DESIGN AND ANALYSIS OF LIFT ARM FOR THREE POINT HITCH OF TRACTOR

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Abstract - *The main objective of this work is to strengthen performance of the three point hitch system. It is achieved by using experiment tests. The lift capacity of three point hitch mechanism is established according to ISO. The lift arm is good safe enough for lifting of a usual plow but it may be failed when the three-point hitch works with maximum load lifting capacity. The force of 13980 N was applied on the lift arms at the rear end. The lift arm was design in catia software. The ansys software were used to estimate the stress distribution and safety factor of lift arm .A tractor is vehicle specifically designed to deliver a high tractive effort at slow speeds for carrying out various agriculture operations like ploughing, rotavation etc. using implement. Lift arm system is a key feature which connects the different farming equipment with the tractor. The   position of the lift arm is changed depending upon the type of crop, farming stage, implement type and soil conditions.*

Key Words: ISO, ANSYS, Catia, three point hitch, tractor lift arm, design and analysis, etc

1. INTRODUCTION

The three-point hitch also called three-point linkage is a simple way of joining any implement to the tractor. The implement can be attached on to the tractor by one operator, as well as I mplement that are pulled they can be lifted up for transport. The three-point hitch is made up of several components working together. These include the tractor's hydraulic system, lifting arms, leveling rod, lower link and top link. There are three movable arms in Three point Linkage. The two lower arms—the hitch lifting arms—are controlled by the hydraulic system, and provide lifting & lowering of arms. The upper center arm—called the top link—is movable, but is usually not powered by the tractor's hydraulic system. Each arm has an attachment device to connect implements to the hitch.

Although the lifting capacity is the main parameter used by manufacturers to define three-point hitch performance. Measures of the lifting performance are regulated by standards including ASAE S217.12 which define the procedures for measuring the lifting force at the hitch points.
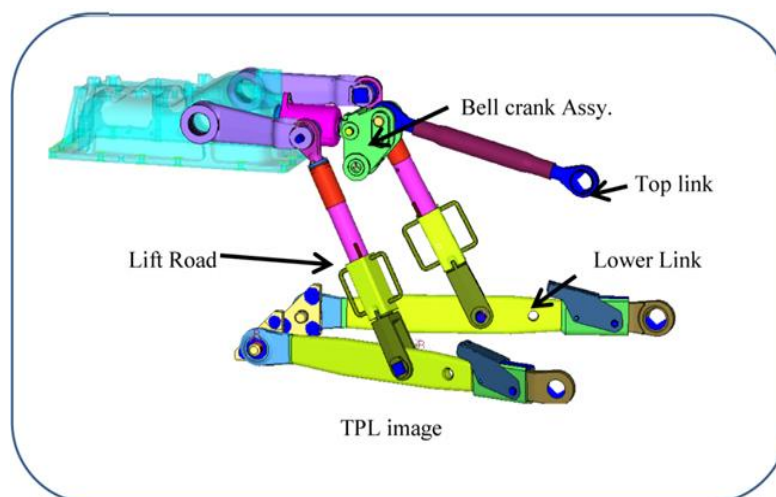

Fig 1. Image of tractor hydraulic three point linkage system

The mechanisms under consideration are mainly for lifting applications. The main objective is to check the mechanism feasibility, maximum lift capacity, Height and play of the lift arm, Phase difference between right and left lift arm, Lever angle, Natural Drop ,Slow return performance. The extracted force information can be further used for optimum selection of the

components such as Lower link, levelling rod, ram arm, etc. The hydraulic three point linkage system shown in Figure 1 was introduced for lifting and lowering the implements at the headland and for transportation.

The implement cannot be fixed in a constant position due to the large variations of the working depth of the plough on undulated soil-surfaces.

To prevent this, a system-variable is needed, which can be held constant by a closed loop control system, without the implement being in a fixed position to the tractor. The pulling-forces (draft control) of links is in the three point linkage system. The draft control system of the tractor is incorporated to automatically keep tractor effort constant by varying the depth of operation within narrow limits by bell crank assembly.

The FEM was used to obtaining maximum stress and fatigue analysis of connecting rod in the engines of MF-285 and universal 650 tractors.

