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Stress Relief Factor for Overlapped Fillet Welded Plates

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Abstract

The paper analyzes the effects of the geometric shapes of the weld seam cross section of the overlapped fillet welded plates , on the bearing capacity of the welded joint, as assessed by the stress relief factor k_t

This analysis is done with the Finite Element Method. The study treats the optimization of welded seam geometry of fillet welded overlapped plates by reducing the stress relief factor, and analyzing its variation in different forms of cross section of the weld, namely:a) level polished surface; b) convex surface; c) polished concave surface.

It is noted that, in all options considered, the geometrical shapes of welding seams of fillet welded overlapped plates, with polished concave surface, gives a superior bearing capacity compared with the polished convex surface on the plausibility field of variation of the dimensional parameters h_{CVX} *and* h_{CAV} *for plates with wall thickness s.*

For concave shapes of welding seams of fillet welded overlapped plates to identify two areas having a local stress relief, located in A zone of the cross section of the HAZ of the base material at the bottom of the fillet welded seam and B zone, on the transverse closing contour of the blank between the two overlapped plates.

In all analyzed cases this factor is significantly lower than the values comply with the fillet welded seams with polished convex surface.

Key words: *fillet welded plates, stress relief factor, finite element method, ultrasonic impact treatment.*

Introduction

The paper analyzes the effects of the geometric shapes of the weld seams cross section of the overlapped fillet welded plates , on the bearing capacity of the welded joint, as assessed by the stress relief factor k_t [1, 2, 3].

To determine the stress relief factor k_t, values, uses the finite element method - MEF [4, 5, 6] and the simplex to define it:

$$k_t = \frac{\max \sigma_{III}^{MEF}}{\sigma_n}, \tag{1}$$

$\max \sigma_{III}^{MEF}$ is the max value of the comparison stress in the third stress theory T τ, Coulomb-Tresca-Guest, (generated by the mechanical load) in the seam zone (seen as a stress relief) analysed by FEA [7, 8] and σ_n – nominal(design) stress (generated by the mechanical load) in the construction component containing welded joint (in the area unaffected by this stress relief).

The study purpose is to optimize the geometry of the overlapped fillet welded plates by reducing the stress relief factor k_t.

Assessment of the Response Range of Stress Relief Factor k_t for Overlapped Fillet Welded Plates

The general pattern of FEA simulates the isolation technique of the specimens used in experimental tests, cutted by mechanical cutting from the specimens presented in the photo from Figure 1, the model analysis dimensions shown in Figure 2.

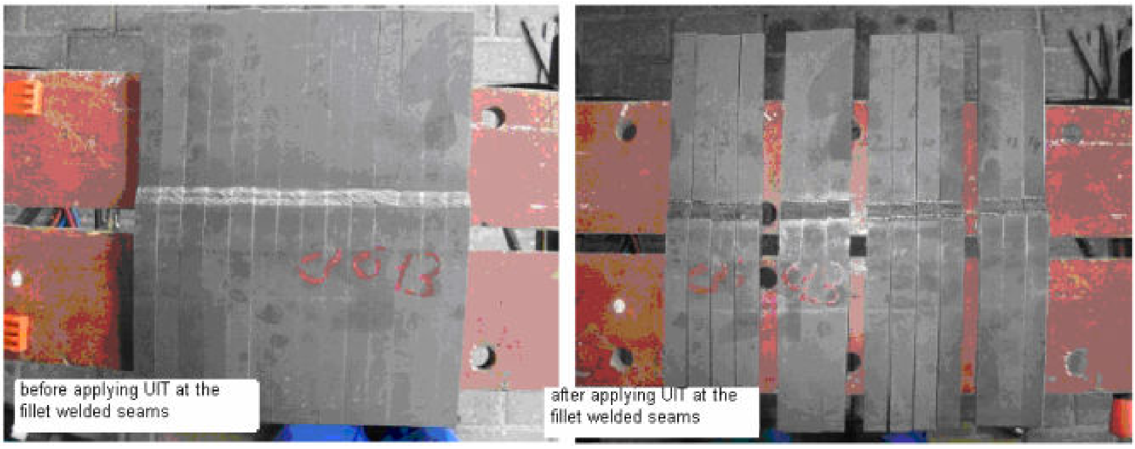


Fig. 1. The appearance of specimens prepared by UIT accordingly the experimental research program [1, 9, 10], Ultrasonic Impact Treatment – UIT

