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STRESS ANALYSIS OF BELL CRANK LEVER

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ABSTRACT

Bell Crank Lever is important components from safety point of view since they are subjected to large amount of stresses. Hence to study the stress pattern in bell crank lever; analytical and numerical methods are used. For analysis purpose virtual model of bell crank lever is prepared by picking data from design data book. Bending stresses in lever formula is used for determination of stresses in bell crank lever analytically. For numerical analysis bell crank lever is prepared using ANSYS and this model of bell crank lever in ANSYS where stress analysis is done by FEM. Finite Element Analysis have been performed on various models of varying fillet radius, optimization for volume and reduction of materials form bell crank lever. Also for bell crank lever stress analysis is done by using method of FEM. From the output of these analyses it is observed that results obtained are in close agreement with each other and maximum failures stress concentration occurs at maximum bending surface. Comparison between numerical and FEM are observed that results obtained are in close agreement with each other.

Keywords*: bell crank lever, bending Stresses in lever, FEA.*

I. INTRODUCTION

The most important task before design engineer is to maintain the working stresses within predetermined specific limits, in order to avoid the failure of a member. To improve the product quality, it is necessary to determine the stresses in various components. It is also necessary to know the stress distribution in order to predict the failure of component.

Bell crank lever is used to reduce a load by applying of a small effort. Bell crank lever is used in the machine to lift a load by the application of a small effort. In a bell crank lever load (W) and force (P) acts at right angles. The cross-section of the lever is obtained by considering the lever in bending. It is assumed that the lever arm extends up to the centre of the fulcrum from the point of application of load. This assumption results in a slightly stronger lever, the weakest section of failure at Y-Y. The bell crank lever is used in many applications, such as the Hartnell governor. The two arms of the lever are at right angles to each other to lift a load *W* or to resist a force P .

II. PROBLEM, SCOPE AND METHODOLOGY

The objectives of the project include modelling and analysis of bell crank lever using software packages. Also analytical calculation of the induced stresses and comparing them with results obtained through software. So that we can suggest best method for analysis and best cross section for the bell crank lever.

The objectives of this study is to

- Analysis the bell crank lever using finite element method.
- Determine stresses of bell crank lever analytical.
- Determine maximum bending stress occur on bell Crank lever.

METHODOLOGY

The stress analysis of bell crank lever is carried out as follows:

- The models of bell crank lever are prepared using ANSYS software.
- Stress analysis of bell crank lever is carried out by Finite Element Method using ANSYS.
- Results are verified analytically and compared with FEA analysis.

In this project work stress analyses of bell crank lever with varying fillet radius, optimization of volume, reducing materials of bell crank lever and for the safe working load 100N. Properties of material used for bell crank lever are given in Table 1.1.

Table1. Properties of material SAE 1030

Property	**Symbol**	**Value**
Modulus of Elasticity	E	2×10^5 MPa
Poisson's ratio	μ	0.30

III. ANALYTICAL ESTIMATION OF STRESSES

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/mm^2

Shear stress of lever, in N/mm2 ($f\tau$) = 60 Mpa

= 60 N/mm^2 ;

Calculate the effort (P) required to raise the load (W)100 N.

Taking moments about the fulcrum (F)

$W \times 210 = P \times 70$

$100 X 210 = P X 70$

$\therefore P = 300$ N

Reaction at the fulcrum at F,

$RF =(W^2 + P^2)$

$=316.22$ N

1. Design for fulcrum

Let d = Diameter of the fulcrum.

And l = Length of the fulcrum.

The bending stress induced in the lever arm at the fulcrum.

M = W × FB

= 100× 210

= 21000 N-mm

Section modulus (Z)

$Z = 1/6 \times t \times b^2$

$= 1/6 \times 6 \times 18^2$

$= 324\ mm^3$

∴Bending stress,

fb =M/Z

=21000/324

$= 64.81\ N/mm^2$

2. Stress on effort arm

Let t = Thickness of the lever.

b = Width or depth of the lever .

Maximum bending moment at X-X,

= 100 (210 – 18)

= 19200 N-mm

and Section modulus,

$Z = (t \times b^2)/6$

$= t(3t \times t)/6 = 1.5\ t^3$ …(Assuming b = 3 t)

We know that the bending stress (fb),

Fb =M/Z

=19200/324

$= 59.25\ N/mm^2$

3. Stress on load arm

Let *t* = Thickness of the lever and

b = Width or depth of the lever.

