Design Modifications and Analysis of Excavator Boom

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Abstract - *Excavators are considered as earthmoving equipments and generally used for excavation process. During the process unknown large amount of resistive forces offered by the terrain, stones to the bucket teeth adversely affect on the excavator parts and may fail during excavation process. Design engineer has a challenge for robust design of earth moving equipments which can work against unpredicted forces and under critical working condition. Thus, designers should provide not only a better design of parts that has maximum reliability but also minimum weight and cost, keeping design safe under all operating conditions. In this paper, Finite Element Analysis (FEA) tool is used for analysis and modifications of excavator boom. A modified design is proposed having rib structure with reliability. A 3D model of a boom is drawn by reverse engineering of existing structure in CATIA V5R19, Hypermesh 12.0 is used for meshing, and Ansys R15.0 will be used for solutions.*

Keywords – FEA, Boom, Rib structure, modification.

I. INTRODUCTION

A bucket type excavator consists of an upper rotatable chassis and a hydraulically mounted mechanism consisting of bucket, boom, and arm which is as shown in fig. 1.Excavator is used as a utility machine for general excavation process, loading of hoppers and trucks, the cleaning of canals and ditches, solid waste management, demolition and mining work. Excavator goes through various motions like digging, pushing or pulling soil, lifting, swinging to carryout excavation task. Human operator controls this motion of the machine manually [1].

As use of this earth moving machine is increasing, more and more attention is provided for increasing its strength and making robust design with reducing cost. Generally, excavator is used to excavate soil by applying the force on the surface of earth using hydraulic system. Force is transmitted from ground then bucket to different parts of excavator.

Excavator comes in various sizes depending on size of bucket, boom length, arm length and operational working speed. The material considered for the excavator boom is Hardox400.

Hardox is also known as high strength steel with a great combination of hardness and toughness. Hardox has the yield strength of 1000 MPa[3].

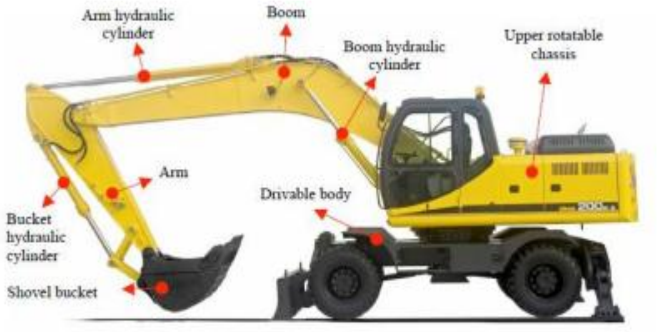

Fig.1: General view of an excavator

II. LITERATURESURVEY

Amol B. Bhosale, et. all[1], analyzed existing boom structure of an excavator. Forces were calculated and found that maximum von mises stress is below than its yield stress. Thickness of the structure was reduced for optimizing it. Results gave 36.4% reduction in weight.

JanmitRajet. all[2], highlighted the most relevant work done by researchers in the area of excavator boom. Static structural analysis, fatigue analysis, modal analysis, shape optimization of excavator boom were topic of interest of the authors.

S.SekharBabu, et. all [3], performed structural analysis on bucket of an excavator. The main aim of the author was to design excavator bucket by certain parameters and to improve its life. It was found that ribs have to be changed periodically to protect the bucket.

R M Dhawale, et. all [4], studied various research works in the area of excavator and its attachment. Calculations of forces are done which are further taken for analysis purpose.

This paper is important for researchers who are working in the field of finite element analysis of excavator.

AiminJiet. all [5], a method of integrated design of boom and analysis is put forward by considering all the problems in in development of actual product and working process of boom. Integrated design and analysis includes parametric design of excavator boom along with database design, mid surface extraction, static structural analysis. Simplification in structure is done based on parametric calculations.

Bhaveshkumar P Patel, et. all [6],has done the analysis on all the excavator components like bucket, boom, arm, swing link. Stresses and deformation were found out. With this , analysis of excavator taking welding consideration is done in which strength of the material for the welding should be less than the strength of the base metal.

Bhaveshkumar P Patel, et. all [7], provides a platform for analyzing and optimizing backhoe excavator attachment. In this, boom was modeled as a flexible body by using NASTRAN and the joint reaction forces of a rigid model and a flexible model are compared.

Gaurav K Mehta, et. all [8], found out force acting on each part of excavator linke bucket, boom, arm by static force. Analysis method by considering different operating conditions. It was found that critical condition for mechanism is where the maximum digging force acts. Each component was considered as free body for carrying force acting on it.

