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DIMENSIONING AND FEM ANALYSIS OF THE LEVER TONGS HOLDING THE LOAD BY THE FRICTION FORCE

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ABSTRACT

The tongs are devices purposed for catching and holding of the compact unit loads during their relocation. They are consisted from the parts whose shape and dimensions need to provide the necessary friction force. Taking into the account the responsibility and possible consequences when one of the consisting parts is broken, the request for detailed calculation of each and every consisting parts is completely justified. The standard calculation consider accurate dimensioning of their load capacity and secure carrying of the catched load. This paper is showing the example of the dimensioning lever tongs characteristic parts satisfying the construction rule of secure load holding. The aim of the assignment is to calculate the lever dimensions, which ensures the minimal construction weight, with the rule of satisfying given restrictions. The mathematical model is solved using the method of nonlinear programming – SUMT (sequential unconstrained minimization technique) where we use cost function with constraints, introduce penalty function, in that way new function without constraints is formed and we are loking for its minimal value. After defining shape and dimensions of the consisting parts, FEM analysis of the tongs has been performed using CATIA V5 software package.

Keywords: lever tongs, optimizing, nonlinear programming method

1. INTRODUCTION

The lever tongs are devices purposed for catching and holding of the compact unit loads (trunks, stone blocks, pipes, etc.) during their relocation. Their construction should be adjusted to the shape, weight and dimensions of these loads so their catching and laying down would be easier and faster. The lever tongs shape and dimensions should enable secure holding of the catched load which is also the primary request of this device. In order for the load to be securely held it is necessary to achieve required holding force (friction force). This is also the reason why the load carried by tongs should be insensitive to the pressure.

2. TONGS LEVER DIMENSIONING

Considering the responsibility and possible consequences in case of breaking some of the consisting tongs parts or when holding of the catched load is not secure enough, it is completely justified request for detailed analysis and calculation each and every consisting part as well as the device as a whole. The first step consists of defining the levers length (distance between cranks), shown in Figure 1. For the secure load holding, the following condition should be fulfilled:

$$2\mu F_N \geq Q S \qquad \text{... (1)}$$

where: μ - friction coefficient, $S = 1{,}5 \div 2$ - safety level, Q - catched load weight.

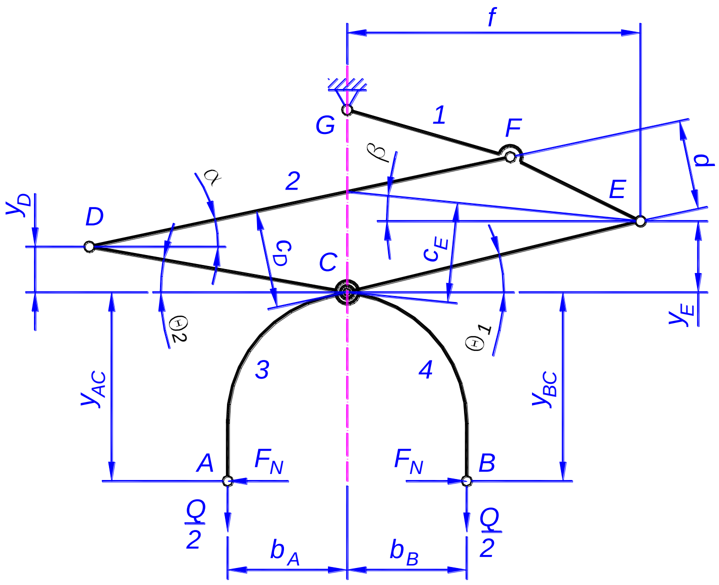

Figure 1. Lever tongs,calculation draft

According to the conditions of the lever equilibrium, for the known values of $b_A = b_B$ and $y_{AC} = y_{BC}$ the lever lengths have been calculated. The results of the analysis have shown that the most loaded crank is the crank C while holding thicker blocks ($b_{A,\max} + b_{B,\max}$). For dimensioning of the characteristic lever intersections, the assumed load was in a shape of a flagstone, 100mm wide with 500 kg weight. In this paper a procedure for dimensioning intersections I-I and II-II ($\varphi = 0^\circ \div 75^\circ$) for lever 3 is shown, Figure 2.