Taking distance from the centre of the fulcrum at 18 mm,

Therefore maximum bending moment

= 300(70 – 18)

= 15600 N-mm

and Section modulus,

$Z = (t*b^2)/6$

$= t*(3t* t)/6 = 1.5\, t^3$ (Assume $b = 3\,t$)

We know that the bending stress (f*b*),

Fb =M/Z

=*15600/324*

= *48.14 N/mm*^{2}

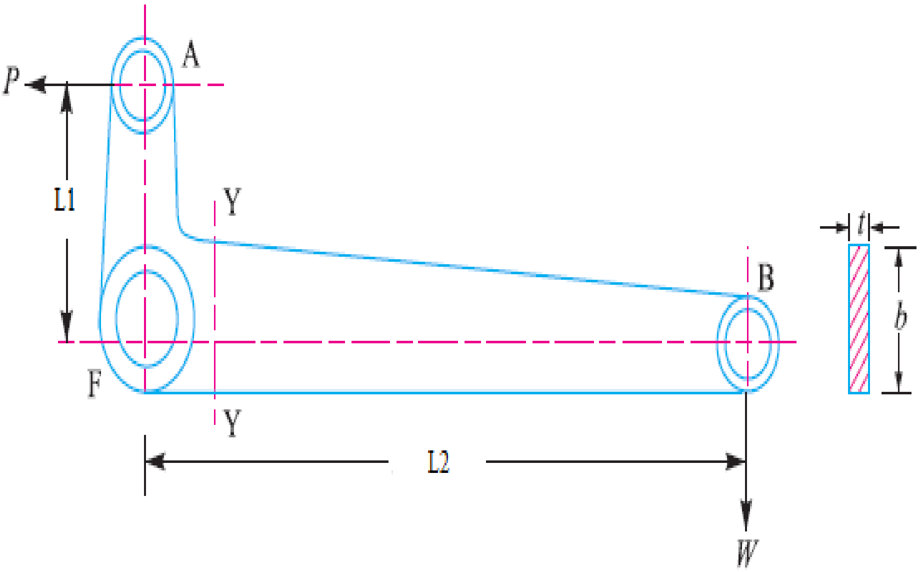

Fig.1- Bell Crank Lever.

Table 2 - Analytical Calculation for Volume Optimization of Bell Crank Lever.

4 Preparation of ANSYS Model of bell crank lever

A model of a bell crank lever is prepared by using ANSYS software as per the dimensions. Some features are approximated for simplification ANSYS software is used for creating solid model of bell crank lever. Complete Solid ANSYS model is prepared which is shown in fig. 2 similarly for all required cross section solid ANSYS model is generated.

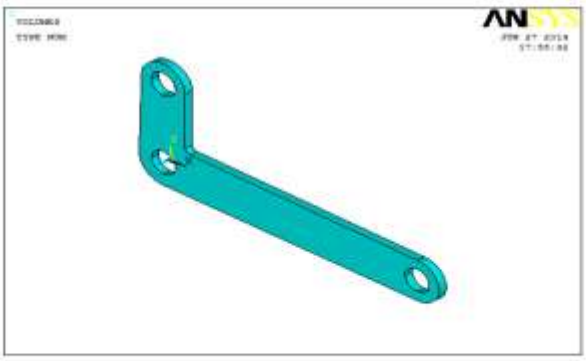

Fig.2-ANSYS Model of Bell Crank Lever.

3.5 Stress Analysis Using FEM

The solid bell crank lever model is prepared in ANSYS for FEA. A structural 20 node Tetrahedral Solid 186 element is selected for creating FE model of the bell crank lever. Material properties as shown in table 1 are assigned and model is meshed using free meshing and smart size option. The FE model created is shown in fig.3.

Fig.3- Finite Element Model of Bell Crank Lever

For imposing boundary condition all degrees of freedom are restricted at the top end of load arm and the force of 100 N is applied on effort arm of nodes at lower centre of arm in downward direction. Then model is submitted to the ANSYS solver where it is solved. This is called as solution phase. Then results are presented by general post processor in graphical as well as table format. The pattern of first principal stress distribution in bell crank lever is shown in figure 4.

