15th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2011, Prague, Czech Republic, 12-18 September 2011

THE WELD PROFILE EFFECT ON STRESS CONCENTRATION FACTORS IN WELDMENTS

Zoran D. Perović
Department of Mechanical Engineering, University of Montenegro
George Washington s/n, 81000 Podgorica
Montenegro

ABSTRACT
The assessment of beneficial effects of weld geometry modification methods is considered in this paper. Since all these methods significantly increaese weld toe radius, its influence on stress concentration factors is analised. The dependance of theoretical stress concentration factors vs. weld toe radius was determined by using both finite element analisys and photoelasicity method for various types of welded joints. Ratio of coresponding values of fatigue stress concentration factors of as-welded and improved joint, determined by using empirical formulas including also hardness in heat affected zone, gives magnitude of beneficial effects of mentioned weld improvement methods. The results obtained by these calculations for one type of welded joints are compared with experimental results reported in literature.
Keywords: welded joints, stress concentration factor, weld profile, assessment of beneficial effects of weld geometry modification methods

1. INTRODUCTION

The fatigue fracture of structural details subjected to cyclic loads mostly occurs at a critical cross section with stress concentration. In a welded joints fatigue crack initiates at the weld toe and propagates through the main plate to a final fracture. Various methods for improving the fatigue resistance of welded joints were developed. These improvement methods can be placed in two broad categories: (a) weld geometry modification methods and (b) methods introducing beneficial compressive residual stress. In the first of these groups are burr or disc grinding and TIG or plasma dressing. Each of these methods reduces the stress concentration factor of the weld by providing a smooth transition between the plate and the weld face i.e. significantly increases weld toe radius. At the same time it aims to remove the weld toe flaws. The fatigue strength increase is equal to the decrease of fatigue stress concentration factor produced by increasing the weld toe radius. Because of this reason the influence of weld toe radius on stress concentration factors for various types of welded joints is analysed in this work.

2. STRESS CONCENTRATION FACTORS FOR VARIOS TYPES OF WELDED JOINTS

Dependence of the theoretical stress concentration factor vs. weld toe radius was analysed for various types of welded joints: a) two-sided transverse attachment, b) one-sided transverse attachment and c) cruciform joint (Fig.1.). Stress concentration factors were determined by using both finite element analisys and photoelasicity method (Fig.2.). The analysis was performed for various values of geometric parameters r/t and a/t (r = the notch root radius; t = the main plate thickness; a = the weld throat thickness). Only the stress concentration factor at weld toe is analysed in this paper because mentioned improvement methods can be performed only at this location (not at the weld root).

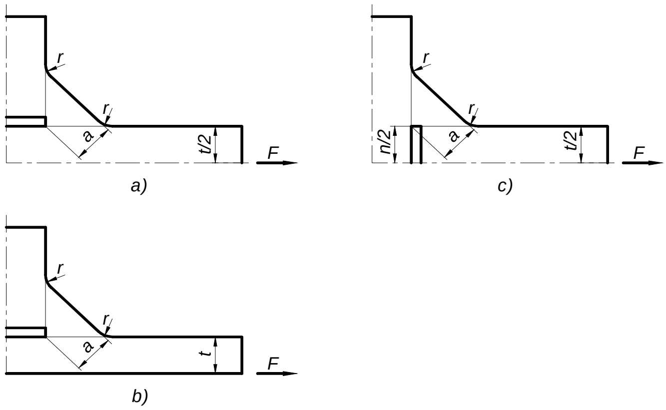

Figure 1. Types of analysed welded joints : a) two-sided transverse attachment, b) one-sided transverse attachment and c) cruciform joint

The obtained results are shown in Fig.3 and Fig.4. It can be noticed that the bigest increase of stress concentration factor occurs at r/t < 0.2. The bigest theoretical stress concentration factor is in cruciform joints without penetration (Fig.3). The influence of weld throat thickness on stress concentration factor is shown in Fig.4.

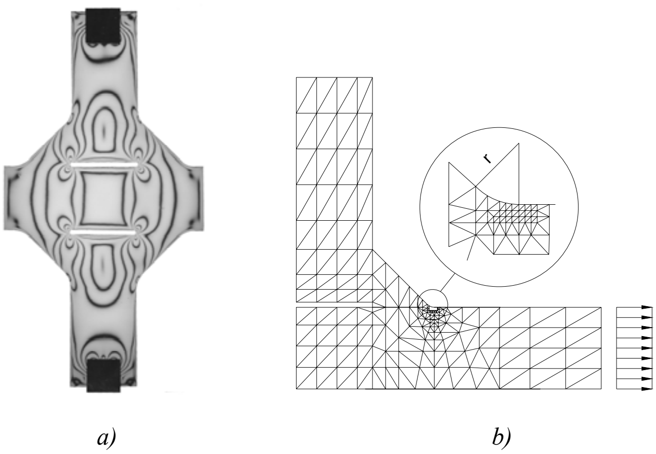

Figure 2. Determination of stress concentration factors in welded joints by using: a) photoelasticity method; b) finite elements method

