

An Efficient Product using Modeling, Simulation and Optimization

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Abstract—Analysis is relatively new method for simulating real world situations and finding their feasibility in actual use. Modeling and simulation is taught and explained with bell crank lever as an example. In the modern day to day applications like automobiles, trusses, and other structural components play a major role. So it's very important to study their deformations under loads in order to understand their behavior and possible conditions of failure. The geometry was modelled in Solidworks 2016. Analytical evaluations were performed with the commercial, general-purpose finite element software Solidworks Simulation.

Index Terms— Analysis, Bell Crank Lever, Modelling, Optimization, Simulation, Solidworks

1 INTRODUCTION

THERE is a worldwide trend to use more computer simulation during the development phase, in order to improve structural behavior, and decrease the time and costs. Accurate finite element model must be generated in order to predict the system structural behavior and to allow fast optimization processes. In the modern day to day applications like automobiles, trusses, and other structural components mechanical joints play a major role. So it's very important to study their deformations under loads in order to understand their behavior and possible conditions of failure.

1.1 Objectives

- To learn modeling and analysis.
- To model a bell crank lever
- To analyze strength of the modelled bell crank lever using Finite Element Analysis.
- To analyze stresses developed in lever during static loading.
- To optimize the prepared model.
- To compare results with classical methods.

2 MODELING

In 3D computer graphics, 3D modeling (or three-dimensional modeling) is the process of developing a mathematical representation of any three-dimensional surface of an object (either inanimate or living) via specialized software. The product is called a 3D model. It can be displayed as a two-dimensional image through a process called 3D rendering or used in a computer simulation of physical phenomena.

The model can also be physically created using 3D printing devices. Models may be created automatically or manually. The manual modeling process of preparing geometric data for

3D computer graphics is similar to plastic arts such as sculpting.

Three-dimensional (3D) models represent a physical body using a collection of points in 3D space, connected by various geometric entities such as triangles, lines, curved surfaces, etc. Being a collection of data (points and other information), 3D models can be created by hand, algorithmically (procedural modeling), or scanned. Their surfaces may be further defined with texture mapping.

2.1 Comparison with 2D methods

3D photorealistic effects are often achieved without wireframe modeling and are sometimes indistinguishable in the final form.

Advantages of wireframe 3D modeling over exclusively 2D methods include:

- Flexibility-ability to change angles or animate images with quicker rendering of the changes;
- Ease of rendering, automatic calculation and rendering photorealistic effects rather than mentally visualizing or estimating;
- Accurate photorealism, less chance of human error in misplacing, overdoing, or forgetting to include a visual effect.

Disadvantages compare to 2D:

- Photorealistic rendering may include a software learning curve
- Difficulty achieving certain photorealistic effects.

For the best of both worlds, some artists use a combination of 3D modeling followed by editing the 2D computer-rendered images from the 3D model.

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2.2 How to model?

From conceptualization to execution, from drawing to production, there's just one single largest force that drives the designer which is the idea. To model any object, the basics of orthographic views and isometry should be known to a designer. Introducing newer and innovative products, continuously improving upon the existing ones can be greatly achieved by modeling.

A list of notable 3D modeling software, computer programs are used for developing a mathematical representation of any three-dimensional surface of objects. A few frequently used one's are:

- ❖ AutoCAD
- ❖ SolidEdge
- ❖ Catia
- ❖ ProE
- ❖ Unigraphics

The most basic features used for 3D modeling in these software are extrude, sweep, revolve and loft etc. These features are briefly explained as below:

1) Extrude:

Shape (a material such as metal or plastic) by forcing it out and giving it a property of being a 3D object from a simple 2D draft.

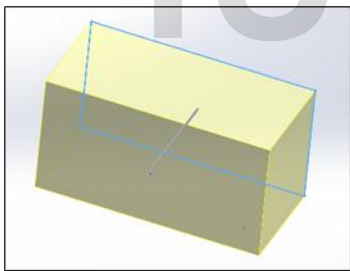


Figure 1: Extruded object in Solid Works

2) Sweep:

A long, swift curving movement following a well-defined path that would join two different profiles and cross sections and make them into a single 3D object.

3) Revolve:

Move in a circle about a central axis. Half of the sketch is created and moved in a circular pattern with reference to the central line.