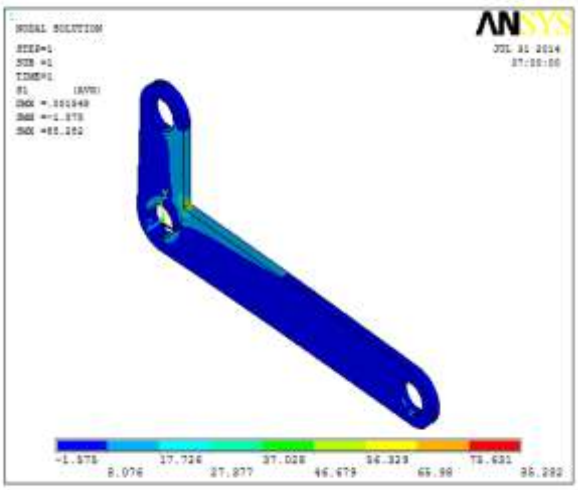

Fig. 4 - 1st Principal Stress of Bell Crank Lever with

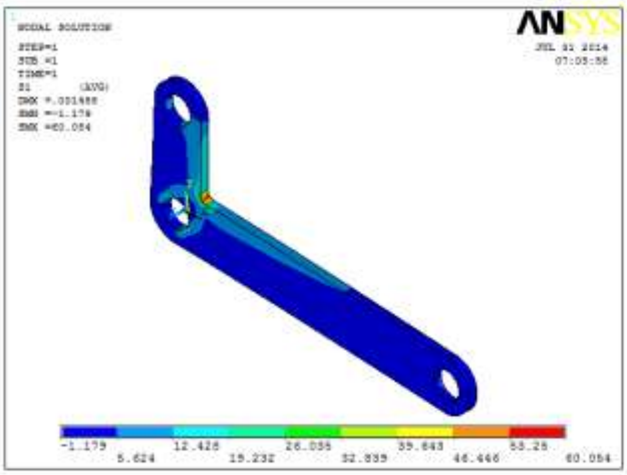

Fig. 5.- 1st Principal Stress of Bell Crank Lever with Fillet Radius 4 mm.

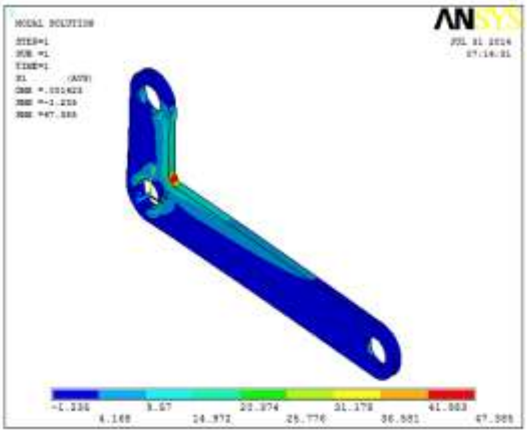

Fig. 6 - 1st Principal Stress of Bell Crank Lever with Fillet Radius 6 mm.

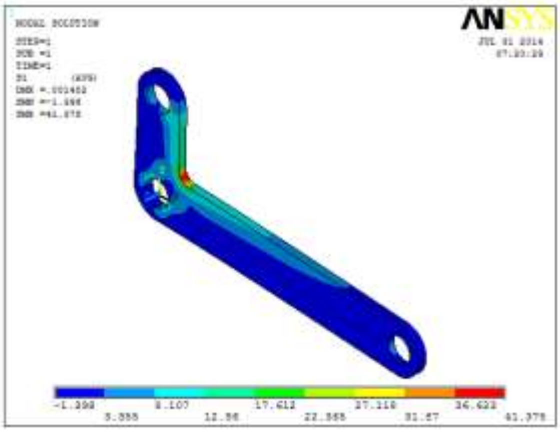

Fig. 7 - 1st Principal Stress of Bell Crank Lever with Fillet Radius 8 mm.