1.1 Three-Point Linkage Mechanism:

The machines/implements are attached/hitched to tractors through linkage provided at the rear end of tractor that is known as three point linkage, which is hydraulically controlled. The important terminologies and dimensions of three point linkage for the purpose of the research work were applied for linkage components and dimensions and most of them are defined below and presented in Fig. below
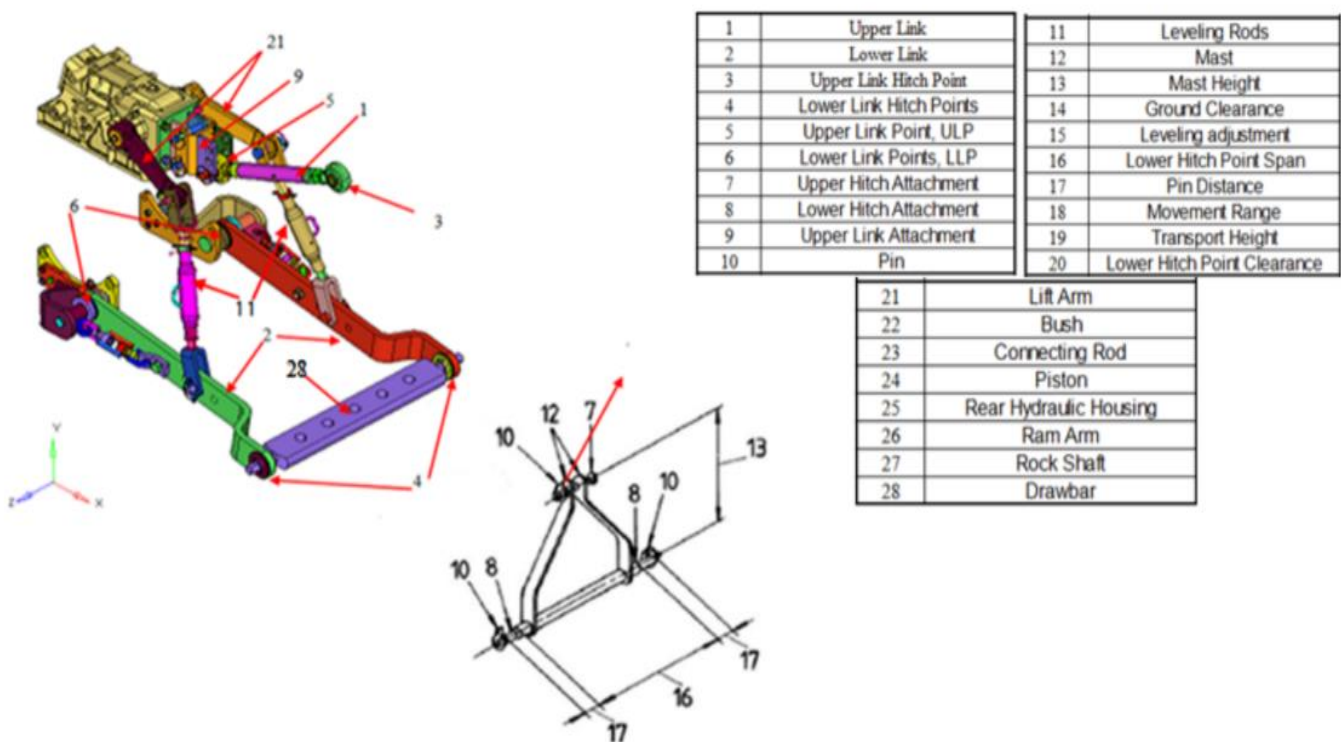

1	Upper Link	11	Leveling Rods
2	Lower Link	12	Mast
3	Upper Link Hitch Point	13	Mast Height
4	Lower Link Hitch Points	14	Ground Clearance
5	Upper Link Point, ULP	15	Leveling adjustment
6	Lower Link Points, LLP	16	Lower Hitch Point Span
7	Upper Hitch Attachment	17	Pin Distance
8	Lower Hitch Attachment	18	Movement Range
9	Upper Link Attachment	19	Transport Height
10	Pin	20	Lower Hitch Point Clearance

21	Lift Arm
22	Bush
23	Connecting Rod
24	Piston
25	Rear Hydraulic Housing
26	Ram Arm
27	Rock Shaft
28	Drawbar

Fig.2 Measurements standardized by ASAE

    a.   Upper link: Upper linkage element, fitted with an articulated connection at both ends.
    b.   Lower link: Lower linkage element, fitted with an articulated connection at both ends.
    c.   Upper hitch point: Articulated connection between the upper link and the implement.
    d.   Lower hitch point: Articulated connection between a lower link and the implement.
    e.   Upper link point: Articulated connection between the upper link and the tractor.
    f.   Lower link point: Articulated connection between a lower link and the tractor.
    g.   Lift rods: Connections that transmit force to the lower links for raising and lowering.
    h.   Mast: Component that provides location of the upper hitch point on the implement.
    i.   Mast Height: Vertical distance between the upper hitch point and the common axis of the lower hitch points.

Table.1. Details of three point linkage

COMPONENT	WEIGHT (KG)	VOLUME (CM3)
Lower Link	18.8	2410
Upper Link	10.1	1293
Lift Arm	5.54	710
Lift Link	8.27	1060
Joint	0.62	79

1.2 Tractor in India

Total number of tractors in Indian farm at present are more than 3.5 millions and every year approximately 2.9 lakhs tractors are inducted in Indian farm.
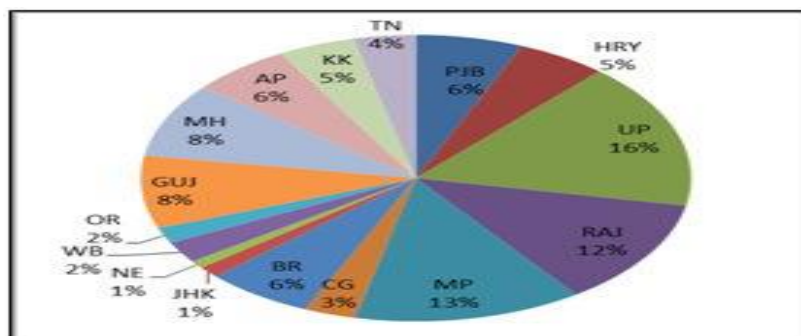
The details of tractor use are given as below:-

