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GEOMETRY OPTIMIZATION OF TOOLS FOR DEEP DRAWING

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ABSTRACT
This paper presents the optimization of geometric parameters in deep drawing tools to reduce stress concentrations. Optimization is performed using numerical analysis using parametric optimization. Non-uniform stress distribution around the discontinuity geometry is represented by the stress concentration factor. Control of the results and validity of the model was done using tens metric measurements on a real model.
Keywords: deep drawing tools, optimization

1. INTRODUCTION

Using the methodology of the numerical calculation it is possible to obtain reliable data on the behavior of flawed structures and determine the size and distribution of stress concentration in the structure that will not jeopardize the load capacity of the structural elements, which is the topic of further analysis in this paper. Given the perceived deviation of intensive stress variations in the radius curvature, and increase of stress concentration intensity, it is necessary to perform a detailed analysis of the geometrical parameters as well as the reconstruction of critical points to the extent allowed by usability of treated section.
Analysis of the structure matrix tool which is the subject of this analysis is carried out through geometrical parameters optimization procedure. This procedure ensures that the basis of previous analysis performed is used for optimization of parameters of desired geometrical sizes and to compare effect of these changes to stresses in the critical cross-section. This method is numerically structured for adopted deviation and desired number of steps for calculation of models with altered geometry and this effect is then compared to stress changes. Restrictions which are placed as well as the number of steps depend on the type of construction and limitations related to its usefulness and required geometrical shape and size. Therefore, optimization of this process in reality will not provide the ideal matrix form but the best among the chosen, [1].

2. NUMERICAL ANALYSIS AND OPTIMIZATION

Numerical analysis is carried out on disassembled numerical model of lower shaper which is the subject of optimization procedure of chosen geometric parameters. Chosen critical parameters are radii curves R1 and R2 as well as the groove depth for the lid. These geometrical units are selected because these are the locations where maximum values of equivalent stress values are obtained through numerical analysis.

Initial dimensions of selected geometrical parameters of the original segment, according to technical documentation, are as follows: R1 = 1.0 mm, R2 = 0.5 mm and depth of slots h = 5.5 mm, Figure 1 Optimization procedure is performed through a total of 7 steps whereby following deviations are adopted in comparison to original dimensions as given in step 4, Figure 2.

Geometrical parameter, the original	**Deviation in the optimization process, mm**
Radius R1 = 1.0 mm	0,1
Radius R2=0,5 mm	0,4
Slot = 5,5 mm	0,55

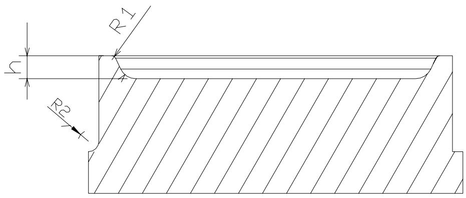

Figure 1. Selected geometrical parameters of the lower shaper-original

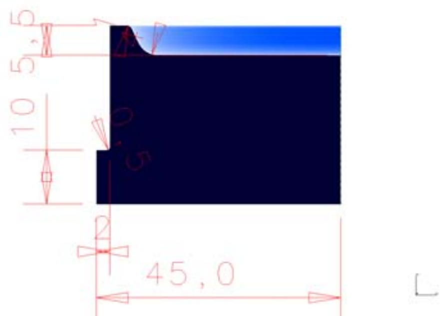

Figure 2. Disassembled FEM models of shaper

Figures 3, 4 and 5 give calculation results of equivalent strain on the lower shaper for the first, original and final step of parametric optimization.

The highest calculated stress is 686 [MPa] and appears in smallest radius R1, which is 0.7 mm, while the stress on the original section 492 [MPa], and at last, the seventh, a sample of 456 [MPa].

