-1 (Cu) debljine 5 mm je isporučen u kontrolisanom toplo valjanom stanju. Ovaj tip čelika se upotrebljava za posude pod pritiskom i za razne zavarene konstrukcije, gde je važna težina i cena. Mehaničke karakteristike su prikazane u tab. 1 /1/.

Tabela 1. Mehaničke osobine osnovnog i dodatnog materijala
Table 1. Mechanical properties of base metal and consumables.

Materijal Material	Napon tečenja Yield strength $\sigma_{0.2}$ [MPa]	Zatezna čvrstoća Tensile strength σ_u [MPa]	Izduženje Elongation A_5, %
Nb/Ti-1 (Cu)	480–504	560-580	
EVB-Ni	> 490	570-650	> 22%

Projektovanje zavarenog spoja

Zavarene su dve ploče, dimenzija 1000×1000×5 mm i 1000×800×5 mm. Za potrebe istraživanja izabran je oblik žleba ½ V, sl. 1, zbog lakšeg pozicioniranja prsline u zoni uticaja toplote (ZUT), sl. 2. Spoj je izveden u tri prolaza, elektrodama EVB-Ni (2,5 mm) (videti tab. 1). Ideja ovakvog projektovanja je da se dobije podudarnost čvrstoće u spoju ili neznatni *overmečing*. Prsline su izvedene primenom elektroerozije, sa radijusom vrha od oko 0,1 mm.



a) metal šava (weld metal) b) ZUT (HAZ)

Slika 2. Položaj prsline u zavarenim spojevima
Figure 2. Crack position in the weldments.

Tabela 2. Položaj, dubina i dužina prsline u zateznoj ploči
Table 2. Location, depth and length of a crack I tensile panel.

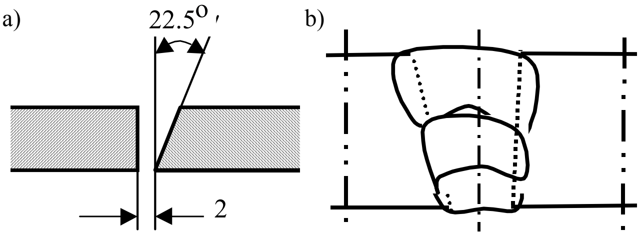
Epruveta	Položaj prsline	Dubina (mm)	Dužina (mm)
Specimen	Crack position	Depth (mm)	Length (mm)
TP 1	HAZ	2.5	8
TP 7	WM	2.5	8
TP 4	WM	1.0	8

Analiza raspodele deformacija

Zatezne ploče sa prslinom u MŠ ili ZUT su instrumentirane mernim trakama radi određivanja raspodele deformacija u blizini prsline, sl. 3. Ukupno je upotrebljeno 12 mernih traka (MT) i 2 deformaciona lanca od po pet traka za svaku zateznu ploču. Jedan deformacioni lanac je postavljen u zoni metala šava sa obe strane ploča. Šest mernih traka je postavljeno na rastojanju od dva, tri i četiri centimetra od centra šava na obe strane ploče. Podaci ispitivanja su prikupljeni na personalnom računaru preko višekanalnog uređaja za akviziciju podataka. Podaci o ispitivanju ploča sa prslinom dati su u tab. 2, a rezultati su prikazani na sl. 4-9.

EXPERIMENTS AND RESULTS

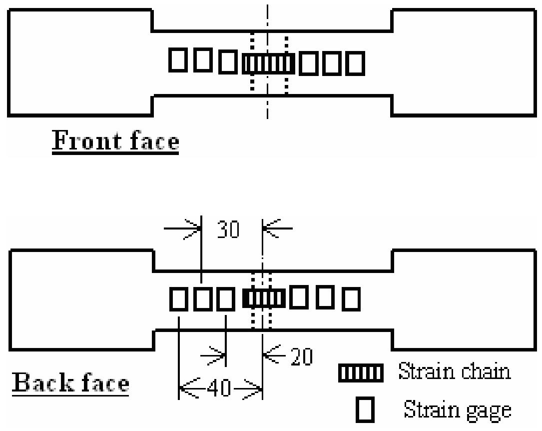
The high strength low alloy steel Nb/Ti-1 (Cu), 5 mm thick, is delivered in controlled hot rolled state. This type of steel is used for pressure vessels and different welded structures, where weight and cost are important. Mechanical properties are given in Table 1 /1/.



Slika 1. a) Priprema zavarenog spoja ½ V, b) zavareni spoj
Figure 1. a) Welded joint preparation ½ V, b) welded joint.

