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Fillet Radius Optimization of Bell Crank Lever

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Abstract— Bell Crank Levers are used when it is necessary to change the direction of movement or force through 90˚. For analysis purpose virtual model is prepared by using data from design book. In this paper fillet optimization is carried out for reducing the maximum bending stress. Fillet is the region where localized stresses are maximum and is a measure of Stress Concentration Factor (SCF). Modeling, analysis and optimization is done using various workbenches in CATIA V5. Optimization is carried out using Simulated Annealing Algorithm in CATIA Product Engineering Optimizer workbench.

Keywords-Bell Crank Lever, fillet, CATIA V5, Product Engineering Optimizer, Simulated Annealing Algorithm, Stress Concentration Factor (SCF).

I. INTRODUCTION

The simple stress distribution no longer holds good when a machine component changes its shape. This irregularity in the stress distribution caused by abrupt changes of form is called stress concentration. Presence of fillets, notches, holes, keyways, splines, surface roughness, shoulders, etc on parts of structural members results in modifications of the simple stress distributions, so that localized high stress regions occurs. This localization of high stresses is known ay stress concentration and is measured by a factor known as the stress concentration factor (SCF).

Bell Crank Levers are used when it is necessary to change the direction of movement or force through 90˚. Arms of bell crank lever may be of rectangular, elliptical or I-section. A lever is a rigid rod or bar capable of turning about a fixed point called fulcrum. Bell-crank lever is used as a machine to lift a load by the application of a small effort. The ratio of the load lifted to the effort applied is called mechanical advantage.

Localization of stress mainly occurs at the fillet region of bell crank lever. And thus, stress concentration at the fillet region is a matter of concern for any designer. Optimum fillet can reduce the stress concentration. Optimization can be done by changing the fillet radius and analyzing the effects or by using algorithms to find the optimum geometry which will reduce the stresses. The stress concentration factor can be defined as the ratio of the peak stress in the body to some other stress taken as the reference stress (nominal stress). The stress concentration factor is a function of the geometry, and not of its size. Stress concentration factors can be calculated analytically from elasticity theory, computationally from finite element method, and experimentally through the usage of photo-elasticity or strain gauges.

In this paper, a model of bell crank lever is created and analysis is carried out using CATIA V5 workbench. Further this analyzed data was used to optimize the fillet using CATIA Product Engineering Optimizer workbench. Simulated Annealing Algorithm is used to optimize. Minimization case was used minimize the Von Mises Stress.

II. ANALYTICAL CALCULATIONS.

Length of lever in mm.(FB) = 210 mm ;
Load applied on the lever (W) = 100 N ;
Length of lever in mm (FA) = 70 mm ;
Tensile stress of lever, in N/mm2 (σt) = 75 M Pa = 75 N/mm2 ;
Shear stress of lever, in N/mm2 (fτ) = 60 Mpa = 60 N/mm2 ;
Calculate the effort (P) required to raise the load (W)100 N.
Taking moments about the fulcrum (F) W × 210 = P × 70 100 X 210 = P X 70
∴ P = 300 N
Stress concentration factor (Kt) = Maximum stress / Nominal Stress.