III. PROBLEMSTATEMENT

Excavators are subjected to high corrosive effects and loads. The excavator mechanism must even work under unpredictable operating conditions. Poor strength properties of the excavator parts like boom, arm and bucket limit the life of the excavator. Therefore, excavator parts should be robust enough to cope with caustic operating conditions of the excavator. The skilled operator is unaware of condition of road, soil parameter and sand force transmitted from soil during excavation process. These forces should consider for better design of tools, other parts of excavators, and for planning trajectory motion. Excavator has a cyclic motion during excavation. Because of this repetitive nature of work, cyclic stress are developed in the parts of excavator. In today's world, weight is one of the major concern while planning and designing any machine parts. So for reducing the overall price further as for smoothing the performance of machine, modification is required. Analysis for weight reduction of boom to save material cost and fuel economy throughout the excavation operation under safe loading condition is needed [4, 6, 7]

IV. OBJECTIVES

This project, which will become alternate design for boom, comprise of rib structure to withstand high stresses developed during unpredictable working condition.

1. Structural analysis which determines the area under high stress using FEA.
2. Reduction in material which will reduces weight of structure by modification and ultimately reduces basic and operating cost.

V. METHODOLOGY

Steps followed for analysis of complete assembly of excavator are as follows

A. Analysis of existing model

1. Reverse engineering of existing model.
2. Generation of 3D model in CATIA V5R19software.
3. Meshing of assembly, applying connections etc in Hypermesh12.0
4. Analysis of the assembly is done on AnsysR15.0 to

Predict the stresses area developed on surface of boom of excavator which is then considered for modification.

B. Analysis of modified model

1. Modification is done in form of iterations by reducing thickness of plates and by adding ribs structure in boom for each iteration and CAD model is done.
2. Analysis is done for each iteration of modified model to check maximum scope of weight reduction.

C. Fabrication ,testing

D. Validation (software and experimental)

VI. ANALYSIS OF EXISTING MODEL

1 CAD modelling

Dimensions are taken through reverse engineering i.e. through manual calculations. CAD model of bucket, link, boom and arm is done. Fig.2 shows assembly in which components are arranged in such way that maximum digging force will act on bucket.

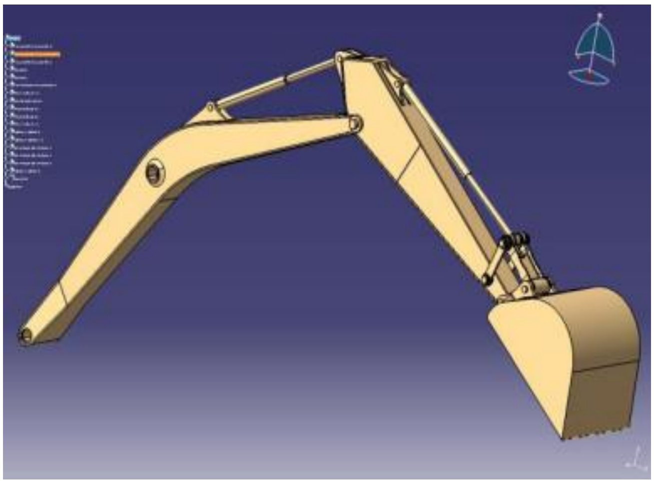

Fig.2: Assembly of excavator in CATIA

Preprocessing:

Certain steps in formulating a finite element analysis are meshing, applying of boundary condition, assigning material properties etc. The .igs file is imported to the meshing software like Hypermesh. The CAD data of the excavator structure is imported and the surfaces were created and meshed. Since all the dimensions of boom are measurable (3D), the best element for meshing is the tetra-hedral. Individual component of an excavator is meshed independently and then connected by giving proper connectivity between elements. Element connectivity is a biggest issue in this assembly meshing. Each meshed component should have connectivity with its adjacent component mesh. After meshing elements are to be checked for Quality i.e. elements have some definite quality criteria which should be met by all elements. An important element criterion for 3D mesh is tetra-collapse.

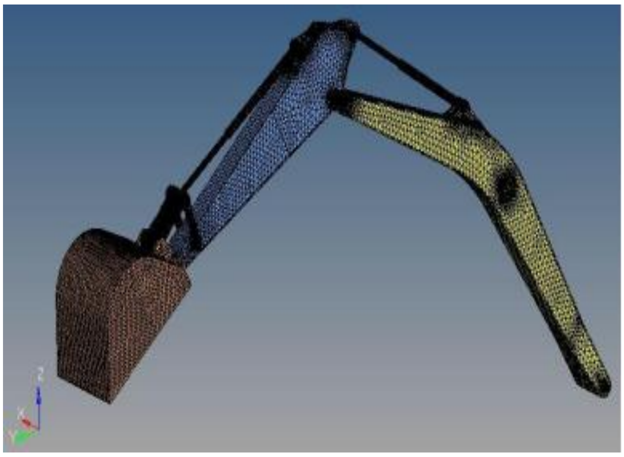

Fig. 3: Meshed model of an excavator.

