

PRORAČUN POTREBNE DEBLJINE ZAVARA NOSIVE KONSTRUKCIJE DODATKA ZA DALJINSKO UPRAVLJANJE KOSILICE

WELD THICKNESS CALCULATION OF REMOTE CONTROL LAWN MOWER ADD-ON FRAME

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Ključne riječi: zavareni spojevi, tehnike proračuna naprezanja zavara, nominalno naprezanje

Key words: welded joints, weld stress calculation techniques, nominal stress

Sažetak:

U ovom radu je prikazana metoda provjere prethodno definirane veličine zavara na primjeru nosive konstrukcije dodatka za daljinsko upravljanje kosilice, odnosno izračuna potrebne veličine zavara u programskom paketu SolidWorks. Dobivena veličina zavara je provjerena programskim paketom ANSYS Workbench. Model nosive konstrukcije dodatka za daljinsko upravljanje kosilice je diskretiziran trokutnim elementima. Prednost korištenja programskog paketa SolidWorks je brza provjera postojećih zavara ili izračun potrebne veličine zavara, metoda je jednostavna ako se posjeduju znanja numeričkih metoda. Proračunom zavara putem programskog paketa SolidWorks nisu vidljive raspodjele naprezanja zavara, te nije moguće koristiti sve vrste zavara što su i najveće mane ovakvom pristupu.

Abstract:

This paper presents a method of checking predefined weld size or calculating the required weld size in program SolidWorks on the example of remote-control lawn-mower add-on frame. The resulting weld size was verified by program ANSYS Workbench. The model of the remote-control lawn-mower add-on is discretized by the triangular elements. The advantage of using the SolidWorks software is to quickly check existing welds or calculate the required weld size, the method is simple if you have the knowledge of numerical methods. The weld calculations do not show the weld stress distributions using the SolidWorks software, and it is not possible to use all types of welds, which are the biggest disadvantages of this approach.

1 INTRODUCTION

Welding has become one of the most important joining processes, because it saves costs on models or tools and it also benefits from lower material consumption. With clever design, the welded part can be 50% lighter without loss of strength and rigidity. Welded structures are usually better than riveted structures because of their simple design. For large structures that have a lot of welds in them, analytical calculations can quickly become a time-consuming process. The SolidWorks software offers the ability to calculate weld thicknesses using numerical methods, which can greatly reduce the calculation time of weld thickness. When calculating welds through the SolidWorks software package, it is possible to check welds of existing dimensions and calculate the required weld dimensions. When calculating welds, the size of the weld can be calculated or controlled. In addition to the required weld size, the required weld size can be shown along the entire length of the weld seam by graph. An example of the weld thickness calculation will be shown on the remote-control lawn-mower add-on. Remote-control lawn-mower add-on is an accessory that converts a manually operated lawn-mower into a remote controlled lawn-mower. The frame is loaded with the weight of the lawn-mower, the weight of electric motors, batteries and other electronic components, as well as its own weight. The frame is made of E235 steel which joints are welded.

2 WELD STRESS CALCULATION

There are four methods generally used for calculating stress in welds. Nominal stress method is based on classical analysis or hand calculation approach. This method is focus of most welding standards. Nominal stress is calculated as the average stress in the cross section. Since nominal stress is calculated as the average stress at the cross section, local stress raising effects due to irregularities or geometrical discontinuities are disregarded. [1]

It is sometimes difficult to approximate the correct stresses using the nominal stress method due to apparent stresses from e.g. warping and torsion. In these cases, the structural hot-spot stress method approximates the stresses better. The method can be done either analytically, numerically or experimentally. Numerical solution is most used due high adoption of Finite element method. The structural hot-spot takes the geometry detail into consideration. [1]

