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3D Modelling and Analysis of Bell Crank Mechanism

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***Abstract:** A Bell crank is a type of crank that changes motion through an angle. The angle may be any from 0 to 360 degrees. Among these, 90 degrees and 180 degrees are most common. Bell cranks are generally used in aircrafts to connect pilot's controls to the control surfaces, in automotive applications etc.*

The objective of the project is to design and analyse the Bell crank mechanism. The design objective of this project is to design a part which is best suitable in aircraft by choosing different materials. In this project, I will consider Aluminum 7075 and Titanium alloy. While designing the project we need to consider cost and weight. The factor of safety also plays a major role in designing.

The works that I will perform in this project is to study the idea of how to design the part in the design modeler (ANSYS). In addition, creating the parameters to the object so that further modifications can be made for the optimization like decreasing the size of the object. The model will be checked with some constraints so that we can be checked with some constraints so that the design is perfect.

The part to be designed is a rectangular solid which is attached to cylindrical shaft. Now the shaft is attached to a plate for a support and then assigning different materials to it like Structural steel and Titanium

I. INTRODUCTION

Mechanism is a process where a system of parts will work together. In other words, it is defined as rigid bodies connected by joints in order to have a desired force and motion transmission.

A machine is a device which receives energy and transform it into some useful work . A machine consist of number of parts or bodies.

Each part of the machine, which moves to some other part, is known as a kinematic link or element. A link or an element need not be a rigid body but it must be a resistant body. A body is said to be resistant body, if it is capable of transmitting the required force with negligible deformation.

A. Types of Mechanisms

Mechanisms can be divided into planar mechanisms and spatial mechanisms, according to the relative motion of the rigid bodies,

1) *Planar Mechanism:* If all the relative motions of the rigid bodies are in one plane or in parallel(2D), then this type is said to be planar mechanism.
2) *Spatial Mechanism:* It there is any relative motion that is not in the same plane or in parallel plane (3D), then the mechanism is known as spatial mechanism.

B. Kinematic Pair

When two links/elements of a machine are in contact with each other, then they are said to be a pair. If the relative motion between them is completely constrained, then the pair is known as kinematic pair.

C. Types of Kinematic Pair

1) *Lower Pair:* When the two elements of the pair have surface contact between them and the surface of an element slides over the surface of the other, then the pair is said to be a lower pair.
   a) *Example:* sliding parts, turning parts etc
2) *Higher Pair:* When the two elements of the pair are in line or point contact then the pair is known as higher pair.
   a) *Example:* cam and follower, ball and roller bearings etc.

D. Kinematic Chain

When the kinematic pairs are joined in such a way that the last link is joined to the first link to transmit motion , it is called as kinematic chain.

Let p = number of pairs forming the kinematic chain

n= number of lines

Then the relation between the number of pairs (p) and the lines (n)can be expressed as

n=2p-4

Another relation between the number of lines (n) and the number of joints (j) which constitute a kinematic chain is expressed as

j=3/2(n)-2

E. Cases

1) LHS>RHS then the link is locked chain
2) LHS =RHS then the link has on degree of freedom
3) LHS<RHS then it is unconstrained chain

F. Degree of Freedom

The number of independent variables (v) which are needed to specify the position of the body.

v=3(n-1)-2-h

G. Crank

A crank is an arm attached at a right angle to rotating shat through which reciprocating motion is imparted to the shaft or received from the shaft. Crank is used to convert circular motion into reciprocating motion or vice versa. Almost all the reciprocating engines have crank with connecting rods to transform motion.

Examples

1) Hand-powered
   a) Pencil sharpener ,
   b) Manually operated car window,
   c) Hand winches etc.
2) Foot-foot powered cranks
   a) The crank that drives a bicycle via the pedals,
   b) Treadle sewing machi

The main function of the crank is to convert linear motion of the piston into rotation motion. The pistons are connected to the crank shaft through the connecting rods. Generally, the crankshaft is mounted in the engine block. The piston connecting rods and crank shaft together form the crank mechanism.

Crank shaft is the backbone of the IC engines. These are subjected to very high dynamic loads during engine load. The type of material and the manufacturing method depends on the type of engine and geometry and design of the crank shaft. So high strength materials are recommended for long life.

H. Materials Used

Crankshafts are generally made from cast iron or forged steel. Nodular cast iron is used for manufacturing of high-volume low load production vehicles this is because the cast iron will have high strength. Forged steels are used for high fuel-efficient engines.