Fig. 4 shows maximum digging force is applied of 54KN and constraints are applied to other end of boom.

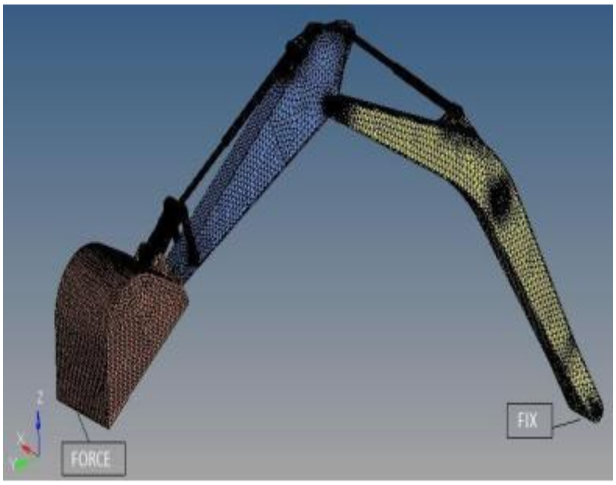

Fig 4: Physical constraints applied on excavator in Hypermesh.

Material properties:

Table 1: Part list of excavator:

Sr No.	Component	Material
1	Bucket	Hardox400
2	Bucket link	Hardox 400
3	Arm	Sailma 450
4	Boom	Sailma 450

Table2:MechanicalpropertiesofHardox400

Sr No.	Property	Value
1	Density	7473.57 Kg/m3
2	Modulus of elasticity	210000 MPa
3	Poisson's ratio	0.29
4	Ultimate strength	1250 MPa

Table3: Mechanical properties of Sailma450

Sr No.	Property	Value
1	Density	7900 Kg/m3
2	Modulus of elasticity	210000 MPa
3	Poisson's ratio	0.3
4	Ultimate strength	700 a

VI. POST-PROCESSING

Analysis and evaluation of the solution results is referred to as post-processing. Post processor software contains sophisticated routines used for sorting, printing, and plotting selected results from a finite element solution. Post- processing is done in ANSYS by importing cdb format of file and then running it. Post-processing will give results of von-mises stress and deformation of excavator assembly. Fig. 5 shows Von-misses stress on excavator assembly. Maximum von-misses stress is 284.3MPa which is less than yield value.

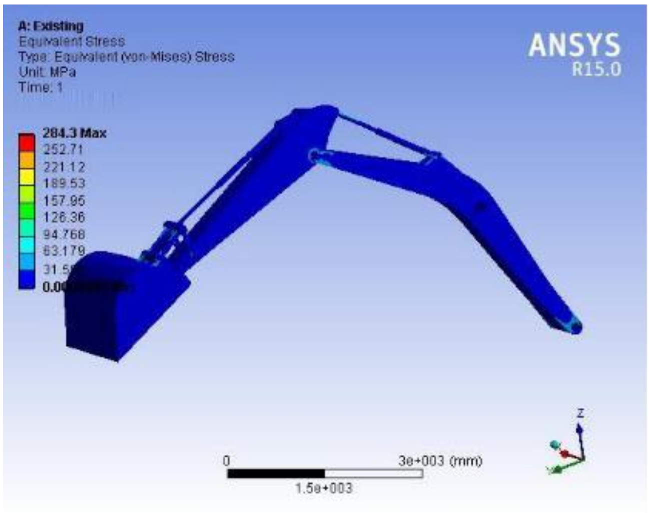

Fig. 5: Von-misses stress on excavator assembly.

Deformation comes to be 15.289mm for maximum digging force applied on bucket. Fig. 6 shows deformation developed on excavator assembly.