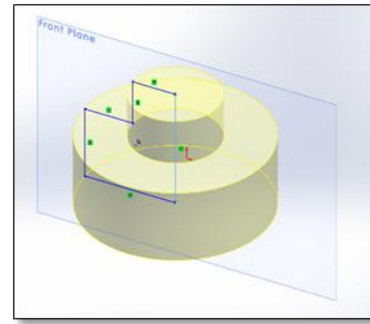


Figure 2: Revolved object in SolidWorks

3 SIMULATION AND ANALYSIS

Simulation is the imitation of a situation or process and the production of a computer model of something, especially for the purpose of study of any part. Simulation is used before an existing system is altered or a new system built, to reduce the chances of failure to meet specifications, to eliminate unforeseen bottlenecks, to prevent under or over-utilization of resources, and to optimize system performance

Analysis is a detailed examination of the elements or structure of a part. The use of numerical methods to simulate the behavior of engineered systems during operations and accidents brings major benefits in understanding, which is essential to decision makers. Complex situations involving statics, dynamics, non-linearity, laminar flows, turbulence, thermal effects, shocks and impacts can be better understood through the use of analysis software in the hands of highly experienced practitioners

3.1 Types of Simulation and Analysis

Simulation on any model is categorized upon the kind of analysis to be carried on the part, these are categorized as:

- a) Static/Structural Analysis
- b) Thermal Analysis
- c) Frequency Analysis
- d) Buckling Analysis
- e) Drop Test
- f) Fatigue Analysis
- g) Pressure vessel design Analysis
- h) Nonlinear Analysis
- i) Motion Analysis

Figure shows a schematic of a simulation study. The iterative nature of the process is indicated by the system under study becoming the altered system which then becomes the system under study and the cycle repeats. In a simulation study, human decision making is required at all stages, namely, model development, experiment design, output analysis, conclusion formulation, and making decisions to alter the system under study. The only stage where human intervention is not required is the running of the simulations,

which most simulation software packages perform efficiently. The important point is that powerful simulation software is merely a hygiene factor - its absence can hurt a simulation study but its presence will not ensure success. Experienced problem formulators and simulation modelers and analysts are indispensable for a successful simulation study.

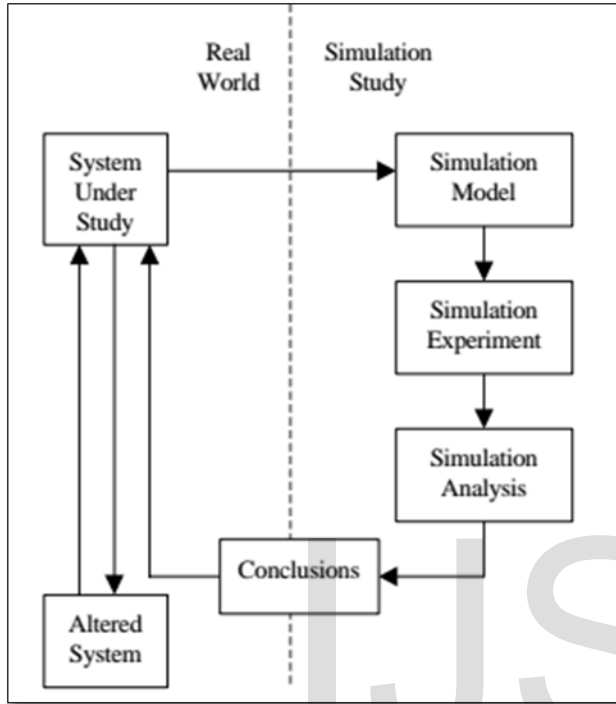


Figure 3: Simulation Study

4 STUDY OF A BELL CRANK LEVER-DESIGN, MODELING AND ANALYSIS.

4.1 Design of the Lever:

Let us consider a bell crank lever of the following dimensions:

- Length of longer arm of lever in mm = 500 mm;
- Length of shorter arm of lever in mm = 150 mm;

The bell crank lever has the following load and stress details:

- Load applied on the lever (W) = 4500 N;
- Tensile stress of lever, in N/mm² (ft) = 75 N/mm²;
- Shear stress of lever, in N/mm² (ft) = 60 N/mm²;
- Bearing strength (P_b)= 10 N/mm²

STEP 1: In order to calculate the effort (P) required to raise the load of 4500N.