Welded joint design

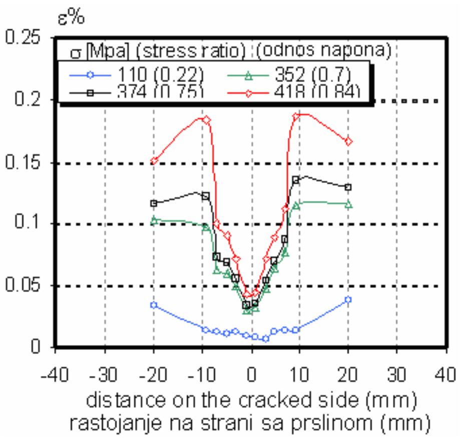
Two plates sized 1000×1000×5 mm and 1000× 800×5 mm are welded. The groove of shape ½ V, shown in Fig. 1, is selected for research because of easier crack positioning in the heat-affected-zone (HAZ), Fig. 2. The joint was welded in 3 passes, using EVB-Ni (2.5 mm) electrodes (see Tab. 1). The idea of such a design is that the welded joint will be even matched or slightly overmatched. Cracks were produced by electro-erosion, with a tip radius of cca. 0.1 mm.



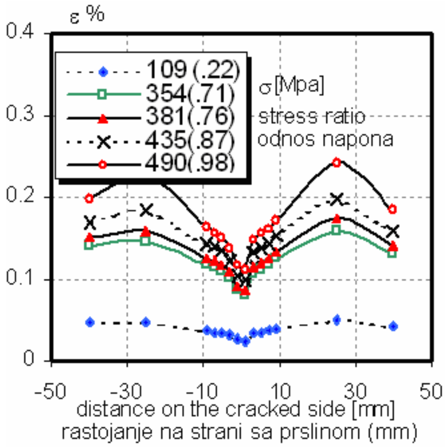
Slika 3. Položaj mernih traka na stranama zatezne ploče
Figure 3. Strain gages positioned at tensile panel faces.

Strain distribution analysis

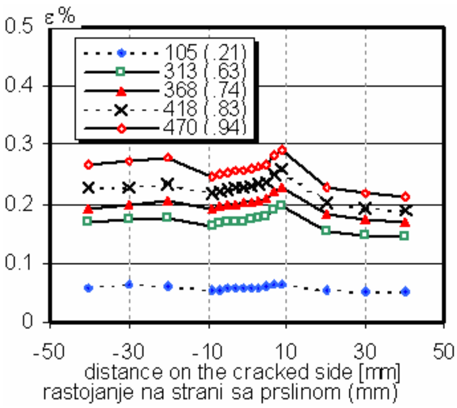
Tensile panels with a crack positioned in the WM or HAZ have been instrumented by strain gauges to determine strain distribution in the vicinity of the crack, Fig. 3. A total of 12 strain gauges (SG) and 2 strain chains, each of five gauges, were used for each tensile panel. One strain chain was positioned in the weld metal zone for both panel faces. Six strain gauges were positioned at distances of two, three, and four centimeters from the weld center on each face. The test data are collected on a personnel computer via multichannel data acquisitioning. The experimental matrix is given in Table 2, and the results are presented in Figs. 4–9.



Slika 4. Raspodela deformacija za TP1
Figure 4. Strain distribution for TP1.



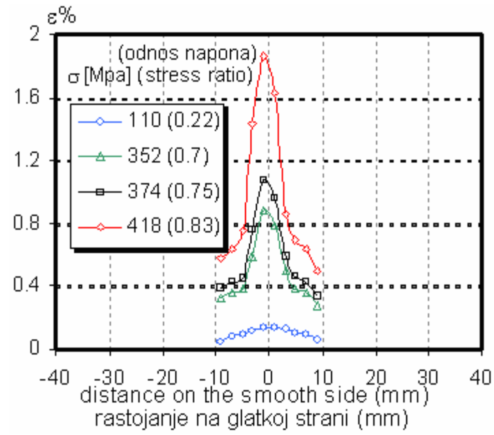
Slika 6. Raspodela deformacija za TP7
Figure 6. Strain distribution for TP7.



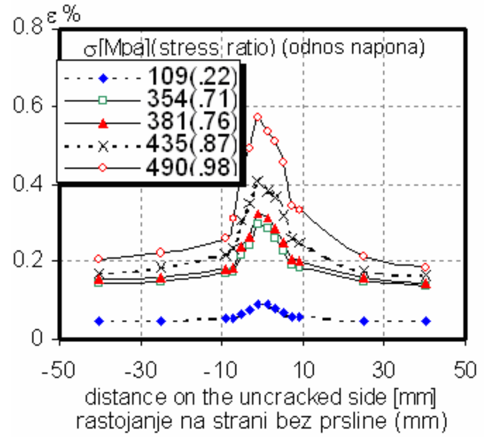
Slika 8. Raspodela deformacija za TP4
Figure 8. Strain distribution for TP4.

Ponašanje deformacija sa aspekta izmerenih lokalnih i srednjih deformacija za epruvete TP1, TP4 i TP7 je prikazano na sl. 10–12.

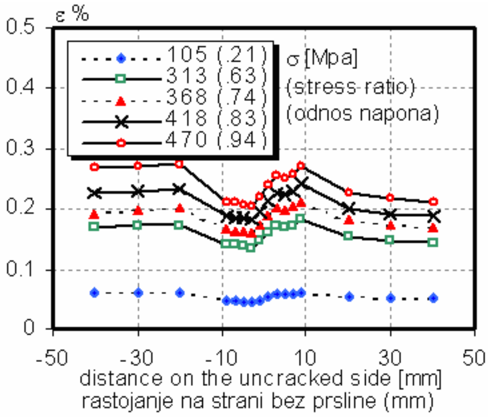
U slučaju male površinske prsline (SSC), epruveta TP4, nije primećen značajan pad kapaciteta nosivosti opterećenja zbog smanjene površine preseka sa prslinom, sl. 10. Zavarena ploča ima veću plastičnu deformaciju od ploče OM, i manji koeficijent ojačavanja materijala, sa gotovo elastično-idealno plastičnim ponašanjem. Deformacija se može opisati kao tečenje po celom preseku (GSY).



