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Design, Modelling and FEM Analysis of Excavator Arm

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Abstract: Excavators are intended for excavating rocks and soils. It consists of four link members: the bucket, the stick, the boom and the revolving super structure (upper carriage). Excavator arm is one of the most important attachments of an excavator. The excavators arm has to work reliable under many different working conditions with high amount of load. Hence it is required to design an equipment which has maximum reliability and minimum weight, maintaining all the factors of safety under all working and loading conditions. The excavator mechanism must work reliably under unpredictable working conditions. Thus, it is very much necessary for the designers to provide not only an equipment of maximum reliability but also of minimum weight and cost, keeping design safe under all loading conditions. The aim is to design and develop an excavator which will be focused on the rigid and flexible arm-boom-bucket linkage called "Design and Development of Excavator Arm using FEM Analysis ". A detailed inspection has been carried out by finite element analysis (FEA) using the ANSYS software to observe and examine the stress developed in the arm for all design considerations. At the end, the stress developed due to working load for every single design has been observed and examined to check whether they are safe or not. The results of this research and observation are that the weight of the excavator arm can be modified by making some sort of design and material changes, keeping the all Factor of Safety as they were. Excavators are earth moving equipment and the main component to get the work done is its function is arm, which directly affect the working performance and reliability of the excavator. However, using the finite element analysis (FEA) method for Design and structural analysis of the excavator arm is required and mandatory for the structural design of the arm.

Keywords: Excavators, Excavator arm, unpredictable working conditions, FEM Analysis, ANSYS software, safe limit

I. INTRODUCTION

Primarily, the excavators are used to excavate below the rough surface of the ground on which the machine rests and load it into conveyors, trucks or tractor. The Excavators made up of four connecting members named as the bucket, the stick, the boom and the base structure rotating or revolving super structure (upper carriage). Due to some certain working conditions, the excavator parts are subjected to working under high load conditions. The excavator's mechanism must work reliably and efficiently under unpredictable or uncertain working conditions. Poor strength properties of the excavator parts like boom, arm and bucket limit the life expectancy of the excavator. Generally, the excavator always works under cyclic motion during excavation process. Due to this continuous repetitive nature of work, cyclic stresses are developed in the parts of every attachment. High level of stresses can cause the internal damage of critical parts of the excavator and it will adversely be affecting on productivity of machine. Now a days, the weight factor is major concern while examining and designing the machine components. That's why, for reducing the overall cost as well as smoothing and increasing the softness in the performance of machine, the optimization is required for sure.
Thus, it is very much necessary for the designers to provide not only an equipment of maximum reliability but also of minimum weight and cost, keeping design safe under all loading conditions. Finite Element Analysis (FEA) is the most powerful technique in strength calculations of the structures working under known load and boundary conditions. A detailed investigation has been carried out by finite element analysis using ANSYS software to understand the stress developed in the arm for all design considerations.

II. EXPERIMENTAL METHODS OR METHODOLOGY

As per as the digging task is considered repetitive in nature and during this task, all entire link mechanism working under the dynamic conditions. If the damage rate goes higher then it will lead to higher maintenance and higher downtime (the lower machine ability) which subtract from the net working capacity of the machine. The first arm, which is close

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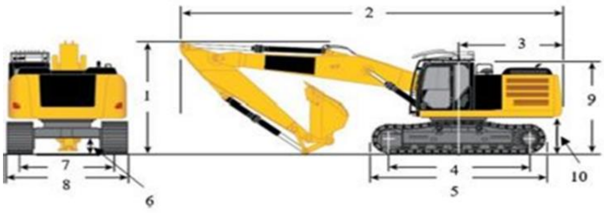
to the control cabin and the axis of rotation of the machine has a length of 6.9 meter. While the second arm, the one with the bucket is attached has a length of 3.6 meter.

A. Analysis of existing model

The machine at the base of this study is a commercial excavator produced by the CAT company whose acronym is 336F. This machine has a motor with a power of 234 kW and an operating weight of 40800 kg. The main dimensions of the excavator are shown in Figure 1. The machine is equipped with two arms. The first one close to the control cabin and the axis of rotation of the machine has a length of 6.9 m while the second arm, the stick, the one to which the bucket is attached, has a length of 3.6 m.