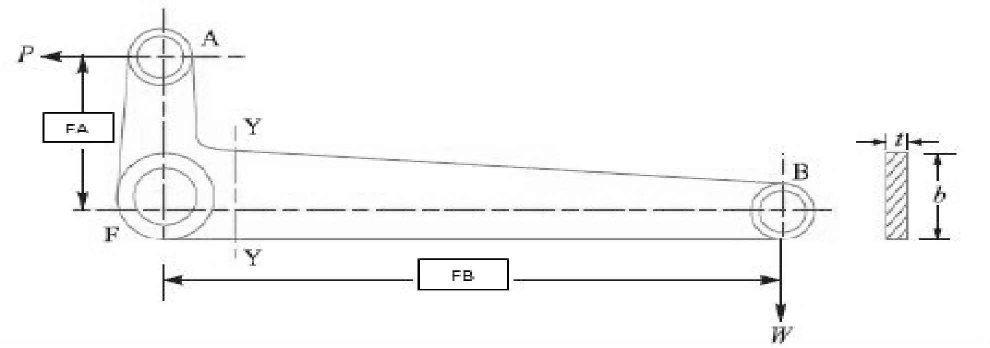


Figure 1. Bell Crank Lever

III. MODELING AND ANALYSIS OF BELL CRANK LEVER.

Modeling of bell crank lever was carried out in CATIA part design workbench and analysis was carried out in CATIA Generative Structural Analysis workbench. Load and supports were defined and computation was done to analyze the Von Mises Stresses and Translational Displacement. A Global sensor for Max. Von Mises Stresses and Mass were created which were used as input parameters for optimization.

Parabolic type of elements were to mesh the model with a mesh size of 14.263mm and
Absolute sag of 2.282mm. Stress concentration at the fillet was found to be maximum as shown in the figure 2. Material applied is Steel. Modulus of elasticity is taken as $2x10^5$ Mpa and Poisson's ratio (µ) as 0.30.

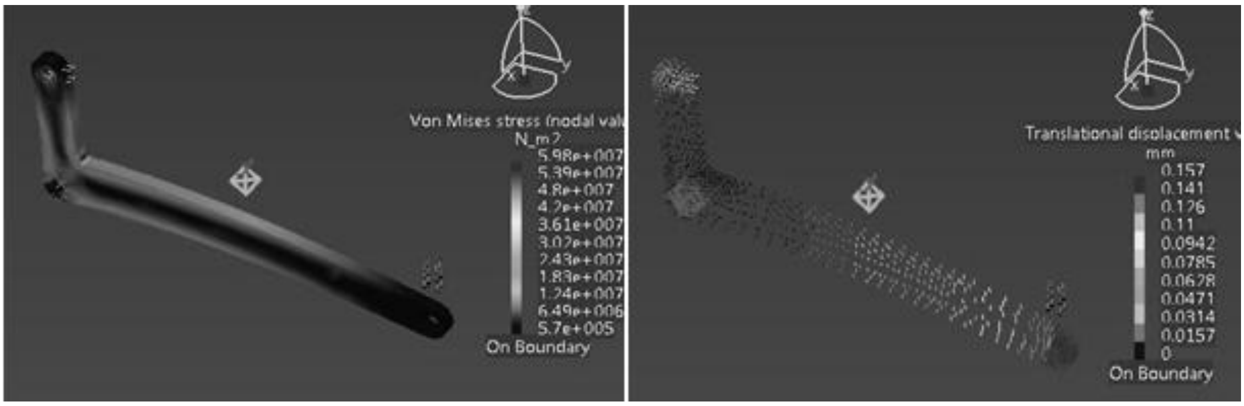


Figure 2. Original design with Max. Von Mises Stresses and Translational displacement

IV. OPTIMIZATION OF BELL CRANK LEVER.

Optimization of bell crank lever is carried out using CATIA Product Engineering Optimizer workbench. For optimization, the fillet is divided into four parts by using points. Parameters and relations are defined between each lengths and the model. These lengths are added as free parameters and a range is set for each length. The Global Maximum Von Mises Stress sensor is used as Minimization constraint. And finally, Simulated Annealing Algorithm is selected to carry out the optimization. 82 iteration were carried out to find the final optimal solution. As shown in the figure 7, difference between the original and the optimized model.

Free parameters:- Length1, Length2, Length3, Length4 (all are set with a range of 0.2mm to 50mm).

Algorithm type:- Simulated Annealing Algorithm.

Optimization parameter:- Von Mises stress.

Optimization type:- Minimization.