Taking moments about the fulcrum (F)

$$W \times 210 = P \times 70$$

$$4500 \times 210 = P \times 70$$

$$\therefore P = 15000 \text{ N}$$

Reaction at the fulcrum at F,

$$R_F = \sqrt{(W^2 + P^2)} = 15660.46 \text{ N}$$

STEP 2: Design of fulcrum pin

Let d_f= Diameter of the fulcrum pin

L_f=length of fulcrum pin

$$R_f = P_b \times d_f \times l_f \quad (l_f = 1.25 d_f)$$

$$\therefore R_f = P_b \times 1.25 d_f^2$$

d_f = 36mm

l_f = 45mm

STEP 3: Design of Load pin

Let d_w= Diameter of the load pin

L_w=length of load pin

$$R_w = P_b \times d_w \times l_w \quad (l_w = 1.25 d_w)$$

$$R_w = P_b \times 1.25 d_w^2$$

d_w = 20mm

l_w = 25mm

STEP 4: Design of effort pin

Let d_p= Diameter of the effort pin

L_p=length of effort pin

$$R_p = P_b \times d_p \times l_p \quad (l_p = 1.25 d_p)$$

$$R_p = P_b \times 1.25 d_p^2$$

d_p = 35mm

l_p = 44mm

4.2 Modeling of the lever in Solid Works

STEP 1: Prepare to Sketch according to the calculated dimensions.

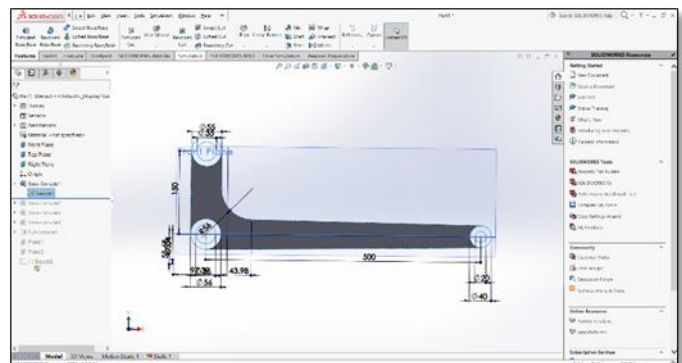


Figure 4: Sketch as per calculated dimensions.

STEP 2: Complete the Body by Extruding.

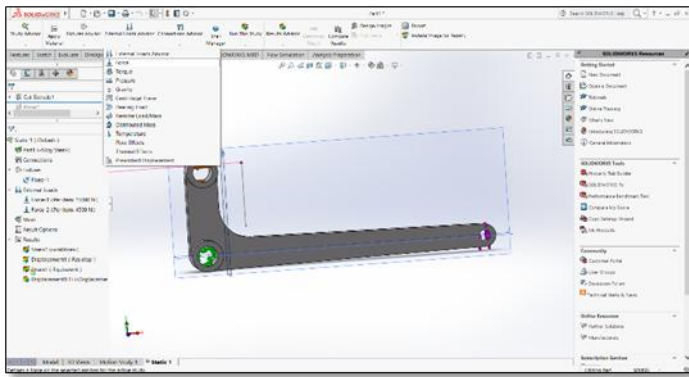


Figure 5: Extruded model.

- 4) Apply the Mesh (Better refinement of the mesh gives us more accurate results)