1	2	3	4	5	6	7	8	9	10
3.7	11.4	3.5	4.0	5.0	0.5	2.6	3.2	3.5	1.2

Fig.1 Excavator Dimensions

B. Reverse engineering of existing model.

The Reverse engineering is the design process in which a product is examined and analyzed using a physical part as a starting point. During the design process as per a new product is considered, modeling can be used in context to test, examine, evaluate and validate the conceptual design. This process requires some sort of modifications in the original design. For that reason, the reverse engineering could be considered as a important solution for innovating the original product design.

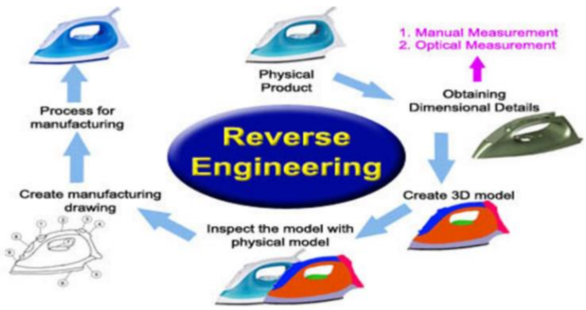


Fig.2 Reverse Engineering.

C. Generation of 3D model in CATIA V5R19 software

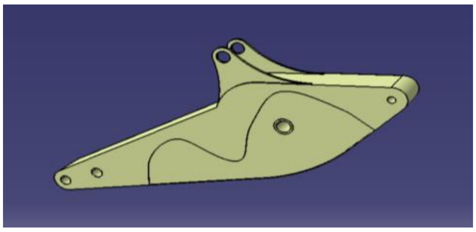


Fig3 Excavator Arm Model

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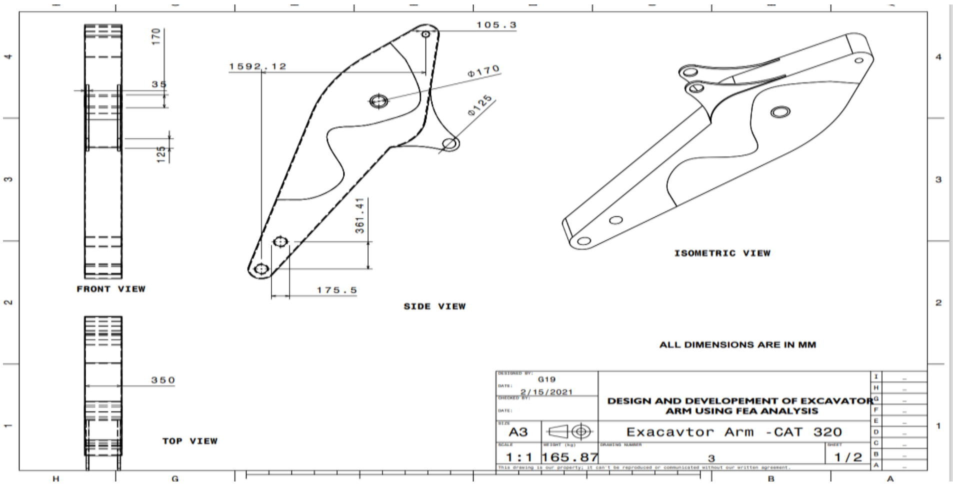

Fig.4.Excavator Arm Dimensions

D. Materials Used

1.Excavator Arm

For the construction of the excavator in its original configuration, the use of the classic S355 UNI EN 10025-3 construction steel is assumed.Table shows the characteristics of the materials used for the study and design of the excavator arms.

Structural Steel	
Young's Modulus	2×105 MPa
Poisson's Ratio	0.3
Density	7.85e-006 kg/mm³
Thermal Expansion	1.2e-005 1/°C
Tensile Yield Strength	250. MPa
Compressive Yield Strength	250. MPa
Tensile Ultimate Strength	460. MPa

Table 1: Physical properties of Arm Material

E. Excavator Assembly

Fig.5 Assembly of an Excavator

F. Meshing of assembly, applying connections etc. in ANSYS.

In this section calculation for the static force analysis of the bucket and arm excavator for the condition in which the mechanism produces the maximum breakout force has been done. The most critical condition in the force analysis, is the maximum breakout force condition, as it produces the highest breakdown force and due to this condition, the force analysis is done and will be used as a boundary condition for static FEA.The free body diagram of bucket and arm, with directions and magnitudes of the forces are explained in this section.