Fig.3. Indian Tractor Market State Wise Contributions

Uttar Pradesh has the largest and Madhya Pradesh has second large contribution in the tractor market due to the adoption of new technologies and good land holding capacities of farmers. Jharkhand, west Bengal and Orissa has the least contribution in the tractor market due to the less land holding capacity and poor condition of farmers.
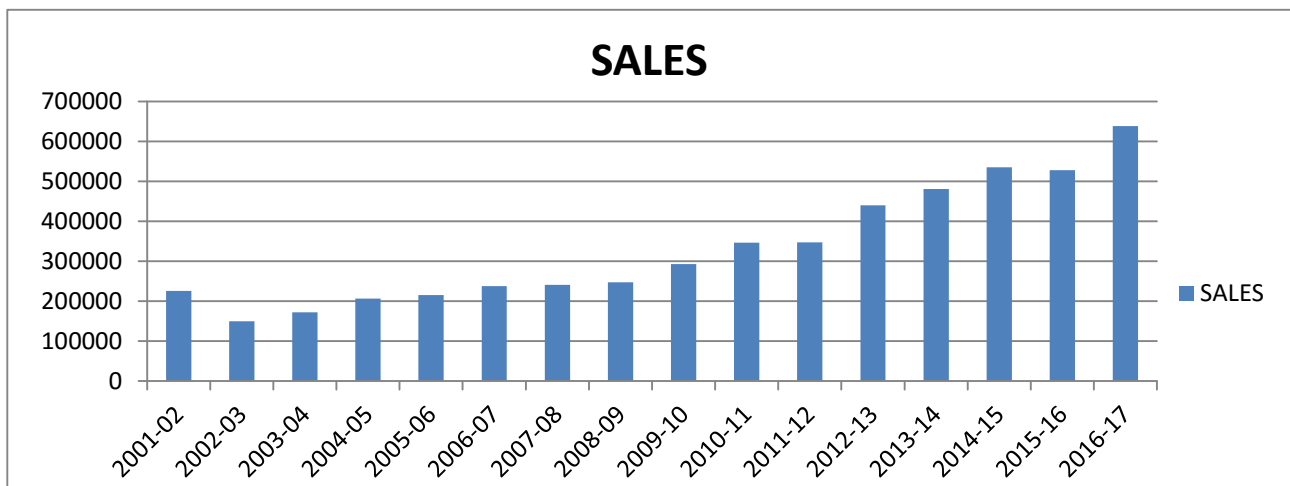
1. Tractor Market Growth Trends

Chart.1 Tractor market growth trend

The above graph shows that the demand of tractor is increasing very fast each year.

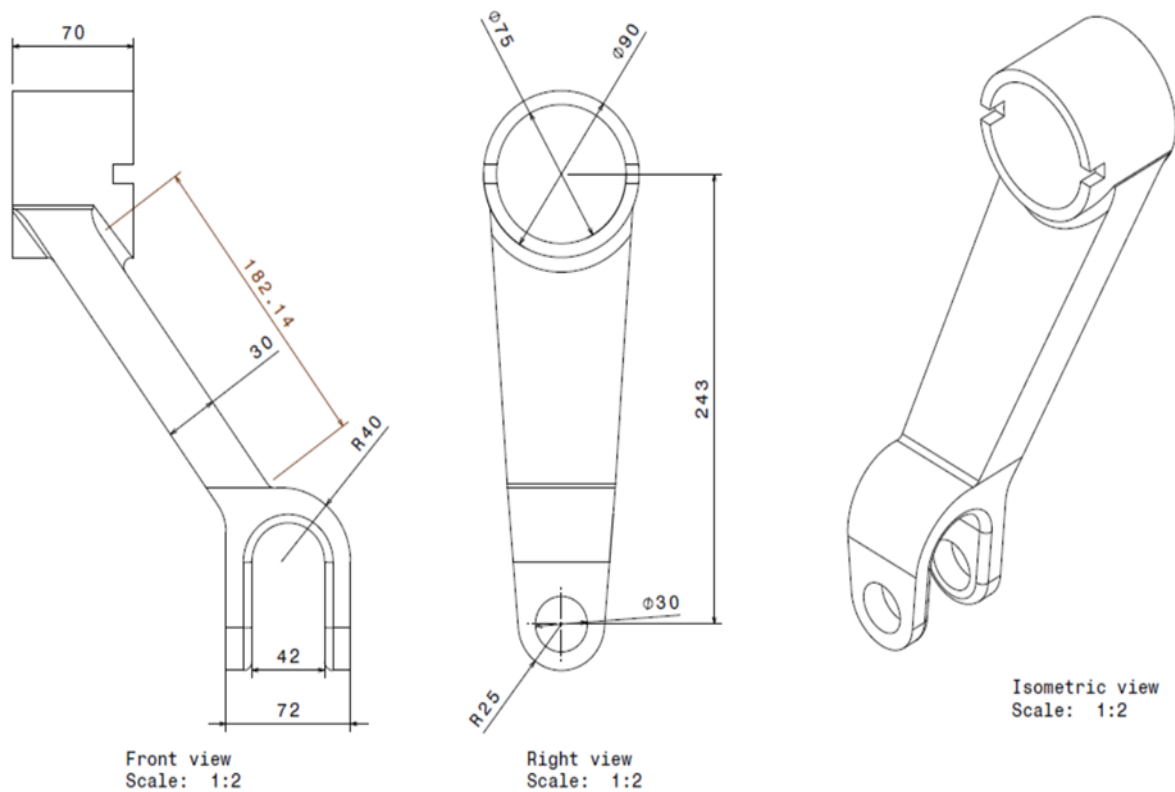## 2. MESHING USED IN PART ANALYSIS:

Lift Arm Dimensions: Part 1

Fig.4. dimension and geometric detail of tractor lift arm (units are in mm)

2.1 MESH:

Meshing is defined as the process of dividing the whole component into number of elements so that whenever the load is applied on the component it distributes the load uniformly called as meshing.

Meshing is a process in which the whole complex domain is divided into small rectangular/triangular/ Pyramid/tetrahedral/hexahedral Etc. elements. So that for each element the computer solves the load/heat as specified.

A component is analyzed in two ways. One is with Meshing and the other is without meshing.

   a.   With Meshing: If the load is applied on the structure or a body and the body is considered to be meshed, then the load is distributed uniformly on the entire structure.
   b.   After Meshing, the entire structure is divided into number of elements and each element having its own stiffness while loading.
   c.   Adding all those elements stiffness's, you can get the Global Stiffness Matrix with which you can calculate the stress developed in the structure etc.
   d.   If the Von-mises stress is less than yield stress of the material, then the product analyzed is safe, else it is of failure type.
   e.   Without Meshing: If you are applying the load on the body which is not meshed, then the load distribution is not uniform and you may get the irregular or faulty results.