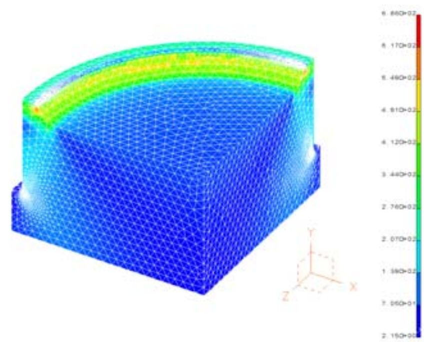

Figure 3. Distribution of equivalent stress on the lower shaper-step 1

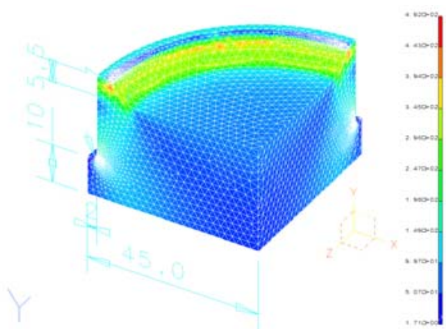

Figure 4. Distribution of equivalent stress on the lower shaper-step 4

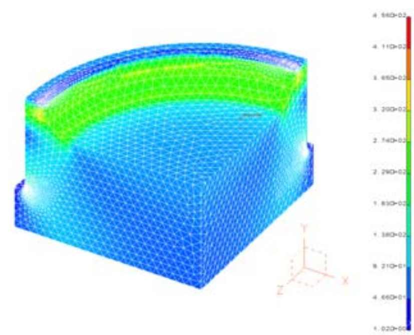

Figure 5. Distribution of equivalent stress on the lower shaper-step 7

Results are shown in the diagram 1 are related to the parameter R1 which most significantly affect observed stress concentration in the critical zone.

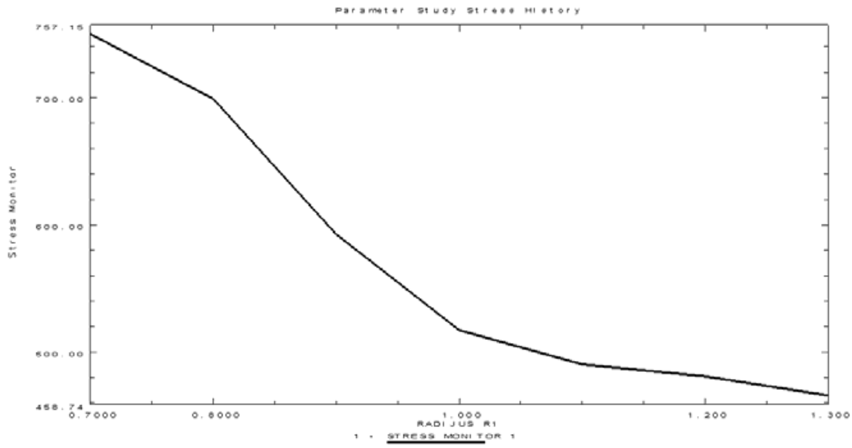

Diagram 1. Stress change curve in the critical zone of the lower shaper with changes of the radius R1

2.1. Analysis of the results of numerical optimization of the lower shaper

Based on the results of numerical analysis, it can be concluded that the selected geometrical parameters differently affect the concentration of stresses observed in the critical zone. The influence of these parameters would probably be higher compared to the strain on the entire shaper radius, given that the aim is to explore the possibility of reduction of stress concentration in the critical zone which is clearly given through parameters: radius R2 and groove h do not affect the change of stresses in the radius R1 zone. Total effect of radius R1 change from 0.7 to 1.3 mm refers to the reduction of the equivalent tension from 686 to 456 [MPa] or almost 50% which is not negligible. Change of stress with change of the radius of the original design of 1.0 mm and its intensity of 492 [MPa] to the maximum radius of 1.3 mm, the intensity is 456 [MPa], or 8%. This change has no great effect, indicating that the chosen radius of 1.0 mm below the original shaper construction is well selected.

2.2. Stress concentration at the lower shaper

The expression for determining the stresses in the cross section of axially loaded elements is based on the assumption of uniformly distributed stresses along the section, ie, the linear distribution [70]. These cases may, under certain circumstances, be contrary to the actual situation and significantly vary in sizes because of following contributors:

- Sudden changes in element cross-section which occurs on shaft in transition from one radius to another, at the slot wedge, cog tooth root, etc.
- Contact stresses in the areas of external load application,
- Material dislocation,
- Initial stresses in the element caused by machining or welding, etc.