Stress raisers such as porosities, sudden geometrical changes and undercuts are highly difficult to avoid completely in a welded structure. The stresses that occur at these positions are often denoted as “notch stresses”. As opposed to the nominal stress method, the effective notch stress method, includes the effect of stress raisers at the examined notch. If the notch is sharp or even coming close

to a notch radius of zero it tends to become a point of singularity, where the stresses goes to infinity. To avoid this problem, it was proposed by Radaj, Sonsino, and Fricke, 2006 that the sharp notch is replaced with a reference notch radius. Radius of 1 mm is recommended for plates thicker than 5 mm. If plates thinner than 5 mm are used, a radius of 0,05 mm is recommended. [1]

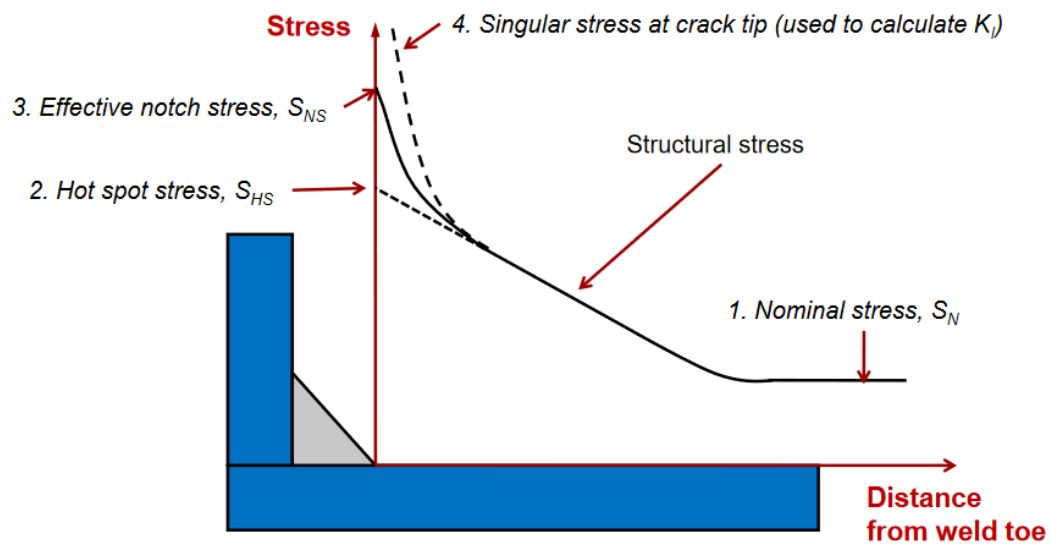


Figure 1. Illustration of the comparison of the different stress calculation techniques [2]

The weld thickness in the SolidWorks software is calculated according to Eurocode EN 1993-1-8:2002, Paragraph 4.5.3. Weld thickness is calculated at each node of the finite element mesh of the discontinued part and a diagram of the weld thickness is obtained depending on the weld length. The weld has satisfactory dimensions if the formulas (1) and (2) are satisfied.

$$\sqrt{\sigma_{\perp}^2 + 3(\tau_{\perp}^2 + \tau_{\parallel}^2)} \leq \frac{f_u}{\beta_w \gamma_{M2}} \quad (1)$$

$$\sigma_{\perp} \leq \frac{f_u}{\gamma_{M2}} \quad (2)$$

Where σ_{\perp} normal stress perpendicular to the weld throat, τ_{\perp} shear stress (in the plane of the weld throat) perpendicular to the weld axis, τ_{\parallel} shear stress (in the plane of the weld throat) parallel to the weld axis, f_u tensile strength of the weaker part in the joint, β_w correlation factor and γ_{M2} partial safety factor.