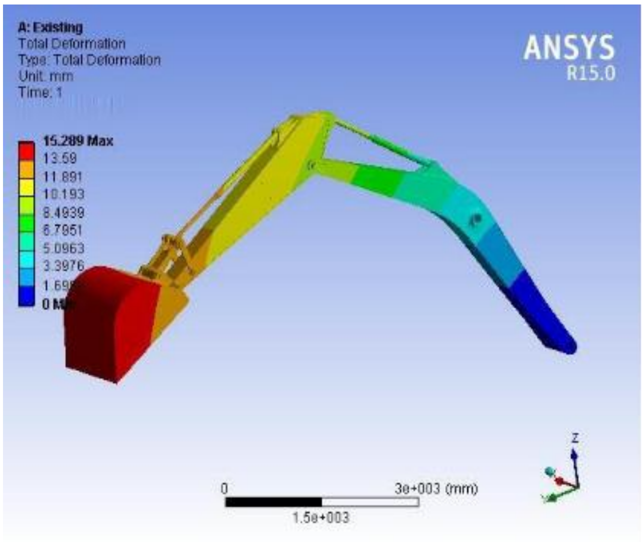

Fig. 6: Deformation plot for excavator

VII. MODIFICATION

From the plots of von-misses stress it can be seen that stress is below critical value so there is scope of weight modification. The aim of this paper is to present a new design of excavator arm that will have better strength. The new design will comprise of ribs to give additional strength to the boom structure. So for modification iterations are done by reducing thickness of boom plates having low stress flow and ribs are provided to maintain strength in boom which will sustain applied digging force.

A. Iteration I:

Cad modelling: 2 mm thickness is reduced from side plate and ribs are made. Fig. 7 shows CAD model of assembly used in iteration I.

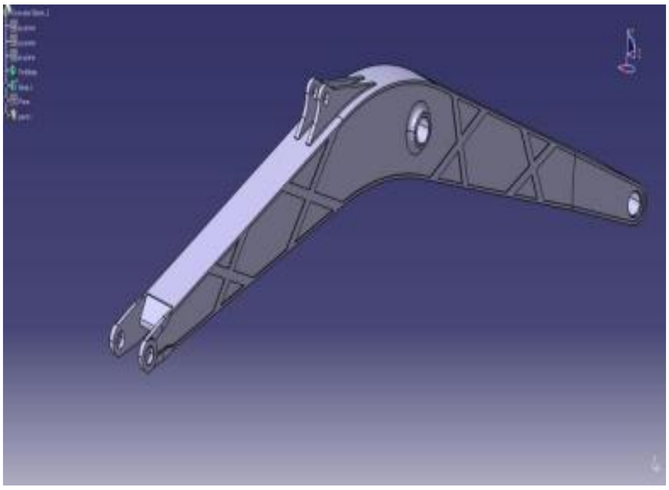

Fig. 7: CAD model of boom with rib for iteration I

Meshing:

Fig. 8 shows Meshed model of assembly with supporting ribs for iteration I

Meshing details:

Type of element: Tetra-hedral element

No. of nodes: 79890

No. of elements: 26214

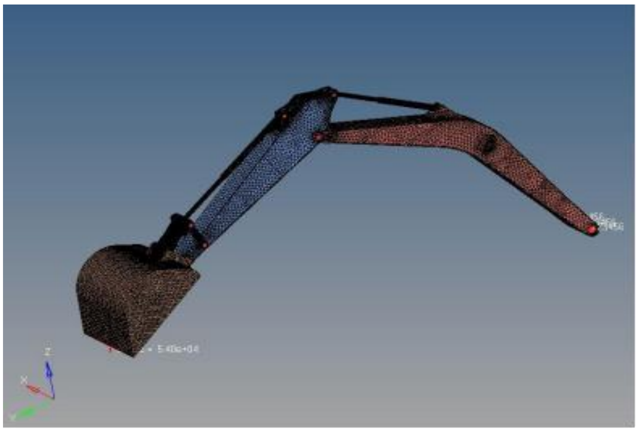

Fig. 8: Meshed model of assembly for iteration I

Analysis:
Fig. 9 Von-misses stress developed on excavator assembly for iteration I. Maximum von-misses stress is 280.35MPa which is less than yield value.

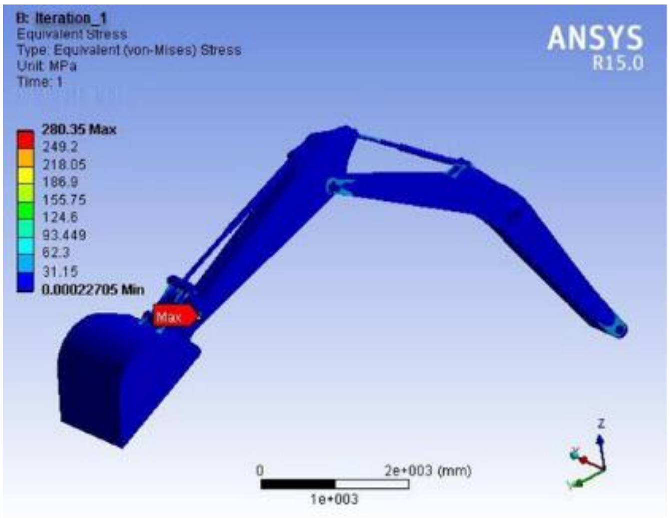

Fig. 9: Von-misses stress on assembly for iteration I

Fig. 10 shows deformation on excavator assembly for iteration I.

