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TRANSIENT STRUCTURAL ANALYSIS OF BACKHOE STRUCTURE IN BACKHOE LOADER

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ABSTRACT

Backhoe loader are used to carryout wide variety of task like trench excavation, digging, pipe lining, canal renovation, etc. Backhoe loader are versatile machine through which the excavation operation made with ease. The backhoe structure is analysed to find the optimised structure. Optimisation is done for easy maneuverability of the backhoe loader. The transient analysis is done to find the dynamic response of the backhoe structure under time varying loads. The dynamic response is analysed to find the deformation on the tooth. The backhoe structure is drawn using SOLIDWORKS software. The backhoe structure is analysed using ANSYSsoftware.

Keywords:Boom, ram, bucket force, arm force, backhoe structure, transient analysis.

I.INTRODUCTION

Backhoe loader is a heavy equipment vehicle that consists of a tractor like unit fitted with a loader-style shovel/bucket on the front and a backhoe on the back. The backhoe is the main tool of the backhoe loader. Enhanced articulation of attachments can be achieved with intermediate attachments such as the tilt rotator.

Figure 1 Backhoe loader Parts

II.LITERATURE STUDY

For digging this trenches which are offset from the road, difficulty occur in placing the backhoe in position for the operation. An attachment mounted between the boom and arm of the Backhoe loader. This attachment will enable the arm of the backhoe loader with respect to its boom to rotate about 140^{o}. So by placing the backhoe on road, the boom can be placed on the excavation position and the arm is then rotated by means of two swing cylinders mounted in an inclined manner to place the arm inline with the trenches. The design for this attachment is done using SOLIDWORKS and analyzed by ANSYS WORKBENCH. The outcomes show that the deformation is slight [1].In next paper, theyhave optimized the boom design by reducing its weight. Since, boom is major, heavier and most critical part in excavator & so design of Boom & its optimization is done by FEA approach [2].

An optimized design of boom for excavation of heavy duty machine is done by optimization. The thickness of the material is reduced in the modeling for optimum weight of the excavator [3].An idea to increase the life of backhoe excavator bucket is done by comparing the two material HORDOX-400 and HORDOX-500 in ANSYS, for the similar force and boundary conditions that of the existing bucket [4]. In a study, static structural analysis of backhoe-loader arms has been performed with the finite element method (FEM). According to analysis result, back and front arms of the backhoe-loader are strengthened with the use of reinforcements. As a result of the study, strength of the arms has been increased by nearly 20% [5].

III.PROBLEM IDENTIFICATION

Backhoe Loader is versatile machine and able to operate in different conditions. It is used in different excavation operation like trench digging, laying pipes, etc. But the problem arises in excavating trenches. The backhoe structure at rear end reduce the maneuvariblilty of the backhoe loader. So, the weight of the backhoe structure is reduced by optimization technique. The optimization is done based on the bucket digging and arm crowd force. So, by reducing weight of backhoe, the maneuvaribility and milage of backhoe loader is increased. The objective of the paper is to analyses the backhoe structure with the offset boom. The analysis is done using ANSYS software by loading the max bucket tear out force to the backhoe structure.

1.MODELING OF THE BACKHOE STRUCTURE

The Backhoe structure consists of the following parts,

1) Boom
2) Arm
3) Bucket
4) Connecting links

The backhoe structure is constructed using the SOLIDWORKS software.