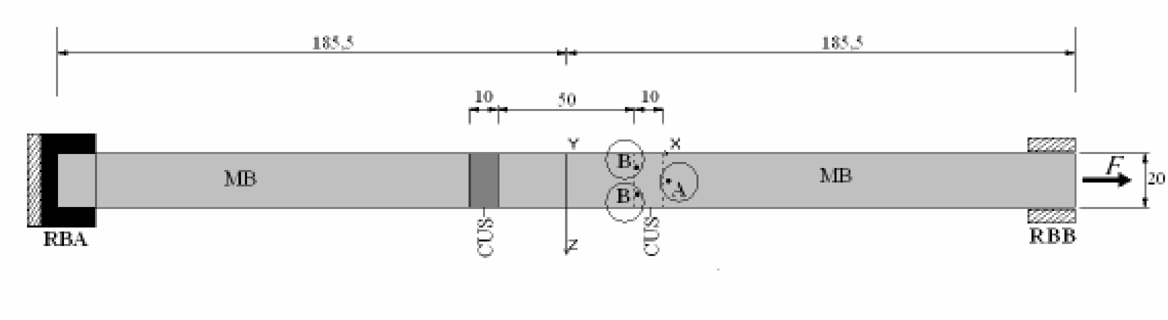


Fig. 2. The FEA pattern, RBA (support bac in A), RBB (support bac in B) - the pattern stroke conditions, total restraint on the lower bac of the testing machine, Sliding 3D spin locking support including the horizontal displacements of the specimen un the upper bac of the testing machine, in RBB; A- stress relief factor in the heat affected zone on the base material at the base of the fillet welded seam; B- stress relief factor identified by FEA on the closing cross contour blank of the overlapped plates located in the filler material (cross section as in fig. 3)

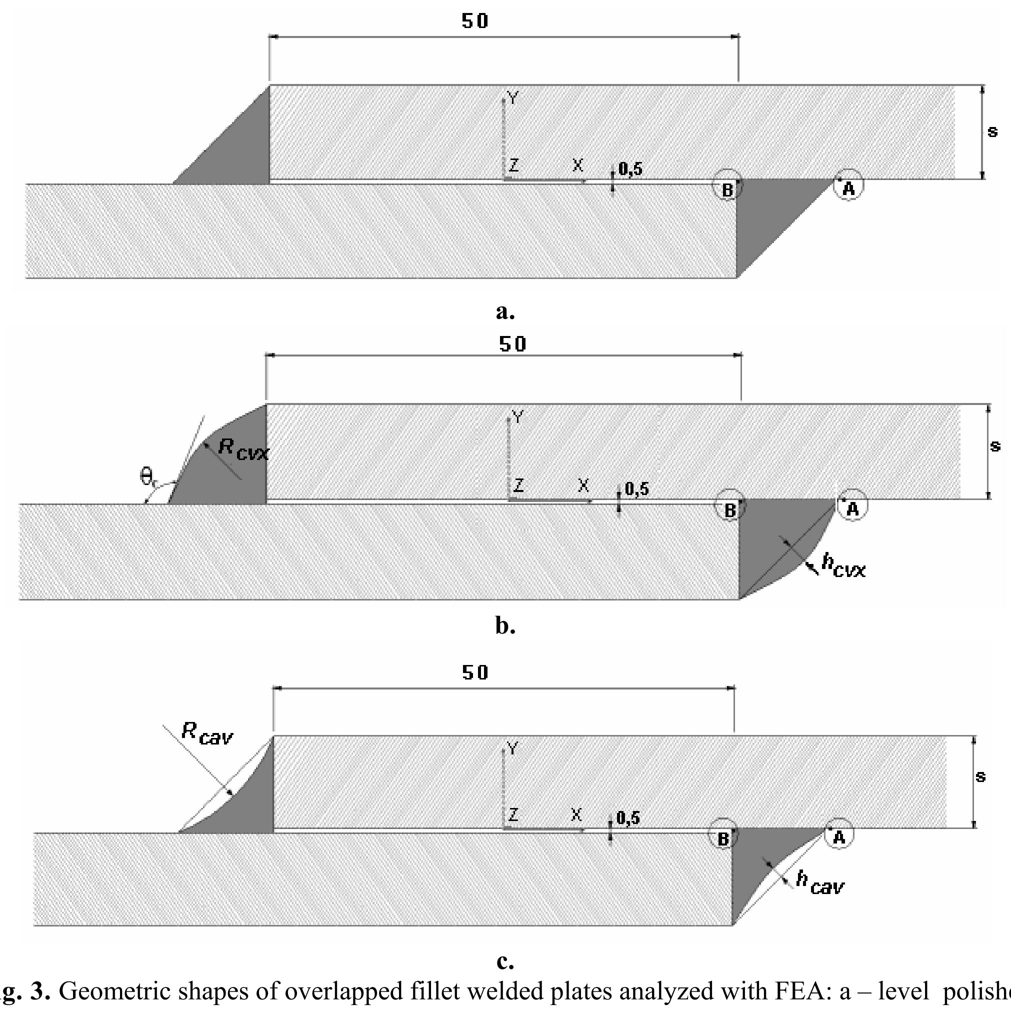
In this paper are analyzed three types of geometric forms of welding seams of overlapped fillet welded plates with cross sections in Figure 3. Finite element discretization was performed in order to achieve the following objectives:

- consideration of all geometric features (shape, size, heat affected zone-HAZ , radii concave, convex) and that respond to a wide range of variation; to achieve these structures were conceived three dimensional parametric variables based on the geometry of the seams welding, using 57856 iso-parametric finite element, SOLID volume type with eight nodes on the element, interconnected in discretization of 63682 nodes, graphical represented in figures 4, and 5.
- the gradual arrangement by increasing frequency of the with finite element in areas of potential stress relief (areas A, B), HAZ, notch-type continue imperfection to the welded seam bottom, in the UIT treated areas, resulting finite elements with minimum sides dimensions of 0.03 mm .

To highlight directly the stress relief values in terms of equivalent stress in third stress theory T τ, of Coulomb-Tresca -Guest, (according to relation 1) analysis models in Figures 2 and 3 are actuated at the end of RBB slide by a centrally static applied force, F = 1N.

Consequently, the mechanical stresses distribution maps such as those presented in Figures 4, 5 can be easily interpreted in terms of quantity as stress relief factors, k_t.

The numerical results are clearly presented by plotting the distribution map in different processing methods for three cases representing the welded seam geometry, s.a. the convex surface of (therefore unprocessed), convex area height h_{CVX} = 3.5 mm in figure 4 and for the concave polished welded seam surfaces, cave area height h_{CAV} = 1.5 mm in figure 5, h_{CAV} = 2.75 mm in figure 6.



c.

Fig. 3. Geometric shapes of overlapped fillet welded plates analyzed with FEA: a – level polished surface; b – convex surface (comply with the specimens tested, see Fig 1); c – polished concave surface

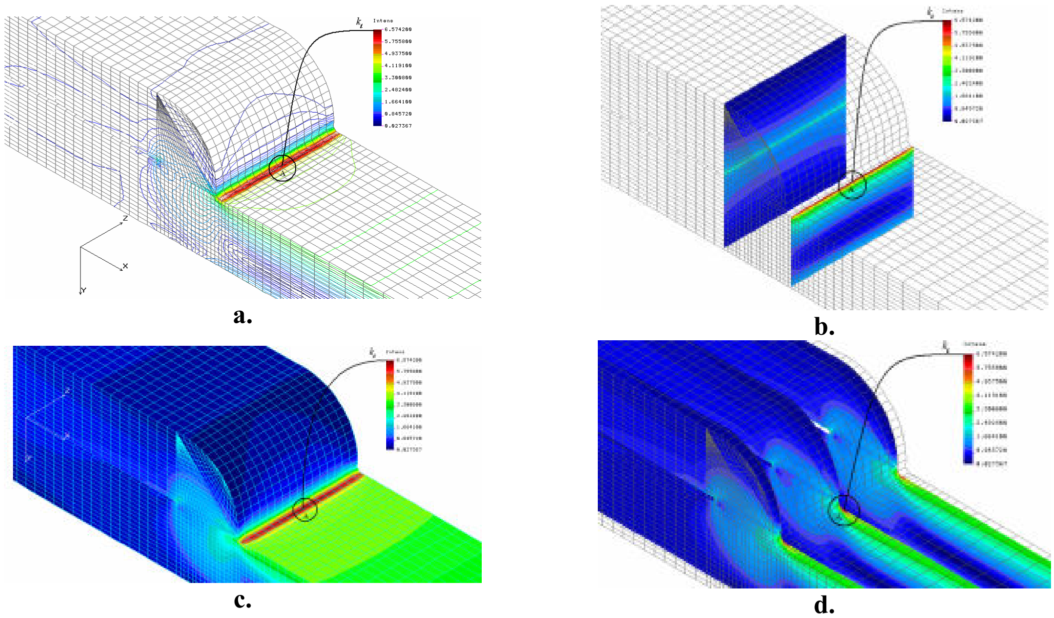


Fig. 4. Processing equivalent stress in the third stress theory III Tτ , in the convex option geometry surface with the height of the convex h_{CVX} = 3.5 mm: a – stress processing as isoliness on the outer contour of junction plates-HAZ-welded seam; b – stress processing in HAZ cross-section of the base material at the bottom fillet weld and on the closing transversal contour of the blank of the overlapped plates; c – processing stress on the outer contour of the model; d – processing stress in longitudinal sections; the stress relief is located in the HAZ in the base material at the bottom of the welded seam in the A zone with maxσ_{III} value = 6.574 MPa, respectively, k_t = 6.574.