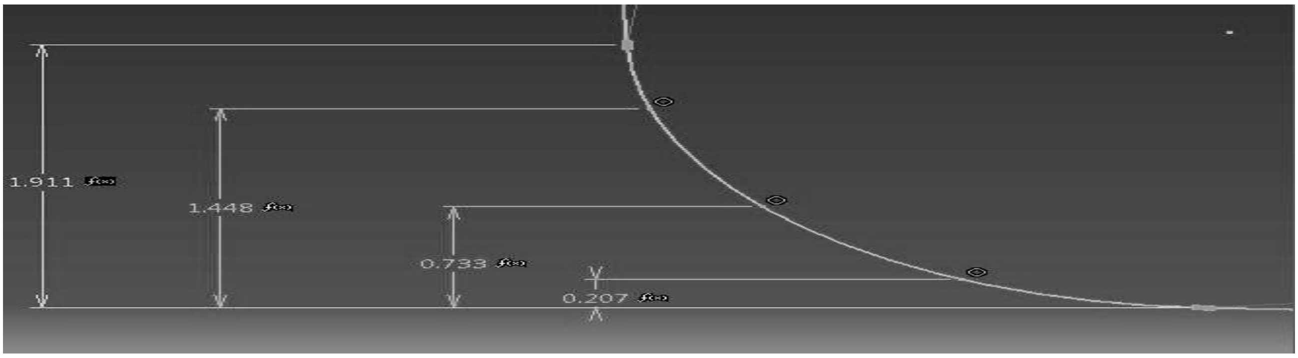
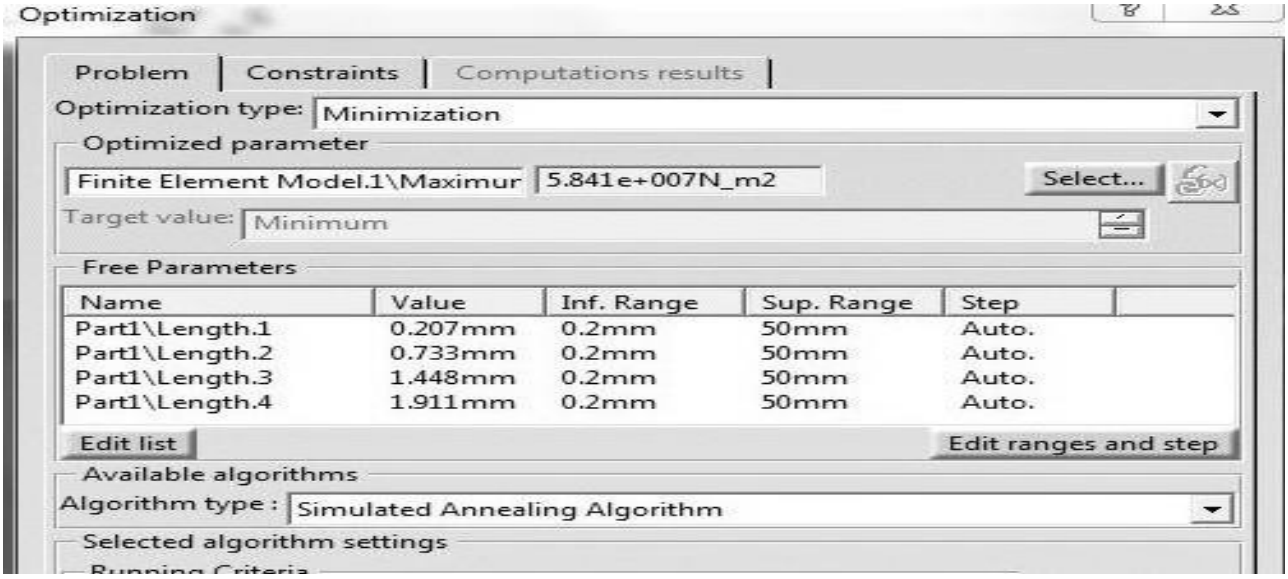