Deformation comes to be 14.8mm for maximum digging force condition that was applied on bucket.

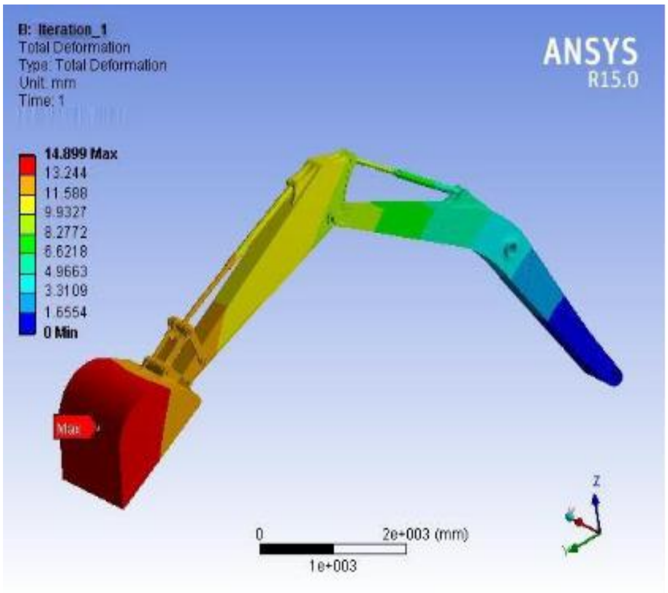

Fig. 10: Deformation on assembly for iteration I.

B. Iteration II:

Cad modelling: Total 4 mm thickness is reduced from side plate and ribs are made. Fig. 11 shows CAD model of boom.

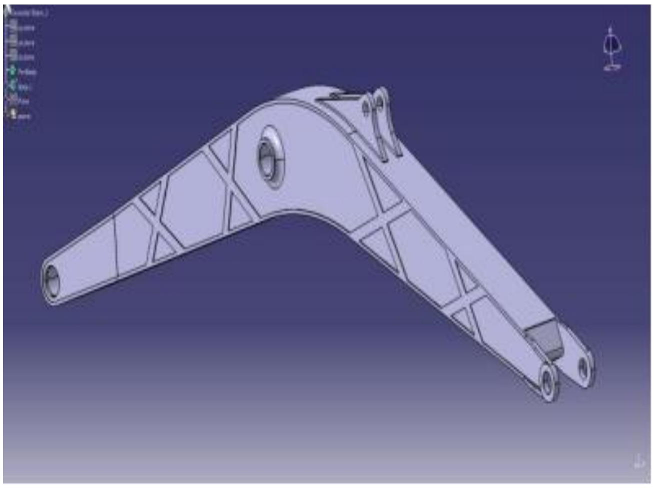

Fig. 11: CAD model of boom with rib for iteration I

Meshing:
Fig. 12 shows Meshed model of boom with supporting ribs for iteration II
Meshing details:
Type of element: Tetra-hedral element No. of nodes: 79860
No. of elements: 26214

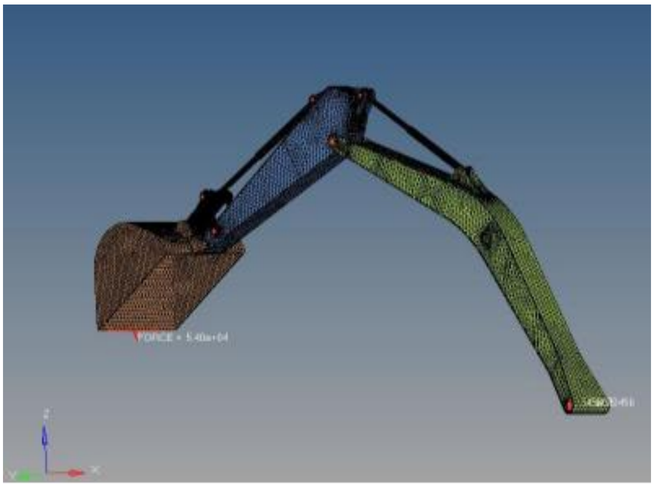

Fig. 12: Meshed model of boom for iteration II

Analysis:

Fig. 13 Von-misses stress developed on excavator assembly for iteration I. Maximum von-misses stress is 284.34MPa which is less than yield value.