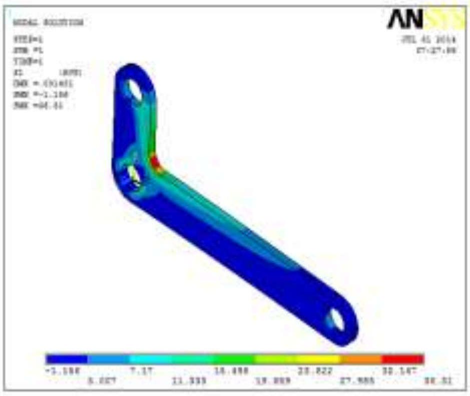

Fig. 8 - 1st Principal Stress of Bell Crank Lever with Fillet Radius 10 mm.

Table No.4- **1st Principal Stress of Bell Crank Lever with Varying Fillet Radius.**

Sr. No.	Fillet Radius(mm)	Max. FE Stress (MPa)	Corresponding Fig.
1	2	85.28	Fig.4
2	4	60.05	Fig.5
3	6	47.38	Fig.6
4	8	41.37	Fig.7
5	10	36.31	Fig.8

CASE-II

FEM STRESS ANALYSIS FOR VOLUME OPTIMAZATION OF BELL CRANK LEVER.

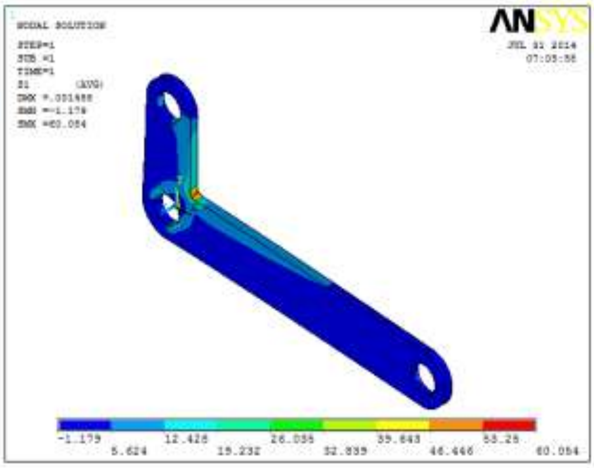

Fig. 9 - 1st Principal Stress Optimization Volume of Bell Crank Lever.

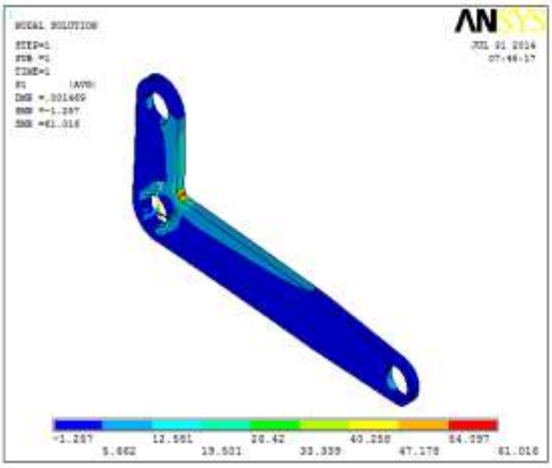

Fig. 10 - 1st Principal Stress Optimization for Volume of Bell Crank Lever.

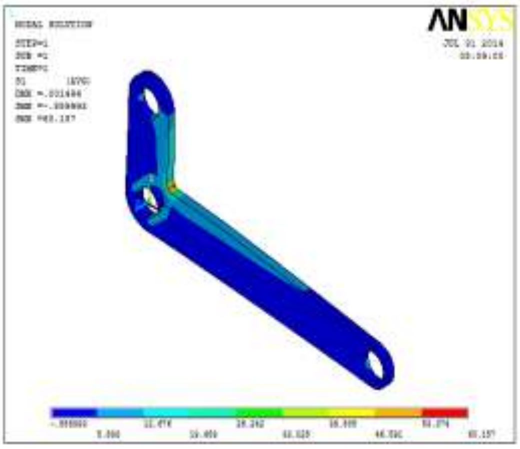

Fig.11- 1st Principal Stress Optimization for Volume of Bell Crank Lever.

Table No. 5 - 1st Principal Stress Optimization for Volume of Bell Crank Lever.