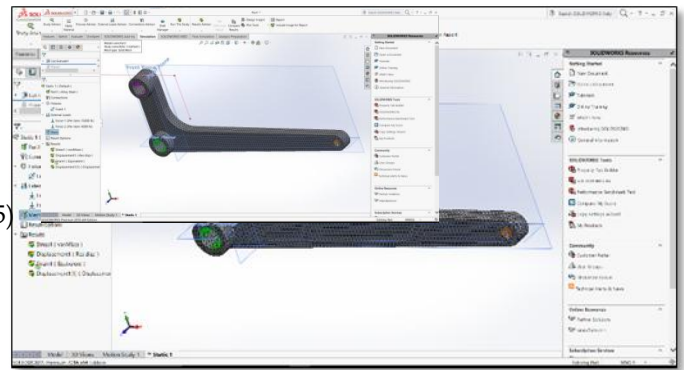
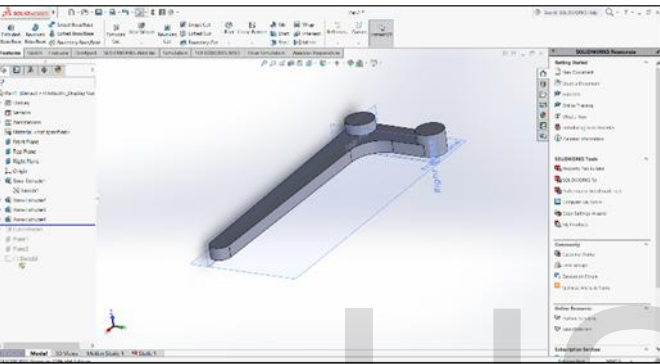
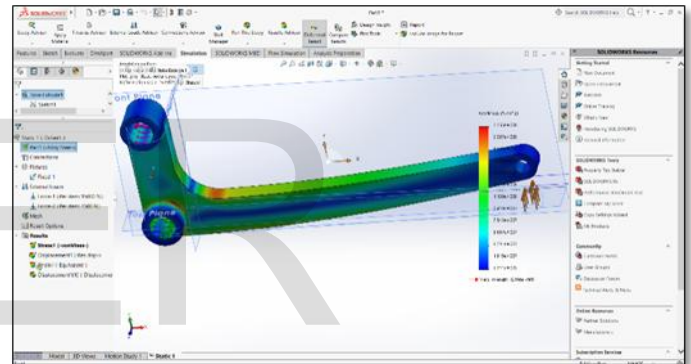


Figure 8: Mesh applied on the lever.

- 5) Run the Study
- 6) We get STRESS, STRAIN and DISPLACEMENT undergoing on the lever.



STEP 3: Use Extrude Cut for Holes.

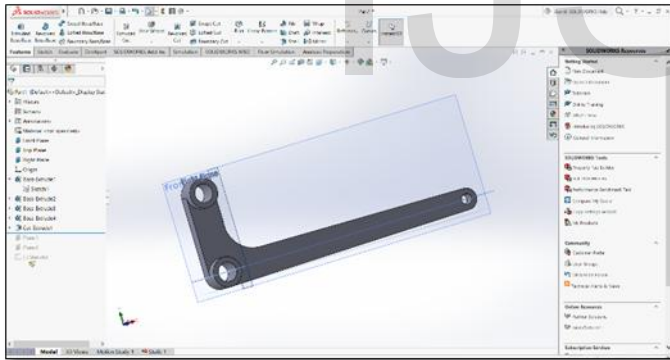


Figure 6: Final model of the Lever.

STEP 4 : STRESS ANALYSIS using Static Load

- 1) Choose Simulation ADD-IN of Solidworks. Then, Apply Material to the Lever. In this case Alloy Steel.
- 2) Fix the Geometry at the Fulcrum(F) i.e applying Fixture
- 3) Apply FORCE at Load End and Effort End, Careful about the Magnitude and Direction.

Figure 7: Model under stress analysis.

- 6) We get the final result of the lever. On the Finite Element Analysis of the lever it is found that the longer arm of the bell crank lever is distorted.