Slika 5. Raspodela deformacija za TP1
Figure 5. Strain distribution for TP1.



Slika 7. Raspodela deformacija za TP7
Figure 7. Strain distribution for TP7.



Slika 9. Raspodela deformacija za TP4
Figure 9. Strain distribution for TP4.

The deformation behaviour in terms of measured local and average strains for specimens TP1, TP4, and TP7 is shown in Figs. 10–12.

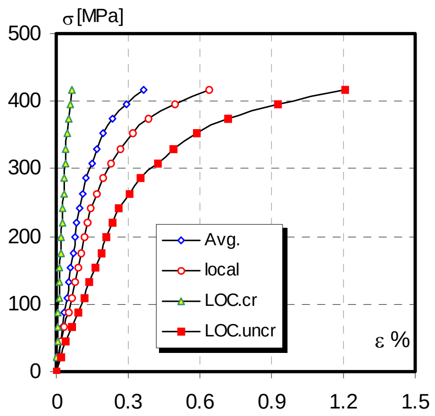
In the case of the small surface crack (SSC), specimen TP4, no significant loss of load carrying capacity due to the reduction of the crack area is noticeable, Fig. 10. The welded plate had a higher yield strain than BM plate with a lower material-hardening exponent and its behaviour was close to elastic-perfect plastic. This deformation mode could be described as a gross section yielding (GSY).

U slučaju velikih površinskih prslina (LSC), korišćena su dva položaja prsline (TP7 sa prslinom u MŠ, i TP1 sa prslinom u ZUT). U prvom slučaju, primećuje se smanjenje kapaciteta nosivosti opterećenja uporedivo sa smanjenjem površine preseka zbog postojanja prsline (napon koji se dobija iz odnosa opterećenja sa početnom površinom preseka), sl. 11. Na lokalnoj glatkoj strani razvija se plastičnost, dok je lokalna strana sa prslinom i dalje elastična. Međutim, slaganje u krivama lokalne i srednje deformacije ukazuje na spoj uravnotežene čvrstoće. Takođe, istraživanjem TP7 posle ispitivanja, tok linija plastičnosti pokazuje da se odgovarajući oblik deformisanja zavarene metalne ploče može opisati kao tečenje neto preseka (NSY) /1/.

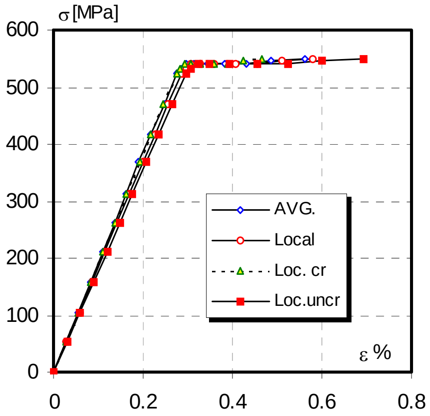
S druge strane, epruveta TP1 je pokazala znatan pad kapaciteta nosivosti, više nego u slučaju TP7, sl. 12. Ovo se može objasniti andermečing efektom čvrstoće u ZUT, gde su se deformacije skoncentrisale u lokalnoj oblasti. Plastičnost se razvila pri nižim vrednostima opterećenja na lokalnoj glatkoj strani, dok je lokalna strana sa prslinom još uvek bila elastična. Oblik deformisanja zarezane zavarene ploče se može opisati kao tečenje neto preseka (NSY), ali ne toliko tipično kao u slučaju TP7.

In the case of the large surface crack (LSC) two different positions of the crack were used (TP7 with crack in WM, and TP1 with crack in HAZ). In the first case, one can notice a reduction of load capacity comparable to the reduction of cross-section area due to the crack (stress obtained dividing applied load by initial cross section area), Fig. 11. Plasticity developed on the local smooth side while the local cracked side was still elastic. However, the agreement between local and average strain curves indicated an even-matched joint. Also, by investigating TP7 after testing, plastic load line flow has showed that the deformation mode of the notched weld metal panel could be described as the net section yielding (NSY) /1/.

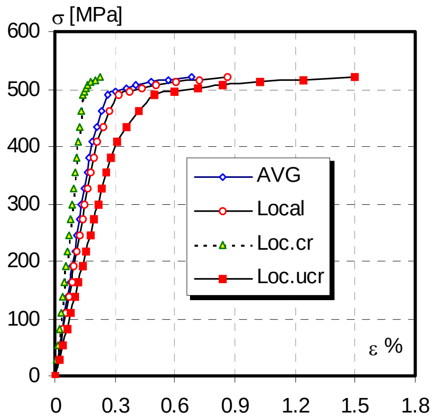
On the other hand, specimen TP1 has shown a considerable loss of load capacity, more than in the case of TP7, Fig. 12. This could be explained by strength undermatched in HAZ, where strain concentrated at the local area. Plasticity developed at low applied loads on the local smooth side, while the local cracked side was still elastic. The deformation mode of the notched weld metal panel could be described as net section yielding (NSY), but not as typical as in the case of TP7.