Figure 3. Defining free parameters (input parameters) to the existing fillet



'Nb Eval'	Best (N_m2)	Maximum Von Mises' (N_m2)	Length.1 (mm)	Length.2 (mm)	Length.3 (mm)	Length.4 (mm)
0	5.84E+07	5.84E+07	0.207	0.733	1.448	1.911
1	5.84E+07	8.61E+07	0.2	0.2	0.2	0.697225491
2	5.84E+07	5.97E+07	2.103779641	0.652989974	1.080482655	1.699610705
3	4.41E+07	4.41E+07	4.769071137	1.287175938	2.313158372	3.102950006
4	3.95E+07	3.95E+07	8.500479233	2.175036287	4.038904376	5.067625027
5	3.18E+07	3.18E+07	13.72445057	3.418040777	6.454948781	7.818170056
80	2.05E+07	2.05E+07	50	49.86437006	48.17429371	48.30017492
81	2.05E+07	2.06E+07	50	49.67674073	48.06062776	48.34334091
81	2.05E+07	8.74E+07	0.2	0.2	0.2	0.697225491
82	2.05E+07	2.05E+07	50	50	48.21084939	48.32444646

Figure 4. Defining input and output parameters in Product Engineering Optimizer and optimized results

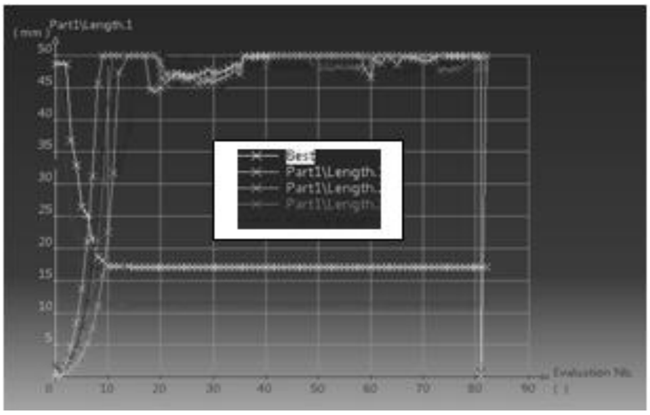


Figure 5. Change in Length(mm) with with respect to iterations"

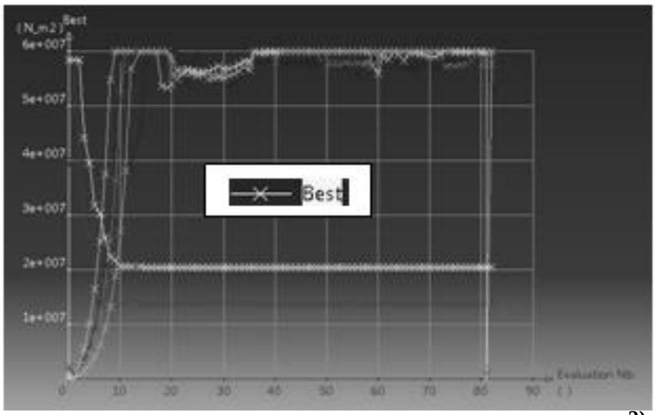


Figure 6. Reduction in stress (N_m²) respect to iterations"