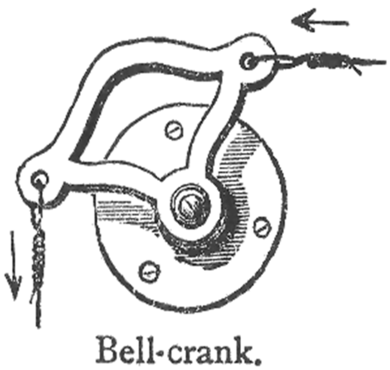
I. Types of Crank Shaft

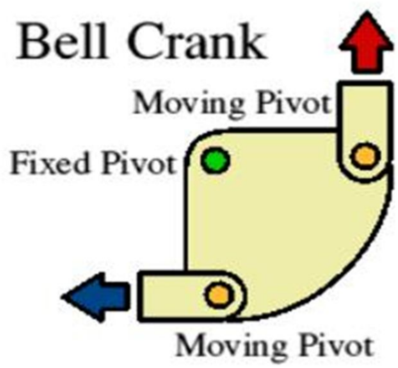
1) *Monolithic Crank Shaft:* This type is used in multi cylinder four stroke engines and marine engines . As the crank shaft is monolithic it is used the assembled connecting rod.
2) *Assembly Type Crank Shaft:* This type is used in single or twin cylinder four stroke engines, two stroke engines. As the crank shaft is assembled, it uses monolithic connecting rods.

J. Bell Crank Mechanism

Bell crank is a type of crank that changes motion through an angle. This angle varies from 0 to 360 degrees. Among these, 90 degrees and 180 degrees are most common.

The name bell crank comes from its first use changing the vertical pull on the striker of the bell. It has a 90 degree bell crank L shaped crank pivoted at the junction of two arms. Moving rods are attached to the ends of the L arms .when one arm is pulled the l rotates about the pivot, additionally pulling on the other arm. A 180 degree bell crank has a straight bar pivoted at the centre .When one of the arm is pulled/pushed the bar rotates about the pivot, pulling or pushing the other arm.





II. LITERATURE REVIEW

The stress analysis of Bell Crank lever in sewing machine was done by Rupali Patel and N.K.Patel. In this project , the thread take up lever is the type of bell crank lever.This thread take up lever is the important part of sewing machine. The take-up lever which is made up of a metal installed with a thread guide that moves up and down, pulling thread from the spool and giving it through the machine. The needle bar and take-up lever mechanism is one of the most important mechanisms used in sewing machines. It is nearly in all classical sewing machines, this mechanism provides sewing by allowing movement of the needle and pulling of the thread for stitch formation. The interactions between the sewing machine's mechanisms and the sewing thread will help us to understand thread loadings in the sewing process. The aim of this work is to analyze the forces in the take-up lever and selecting most feasible shape of thread take up lever.

S.R.Zaveri worked on stress analysis of bell crank lever. Bell Crank Lever is important components from safety point of view as they are subjected to large amount of stresses. They performed Finite Element Analysis (FEA) on various models of varying fillet radius, optimization for volume and reduction of materials form bell crank lever. They found that maximum stress is occurred at fillet. So by increasing the fillet radius stresses are reduced in bell crank lever. The work on modification in the classical needle bars and thread take-up lever mechanism is also done . This study deals with the design of a new modified thread take-up lever mechanism and that can be used as an alternative to the classical mechanism.

Research of the analysis of Bell crank mechanism by M. M. Dange and S. D. Khamankar to study the stress pattern ,they used analytical , numerical and photoelastic methods. For the analytical purpose, they used virtual model of bell crank lever .Bending stress in lever formula is used to determine the stresses in bell crank lever analytically. For numerical analysis, ANSYS was used to prepare the bell crank lever. Stress analysis was done using FEM. Finite Element Analysis was performed on various models of fillet radius , optimization for volume and reduction of materials. From the result, it was observed that the results are nearly equal and maximum failure stress concentration occurs at maximum bending surface.

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III. ALUMINIUM 7075 AND TITANIUM ALLOY

A. Aluminium 7075

This is an alloy of aluminum. Its primary alloy element is zinc. This alloy posses good mechanical properties and has good ductility, high strength, toughness, and high resistance to fatigue. It has better corrosion resistance.

B. Composition

The basic composition of this alloy is
6% zinc
2% magnesium
1.5 % copper
>.5% of silicon, iron, manganese, titanium, chromium and other metal.