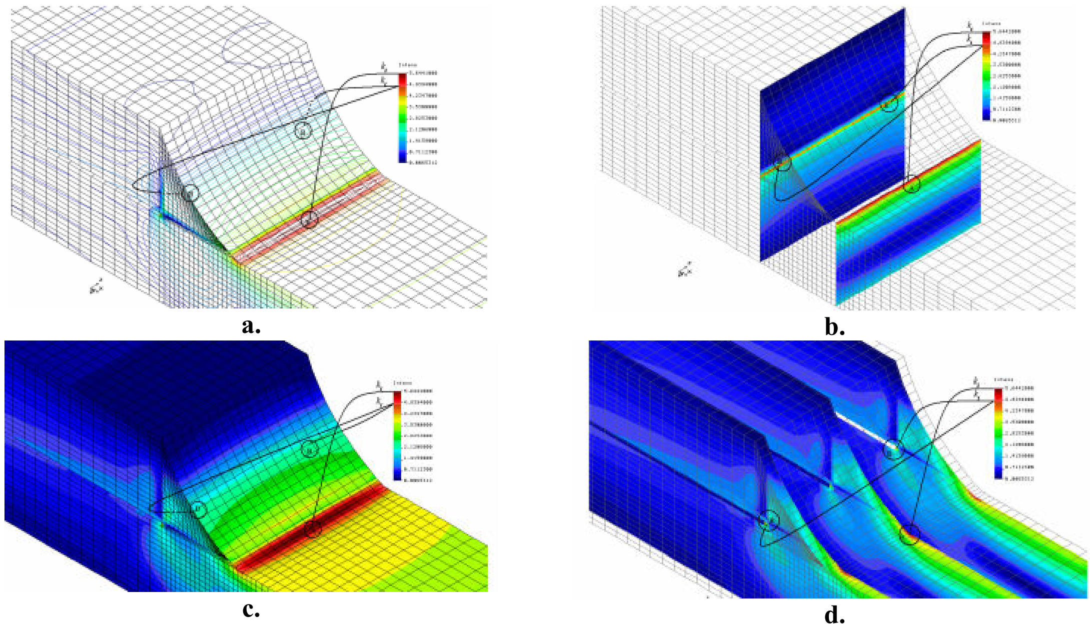
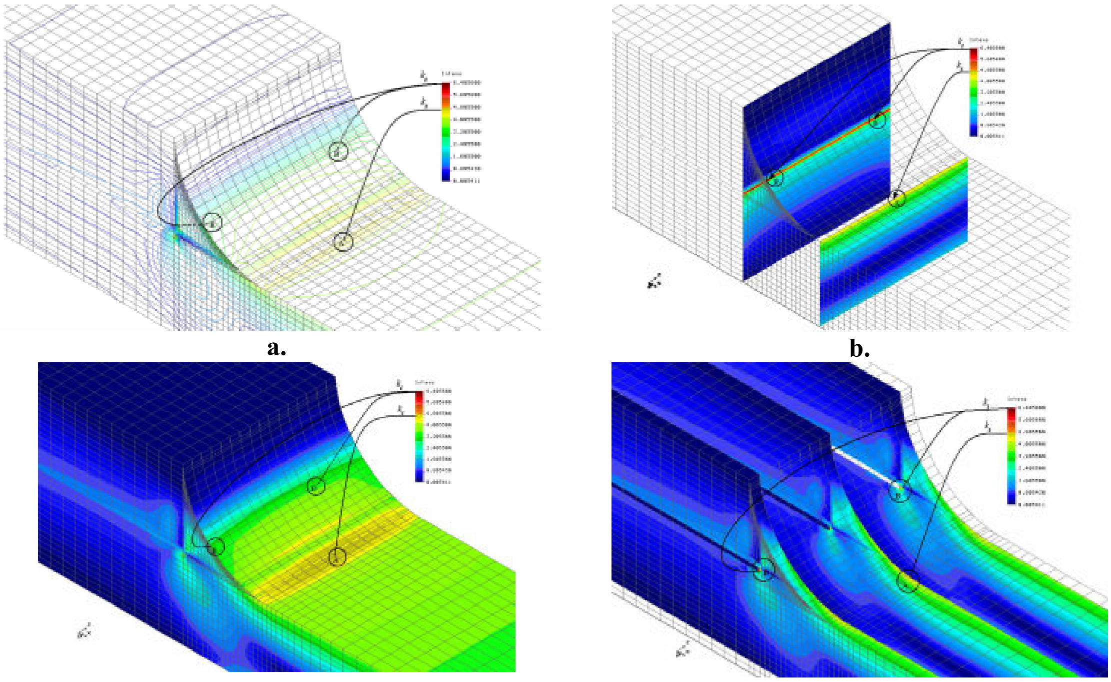