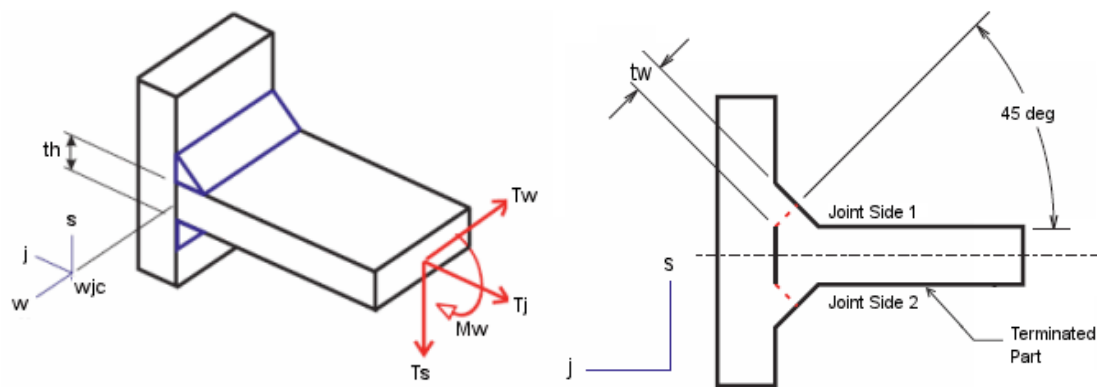


Figure 2. Free body diagram of weld joint [3]

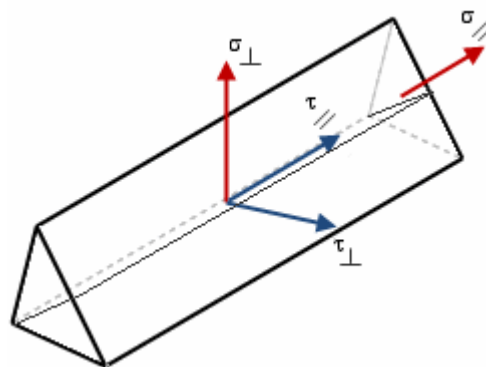


Figure 3. Normal and shear stress in the weld throat plane [3]

3 FINITE ELEMENT MODEL

The frame is made of standard E235 square tubes. A homogeneous linearly elastic material was used for the analysis. The mechanical properties of the material are: modulus of elasticity $E = 190 \text{ GPa}$, yield stress $R_{p0.2} = 265 \text{ MPa}$, Tensile strength $R_M = 400 \text{ MPa}$ and Poisson's ratio $\nu = 0,29$.

In order to use the *Edge Weld Connection* command within SolidWorks, at least one part must be meshed with shell elements. In this paper, the entire model is meshed with shell elements to obtain weld throat thickness using SolidWorks.

When shell elements are used within SolidWorks, the program creates one of two possible element types, depending on the mesh quality options selected. If *Draft quality mesh* is selected, linear triangular elements are created with automatic mesher, and if *High quality mesh* is used, automatic mesher creates parabolic triangular elements. A linear triangular element is defined by three nodes at each vertex and three straight sides, and parabolic triangular elements are defined by three nodes at each vertex of the finite element, three nodes (one centered at each of the sides of the triangle) and three parabolic triangle sides shown in Fig. 4.

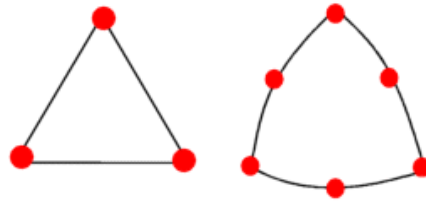


Figure 4. Linear (left) and parabolic (right) triangular element [3]

The model uses parabolic triangular finite elements of 2 mm. It consists 218092 elements and has 437936 nodes. Generated mesh is shown in Fig. 5.