C. Applications

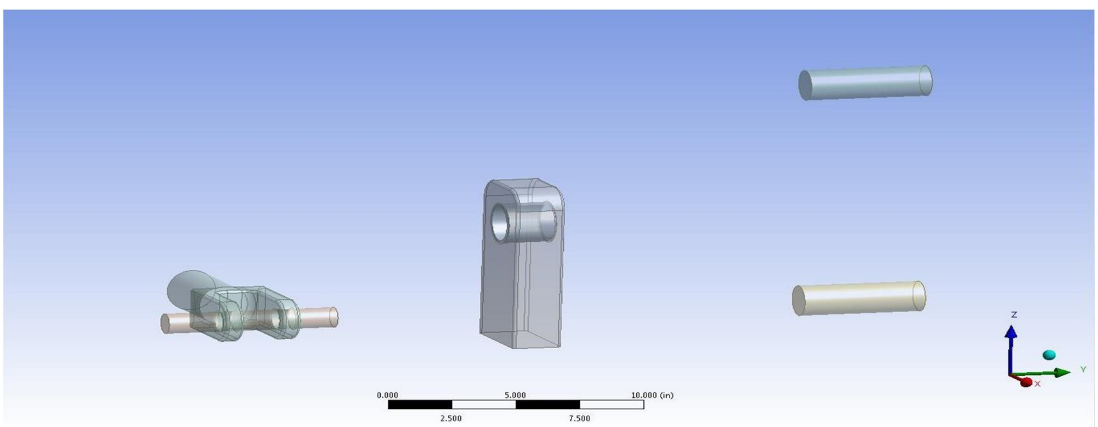
This alloy is mostly used in aeronautical applications.

D. Titanium 64 Alloy

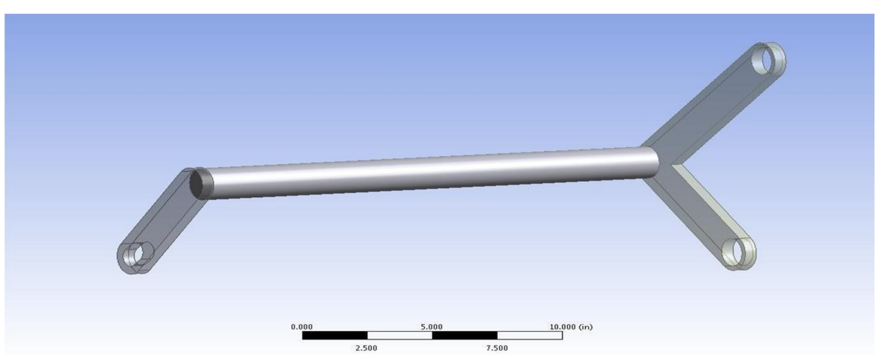
Titanium alloy is of alpha-beta form. Titanium alloy is usually consists of titanium and other alloying elements like aluminum , vanadium etc. These alloys have high tensile strength and toughness. These alloys are used mainly as the strength to weight ratio when compared to other alloys, it is very high. In other words , the weight is less but have good mechanical properties. They can also be used in extreme temperature conditions.

IV. MODEL GENERATIO

Parts I have created in this project



The source design of our project is to design the part between the pins and the hydraulic arm. The cylindrical shaft is drawn through the rectangular block.

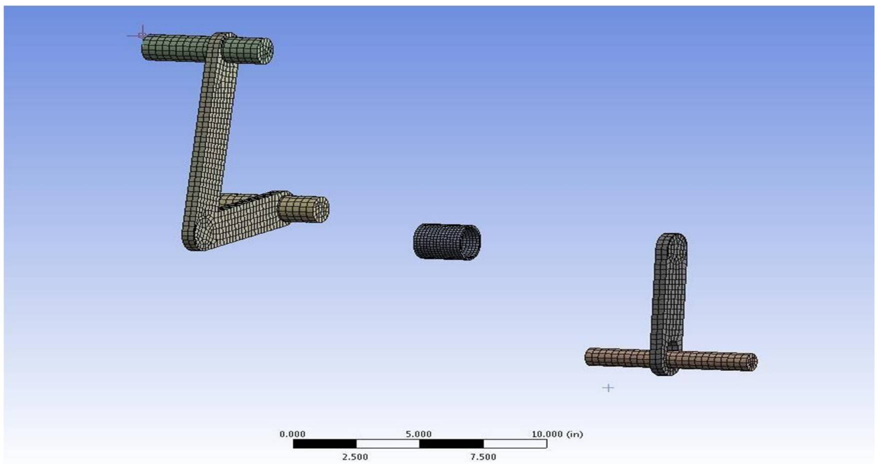


To do this part, I made the operations like

1) Creating new plane
2) Extrude
3) Trim etc.

V. MESHING

Meshing is the major part in this project. In my project I have used
Body Sizing with element size 0.3.
Multizone method on flat parts



Hex Dominant Method with bodysizing of 0.3

VI.RESULT TABLE

The first iteration done for the material aluminium-7075.
The second iteration is done for the Titanium alloy

	Aluminium 7075	Titanium Alloy
Mass	7.4	11.626
Safety Factor	1.23	1.03
Safety Margin	0.23	0.0343
Force Reaction on upper pin	732.68	924.94
Force Reaction on lower pin	619.32	775.93
Min. Frequency	158.3	156.75

VII. CONCLUSIONS

By the works I performed in this project, that is studying the idea of how to design the part in the design modeler in addition creating the parameters to the object so that any modifications can be made for the optimization like decreasing the size of object, I can conclude that Aluminum is better than Titanium alloy for the Bell crank material.