Sr. No.	Volume Optimazation	Max. FE Stress (MPa)	Corresponding Fig.
1	SHAPE 1	60.05	Fig.9
2	SHAPE 2	61.01	Fig.10
3	SHAPE 3	60.15	Fig.11

CASE –III

FEM Stress Analysis of Increasing Number of Holes in Bell Crank Lever.

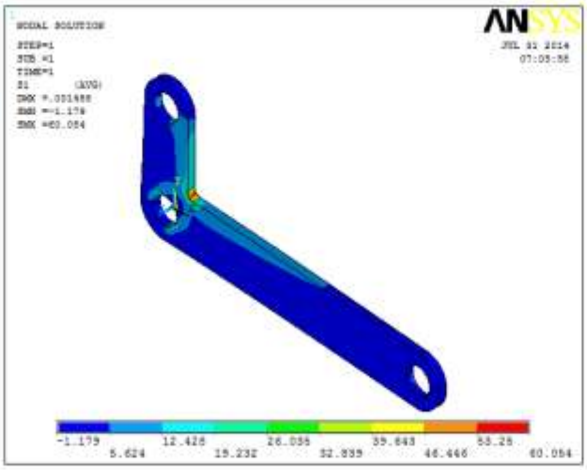

Fig. 12- 1st Principal Stresses of Bell Crank Lever.

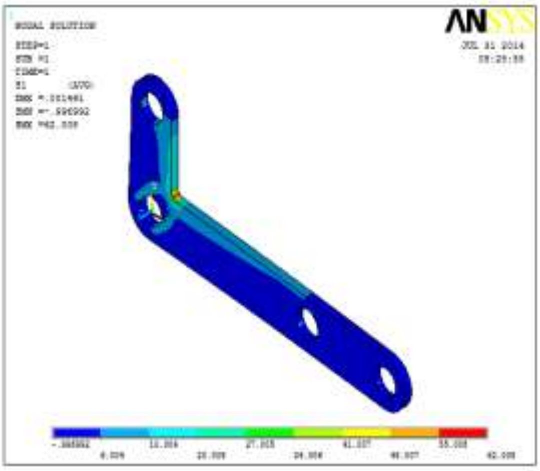

Fig. 13 - 1st Principal Stresses of Bell Crank Lever Increasing 1 Hole.

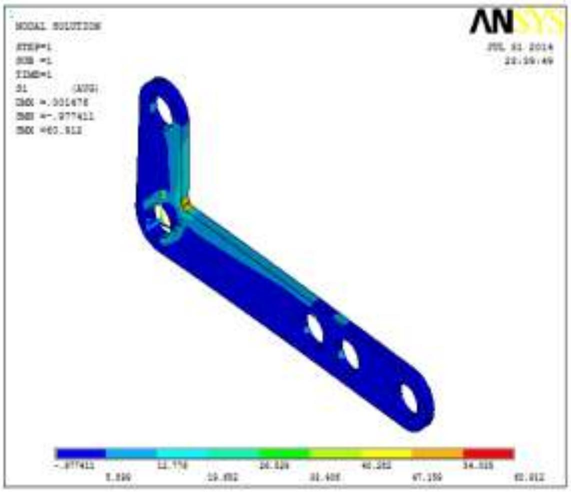

Fig. 14 - 1st Principal Stresses of Bell Crank Lever Increasing 2 Holes.

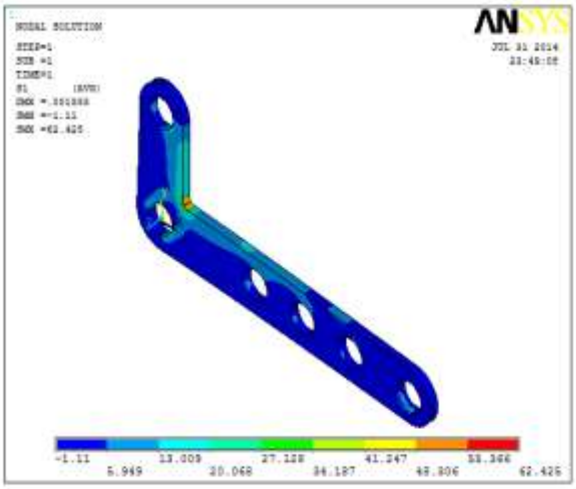

Fig. 15- 1st Principal Stresses of Bell Crank Lever Increasing 3 Holes.