Fig. 5. Processing equivalent stress in the third stress theory III Tτ , in the welded seam geometry option with polished concave surface area with the cave height h_{CAV} = 1.5 mm: a – stress processing as isoliness on the outer contour of junction plates – HAZ welded seam; b – stress processing in HAZ cross-section of the base material at the bottom fillet weld, A zone with maxσ_{III} value = 5.644 MPa and on the closing transversal contour of the blank of the overlapped plates, B zone with σIII=4.767 MPa; c – processing stress on the outer contour of the model; d – processing stress in longitudinal sections; the stress relief is located in the HAZ in the base material at the bottom of the welded seam in the A zone with maxσ_{III} value = 5.644 MPa, respectively, k_t = 5.644.



a. b. c. d.

Fig. 6. Processing equivalent stress in the third stress theory III Tτ , in the welded seam geometry option with polished concave surface area with the cave height h_{CAV} = 2.75 mm: a – stress processing as isoliness on the outer contour of junction plates – HAZ welded seam; b – stress processing in HAZ cross-section of the base material at the bottom fillet weld, A zone with σ_{III} value = 4.77 MPa and on the closing transversal contour of the blank of the overlapped plates, B zone with maxσ_{III}=6.405 MPa; c – processing stress on the outer contour of the model; d – processing stress in longitudinal sections; the stress relief is located in the HAZ in the base material at the bottom of the welded seam in the A zone with maxσ_{III} value = 6.405 MPa, respectively, k_t = 6.405.

To highlight the influence of conformity geometrical variables of the welded seams, h_{CAV} and h_{CVX} on the stress relief factor k_t, continued to develop a parametric study on a wide and covering range of dimensional variation of these variables. The results are collated in Table 1 and graphical processed in Figure 7, 8.

Table 1. Stress relief factor k_t based on dimensional parameters h_{CAV} and h_{CVX}

Fillet welded seam with convex surface		**Fillet welded seam with concave surface**		
h_{cvx} mm	**Stress relief factor, k_t in A zone**	h_{cav} mm	**Stress relief factor**	
			k_t in A zone	**k_t in B zone**
0*	6.398*	0.5	6.368***	3.910***
0.5	6.460**	1.0	5.939***	4.294***
1.0	6.504**	1.5	5.644***	4.767***
1.5	6.534**	2.0	5.357***	5.341***
2.0	6.554**	2.5	6.025***	4.982***
2.5	6.566**	2.75	6.406***	4.77***
3.5	6.574**	3.0	6.803***	4.71***

* with level polished surface, fig. 3
** with convex surface, fig 3.b
*** with concave polished surface, fig 3.c, fig 5,6

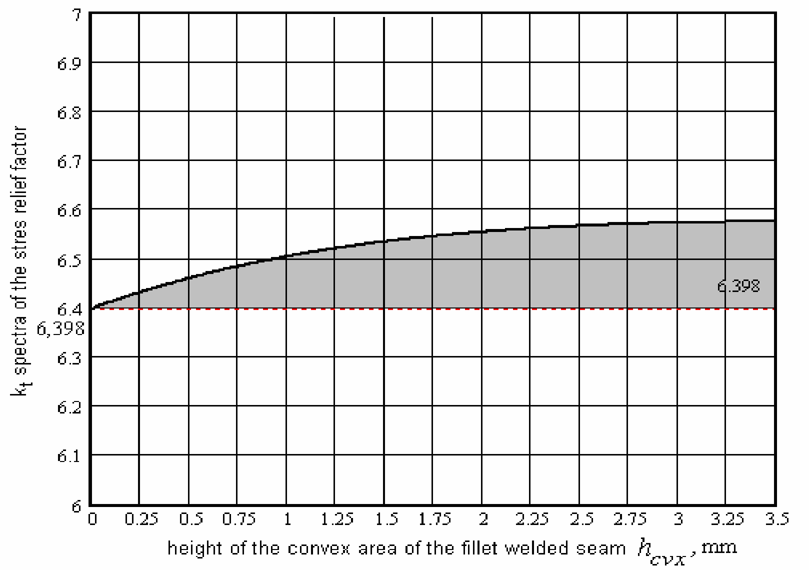


Fig. 7. The range of the stress relief factor k_t depending on the $\boldsymbol{h_{cvx}}$ height of the convex zone of the fillet welded seam.