Slika 10. Zavisnost napon-deformacija TP1
Figure 10. Stress-strain diagram TP1.



Slika 11. Zavisnost napon-deformacija TP4
Figure 11. Stress-strain diagram TP4.



Slika 12. Zavisnost napon-deformacija TP7
Figure 12. Stress-strain diagram TP7.

Avg. – srednja (average); **local** – srednja lokalna (mean local); **Loc.cr** – lokalna sa strane prsline (local cracked side); **Loc.uncr**– lokalna sa glatke strane (local uncracked side).

NUMERIČKA SIMULACIJA

Modeliranje

Osnovna ideja je da se izradi model koji tačno oponaša reakciju epruvete na opterećenje. Epruvete 80x40x5 mm su modelirane kao na sl. 13, zbog simetrije na jednoj četvrtini, za ploču sa površinskom prslinom u MŠ, i na jednoj polovini za ploču sa prslinom u ZUT. Podaci o geometriji su dati u tab. 3, i za materijal u tab. 4.

Tabela 3. Geometrijski podaci (mm)
Table 3. Geometry data (mm).

			Velika- Large	Mala- Small
Površinska prslina	Surface crack		LSC	SSC
Dubina prsline	Crack depth	a	2.5	1
Dužina prsline	Crack length	$2c$	8	8
Vrh prsline	Crack tip	r	0.1	0.1
Dužina MŠ	WM length		2	2

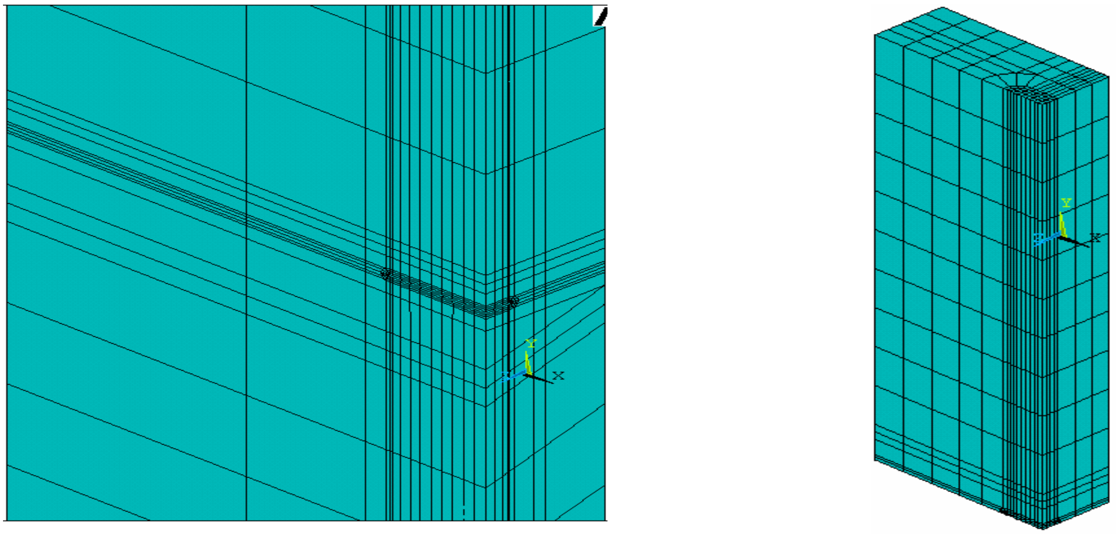
NUMERICAL SIMULATION

Modelling

The basic idea was to make a model, exactly presenting the specimen reaction to loading. Specimens 80x40x5 mm are modeled as shown in Fig. 13, due to symmetry on a quarter for the plate the surface crack in WM, and on a half with the crack in HAZ. The data for the geometry is given in Table 3, and for the material in Table 4.

Tabela 4. Karakteristike materijala – Table 4. Material properties.

	MŠ	OM	GZ ZUT	FZ ZUT
	WM	BM	CG HAZ	FG HAZ
Napon teč. (Y.S.), σ_Y [MPa]	520	485	500	400
Fakt. ojačanja (Strengthening exponent), H [MPa]	300	200	500	800
Modul elastičnosti (Young's modulus), E [GPa]	190	206	206	206
Poasonov koeficijent (Poisson's ratio), ν	0.3	0.3	0.3	0.3



(a) Prslina u ZUT - Crack in the HAZ

(b) Prslina u MŠ - Crack in the WM

Slika 13. Mreža konačnih elemenata
Figure 13. The finite element mesh.