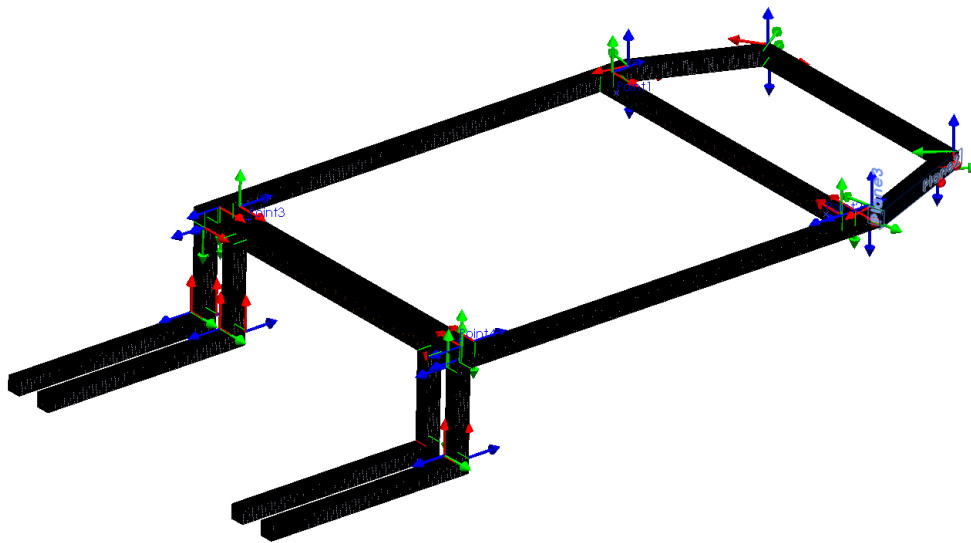


Figure 5. Shell model of frame with parabolic triangular mesh

4 RESULTS

The assumed weld size is 3 mm. After the analysis has been done in SolidWorks, all welds are satisfied as shown in Fig. 6. All welds have been inspected and the maximum weld required is 2,634 mm. The detail where this weld is located is shown in Fig. 7.

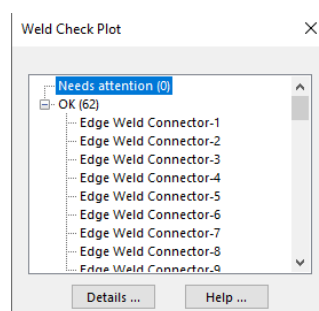


Figure 6. Weld check plot

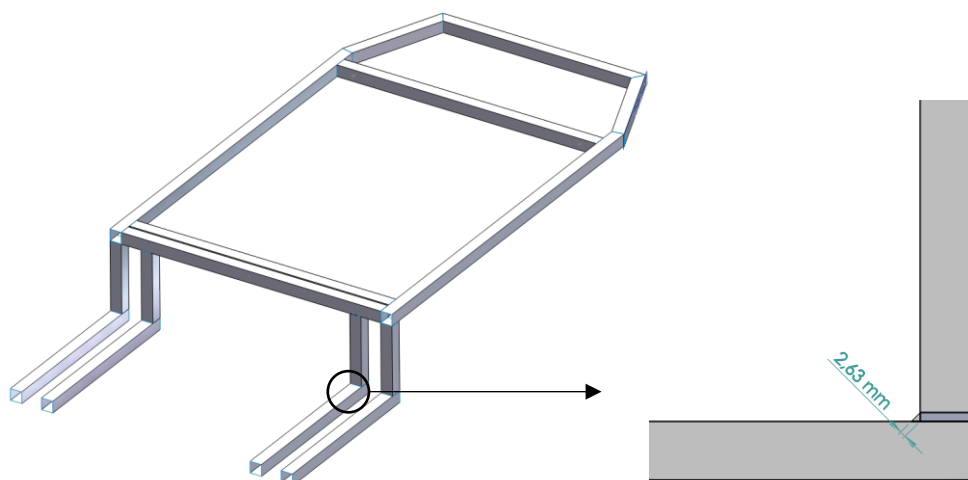


Figure 7. Critical weld

The ranges of required weld throat sizes are shown in Table 1, and Table 2 shows the stresses at the most loaded node, equivalent stress is calculated, and it is equal to 200 MPa.

Table 1. Weld throat size

	Min	Max	Mean
Weld throat size (mm)	0.92912	2.634	1.5537

Table 2. Stress values at critical location

σ_{\perp} (MPa)	99,884
τ_{\perp} (MPa)	-99,984
τ_{\parallel} (MPa)	-5,5595

Submodel of connection with required maximum weld throat was made and the weld was checked in Ansys Workbench. Fig. 8,9,10,11 show equivalent von-Misses stress at weld root, toes and weld throat cross section.