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Figure 2 Boom

Figure 3 Arm

Figure 4 Connecting links

Figure 5 Bucket

The assembled View of the Backhoe structure is shown below

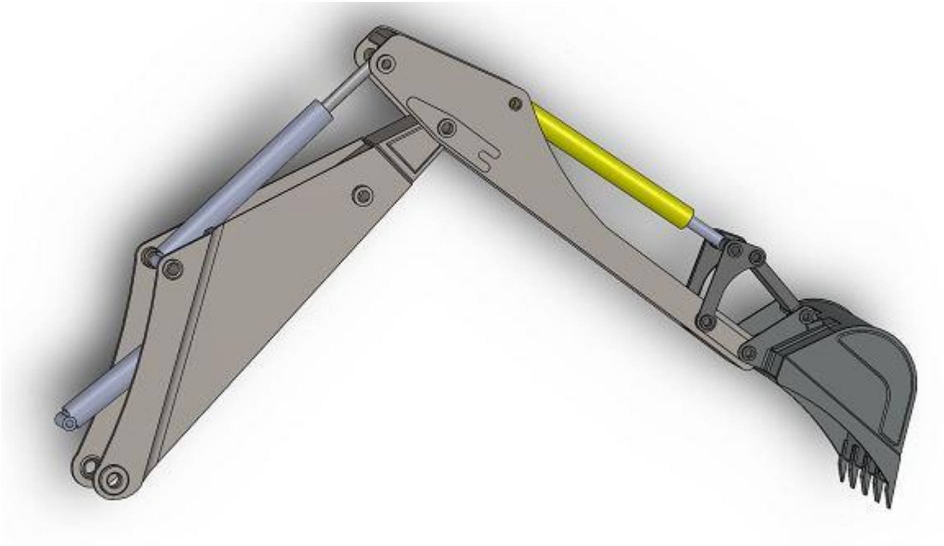

Figure 6 Backhoe Structure

IV.TRANSIENT ANALYSIS OF BACKHOE STRUCTURE

The transient analysis is done using the ANSYS software. The max bucket tear out and arm tear out forces is applied on backhoe structure to check for the deformation and stress action. The rating of these digging forces is set by SAE J1197 [6] standard "Surface Vehicle Standards - Hydraulic Excavator and Backhoe Digging Forces".

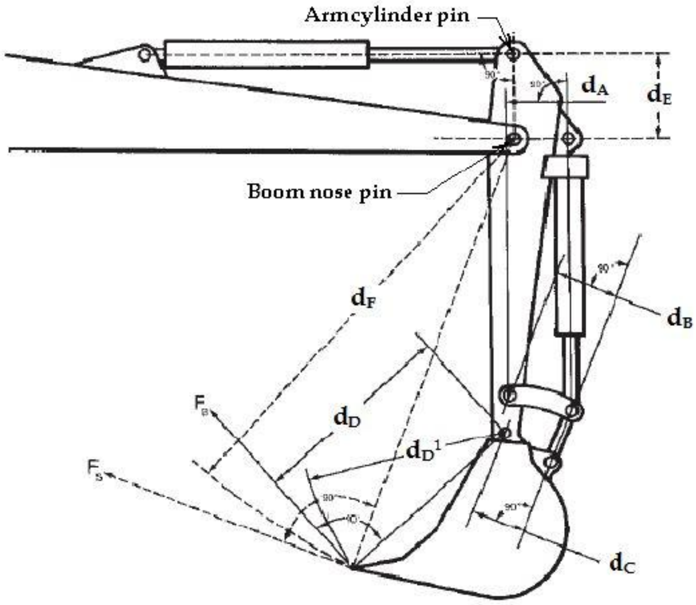

Figure 7 Digging Force Calculation – SAE J1197

The bucket tearout force is calculated by the formula given below.

$$F_B = \frac{Bucket\ cylinder\ force\ x\ sin\phi}{d_D}\left(\frac{d_A\ x\ d_C}{d_B}\right)$$

The value ϕ varies from 12^o to 105^o. At ϕ = 90^o, F_B =Max bucket fear out force. The length of d_A, d_B, d_C, d_D is measured. The bucket cylinder force is found to be 127170 N. The table below gives the various bucket tear out force at different angle ϕ.

Table 1 Bucket Tear out Force

F_B (N)	ϕ (^{o})	Force on Each tooth (N)
8398.94	12	1679.79
19997.48	30	3999.50
34635.64	60	6927.13
39994.97	90	7998.99
38595.14	105	7719.03

The Arm Crowd force is calculated by the formula below.

$$F_S = \frac{Arm\ cylinder\ force\ x\ sin\alpha\ x\ d_E}{d_F}$$

The value αvaries from 44^o to 128^o. At α = 90^o, F_B =Max Arm crowd force. The length of d_E,d_F is measured. The bucket cylinder force is found to be 189970 N. The table below gives the various arm crowd force at different angle α.

Table 2 Arm Crowd Force

F_S (N)	α (^{o})	Force on Each tooth (N)
20599.87188	44	4119.97
25705.31563	60	5141.06
29682.8125	90	5936.56
27872.16094	110	5574.43
23390.05625	128	4678.01

4.1 Analysis of backhoe structure

The material considered for the both arm crowd and bucket tear out force analysis is HARDOX 400. The figure 8 shows the meshing of the backhoe structure for both the Arm crowd and bucket tear out force.