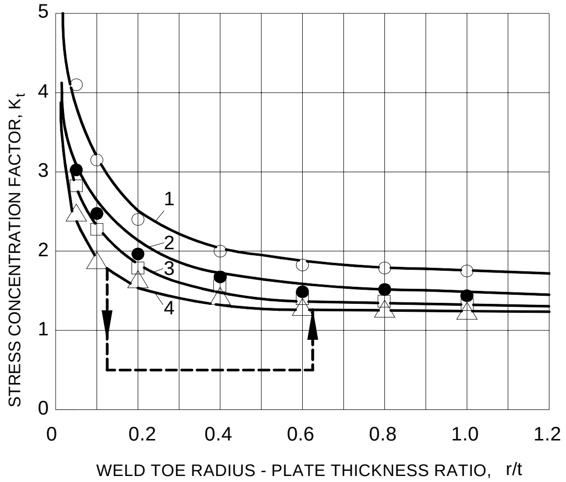

Figure 3. Stress concentration factor for various types of welded joints under tensile load:
1- cruciform joint without penetration n/t=1; 2- cruciform joint with partial penetration n/t=0.5;
3- two-sided transverse attachment, 4- one-sided transverse attachment

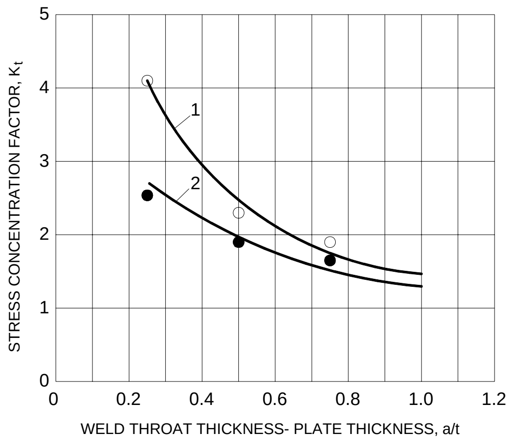

Figure 4. Influence of weld throat thickness on stress concentration factor K_t
1- cruciform joint without penetration n/t=1; 2- cruciform joint with partial penetration n/t=0.5;

3. ASSESSMENT OF BENEFICIAL EFFECTS OF WELD GEOMETRY MODIFICATION

The fatigue stress concentration factor K_f can be calculated from the presented values of the theoretical stress concentration factor K_t and the notch sensitivity which depends on the notch radius and material. This dependency of K_f on notch size and material has been expressed by means of empirical formulas:

Peterson's formula [1]

$$K_f = 1 + \frac{K_t - 1}{1 + \frac{a*}{r}} \tag{1}$$

Neuber's formula [2]

$$K_f = 1 + \frac{K_t - 1}{1 + \sqrt{\frac{A}{r}}} \quad (2)$$

Siebel's formula [3]

$$K_f = \frac{K_t}{n_\chi} \quad (3)$$

where K_t = the theoretical stress concentration factor, a^*, A = the material constants determined for tensile strength in heat affected zone, r = the notch root radius, n_χ = the factor accounting for the relative stress gradient χ and the type of material. Henel and Wirtgen [4] derived the expression (4) by approximation of n_χ diagrams given in reference [3] :

$$n_\chi = 1 + \sqrt{\chi} \cdot 10^{-\left(0.33 + \frac{R_e}{712}\right)} \quad (4)$$

Since all the others influential parameters remain unchanged then the fatigue strength increase (at 2 million cycles), produced by TIG dressing, is equal to the ratio of the as-welded (aw) to TIG dressed (Td) fatigue stress concentration factors:

$$\left(\frac{\Delta\sigma_{Td}}{\Delta\sigma_{aw}}\right)_{calculated} = \frac{K_{f\,aw}}{K_{f\,Td}} \quad (5)$$

For instance, this procedure was applied on fillet welded one-sided attachment joints treated by TIG dressing. In this case the weld toe radius (mean value) was increased from 1 mm to 5 mm (dashed line in Fig.3). The welded joints were fabricated from low-carbon structural steel S355 conformed to MEST EN 10025-2 Standard specification – thickness of main plate was 8 mm. The increase of fatigue strength (eq.5) was equal 1.31. The obtained results were compared with experimental results reported in literature [5] and shown excellent agreement.

4. CONCLUSIONS

The increase of fatigue strength of welded joints produced by weld geometry modification methods could be attributed to the increase of weld toe radius. The magnitude of this increase can be estimated determining fatigue stress concentration factors for initial and final weld geometry. For this purpose the theoretical stress concentration factors for various types of welded joints were determined and presented here as useful tool for this assessment. According to this procedure, for any particular joint, weld toe radius should be determined for as-welded and improved conditions, as well as corresponding theoretical stress concentration factors, hardness in vicinity of the weld toe and corresponding fatigue stress concentration factors by using empirical formulas. Ratio of these factors represents an accurate assessment of beneficial effects of the applied weld geometry modification method.

5. REFERENCES

[1] Peterson R.E.: Stress concentration factors, John Wiley, New York, 1974
[2] Neuber H.: Theory of notch stresses, J.W.Edwards, Ann Arbor, 1946
[3] Siebel E. and Stieler M.: Significance of sissimilar stress distributions for cyclic loading (in German). ZVDI , 97(5), p.146-148, 1955
[4] Henel B. and Wirtgen G.: Zum DDR – Standard TGL 19340, Dauerfestigkeit der Maschinenbauteile, IFL Mitteilungen, No. 1, p.2-35, 1983
[5] Perovic Z.: Investigation of the fatigue strength of the welded joints treated by TIG dressing, Archives of Materials Science, Vol. 28, No.1-4, p.113-117, 2007