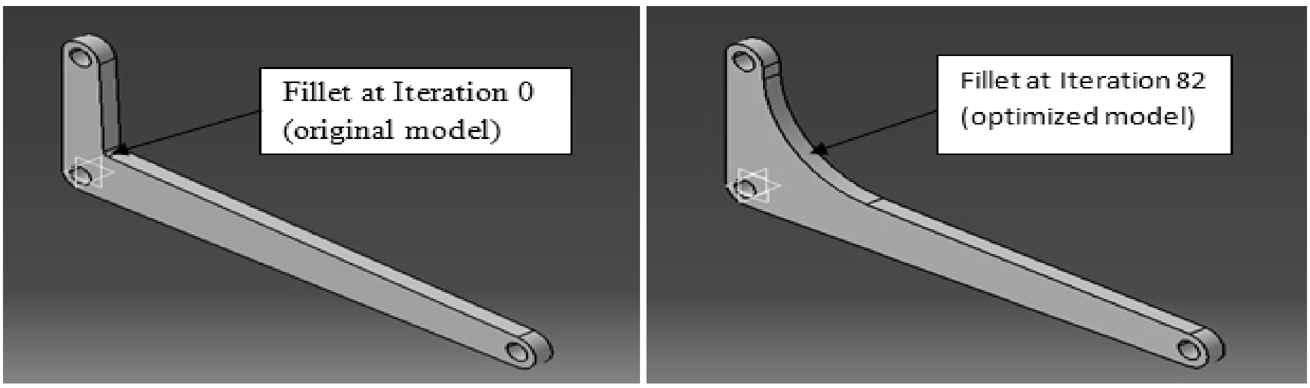


Figure 7. Original and optimized model of bell crank lever

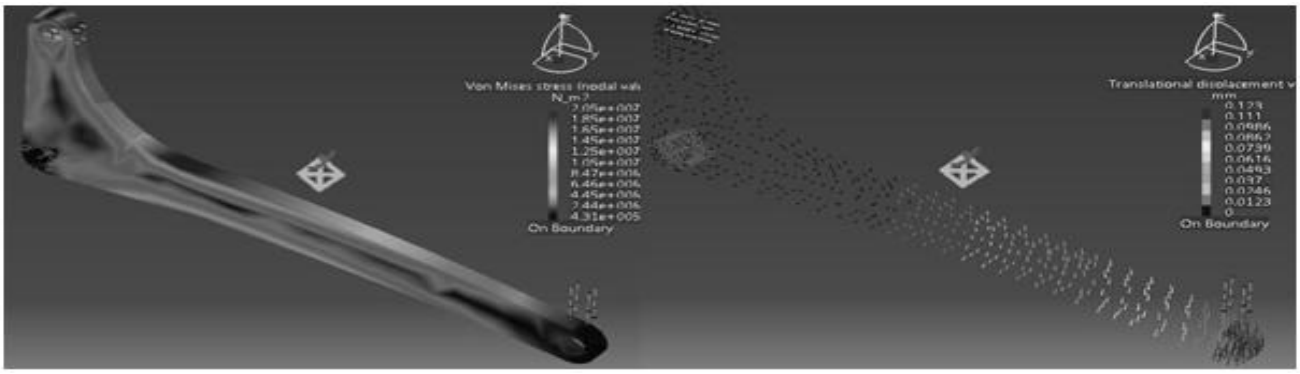


Figure 8. Iteration number 82 with Optimal Max. Von Mises Stress and Translational Deformation

V. RESULTS

Table 2. Effect of change in fillet at different iterations

Iteration number	Von Mises Stress (N_m^2)	Translational Displacement (mm)	Mass (kg)	Radius(mm)
0 (original)	5.98e+007	0.157	0.377	2
6	3.04e+007	0.152	0.378	12.213
8	2.24e+007	0.143	0.384	25.755
82(most optimal)	2.05e+007	0.123	0.405	50.579