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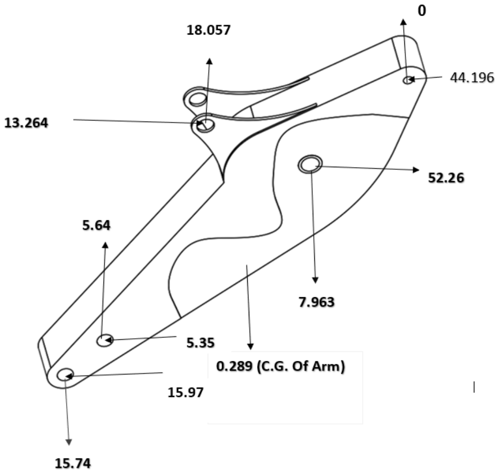

Fig.6: Free body diagram of arm of excavator

Joint	Horizontal Component	Vertical Component
A1	-15.97	-15.74
A2	-5.35	5.64
A3	52.26	-6.963
A4	13.264	18.057
A5	44.196	0

Table 7. Forces on arm

G. Analysis

Particularly analysis is carried out in three stages by performing various operations in software.

1.) Preprocessing

a) Meshing

In this stage, igs file is imported to the meshing software like Hypermesh. The CAD data of the arm structure is imported and the surfaces were created and meshed.

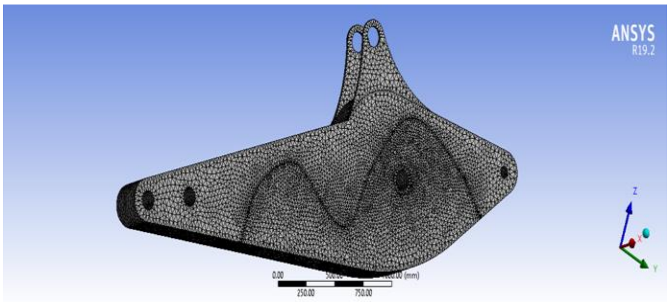

Fig.7. tetra-hedral meshing on arm of excavator

Number of nodes: 132891
Number of elements:66049 Element size = 20 mm

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b) Solution and Post-processing

After that, the meshed and boundary conditions applied object is imported to the solver section. After applying run in the solver software. The analysis process starts immediately.

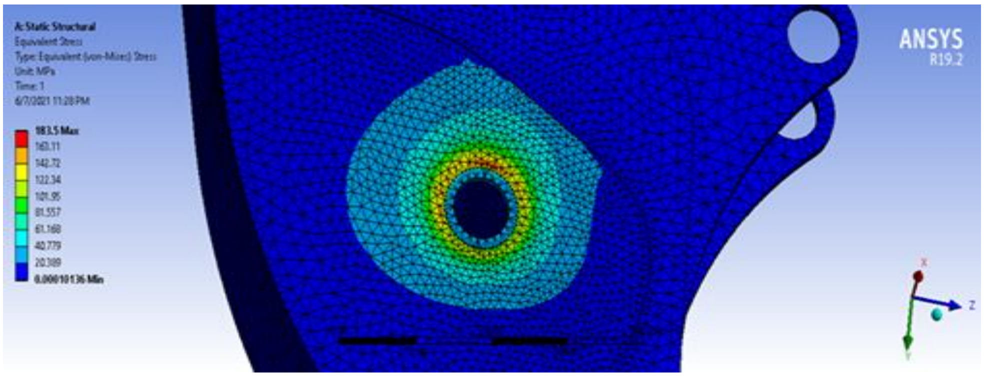

Fig.8: Von-mises stress at joints of excavator arm

The stress value determined for excavator arm is 234.45 N/mm2 which is well below the critical value. Hence, design is safe.

