Design of Boom Attachment in Backhoe Loader to Excavate Inaccessible Location

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Abstract

Backhoe loaders are used for a widespread of job like construction, small destructions, light conveyance of building materials, powering building equipment, digging holes, excavation, and paving roads. Normally, the trenches are constructed at an offset distance from road. For digging this trenches which are offset from the road, difficulty occur in placing the backhoe in position for the operation. At present, a Knuckle boom is attached to the boom for rotation of the arm. This knuckle boom able to rotate the arm only 30^o and another attachment, tiltrotator is used to rotate the bucket inline to trenches and excavation is made possible, which can rotate upto 360 ^{o}. However, this tiltrotator able to dig only 2 feet depth. The aim of the project is to overcome the above problem by mounting an attachment 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. Stresses developed are less than yield strength of the material.

Keywords —*Offset boom Carriage, Offset boom kingpost, boom, backhoe loader, Static Analysis, Boom attachment.*

I. INTRODUCTION

The backhoe is the chief tool of the backhoe loader.

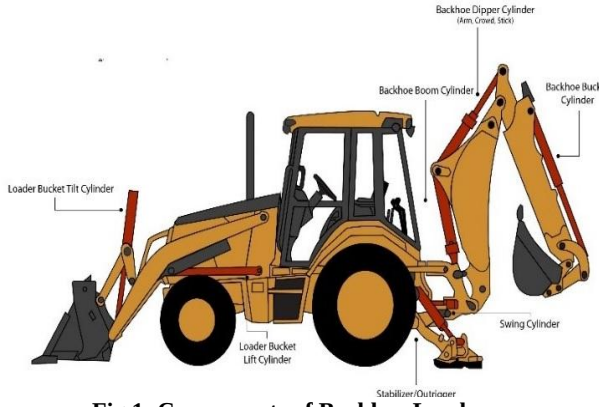

Fig.1: Components of Backhoe Loader

Backhoe loader normally known as earth movers, that contains a tractor unit fitted with a loader-style shovel on the forward-facing and a backhoe on the rear. Improved articulation of add-ons can be achieved with intermediate attachments such as the tilt rotator.

II. PROBLEM IDENTIFICATION

Backhoe Loader is versatile machine and able to operate in different conditions and used in different excavation operation like trench digging, laying pipes, etc. But the problem arises in excavating trenches. For excavating the trench, it is need that the backhoe must be placed inline to the trenches. So the trenches are excavated with greater depth with ease. But in real case, the trenches are constructed at an offset distance from the road. The excavation is done by placing the machine in an inclined manner to the trench, then the boom is lowered down and then the arm is moved for making the trenches. So each time it is needed to lower down the stabilizers legs and then again retraced. The time taken for the excavation of offset trench is higher when compared to inline trenches. The depth of trench is also small when compared to inline trenches. To overcome this problem, a specially designed boom is made known as knuckle boom which able to rotate the arm of the backhoe about 30^o. In that case, there's no chance of digging a flat-bottomed trench, as the contour it then follows is more like a giant salad bowl with a curved bottom on the outer edges.

III. MODELLING OF BOOM ATTACHMENT

The Boom attachment for backhoe loader were modelled by using the software SOLIDWORKS in order to get a deep understanding on the construction.

A. Construction

The Boom Attachment for Backhoe loader Consists of following components,

1. Offset boom carriage,
2. Offset boom kingpost,
3. Swing set Cylinder
4. Arm cylinder.

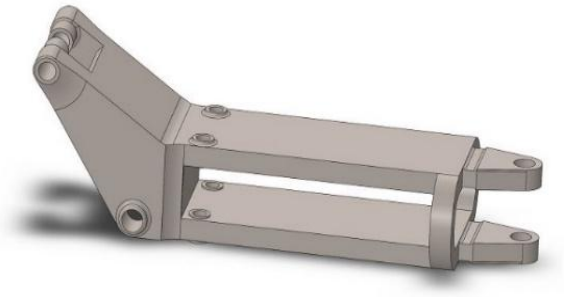

Fig.2: Offset Boom Carriage

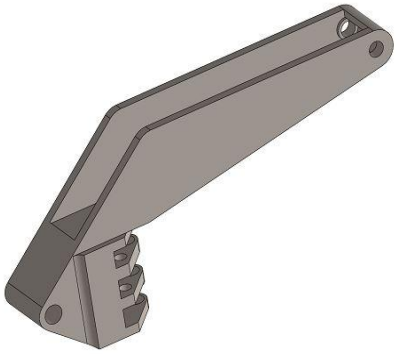

Fig.3: Offset Boom Kingpost

Fig.4: Swing Set Cylinder

The swing set is inclined at angle of 17^{o} with respect each other. The maximum swing angle made by the cylinder is 148^{o}.