2.2 TYPES OF MESH:

   a)   Two-dimensional

Basic two-dimensional Cell shapes[1]
There are two types of two-dimensional cell shapes that are commonly used. These are the

1) Triangle
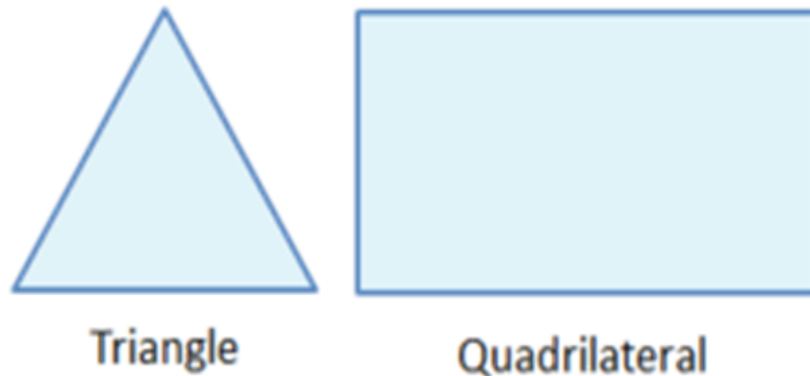2) Quadrilateral

Fig.5. Two dimensional Meshing type

1)   Triangle:

This cell shape consists of 3 sides and is one of the simplest types of mesh. A triangular surface mesh is always quick and easy to create. It is most common in unstructured grids.

2)   Quadrilateral:

This cell shape is a basic 4 sided one as shown in the figure. It is most common in structured grids. Quadrilateral elements are usually excluded from being or becoming concave.

b)   Three-dimensional:

The basic 3-dimensional elements are the tetrahedron, quadrilateral pyramid, triangular prism, and hexahedron. Extruded 2-dimensional models may be represented entirely by the prisms and hexahedra as extruded triangles and quadrilaterals.
In general, quadrilateral faces in 3-dimensions may not be perfectly planar. A non-planer quadrilateral face can be considered a thin tetrahedral volume that is shared by two neighboring elements. They all have triangular and quadrilateral faces.

1)   Tetrahedron

A tetrahedron has 4 vertices, 6 edges, and is bounded by 4 triangular faces. In most cases a tetrahedral volume mesh can be generated automatically.

2)   Pyramid:

A quadrilaterals-based pyramid has 5 vertices, 8 edges, bounded by 4 triangular and 1 quadrilateral faces. These are effectively used as transition elements between square and triangular faced elements and other in hybrid meshes and grids.

3)   Triangular prism:

A triangular prism has 6 vertices, 9 edges, bounded by 2 triangular and 3 quadrilateral faces. The advantage with this type of layer is that it resolves boundary layer efficiently.

4)   Hexahedron:

A hexahedron, a topological cube, has 8 vertices, 12 edges, bounded by 6 quadrilateral faces. It is also called a hex or a brick. For the same cell amount, the accuracy of solutions in hexahedral meshes is the highest .The pyramid and triangular prism zones can be considered computationally as degenerate hexahedrons, where some edges have been reduced to zero. Other degenerate forms of a hexahedron may also be represented.
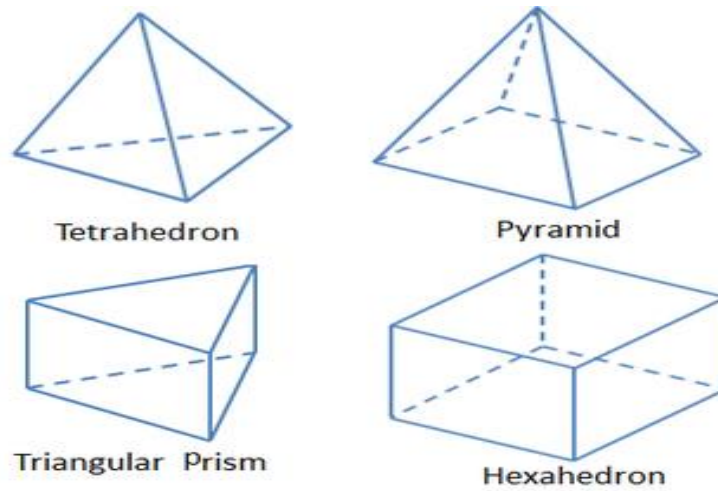

Fig.6. Three dimensional meshing type

Selection of mesh for basic lift arm of tractor:
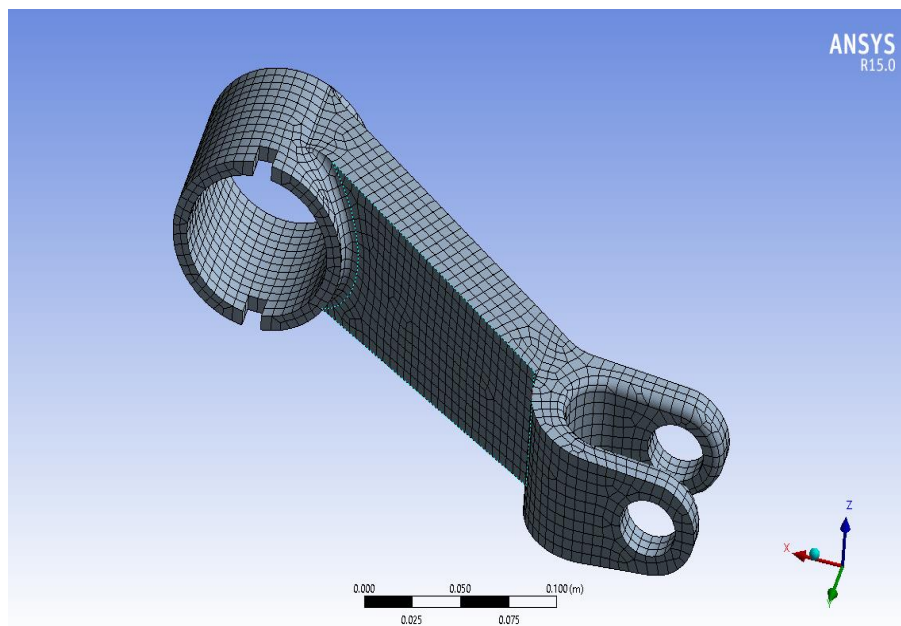
1)   By using Hexahedron mesh:

Fig.7. Meshing using hexahedron meshes type.
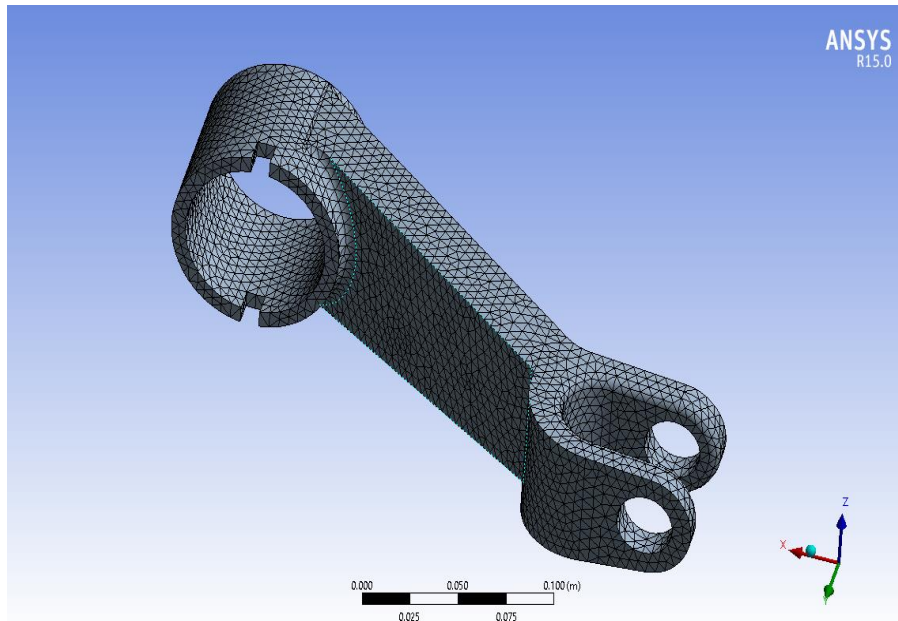
2)   By using Tetrahedron mesh:

Fig.8. Meshing using tetrahedron meshing type

Comparison of Two Different Meshes:

Table.2. Details of three point linkage

Parameters	Hexahedron mesh	Tetrahedron mesh
Total deformation (m)	0.00026399	0.00026374
Equivalent stress (pa)	8.9239e+7	7.7937e+7
Equivalent strain	0.00037286	0.00032603
Safety factor	0.96595	1.106
No of nodes	26523	51455
No of elements	6859	32772

2.3 Conclusion For this meshing comparison:

By considering the values of total deformation and safety factor between these two mesh types, it is clear that tetrahedron mesh is better than hexahedron. From this conclusion we preceded further analytical process using tetrahedron mesh.
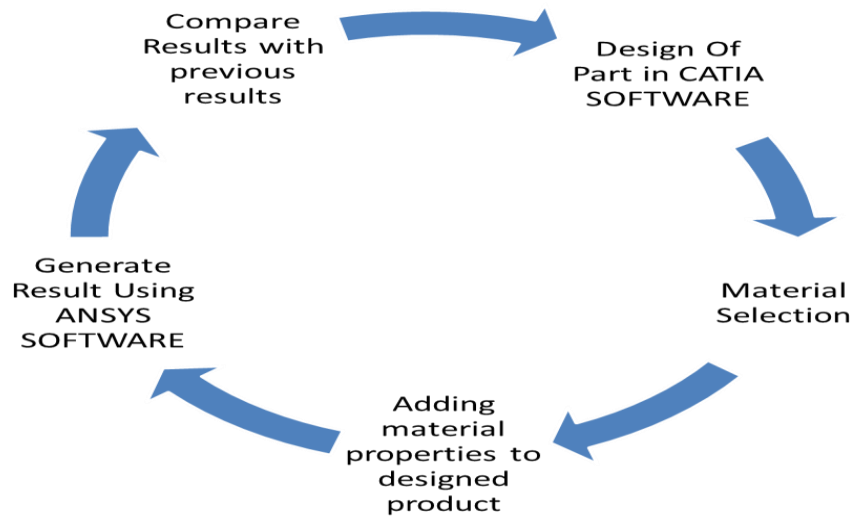
3. Working Process:

Chart.2. dimension and geometric detail of Part 1- trial 1

4. Trial and Error Methods:
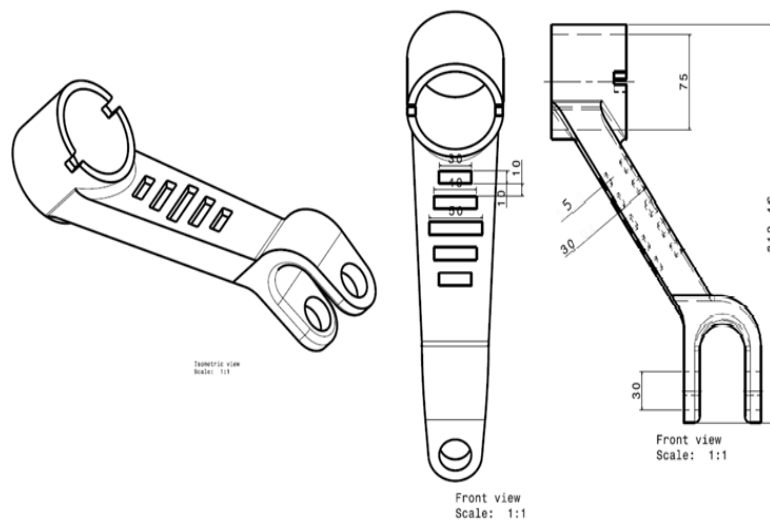
Part 1- Trial 1:

Fig.9. dimension and geometric detail of Part 1- trial 1

In trial 1 the basic part is modified by adding slots on the middle horizontal surface of the lift arm. The slots of 30X10, 40X10,50X10 were sketched and placed at equal distance of 10 mm apart from each other. The depth of slots were 5mm. The width of middle horizontal surface is 30mm.
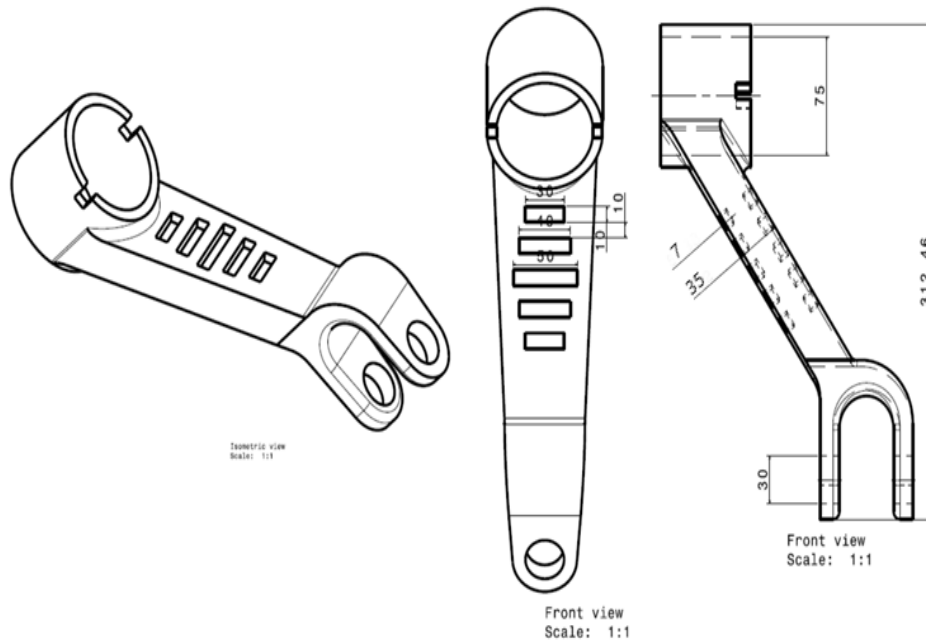
Part 1- Trial 2:

Fig.10. dimension and geometric detail of Part 1- trial 2

In trial 2, trial 1 part is further modified by increasing the width of middle horizontal surface of the lift arm by 5mm. The slots of 30X10, 40X10,50X10 were sketched and placed at equal distance of 10 mm apart from each other. The depth of slots was increase from 5mm to 7mm.
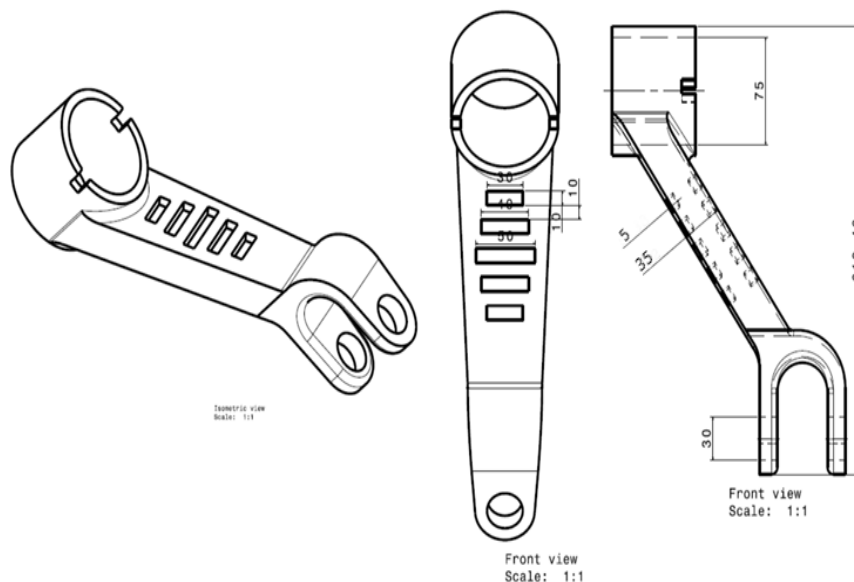
Part 1- Trial 3:

Fig.11. dimension and geometric detail of Part 1- trial 3

In Trial 3, trial 2 Part is further modified by decreasing the depth of slot from 7mm to 5mm as result to increase safety factor of lift arm.
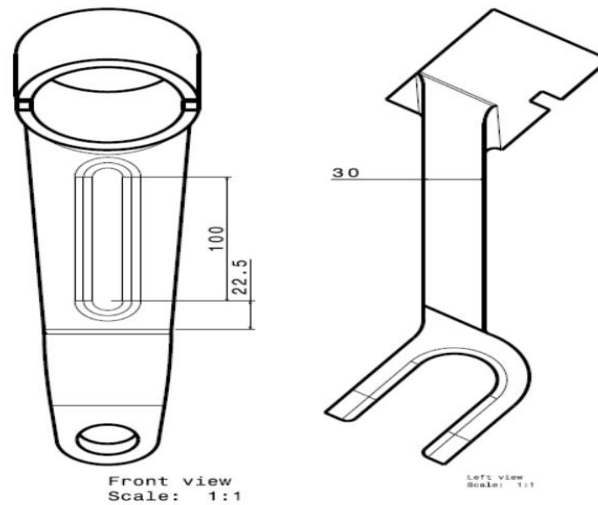
Part 2- Trial 1:

Fig.12. dimension and geometric detail of Part 2- trial 1

This Part was designed by modifying the basic part by providing elongated hole of length of 100mm with the radius 12.5mm. The depth of elongated hole is 5mm.
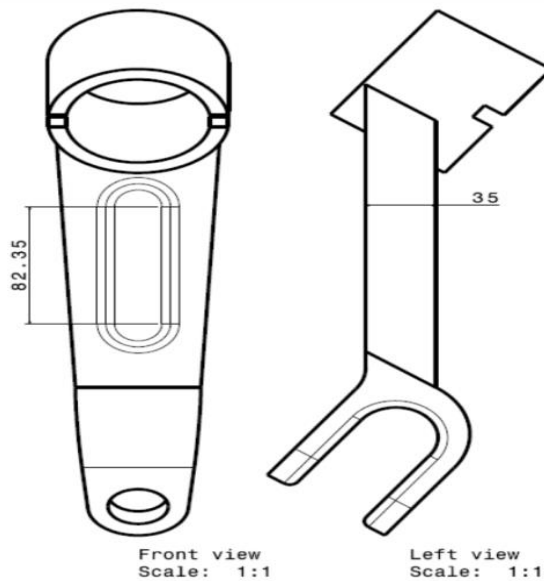

Part 2- Trial 2:

Fig.13. dimension and geometric detail of Part 2- trial 2

In Trial 2, the trial 1 part was modified by increasing the width of the horizontal surface of the lift arm from 30mm to 35mm. The elongated hole length is reduced from 100mm to 80mm and depth remain same.

Part 4- Trial 1:
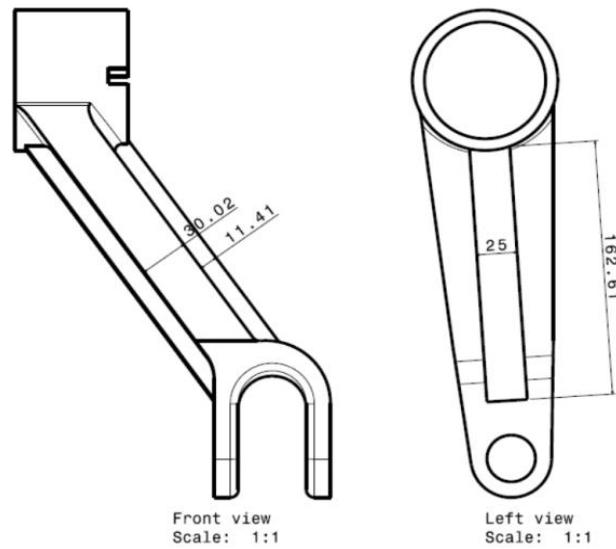
Fig.14. dimension and geometric detail of Part 4- trial 1

In Part 3, the basic part was modified by providing support to the exterior ends by extruding the rectangle of width 25mm and the length was extended till the next surfaces.

Part 4- Trial 2:

Fig.15. dimension and geometric detail of Part 3- trial 2

In this Trial of part 3, wedge shape support was added from the rear ends till the middle of the horizontal surface of lift arm. The width of wedge shape support is 30mm.

4. Finite Element Analysis on lift arm:

Trials For material AISI 1020:

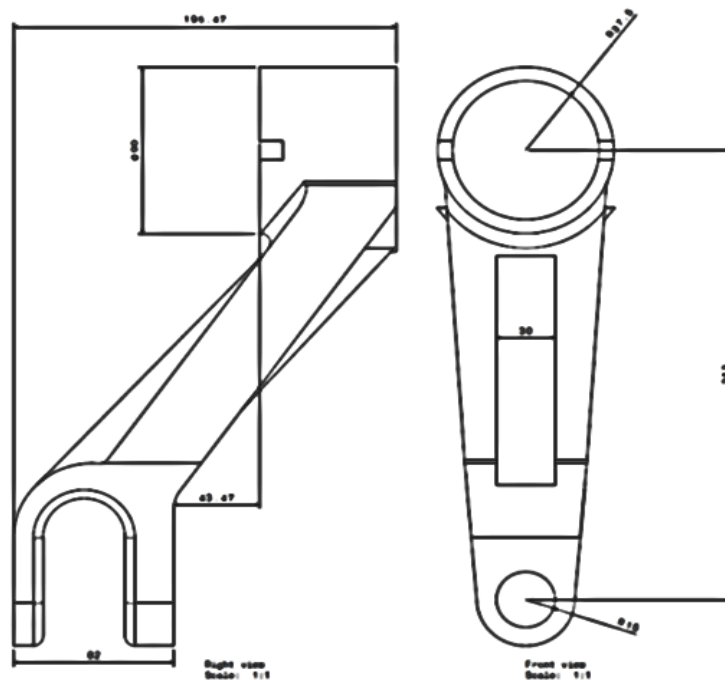**Table.3.** Properties of AISI 1020 material.