REZULTATI I DISKUSIJA

Konture ekvivalentnog fon Mizesovog napona su prikazane na sl. 14–15. Na sl. 14a se jasno vidi tipična raspodela napona za malu površinsku prslinu sa maksimumom za najveću dubine prsline. Iako je raspodela napona za OM pri manjem nivou opterećenja (418 MPa) tipična za ograničeno tečenje /2/, primećuje se i karakter promene ove raspodele ka NSY i GSY za viši nivo opterećenja (470 MPa), sl. 14b. Uticaj overmečing efekta je prikazan na sl. 15. za dva položaja prsline, od kojih je jedan u MŠ (a), a drugi u ZUT (b). U oba slučaja je tečenje ograničeno na manju oblast, ali još uvek izazivajući NSY.

Na sl. 16. prikazana je raspodela fon Mizesovog napona za ploču sa velikom površinskom prslinom u ZUT (TP1). Prikazane su dve vrednosti nominalnog napona, od 418 i 460 MPa. Jasan je osnovni uticaj zavarenog spoja u izazivanju LY u početku (pri nižem opterećenju, a), a zatim NSY (pri većem opterećenju, b). Slika 17 pokazuje raspodelu fon Mizesovog napona za ploču sa velikom površinskom prslinom u MŠ (TP7). I ovde su date vrednosti za dva nivoa opterećenja, manji (435 MPa) i veći (470 MPa). Vidi se da u ovom slučaju LY dominira kod manjeg opterećenja.

Međutim, očigledno je da kod većeg opterećenja (sl. 22b) LY se ne transformiše u NSY, što ukazuje na različito ponašanje veće prsline u odnosu na manju.

Na sl. 18–19 prikazana je raspodela deformacija duž iste putanje koja je izabrana za eksperimentalno ispitivanje za TP4 (sl. 8–9). Poređenje numeričkih i eksperimentalnih rezultata ukazuje na dobro slaganje, ali sa izvesnim razlikama. Najvažnije razlike su asimetrična raspodela eksperimentalnih deformacija i činjenica da deformacija na strani sa prslinom nije dostigla nulu u blizini usta prsline. Prva razlika se može objasniti geometrijskom nesavršenošću ploče i uticajem savijanja koje je to izazvalo, a I druga razlika se može objasniti istim uticajem i nedostatkom mernih traka dovoljno blizu usta prsline. Treba primetiti da se srednja vrednost eksperimentalne udaljene deformacije (0,24%, sl. 8–9) dobro slaže sa numeričkim podatkom (0,23%, sl. 18-19), što

RESULTS AND DISCUSSION

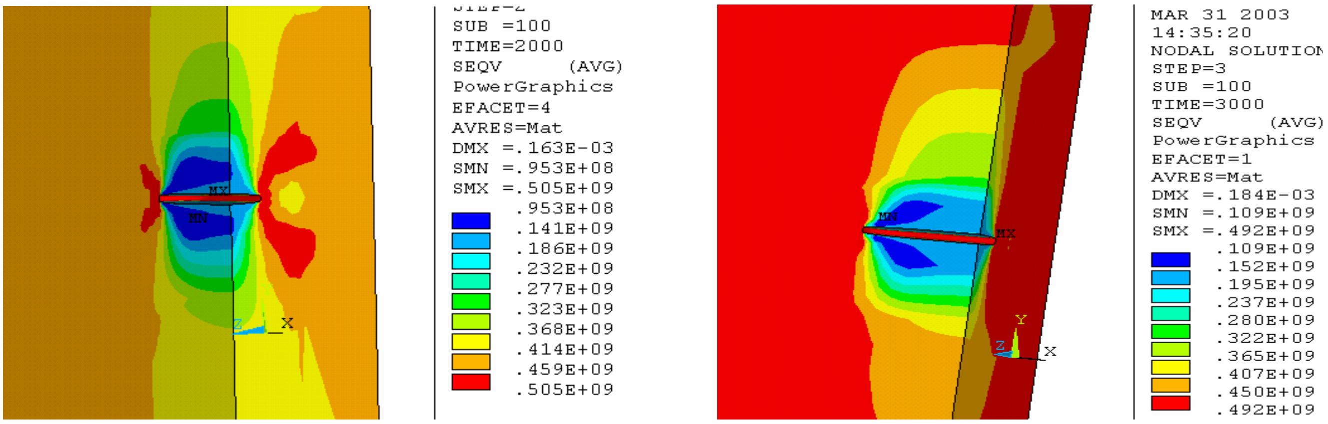
The von Mises equivalent stress contours are shown in Figs. 14–17. Figure 14a clearly shows typical stress distribution for a small surface crack with maximum for the maximum crack depth. Although the stress distribution for BM at the lower loading level (418 MPa) is typical for the confined yielding /2/, one should notice its changing character toward NSY and GSY for higher loading level (470 MPa), Fig. 14b. The effect of overmatching is shown in Fig. 15 for two different crack positions, one in the WM (a) and the other in HAZ (b). In both cases, the yielding is constricted to the smaller region, but still producing NSY.

Figure 16 shows von Mises stress distribution for the plate with large surface crack in the HAZ (TP1). Two levels of remote stress are presented, 418 and 460 MPa. It is clear that the basic influence of weldment is to produce the LY first (at lower loading level, a) and then the NSY (at higher loading level, b). Figure 17 shows von Mises stress distribution for the plate with large surface crack in the WM (TP7). Once again, two levels of loading are shown, the lower one (435 MPa) and the higher one (470 MPa). It is clear that again the LY dominates for the lower loading level.