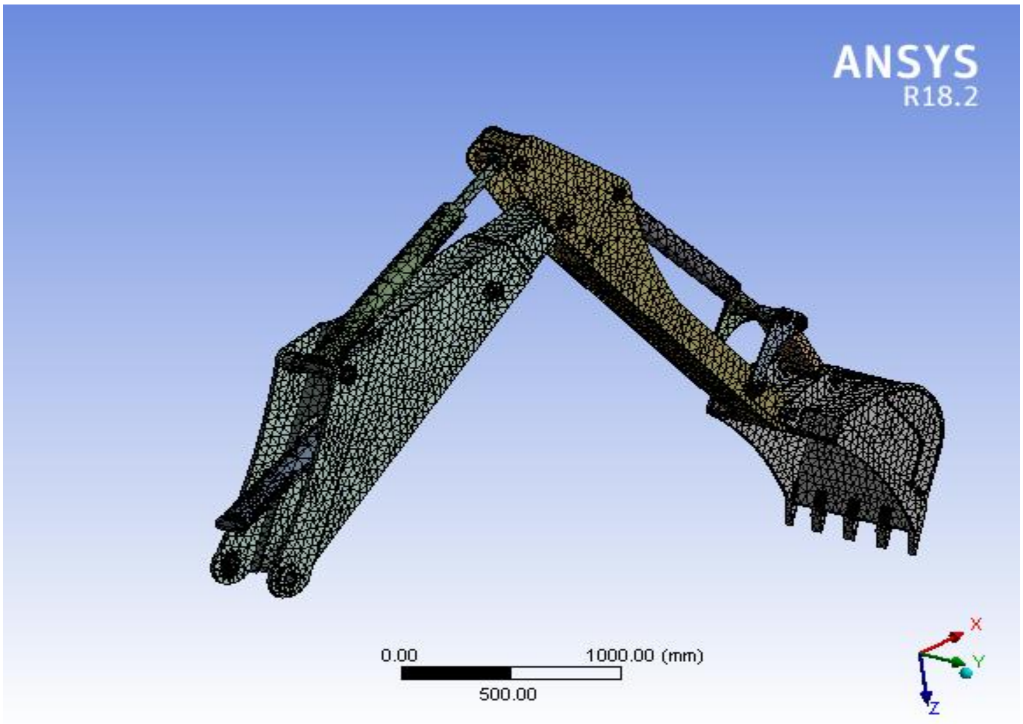

Figure 8 Mesh

Type – Fine   Size – 50 mm

No. of nodes – 104618   No. of elements – 52757

Table 3 Properties of the Hardox 400

S.no	Property	Value
1.	Density	7850 kg / m^3
2.	Poisson's ratio	0.29
3.	Yield Strength	1000 MPa

The material properties of HARDOX 400 is given in the table 3.

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4.2 Bucket Tear Out Force:

The bucket tear out force act in tangential direction to the bucket. So the force are resolved and applied in analysis.