Later in the project, the model was checked with some constraints so that we can be checked with the design. By considering the designs, some modifications are made in the design in different parts and we obtained good mesh between the shaft and the plate.

As newly drawn model was good after keeping the connections, contacts, this generated good results for our project.

Then the important step in the project i.e., inserting loads and supports to the analysis setting and solution folder conclude that loads are Equivalent stress, total deformation, stress tool – safety factor and safety margin and supports like displacement and fixed support.

The first iteration is done for the material Aluminium-7075

The second iteration is done for the Titanium alloy

By comparing mass and all other properties, Aluminum 7075 is recommended to use.

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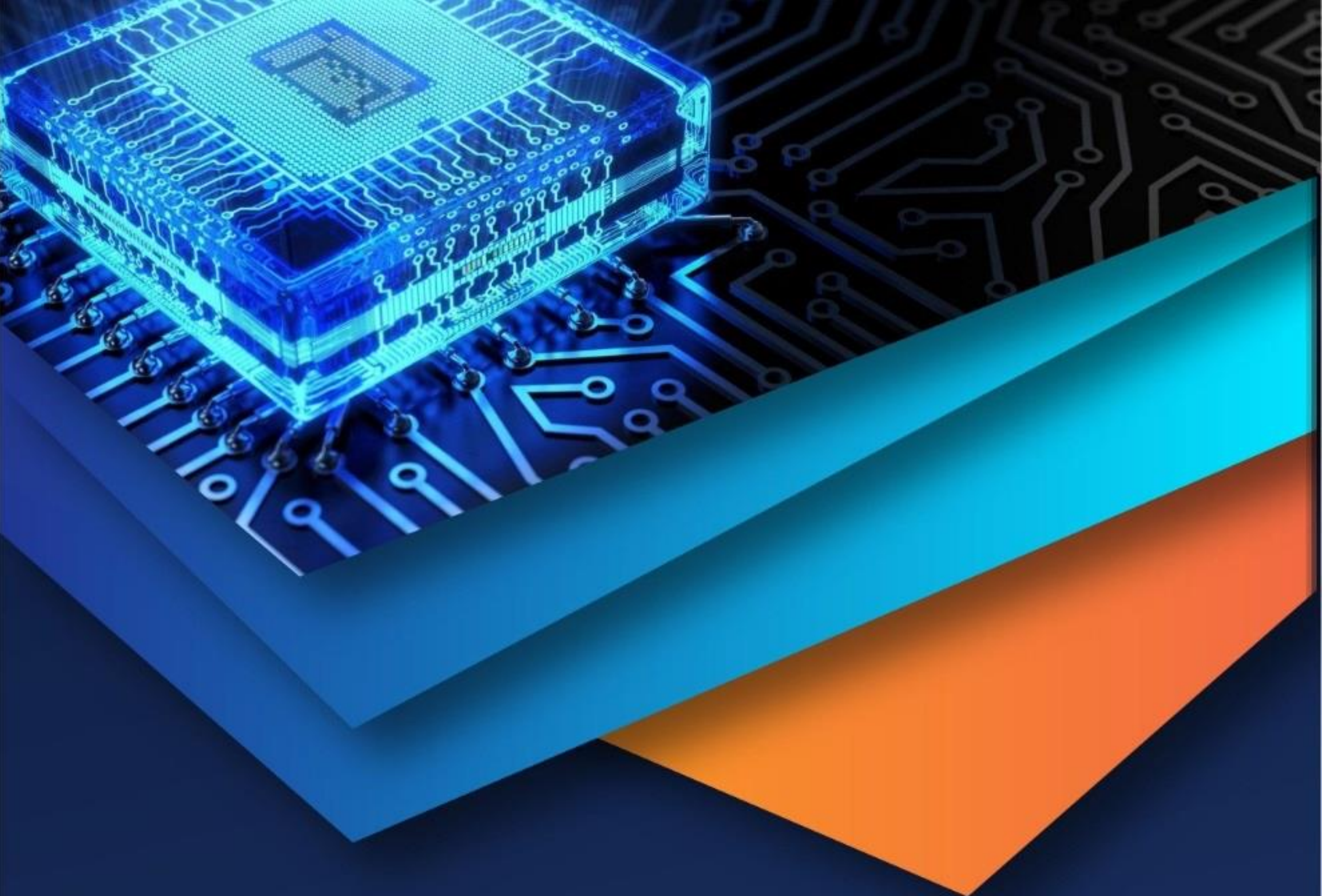

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