Anyhow, it is obvious that for higher loading (Fig. 22b) the LY is not transforming to the NSY, indicating different behaviour of the large crack compared to the small one.

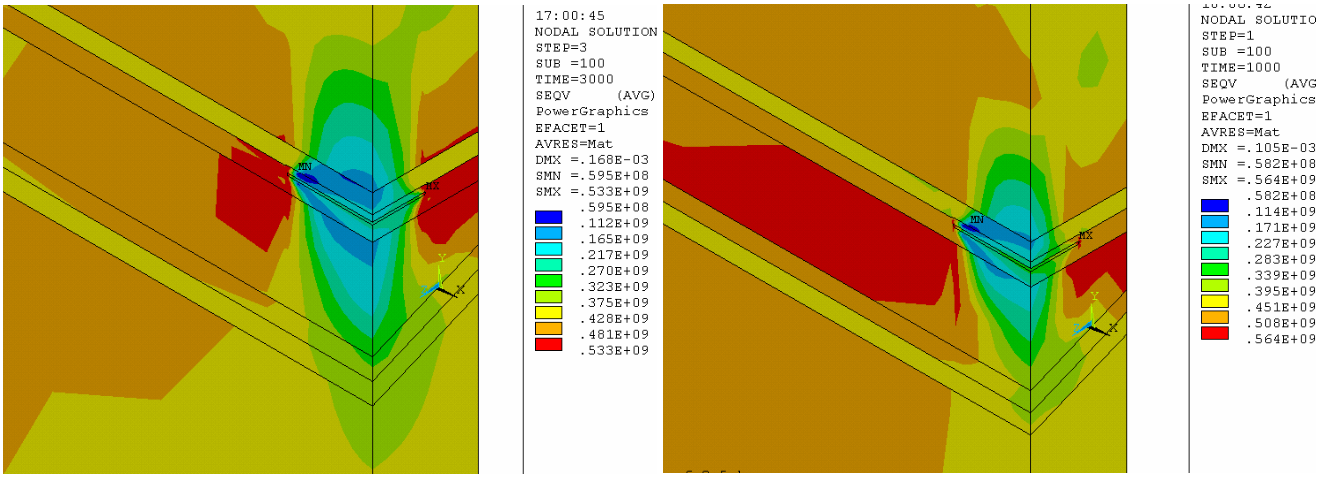
Figures 18–19 show the strain distribution along the same path as chosen for experimental testing of the TP4 (Figs. 8–9). Comparison of numerical and experimental results indicates good agreement, but with few differences. The most important are asymmetrical distribution of experimental strains and the fact that strain on the cracked side failed to approach zero, close to the crack mouth. The first one can be explained by geometrical imperfection of a plate and bending effect caused by it, the latter one can be attributed both to this effect and to the lack of strain gauges close enough to crack mouth. It is clear that the average value of the experimental remote strain (0.24%, Figs. 8–9) agrees well with the numeric value, (0.23%, Figs. 18–19), potvrđuje uticaj savijanja. Drugi mogući uticaj je asimetrični oblik zavarenog spoja. Asimetrična raspodela deformacija primetna i u elastičnoj oblasti. Kako numerički podaci ukazuju na dobru simetriju deformacija, uticaj savijanja je verovatnije objašnjenje.

verifying the effect of bending. Next possible effect is the asymmetrical weldment shape. Asymmetrical distribution of strains is noticable in the elastic range. Since numerical results indicate good symmetry in strain distribution, the bending effect is more probable explanation.



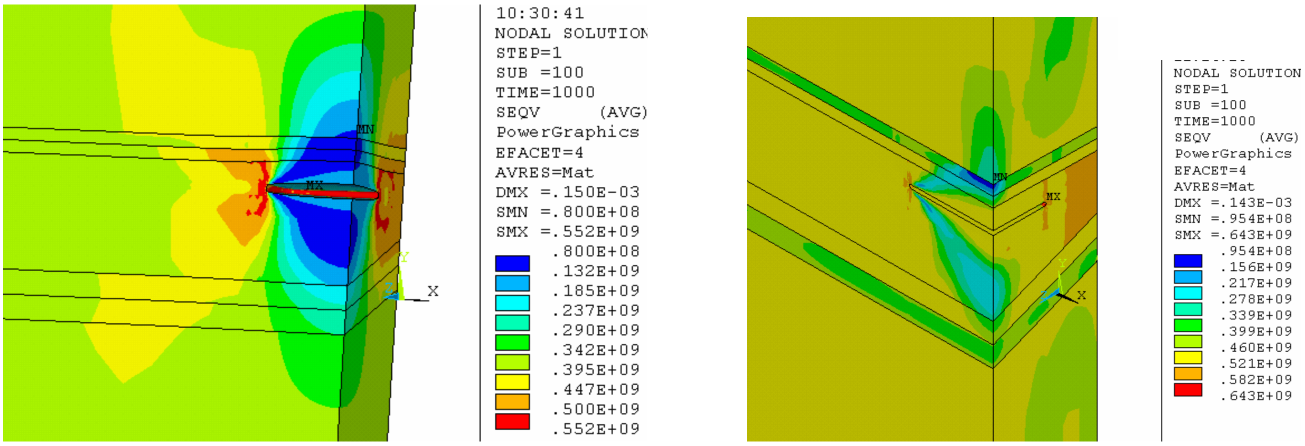
418 MPa 470 MPa

Slika 14. Konture ekvivalentnog fon Mizesovog napona za SSC u OM
Figure 14. Von Mises equivalent stress contours for SSC in the BM.