4.2.1 Loads

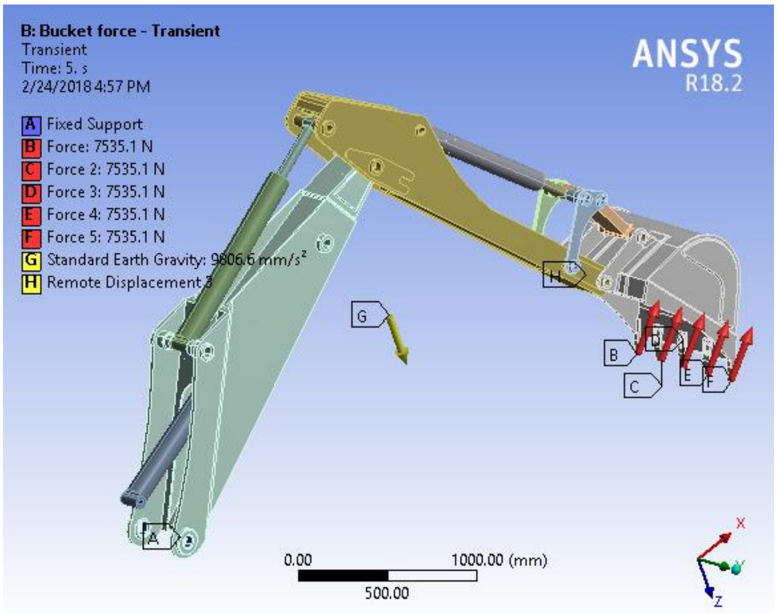

Figure 9 Loads – Bucket Force

4.2.2 Total Deformation

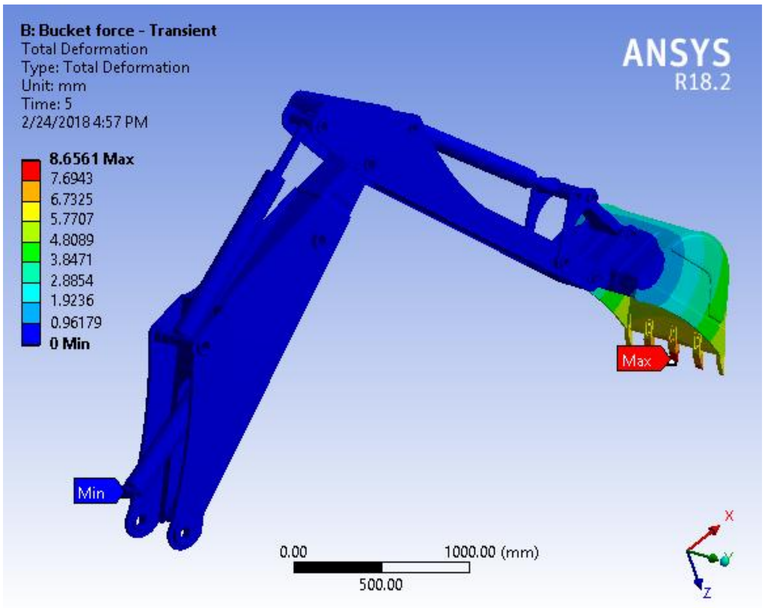

Figure 10 Total deformation – Bucket Force

4.2.3 Von – mises Stress

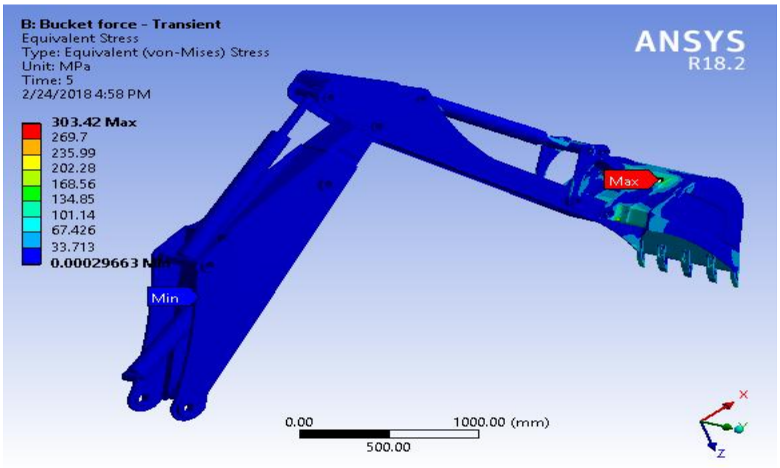

Figure 11 Von-mises stress – Bucket force

4.2.4 Result – Bucket Force

Table 4 Bucket force analysis results

Force (N)	Total Deformation (mm)	Von mises Stress (MPa)
8398.94	1.77	61.57
19997.48	4.40	153.15
34635.64	7.75	271.30
39994.97	8.98	314.79
38595.14	8.65	303.41

At max bucket force the deformation is found to be 9 mm which is less when compare to the tooth thickness.

4.3 Arm Crowd Force:

The Arm crowd out force act in tangential direction to the bucket. So the force are resolved and applied in analysis.