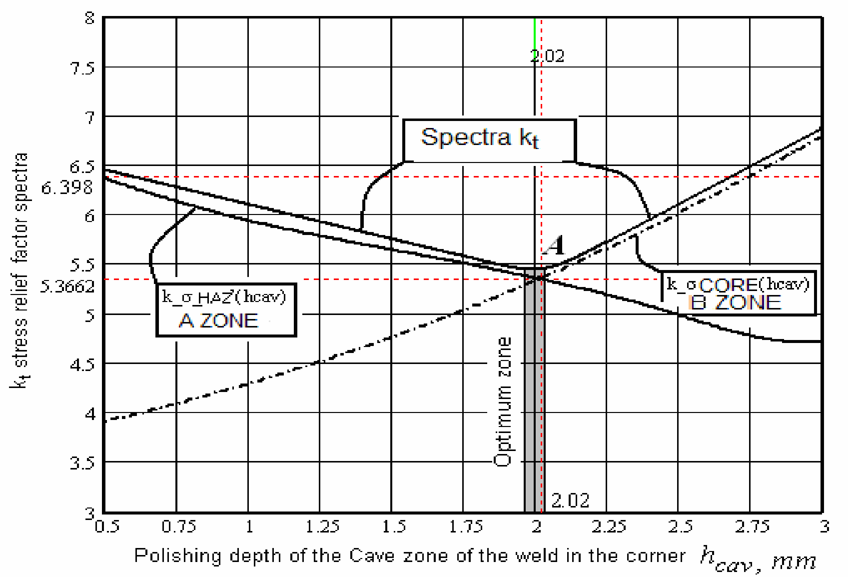


Fig. 8. The range of the stress relief factor kt depending on the hCAV depth of the cave zone of the fillet welded seam

The effect of the Imprints in Plastically Deformed Areas by Ultrasonic Impact Treatment – UIT

After UIT stress relief , plastic deformation results at the bottom of the fillet welded seam as presented in the photos from fig. 9, 10.

This variation form located in the HAZ can significantly increase the stress relief factor.

To reduce this side effect, the methodology for implementing the process [11] requires that depth of the plastic deformed zone does not exceed the admissible imperfection of the form that it can be qualified as a defect (eg 0.5 mm in the case of imperfection ISO 6520-1-5011 continue notch type).

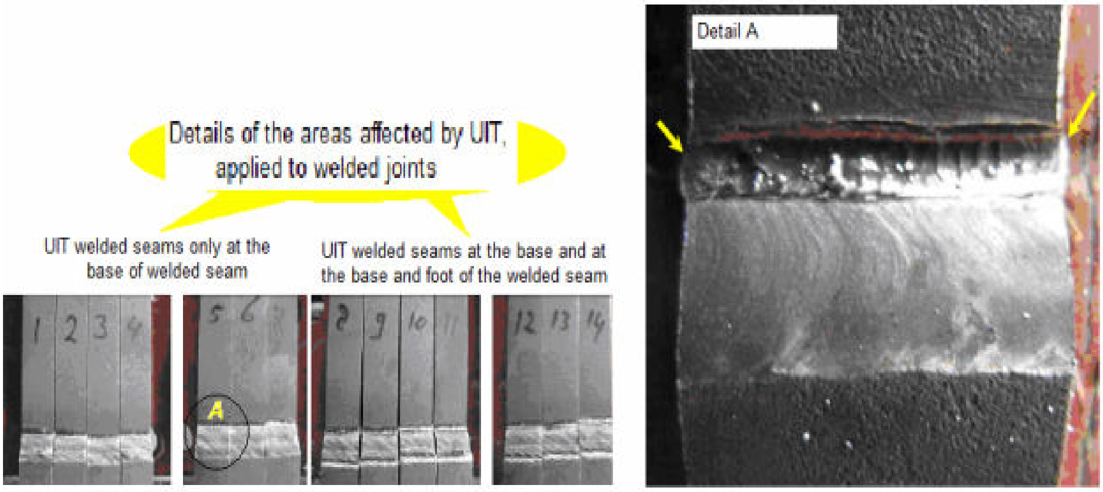


Fig. 9. The appearance of specimens prepared by the UIT for the fatigue test [1, 9].