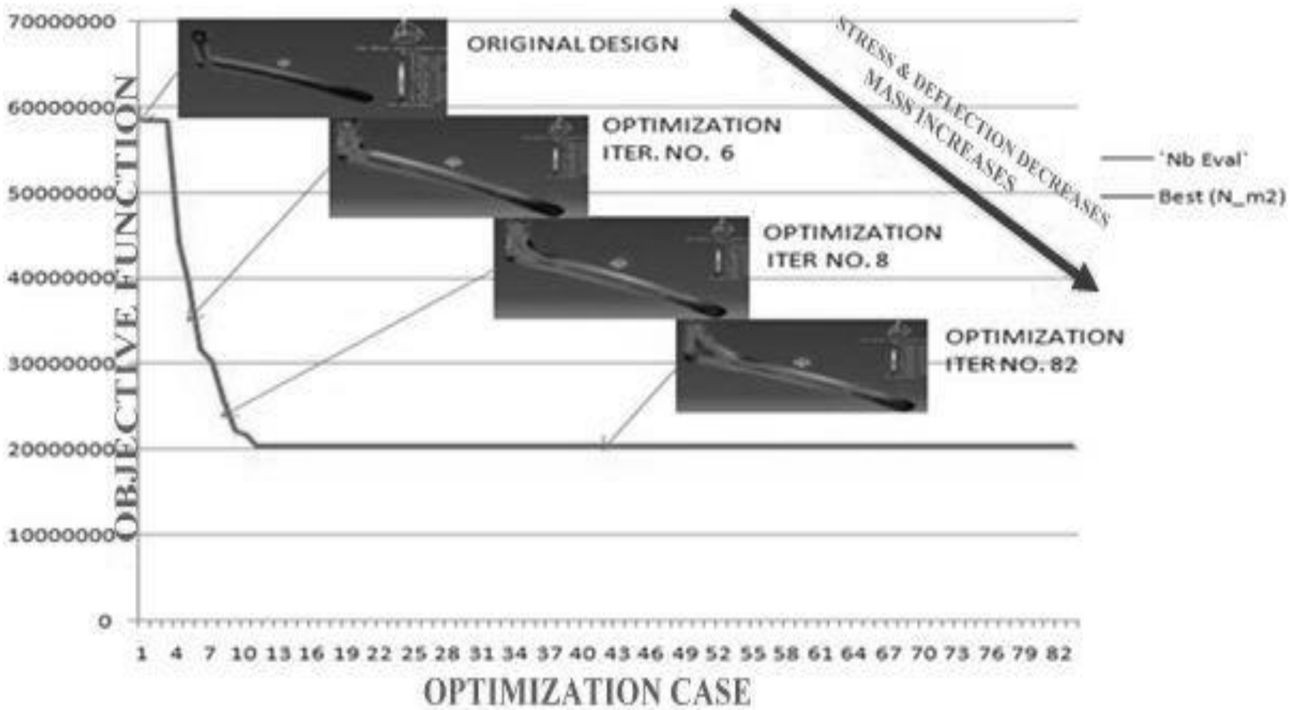


Figure 9. Effect of change in fillet on stress, translational deformation and mass

VI. CONCLUSION

Structural optimization is defined as an automated synthesis of a mechanical component based on structural properties, or as a method that automatically generates a mechanical component design that exhibits optimal structural performance. Iteration 15 to 82 shows a constant optimal value as shown in figure 9. The optimized model shows a reduced Von Mises stress of 2.05E+007 and a translational deformation.

But using the most optimum solution is not always feasible as the mass increases with the increase in fillet radius. As shown in the table, as the iterations increase the Von Mises stress value decreases, translational deformation decreases but mass increases. Moreover, there may be space limitations. Thus, considering all these constraints one must select the feasible optimum iteration. A scope to use the most optimal solution (i.e. iteration 82) can be to further carry out topology optimization.

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REFERENCES

[1] Nenad Marjanovic, Biserka Isailovic, Mirko Blagojevic, Structural Optimization in CAD Software, ADEKO, ISSN 1821-1259, 2009.
[2] Mr. M. M. Dange Prof. S. R. Zaveri Prof.S.D.Khamankar Stress Analysis of Bell Crank Lever, International Journal on Recent and Innovation Trends in Computing and Communication, Volume: 2 Issue: 8, 2014.
[3] Narendra Komarla, Optimization of Shoulder Fillet Specimen using CATIA V5, Bergische Universitat Wuppertal.
[4] Narendra Komarla, Product Engineering Optimization Using CATIA V5, Bergische Universitat Wuppertal.
[5] R. C. Patel, S.S. Sikh, H.G. Rajput (1992-93), Machine Design.
[6] R. S. Khurmi, J. K. Gupta (1979), Machine Design.