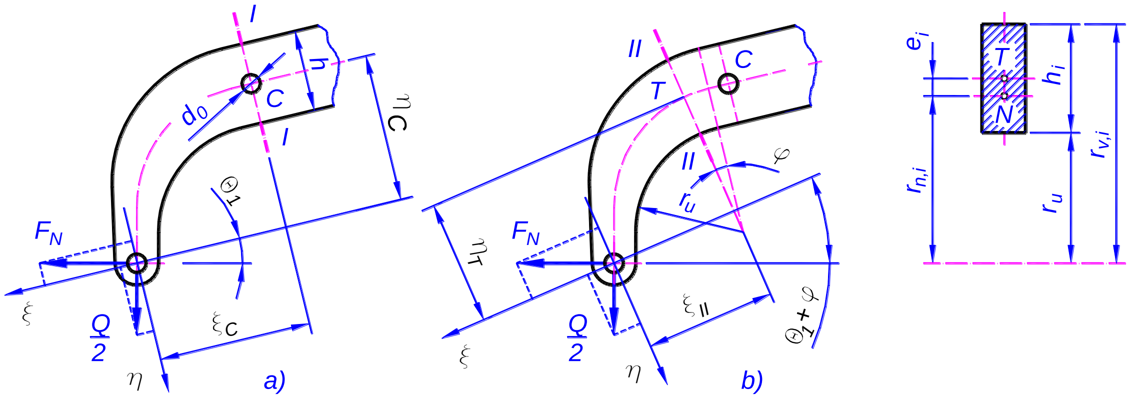

Figure 2. Dimensioning the lever curved part

For the optimal intersection dimensioning I-I it is assumed that the lever is a straight rod, eccentrically loaded. For the cost function a surface of the cross section is chosen:

$$F(t,h,d_0) = A_I = t(h - d_0) \qquad \text{... (2)}$$

The optimal cross section has to satisfy the following conditions:

$$\left.\begin{array}{l}\sigma_u = \sqrt{\sigma^2 + 3\tau^2} \le \sigma_d \\ \tau_s = \dfrac{2F_C}{{d_0}^2\,\pi} \le \tau_d \\ p = \dfrac{F_C}{t\,d_0} \le p_d\end{array}\right\} \qquad \text{... (3)}$$

where: *h, t* - levers width and thickness, d_0- hole diameter (screw tree), σ_u - comparative tension in intersection (by hypothesis of the largest work invested for shape changes), σ - tension in intersection (straight rod eccentrically loaded), τ - gliding tension, σ_d - allowed tension, τ_s - gliding tension in screw tree, τ_d - allowed tension on gliding for screws, F_C - tension on crank C, p - calculated pressure on the hole shell, p_d - allowed pressure on the hole shell.

While dimensioning the intersection II-II a calculation, according to the bending theory of curved rods, is required. For the cost function a surface of the cross section is chosen:

$$F(r_v) = A_{II} = t(r_v - r_u) \qquad \text{... (4)}$$

whereby the optimal intersection has to satisfy the following condition:

$$\sigma_u = \sqrt{\sigma^2 + 3\tau^2} \le \sigma_d \qquad \text{... (5)}$$

where: r_u, r_v - inner and outer radius of the curved rod, σ - tension in the rod's intersection (according to the bending theory of curved rods).

3. RESOLUTION METHOD

The mathematical model is solved using the nonlinear programming method SUMT (sequential unconstrained minimization technique), where cost functions (2) and (4), with restrictions (3) and (5) bearing in mind that $c_j(t,h,d_0) \ge 0$ and $c_j(r_v) \ge 0$, $j = 1,2,\ldots,m$, with introduction of penalty function are transformed into new function without limitations (6) and its minimum is calculated [3]:

$$\phi(t,h,d_0,r_v,r) = F(t,h,d_0,r_v) + r \cdot \sum_{j=1}^{m} \frac{1}{c_j(t,h,d_0,r_v)} \qquad \text{... (6)}$$

For solving this task a computer program in FORTRAN has been created.