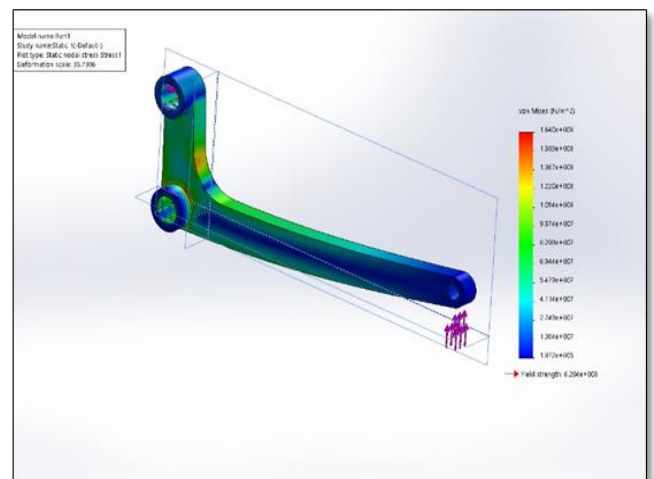


Figure 9: Stress distribution on the lever

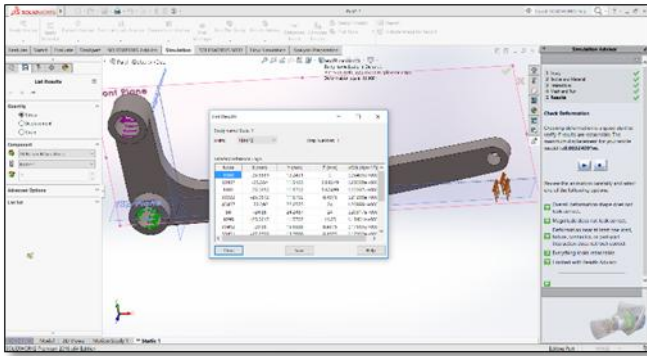


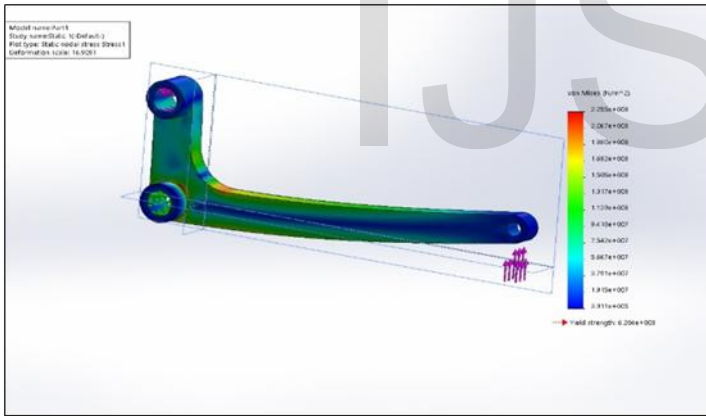
Figure 10: Final Analysis

5 OPTIMIZATION:

Optimization is briefly explained as a process of finding an alternative with the most cost effective or highest achievable performance under the given constraints, by maximizing desired factors and minimizing undesired ones.

The Bell crank lever analysed above is simulated for various change in conditions and the optimized working condition is found. Some instances of this are illustrated below

5.1 Original Stress distribution on the lever:



In the stress distribution using the designed dimensions of the arm the portion showing the bright red color at the junction of the effort and load arm experiences the most amount of stress and is the area from where the lever will break.

5.2 Stress distribution with a change in thickness:

When the thickness of the lever is changed from 24mm to 40mm the distribution of stress on the lever experiences a change as can be visualized in the diagram.

Figure 11: Stress distribution with thickness of lever as 40mm.

5.3 Stress distribution with addition of a supporting rib:

One of the most practical solutions of increasing the strength of the bell crank lever is providing supporting ribs.

Although material of the lever can be changed but it would not be the most economical solution.

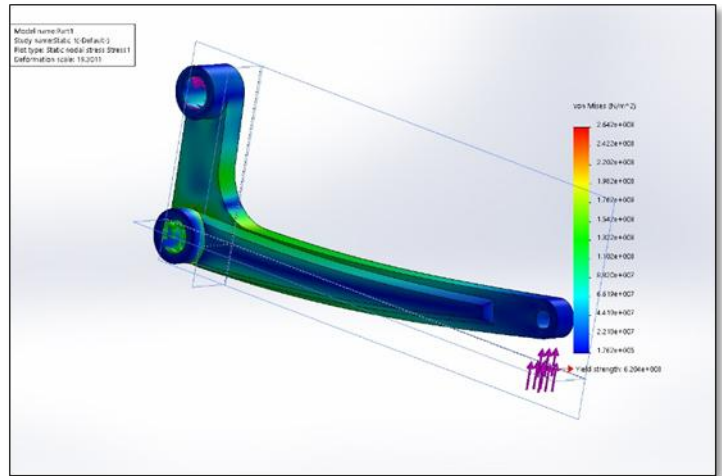


Figure 12: Stress distribution with support rib

By adding a supporting rib it is observed that there is no red area which depicts that the lever will be safe on the given loading and will not break.

CONCLUSION

In conclusion to this paper, an overview of modeling, analysis with simulation is understood using bell crank lever to study the basics of simulation as well as optimization using the best possible solution. Simulation and Analysis method helped to find location of stress concentration, now simple design improvement can reduce stress concentration.

This is the case of all real life scenarios. Modeling and simulation improves the aesthetics, form, shape and ergonomics of all the existing and new products. No need of making a prototype and then optimized the product instead software analysis is a great alternative.

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