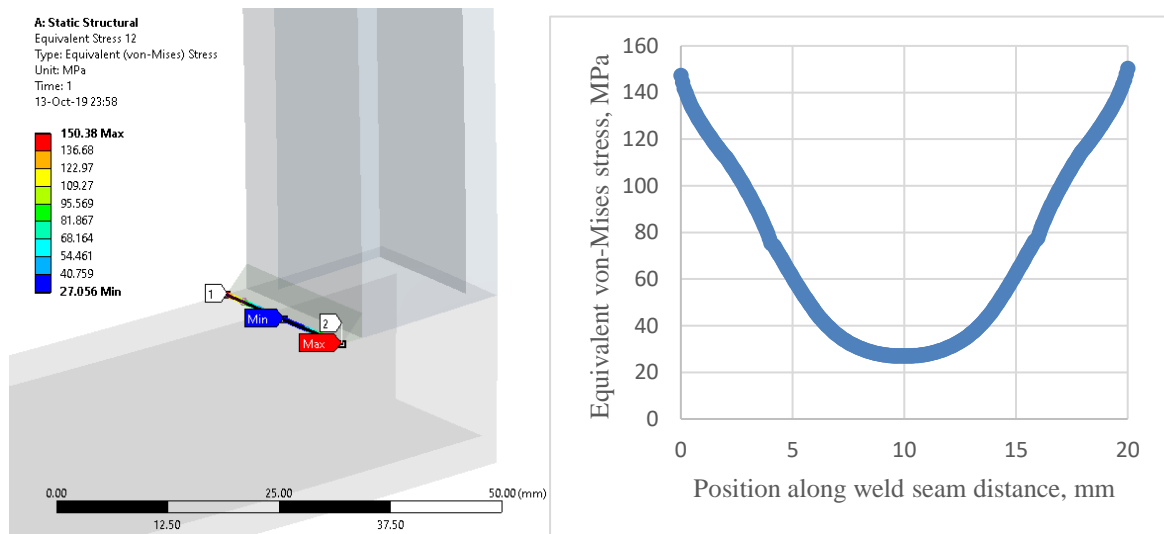


Figure 8. Equivalent von-Mises stress along weld seam at weld toe

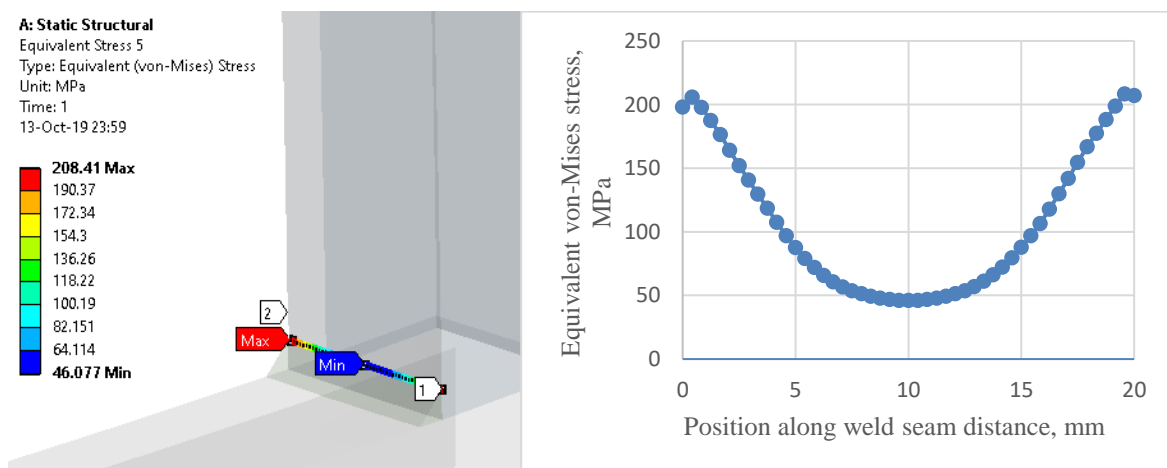


Figure 9. Equivalent von-Mises stress along weld seam at weld toe

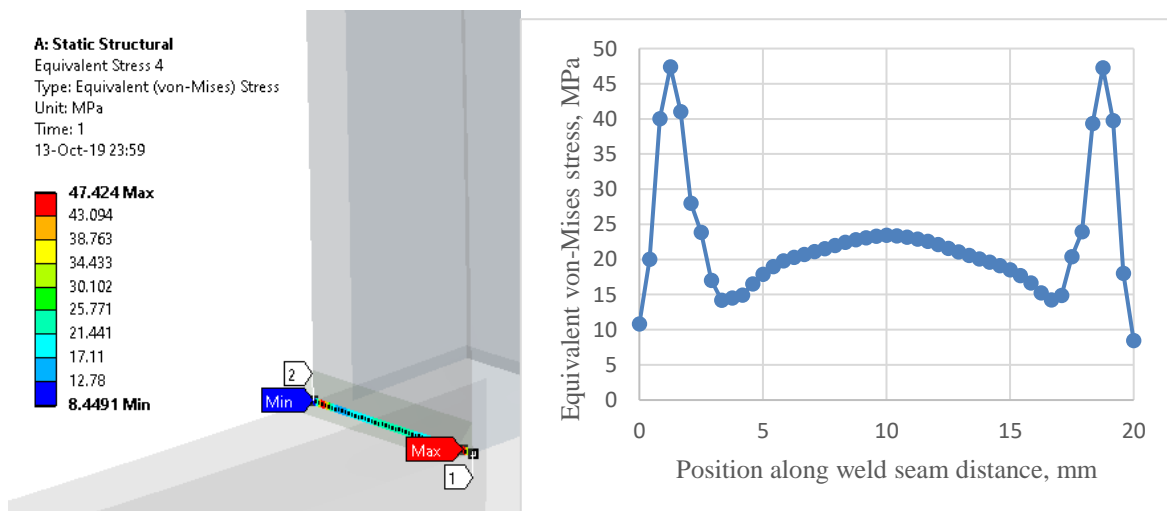


Figure 10. Equivalent von-Mises stress along weld seam at weld root

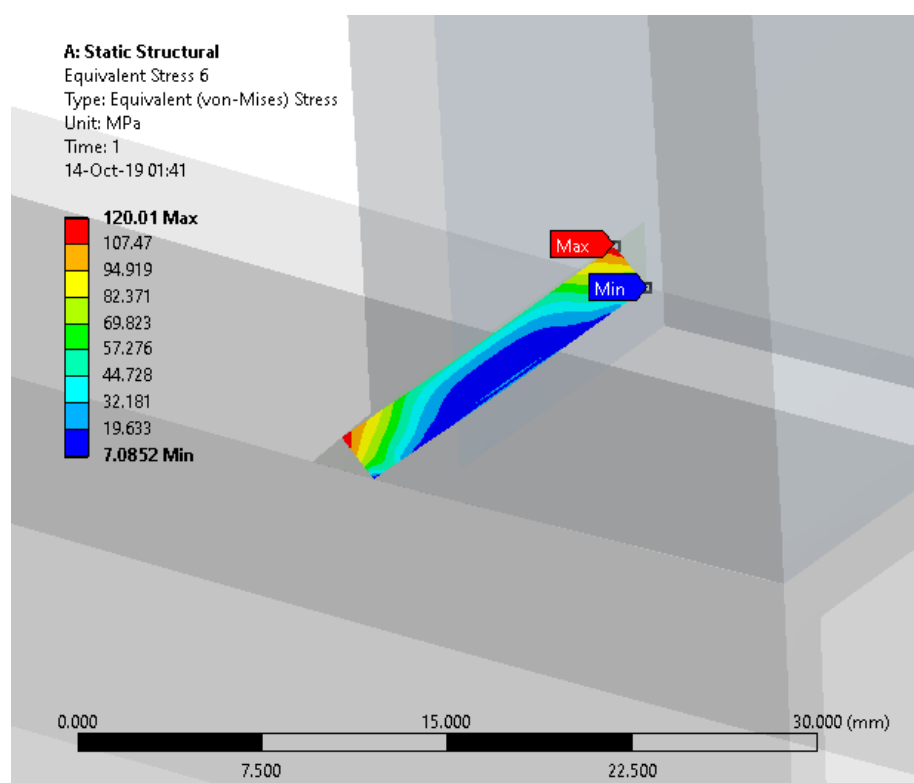


Figure 11. Equivalent von-Mises stress at weld throat cross section