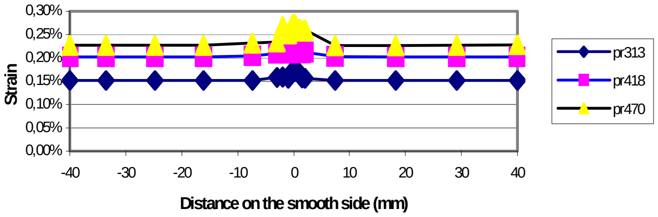
418 MPa 460 MPa

Slika 16. Raspodela fon Mizes napona za TP1
Figure 16. Von Mises stress distribution for TP1.

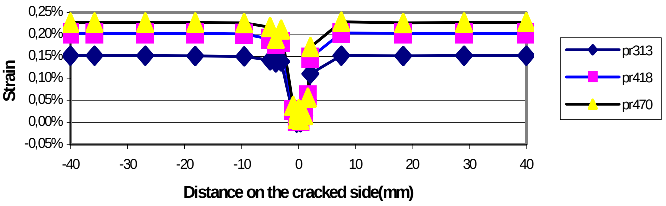


435 MPa 470 MPa

Slika 17. Konture ekvivalentnog fon Mizesovog napona za TP7
Figure 17. Von Mises equivalent stress contours for TP7.



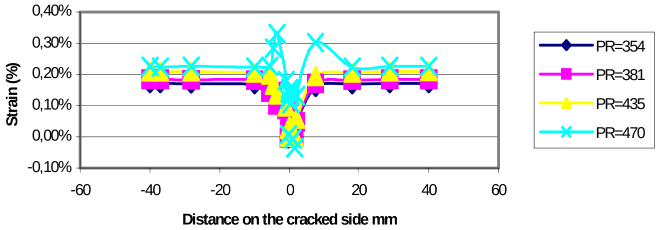
Slika 18. Raspodele deformacija za glatku stranu – TP4
Figure 18. Strain distributions for smooth side – TP4.



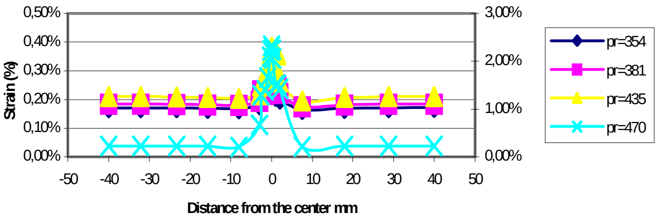
Slika 19. Raspodele deformacija za stranu sa prslinom – TP4
Figure 19. Strain distributions for cracked side – TP4.

Na slikama 20–21 je prikazana raspodela deformacija duž iste putanje koja je izabrana za eksperimentalno ispitivanje TP7 (sl. 6–7). Poređenjem numeričkih i eksperimentalnih rezultata ukazuje na relativno dobro slaganje, ali su male razlike još izraženije. Najvažnija je mnogo veća maksimalna vrednost deformacija, dobijena MKE za opterećenje od 470 MPa, u odnosu na odgovarajuću eksperimentalnu vrednost od 0.55% pri 490 MPa. Treba primetiti odlično slaganje pri 435 MPa, i činjenicu da numerički model ne konvergira za opterećenja iznad 470 MPa, što znači da deformacije postaju prevelike. Ovu razliku verovatno izaziva nepravilno očitavanje MT ili različit redosled razvoja zone tečenja, što je vrlo neizvesno jer se MKE veoma dobro slaže sa teorijom /2/. Na strani sa prslinom su vidljive još neke važne razlike između numeričkih i eksperimentalnih rezultata, prvenstveno u intenzitetu i položaju maksimalne deformacije. Zapravo, umesto oko 27 mm rastojanja do maksimalne deformacije, dobijeno u eksperimentu (sl. 6), rezultati MKE ukazuju da su –5 mm i +10 mm lokacije sa odgovarajućim maksimumima (470 MPa), i bez ikakvih maksimuma na manjim opterećenjima. Ovakva numerička raspodela se objašnjava činjenicom da je položaj prsline nesimetričan u MKE modelu (sl. 13), što je još izraženiji efekat nego u prethodnom slučaju, gde je dubina prsline bila samo 1 mm.