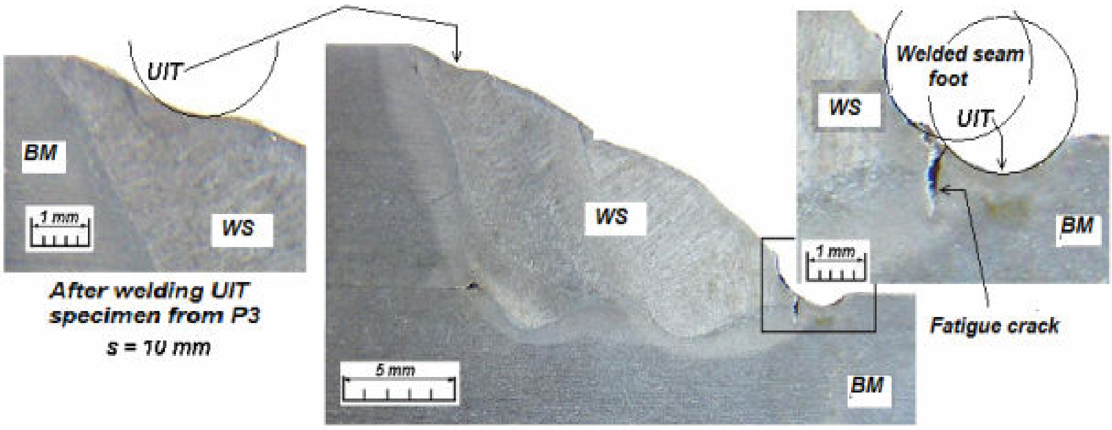


Fig. 10. Areas of fatigue crack initiation in welded joints in fillet welded overlapped plates [1, 9].

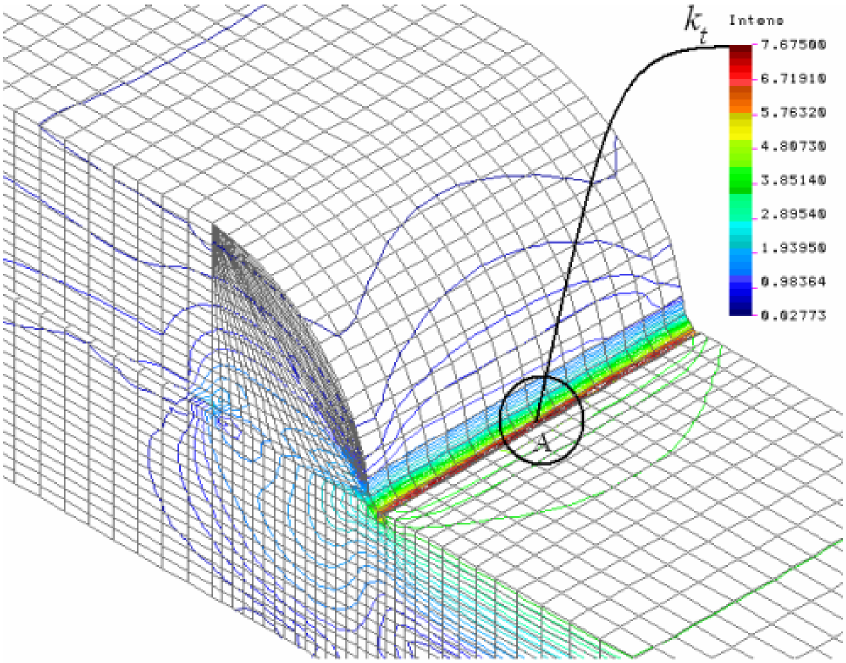
In this context, evaluating the effect of plastically deformed areas imprints by ultrasonic impact UIT **"interpreted" as an imperfection type notch further profiled on a cava profile with depth of the of 0.1 mm and 0.5 mm** wide located in the critical area of the bottom of the wellded seam (see zone A).

Numerical investigations are applied to the analysis model for the fillet welded seam with convex area height, h_{CVX} = 2.5 mm, processed in Figure 11. This study showed an amplification of the value of the stress relief factor from k_t = 6.566 at k_t = 7.65.