Comparison of the Hot-spot stress and Singular stress methods is shown in Fig. 12.

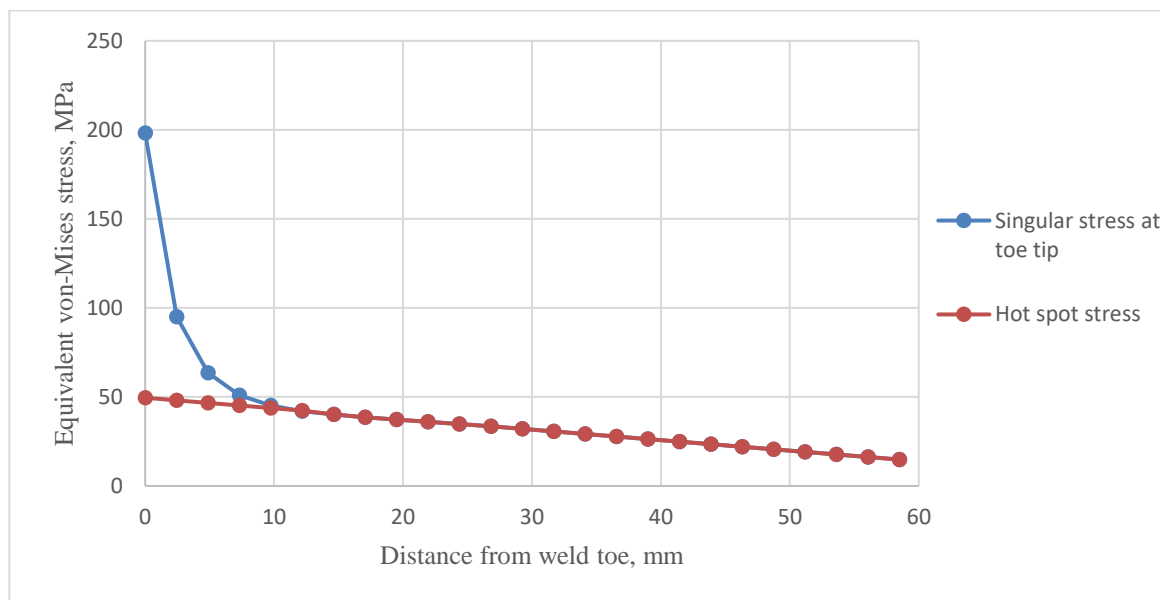


Figure 12. Comparison of the Hot-spot and Singular stress method

5 CONCLUSION

The described method can be used to check the predefined weld size, or to calculate the required weld size in a much faster way than hand calculation. Benefits of this work have people who are familiar with the finite element method and need to quickly calculate the required weld sizes within a structure if they are aware of the loads that occur on that structure. Predefined weld size of 3 mm is satisfactory according to SolidWorks and ANSYS Workbench analysis. After checking the weld sizes by shown methods, it is necessary to analyze the structure for fracture behavior. Structure must be made and experimentally determined the accuracy of the calculation.

6 REFERENCES

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