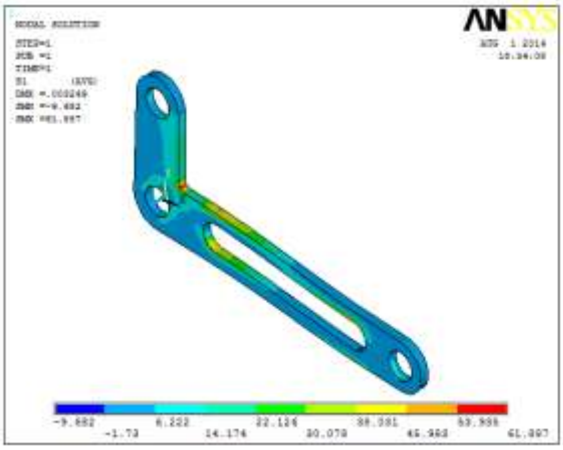

Fig. 16 - 1st Principal Stresses of Bell Crank Lever Removing Material.

Table No. 6 - 1st Principal Stresses Increasing number of Holes.

Sr. No.	Max. FE Stress (MPa)	Corresponding Fig.
1	60.05	Fig.12
2	62.00	Fig.13
3	60.91	Fig.14
4	62.42	Fig.15
5	61.88	Fig.16

IV. RESULT, DISCUSSIONS AND CONCLUSIONS

Table No.7- 1st Principal Stress of Bell Crank Lever of Varying Fillet Radius.

Sr. No.	Fillet Radius(mm)	Max. FE Stress (MPa)	Corresponding Fig.
1	2	85.28	Fig.4
2	4	60.05	Fig.5
3	6	47.38	Fig.6
4	8	41.37	Fig.7
5	10	36.31	Fig.8

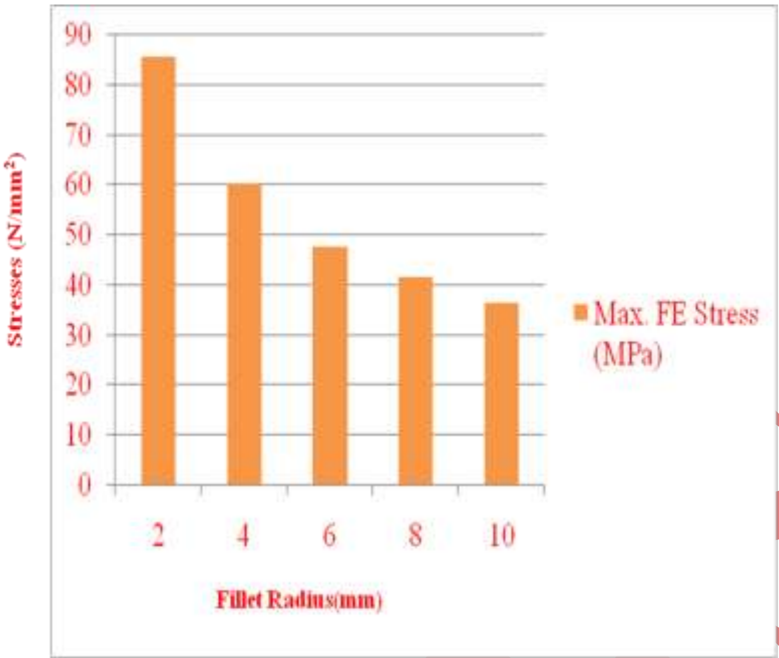

Fig.17- Max. Stresses of Varying Fillet Radius.

Table No.8- FEM Stress Analysis for Optimization of Volume of Bell Crank Lever.