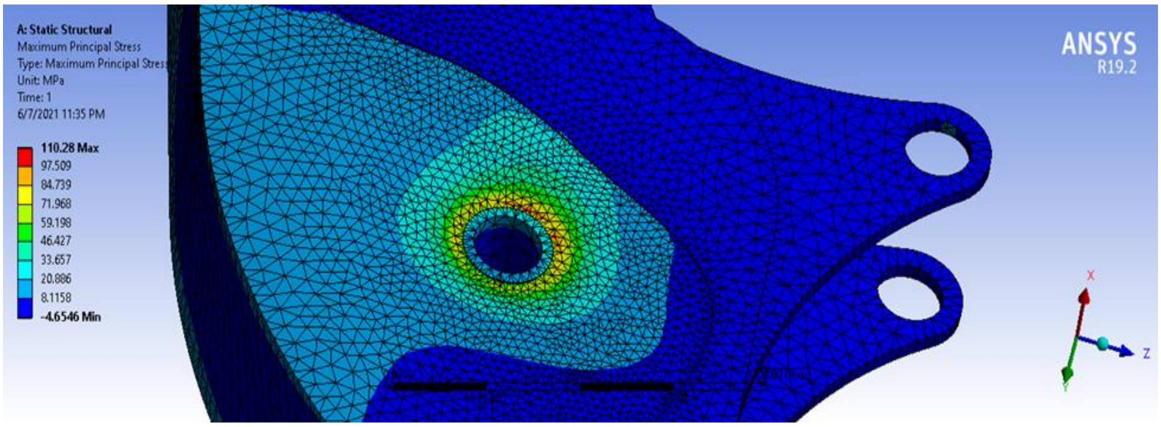

Fig 8. Maximum Principal Stress

The max stress obtained is 183.5 MPa which means the design is safe as the yield strength of the arm is 250MPa.The maximum Principal stress found was 110.28MPa

From the analysis following comparison stresses and deformation are observed.

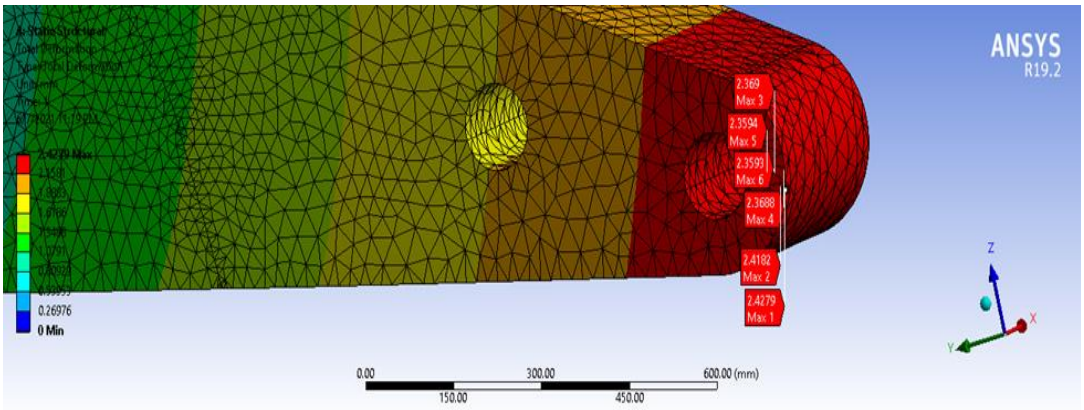

Fig.9 Total Deformation

The Total Deformation was observed to be 2.42 mm which is much lesser thus the minimum plate thickness of any subpart of the arm i.e. 35 mm .Hence the design is also safe in terms of deformation Analysis results.

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IV. CONCLUSION AND FUTURE SCOPE

Conclusion

1. The forces on the excavator are calculated and the forces flowing to excavator arm are determined.
2. The excavator arm is modelled and analysed using software.
3. The analysed part shows there is a scope for optimization.
4. The FEM results and experimental results are made a comparable study and the validation shows close variance.
5. From comparison of weight of existing model and optimized model it is seen that Overall weight reduction of 5% approximately has been achieved.

Future scope

Although Finite Element analysis is a user-friendly process, a lot more can be done in this subject. This will also help the future inventions for the better improvement in this. Finite element analysis for state of Boom, Arm, Buckets while at rest or moving and at its numerous degrees of freedom can play a vital role for future researchers to study, as this will be easy to study and therefore obtain a long lifecycle without breakdown for large machinery such as Excavators.

V. ACKNOWLEDGMENT

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