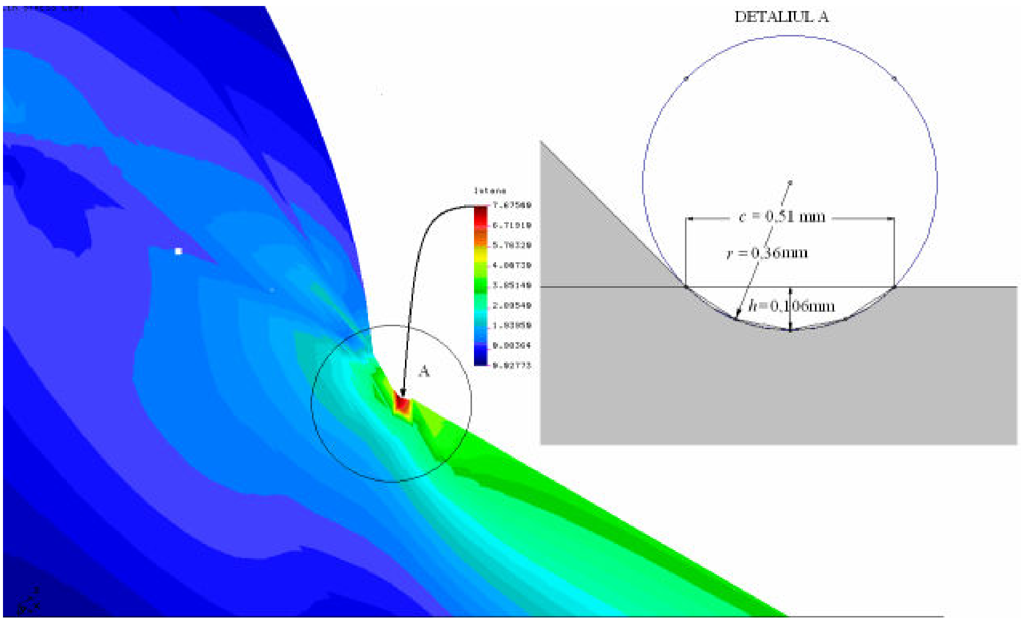
Conclusions

1. In all cases, operating with finite element analysis is remarkable that the geometrical shapes of welding seams of fillet welded overlapped plates, with polished concave surface, gives a superior bearing capacity compared with the geometrical forms of fillet welded seams with polished convex surface, plausible variation field of the dimensional parameters h_{CAV} and h_{CVX} for plates with wall thickness, s.

2. In the case of geometrical shapes of welding seams of fillet welded overlapped plates, with polished concave surface, to identify two areas having a local stress relief, located in the A zone in the cross section of the HAZ of the base material at the bottom of the fillet welded seam and that, on the transverse closing contour of the blank of the two overlapped plates noted area B. The curves range of variation of stress relief factor k_t evolve by downward-upward parabolic curves under the two areas at the intersection which determine an optimum depth of the cave zone (grinding) of the fillet welded seam, h_{CAV}, as reflected in figure 8 for the analyzed case (min k_t = 5.366 for $\boldsymbol{h_{cav}}$ = 2.02 mm).



a.



b.

Fig. 11. Processing equivalent stress in the third stress theory III Tτ , in the convex option geometry surface with the height of the convex h_{CVX} = 2.5 mm with a notch type imperfection continues profiled on a cave contours with depth of 0.1 mm and 0.5 mm wide located in the critical area of the bottom of the fillet welded seam

3. As stated in paragraph 1, in all cases analyzed this factor is significantly lower than the comply values with the filled welded seams with convex polished surface with ~ 18 ... 22%

4. For metal buildings or major machinery, equipment, etc. highly subjected to variable loads required claims to the analysis of the optimization of the welded seam geometry of fillet welded overlapped plates by reducing the stress relief factor k_t, operating with the finite element method.

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Factorul de concentrare a tensiunilor pentru îmbinări sudate în colț pe table suprapuse

Rezumat

În lucrare se prezintă analiza efectelor formelor geometrice ale secțiunii transversale a cordonului de sudură în colț a tablelor suprapuse, asupra capacității portante a îmbinării, evaluate prin factorul de concentrare a tensiunilor.

Acestă analiză este realizată cu Metoda Elementului Finit. Studiul tratează optimizarea geometriei cordonului de sudură în colț a tablelor suprapuse prin reducerea factorului de concentrare a tensiunilor, analizând variația acestuia în diferite forme ale secțiunii transversale a sudurii şi anume: a) cu suprafața polizată la nivel; b) cu suprafața convexă; c) cu suprafața polizată concav.

Se remarcă faptul că în toate variantele analizate, formele geometrice ale cordoanelor de sudură în coț a tablelor suprapuse, cu suprafața polizată concav, conferă o capacitate portantă

superioară fața de cele cu suprafața polizată convex, pe domeniul plauzibil de variație al parametrilor dimensionali h_{CAV} *si* $h_{CVX,}$ *pentru tablele cu grosimea de perete s.*

In cazul formelor concave ale cordoanelor de sudură în colț a tablelor suprapuse se identifică doua zone cu efect concentrator local: zona A amplasată în secțiunea transversală în ZIT pe materialul de bază în zona inferioară a cusăturii în colț şi zona B, pe conturul transversal de închidere al interstițiului dintre cele două table suprapuse.

In toate cazurile analizate acest factor este mai mic fata de valorile conforme cordoanelor de sudură în colț cu suprafața polizată convex.