4. FEM ANALYSIS OF THE TONGS

The hook tension analysis is done in Generative Structural Analysis module in CATIA V5 software, using the finite elements method. Real exploatation conditions were simulated while grabing the plate with 100mm width which weights 500kg. It is considered that tong parts are exposed to highest loads under such conditions, because the load weight is lowered by lowering the plates thickness. Otherwise, operating these devices would be much more dificult. From the presented results (Figure 3) can be seen that the highest tension from the inner side of the curved lever is $\le 122 MPa$ which is a insignificant deviation ($\cong 1{,}6\%$) from allowed tensions in expressions (3) and (5). The deviation can be a result of adapting the outer lever side to the technological requests of its production. On Figure 4 a intensity change of tension pressure allong the screw can be seen, as well that right next to gliding joints planes the tensions are increased (crank C). These are places of force transition from one element to another. From all presented a good results matching can be noticed between FEM analysis and data used while dimensioning lever intersections.

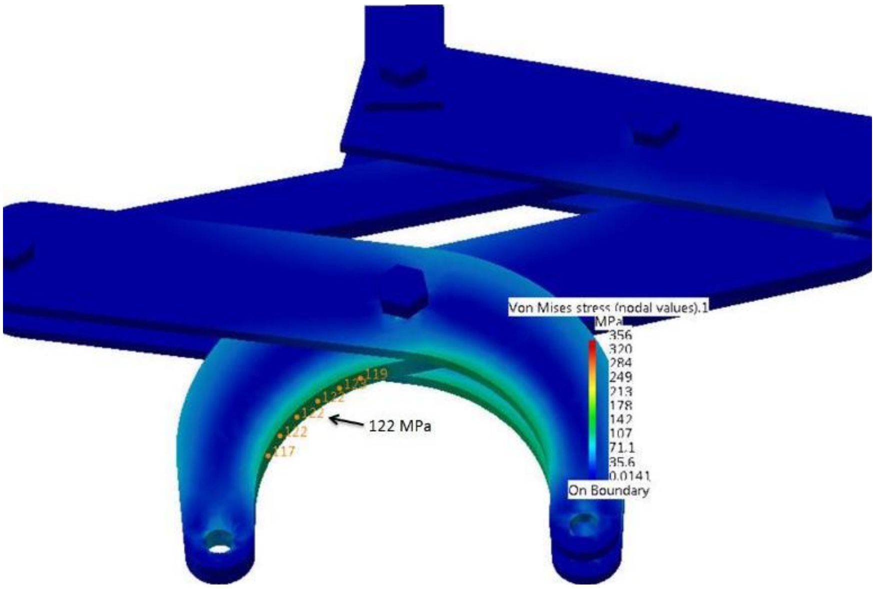

Figure 3. FEM analysis results

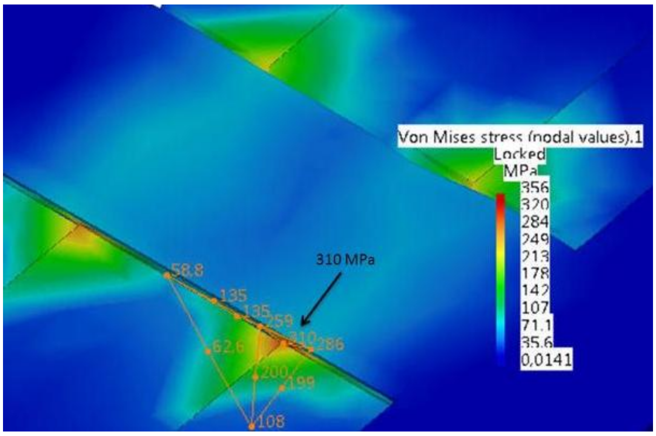

Figure 4. Tensions in C crank

5. CONCLUSION

In this paper a possible approach is given for solving design problems that can occur. While dimensioning critical lever intersections a given mathematical model is solved using nonlinear programing method SUMT, for which a computer program is created. A good results matching is noticed between FEM analysis and data used in the presented procedure. With this a verification between the computer program an presented procedure is made.

6. REFERENCES

[1] Ostric D., Tosic S.: Dizalice, Masinski fakultet, Centar za mehanizaciju, Beograd, 2005.,
[2] Parezanovic N., Kolar D.: Fortran 77, Naucna knjiga, Beograd, 1991.,
[3] Bandi B.: Metodi optimizacii-vvodnij kurs, Perevod s anglijskogo, Radio i svjaz, Moskva, 1988.