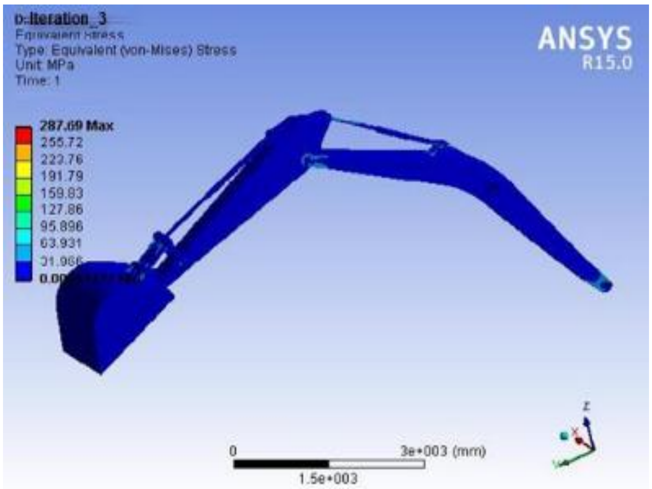

Fig. 13: Von-misses stress on assembly for iteration II

Fig.14 shows deformation on excavator assembly for iteration II.

Deformation comes to be 15.3mm for maximum digging force condition that was applied on bucket.

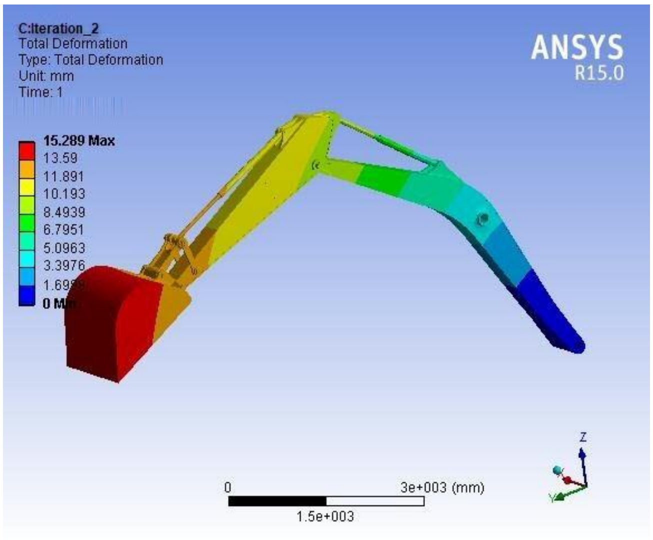

Fig. 14: Deformation on assembly for iteration II.

C. Iteration III:

Cad modelling: Total 4 mm thickness is reduced from side plate, 2mm thickness reduced from upper and lower plates each and ribs are made. Fig. 15 shows CAD model of boom.

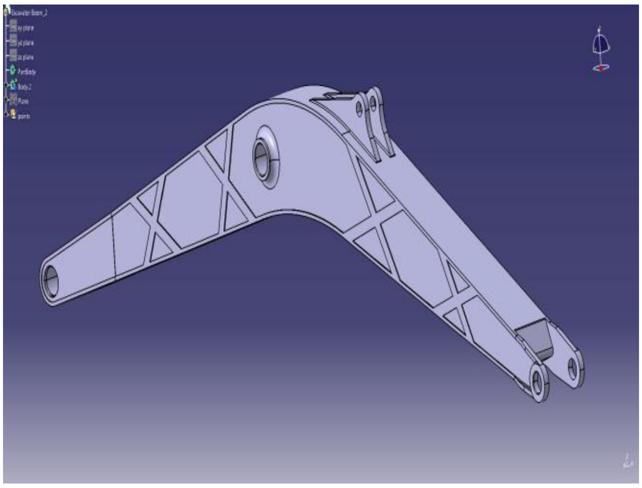

Fig. 15: CAD model of boom with rib for iteration III

Meshing:

Fig. 16 shows Meshed model of assembly with supporting ribs for iteration III

Meshing details:

Type of element: Tetra-hedral element

No. of nodes: 80549

No. of elements: 26348

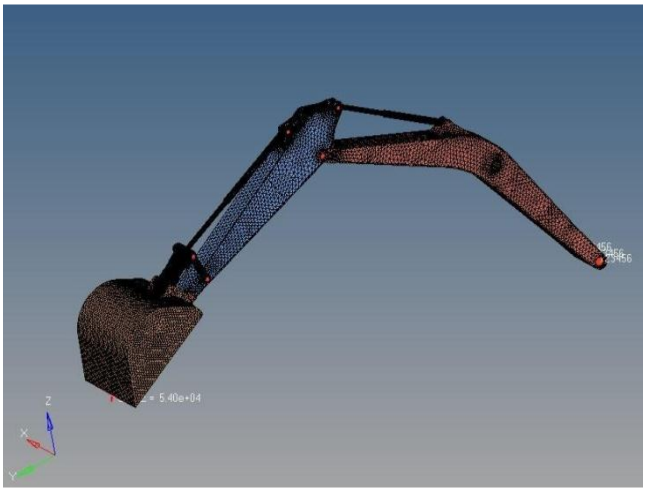

Fig. 16: Meshed model of assembly for iteration III

Analysis:

Fig. 17 Von-misses stress developed on excavator assembly for iteration I. Maximum von-misses stress is 287.69MPa which is less than yield value.

Fig. 17: Von-misses stress on assembly for iteration III

Fig. 18 shows deformation on excavator assembly for iteration III.

Deformation comes to be 15.3 mm for maximum digging force condition that was applied on bucket.

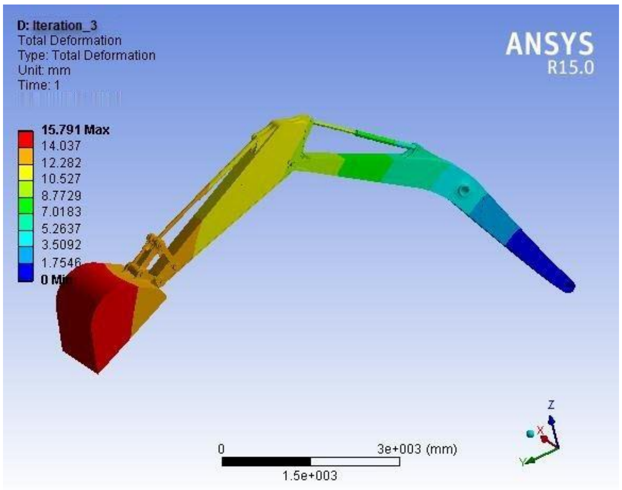

Fig. 18: Deformation on assembly for iteration III.

D. Iteration IV:

Cad modelling: Total 4 mm thickness is reduced from side plate, 4mm from upper and lower plates each and additional ribs are made. Fig. 19 shows CAD model of boom.

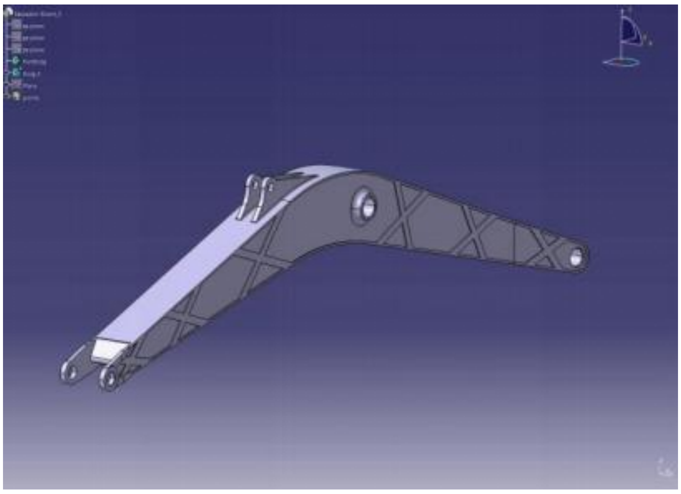

Fig. 19: CAD model of boom with rib for iteration III

Meshing:

Fig.20 shows Meshed model of assembly with supporting ribs for iteration IV

Meshing details:

Type of element: Tetra-hedral element

No. of nodes: 81233

No. of elements: 26542

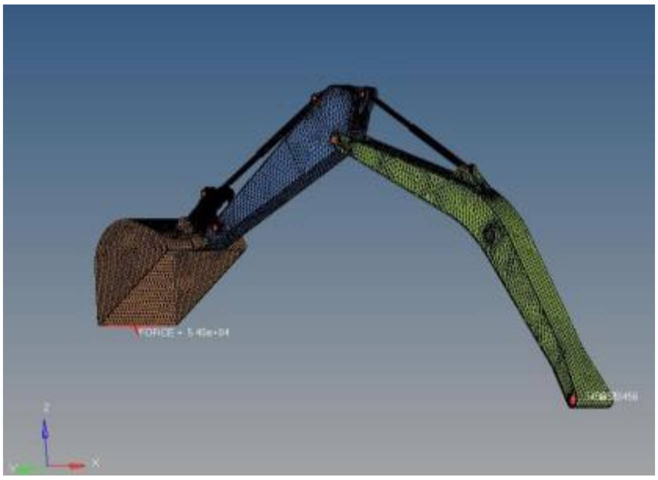

Fig.20: Meshed model of assembly for iteration IV

Analysis:

Fig. 21Von-misses stress developed on excavator assembly for iteration I. Maximum von-misses stress is 282.37MPa which is less than yield value.