Material	Temperature (^{0}C)	Young's Modulus (GPa)	Poisson's Ratio	Bulk Modulus (GPa)	Shear Modulus (GPa)	Density (g/cc)
AISI 1020	22^0	186	0.29	148	72	7.87

Part 1:

Table.4. analysis details for part 1

Trial No	Safety Factor	Total Deformation	Equivalent Stress	Equivalent Strain
Trial 1	1.0429	0.00028281	8.2656e+7	0.00034783
Trial 2	1.2231	0.00023517	7.0474 e+7	0.00029553
Trial 3	1.2638	0.00022917	6.8205e+7	0.00028715

Part 2:

Table.5. analysis details for part 2

Trial No	Safety Factor	Equivalent Stress	Total Deformation	Equivalent Strain
Trial 1	1.0434	8.2617e+7	0.00027839	0.0003464
Trial 2	1.3495	6.3874e+7	0.00024163	0.00029854

Part 3:

Table.6. analysis details for part 3

Trial No	Safety Factor	Equivalent Stress	Total Deformation	Equivalent Strain
Trial 1	0.83339	1.0347e+8	0.00024267	0.00043285

Part 4:

Table.7. analysis details for part 4

Trial No	Safety Factor	Total Deformation	Equivalent Stress	Equivalent Strain
Trial 1	1.1717	0.0002293	7.357e+7	0.00032475
Trial 2	1.5208	0.00017362	5.6679e+7	0.00023683

Result:

 For this AISI 1020 Material we have taken 4 parts with 2-3 trials. In part number 1 we improved factor of safety by changing dimension and adding material to design. Improvements done resulting safety factor from 0.85 to 1.31, which is good result compared with basic design part.

 Further improvising till the part number trial number 2 we got best result of safety factor 1.5208. Now changing materials is most important, so below are the results considering material AISI 1040.

Trials for Material AISI 1040:

Table.8. Properties of AISI 1040 material.

Temperature C	Young's Modulus (GPa)	Poisson's Ratio	Bulk Modulus (GPa)	Shear Modulus (GPa)	Density (g/cc)	Material
22°	210	0.3	140	80	7.845	AISI 1040

Part1:

Table.9. analysis details for part 1

Trial No	Safety Factor	Total Deformation	Equivalent Stress	Equivalent Strain
Trial 1	1.0429	0.00040402	8.2656e+7	0.0004969
Trial 2	1.2231	0.00033596	8.0474e+7	0.00042218
Trial 3	1.2638	0.00032738	6.8205e+7	0.00041021

Part2:

Table.10. analysis details for part 2

Trial No	Safety Factor	Total Deformation	Equivalent Stress	Equivalent Strain
Trial 1	1.0435	0.00039769	8.2611e+7	0.00049484
Trial 2	1.3495	0.00034519	6.3874e+7	0.00042648

Part3:

Trial for this part was not taken as it is already considered fails in material AISI 1020.

Part 4:

Table.11. analysis details for part 3

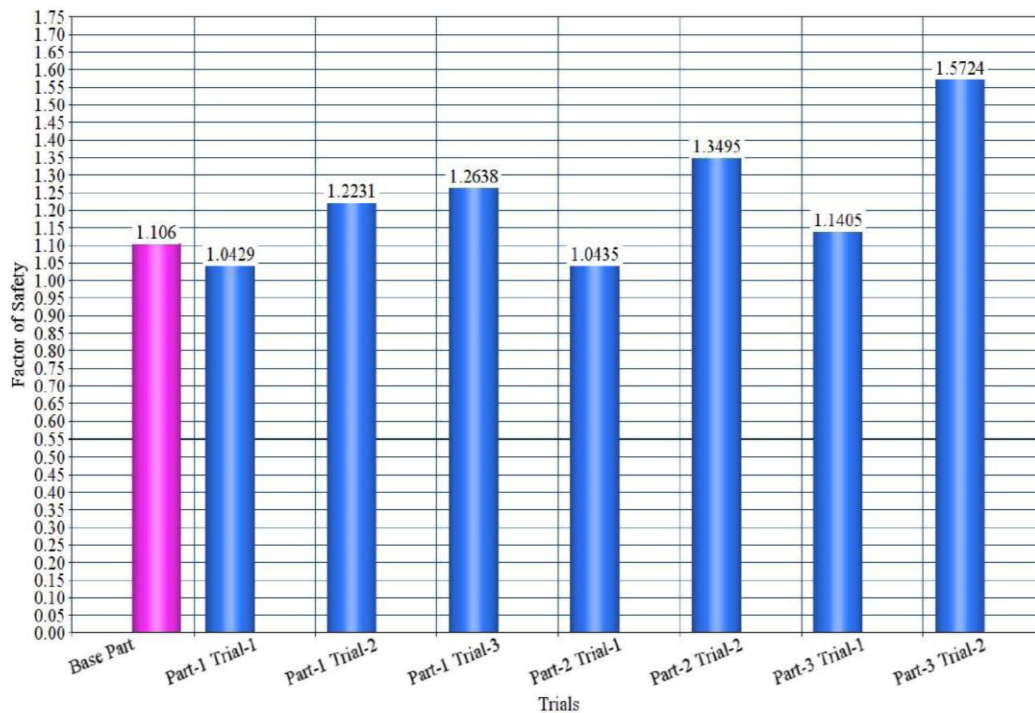| Trial No	Safety Factor	Total Deformation	Equivalent Stress	Equivalent Strain
Trial 1	1.1405	0.00032781	7.5584e+7	0.00047573
Trial 2	1.5724	0.00024484	5.4821e+7	0.00032859

Result:

Graph:

Chart.2. result improvement graph

For this AISI 1040 Material we have taken 4 parts with 2-3 trials. In part number 1 we improved factor of safety by changing dimension and adding material to design. Improvements done resulting safety factor from 0.98 to 1.32, which is good result compared with basic design part.

Part number 4 trial number 2 with material AISI 1040 has safety factor of 1.572. This safety factor is improved from 1.106 as given in chart 2

So part number 4 with material AISI 1040 is suggested for best result.

5. CONCLUSION

In this study, analysis soft was used to find out the stress and safety factor values of lift arm of tractor three point hitch. Basic part with material AISI 1020 has safety factor of 1.106 at load of 13980 N i.e. 1425.07 kg.. This result is improved efficiently with material AISI 1040 resulting safety factor 1.5724. Also deformation decreases from 0.00026374 m to 0.00024484. So this report concludes Part 4 used in this report is suggested for better load bearing capacity.

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