Unequal stress distribution around the geometry discontinuity, given as stress concentration, is expressed through the factor of stress concentration, peak stress, peak stress which appears $\sigma_{\max} = \sigma_{konc}$, nominal stress: $\sigma_n = F/A_n$, A_n over net area over plate cross section.

Stress concentration factor is used to define ratio:

$$\alpha_k = \frac{\sigma_{\max}}{\sigma_n} = \frac{\sigma_{konc}}{\sigma_n} \quad \text{... (1)}$$

If value σ_{max} is value of the local stresses calculated using the theory of elasticity, or some determined approximately through experimental results obtained on models, then the factor is called theoretical or calculated factor of stress concentration and is marked with $\alpha_{k,t}$.

If value σ_{max} is effective and actual strain value, obtained by testing on actual material under service conditions, then this factor is called effective (actual) stress concentration factor and is marked with $\alpha_{k,ef}$.

In order to determine the presence of stress concentration as well as geometrical factors of stress concentration at the lower shaper, results of numerical model tests with stress concentration as well as models with parametric modeling are used.

Figure 6 shows the shaper model without grooves and the radius of the observed top cross-section shaper surface. Numerically calculated values of equivalent stresses in this model are $\sigma_{ekv=}$41 [MPa].

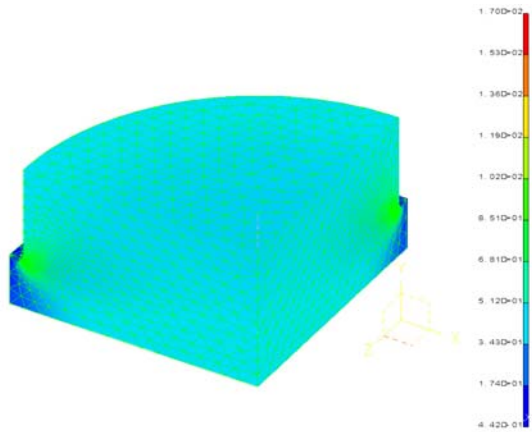

Figure 6. Shaper model without stress concentration on the observed surface, σ_{ekv}*=41 [MPa]*

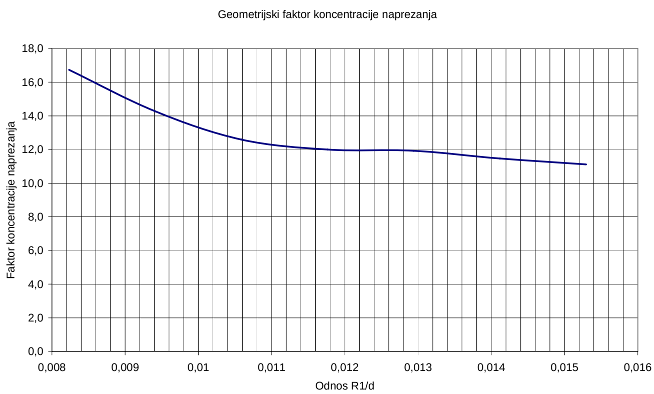

Diagram 2 Geometric stress concentration factor obtained through numerical analysis

The results of calculated equivalent stresses on the actual comparative models (seven-step optimization) are given in the second diagram.

As given in the Diagram 2, the biggest stress concentration factor change occurs at small radii up to the ratio of 0.012 or R1=1,0 mm. Further then this the intensity change is significantly smaller.

3. CONCLUSION

Presented optimization procedure shows that the most intense change in concentration occurs at small radii curves, i.e. largest ratio of R and d. It can also be concluded that the optimization makes sense only to a certain level, after reaching determined ratio change intensity becomes insignificant.

4. REFERENCES

[1] Terzić Muamer: Analysis of the character of force and stress state of tools for cold forming of sheet metal, M.Sc. Thesis, University of Zenica, Faculty of Mechanical Engineering, BiH, 2009.,

[2] Brnić, J., Turkalj, G. : „The Science of Strength II“, University of Rijeka, 2006.