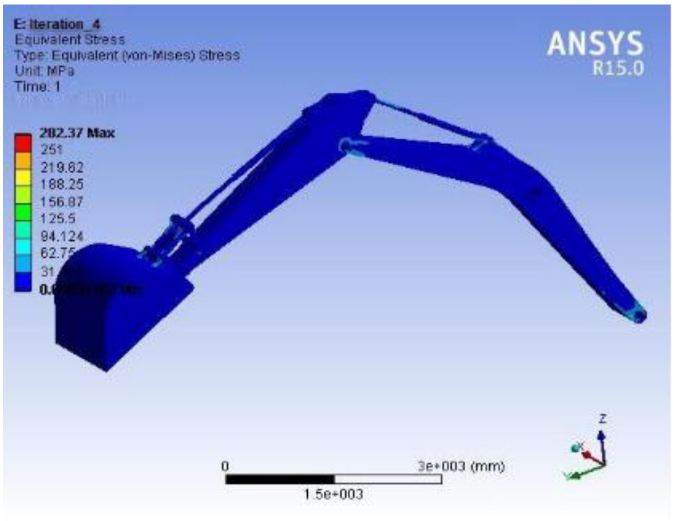

Fig.21: Von-misses stress on assembly for iteration IV

Fig. 22 shows deformation on excavator assembly for iteration IV.

Deformation comes to be 15.182 mm for maximum digging force condition that was applied on bucket.

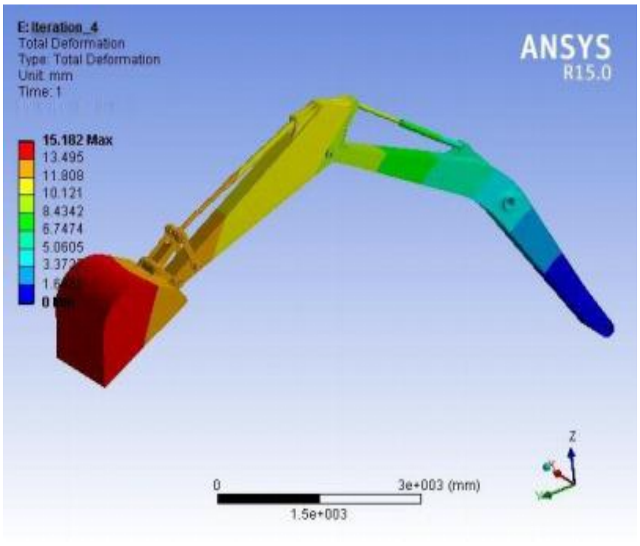

Fig. 22: Deformation on assembly for iteration IV.

VIII. RESULTS ANDDISCUSSIONS

Iteration I: Weight of excavator assembly before modification is 1558.9 kg and after 1st iteration it reduces to 1523.61 kg. Also von misses stresses after 1st iteration is 280.35MPa which is less than yield value.

IterationII: Weight of excavator assembly before modification is 1558.9 kg and after 2nd iteration it reduces to 1474.38 kg. Also von misses stresses after 2nd iteration is 284.34MPa which is less than yield value.

Iteration III: Weight of excavator assembly before modification is 1558.9 kg and after 3rd iteration it reduces to 1448.28 kg. Also von misses stresses after 3rd iteration is 287.69 MPa which is less than yield value.

Iteration IV: Weight of excavator assembly before modification is 1558.9 kg and after 4th iteration it reduces to 1382.7 kg. Also von misses stresses after 4th iteration is 282.37 MPa which is less than yield value.

So, results of above iterations shows there is scope of modification within safe stress limit.

IX. CONCLUSION

Iteration I give 2.26% weight reduction, Iteration II give 5.42% weight reduction, Iteration III give 7.09% weight reduction and Iteration IV give 11% weight reduction within safe limit.

X. PROPOSEDWORK

After this satisfactory result, scaled down model will be fabricated and tested on UTM for validation.

XI. ACKNOWLEDGMENT

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