Sr.No.	Volume Optimisat-ion	Analyti-cal Stresses	Max. FE Stresses	% Error
1	Fig.9	59.25	60.05	1.33
2	Fig.10	64.18	61.01	4.93
3	Fig.11	62.86	60.15	4.31

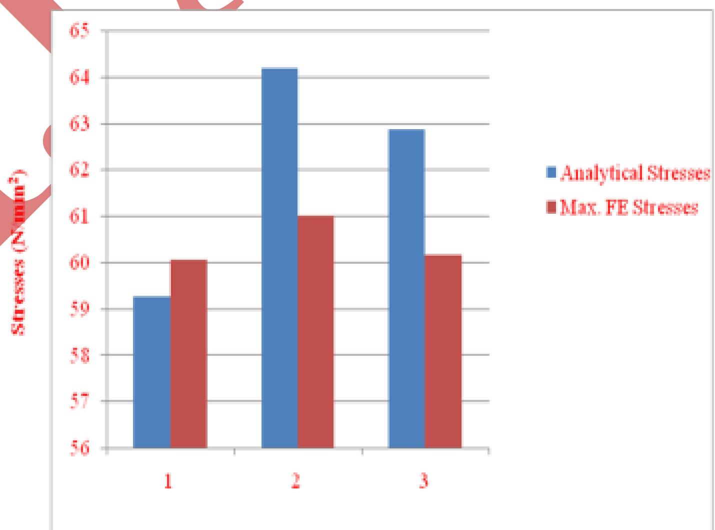

Fig.18-FEM Stress Analysis of volume Optimization

Table No.9-FEM Stress Analysis of removing Number of Holes in Bell Crank Lever.

Sr. No.	Analytical Stresses	Max. FE stresses	Fig. No.
1	59.25	60.05	Fig.12
2	61.58	62.00	Fig.13
3	64.11	60.91	Fig.14
4	66.84	62.42	Fig.15
5	69.63	61.88	Fig.16

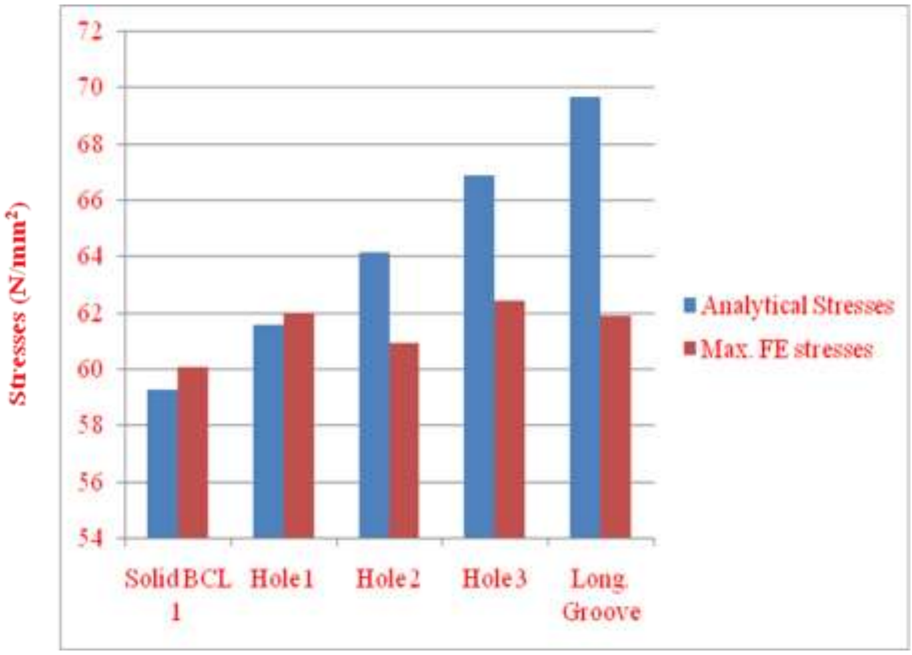

Fig.19- FEM Stress Analysis of Increasing Number of Holes.

V. CONCLUSION

From the above results it is concluded that the maximum stress evaluated in bell crank lever by increasing fillet radius at critical position than decrease maximum bending stresses as shown in fig. 5.3, 5.4, 5.5, 5.6 and 5.7.

For the optimization of volume of bell crank lever volume is reduced by changing the shape of effort arm as shown in fig. 5.8, 5.9, 5.10 as well as increasing the number of holes as shown in fig. 5.11, 5.12, 5.13, 5.14 and 5.15 in effort arm it is observed that though the volume is reduce the maximum principal stresses at the corner of bell crank lever remains nearly constant and it is found to be equal to that of stresses in original model of bell crank lever.

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