Figures 20–21 show the strain distribution along the same path as chosen for experimental investigation of TP7 (Figs. 6–7). Comparison of numerical and experimental results indicates relatively good agreement, but few differences are even more pronounced. The most important is much higher maximum strain value, obtained by FEM for 470 MPa of loading, than the corresponding experimental value of 0.55% at 490 MPa. One should notice the excellent agreement for 435 MPa, and the fact that the numerical model was not converging for loads above 470 MPa, meaning that strains become too high. Such a difference is probably caused by improper reading of SG or by a different pattern of yield zone development, which is highly unlikely because the FEM agrees well with theory /2/. The cracked side also showed some important differences between numerical and experimental results, primarily in the magnitude and location of maximal strain. Namely, instead of cca 27 mm distance for the maximum strain, as obtained in the experiment (Fig. 6), the FEM results indicate –5 mm and +10 mm as locations of corresponding maximums (470 MPa), and no maximums at all for lower loads. Numerical distribution as this one is explainable by the fact that the crack is positioned asymmetrically in the FEM model (Fig. 13), a more pronounced effect than in the previous case, where the crack depth was only 1 mm.



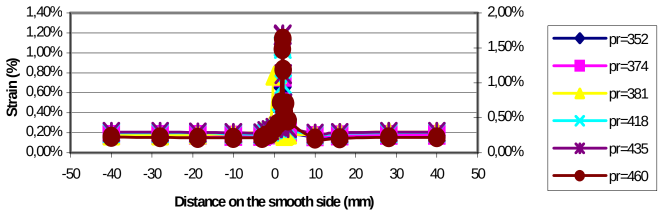
Slika 20. Raspodele deformacija za stranu sa prslinom – TP7
Figure 20. Strain distributions for cracked side - TP7.



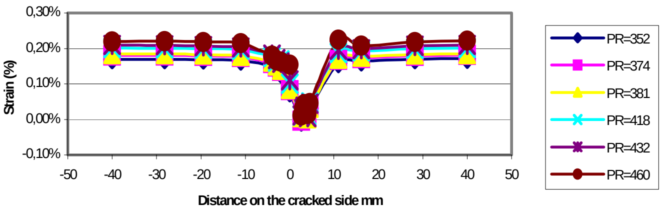
Slika 21. Raspodele deformacija za glatku stranu – TP7
Figure 21. Strain distributions for smooth side – TP7.

Na slikama 22–23 se vidi raspodela deformacija duž iste putanje, koja je izabrana za eksperimentalno ispitivanje TP1 (sl. 4–5). Poređenje numeričkih i eksperimentalnih rezultata ukazuje na dobro slaganje, sa jednom bitnom razlikom u maksimalnoj vrednosti od 1,8% u eksperimentu i 1,1% za numeričku vrednost. Kao i u prethodnom slučaju, moguće objašnjenje je ili u pogrešnom merenju ili u različitom redosledu tečenja. Ipak, u ovom poređenju nedostaju eksperimentalni podaci za opterećenja iznad 418 MPa, a takođe i za rastojanja od usta prsline od preko 20 mm. Primećuje se da asimetrija nije izražena kod eksperimentalnih niti kod numeričkih rezultata.

Figures 22–23 show the strain distribution along the same path that was chosen for the experimental test of TP1 (Figs. 4–5). Comparison of numerical and experimental results indicates good agreement, with only one important difference in the maximum experiment value of 1.8%, and 1.1% for the numerical value. As in the previous case, the possible explanation is either in wrong measurement or in the different yielding pattern. Anyhow, this comparison lacks experimental data for loads above 418 MPa and also for any distance of more than 20 mm from the crack mouth. One should notice that asymmetry was not prounounced neither in the experimental nor in the numerical results.



Slika 22. Raspodele deformacije za glatku stranu – TP1
Figure 22. Strain distributions for smooth side – TP1.



Slika 23. Raspodele deformacije za stranu sa prslinom – TP1
Figure 23. Strain distributions for cracked side – TP1.

ZAKLJUČCI

Procena integriteta zavarenih konstrukcija zahteva detaljnu eksperimentalnu i numeričku analizu. Dok heterogenost materijala ima relativno mali uticaj, geometrija (dimenzije prsline i njen položaj) utiču znatno na ponašanje zavarenih spojeva na sledeći način:

- povećanjem dimenzija prsline (od SSC do LSC) ponašanje zavarenog spoja teži ka promeni sa GSY na NSY i sa NSY na LY,
- promenom položaja prsline sa MŠ na ZUT, ponašanje spoja ima tendenciju promene sa NSY na LY.

LITERATURA – REFERENCES

1. Essamei, M.A., Doctoral thesis, Faculty of Mechanical Engineering, University of Belgrade. (2000)
2. Read, D.T., McHenry, H.I., *Postweld heat treatment criteria for repair welds*, 5th IFMASS, ed. S. Sedmak, EMAS, UK, 1990, p. 235.

CONCLUSIONS

Structural integrity assessment of weldments requirs detailed experimental and numerical analysis. While the material heterogeneity has relatively small influence, the geometry (crack size and position) effects siginificantly on the behaviour of weldments in the following way:

- by increasing the size of a crack (from SSC to LSC) the behaviour of the weldment tends to change from GSY to NSY and from NSY to LY,
- by changing the crack position from the WM to HAZ, the weldment behaviour tends to change from NSY to LY.

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