4.3.1 Loads

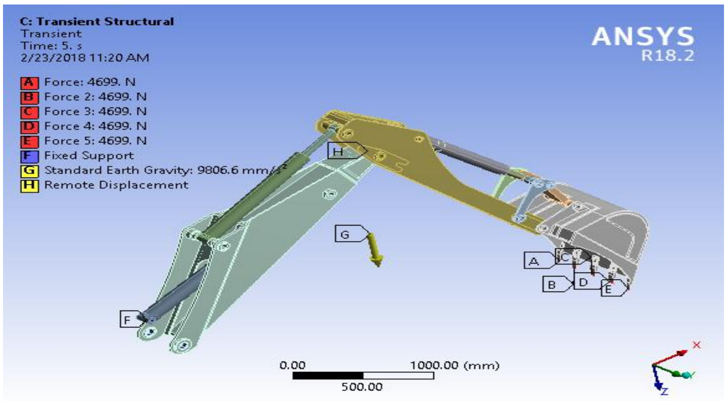

Figure 12 Loads – Arm Force

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4.3.2 Total Deformation

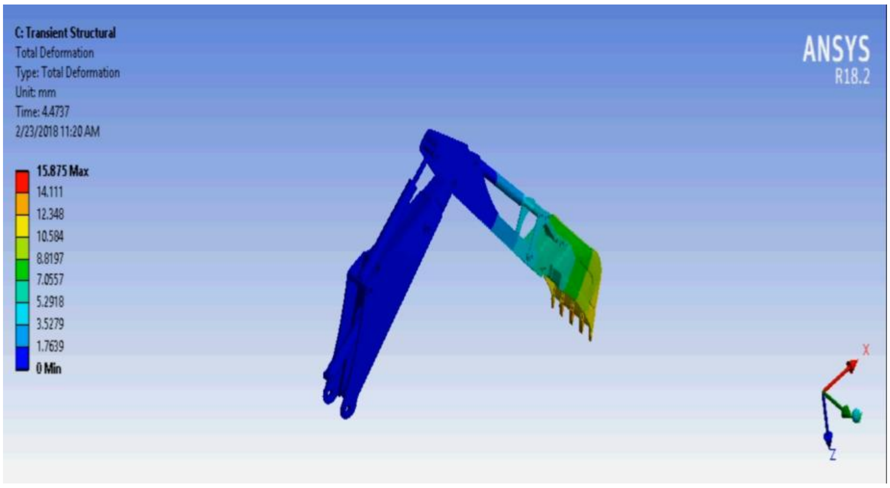

Figure 13 Total deformation – Arm Force

4.3.3 Von – mises Stress

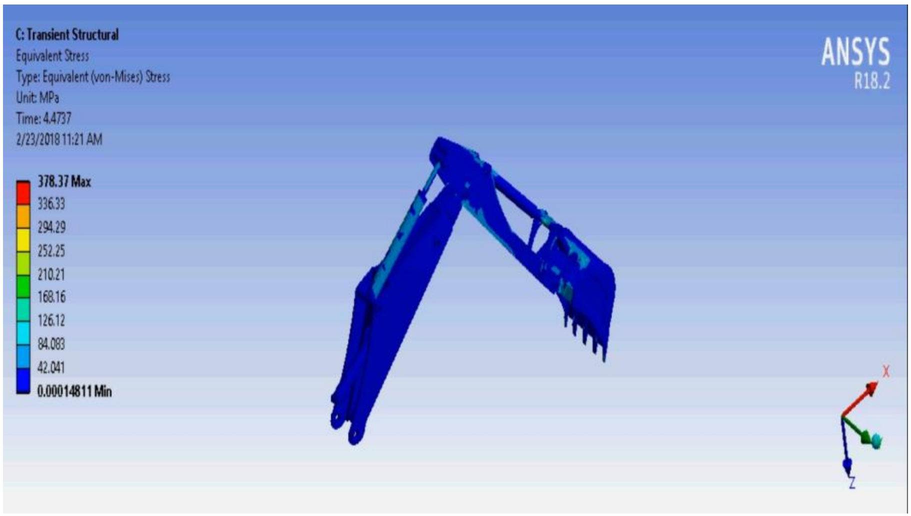

Figure 14Von-mises stress – Arm force

4.3.4 Result –Arm Force

Table 5 Bucket force analysis results

Force (N)	Total Deformation (mm)	Von mises Stress (MPa)
20599.87188	10.75	256.44
25705.31563	13.65	325.26
29682.8125	15.88	378.37
27872.16094	14.88	354.53
23390.05625	12.32	293.67

At max bucket force the deformation is found to be 16 mm which is less when compare to the tooth thickness.

V.RESULTS

Table 6 Analysis result

S.no	Analysis Result	Bucket force	Arm Force
1.	Total deformation (mm)	9	16
2.	Von-mises stress (MPa)	314.79	378.37

From the result it is seen that the

1) Stress developed lies below the yield strength of the material.
2) The total deformation allows less than the thickness of the part.

And hence the design is found to be safe. At max arm crowd force, the deformation is high. Under arm crowd condition, the life of the tooth reduce because of the high deformation.

VI.CONCLUSION

So, from the analysis result we can see the stress developed and total deformation lies below the design criteria. The deformation of tooth is more at arm crowd condition. So, by controlling the force exerted by arm cylinder using a pressure relief valve, we are able to reduce the deformation on the tooth. Optimizing the backhoe structure, we are able to reduce the weight of the backhoe structure. Optimisation is done to reduce the weight imbalance of the backhoe machine. Because the increase in weight at rear end, reduce the maneuverability and performance of the backhoe machine.

VII.ACKNOWLEDGMENT

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