Fig.5: Arm Cylinder

B. Assembled View Of The Offset Boom Attachment

The Offset boom carriage is mounted on the Boom of the Backhoe Loader. The offset boom kingpost is connected to the offset carriage by means of a pin. The arm of the backhoe loader is attached to the offset boom kingpost by means of a pin.

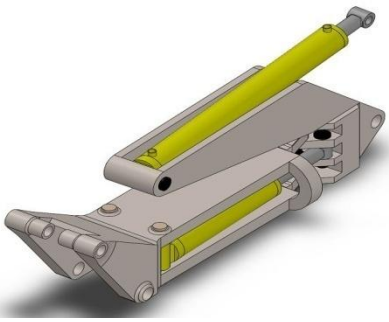

Fig.6: Assembled View Of The Offset Boom Attachment

C. Pin Specifications

The pin is designed on SOLIDWORKS 2013. The Material used for the Pin is Carbon EN 9 Grade.

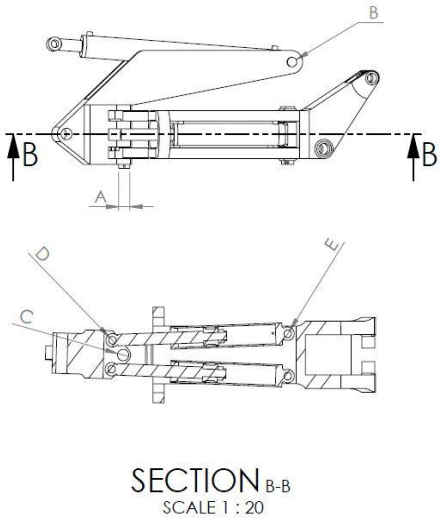

Fig.7: Pin Position of the Design

The length and diameter of the pin used is listed in the table below.

Table I -Shows The Specification Of The Pin

Position	Diameter (mm)	Length (mm)	Effective Length (mm)
A	60	145	125
B	50	230	210
C	60	170	150
D	40	155	135
E	40	290	270

IV. RESULT ANALYSIS

The model of the boom attachment is made using the SOLIDWORKS 2013 and static analysis is done using ANSYS WORKBENCH 18.2.

A. Analysis Of The Offset Boom Carriage

The material considered for the offset boom carriage is HARDOX 400. The material properties of the HARDOX 400 is given below in table

Table Ii - Material Properties Of Hardox 400

S.no	Property	Value
1.	Density	7473.57 kg / m^3
2.	Poisson's ratio	0.29
3.	Yield Strength	1000 MPa

1) Meshing

Size of mesh elements = 0.01 m

Type = fine

Mesh Statistics

No. of nodes = 597666

No. of elements = 410228

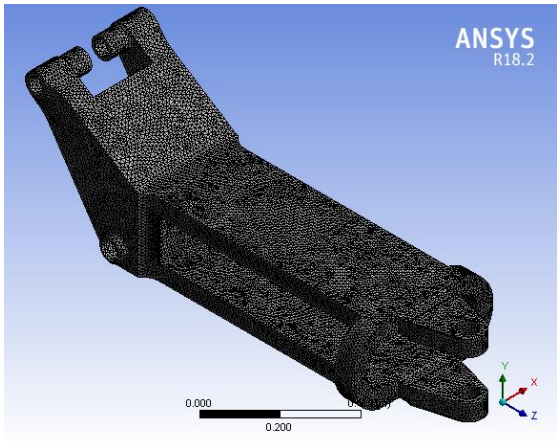

Fig.8 Mesh – offset boom carriage

2) Load Action

The forces are considered based on the cylinder force exerted and the self-weight of the attachment.

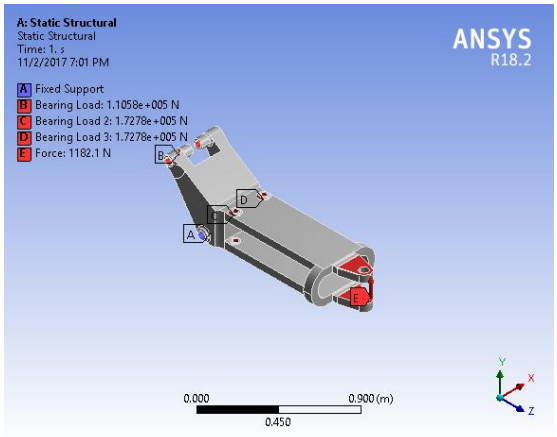

Fig.9 Load action - offset boom carriage

3) Total Deformation

The max deformation of the offset boom carriage was 0.0002 m.

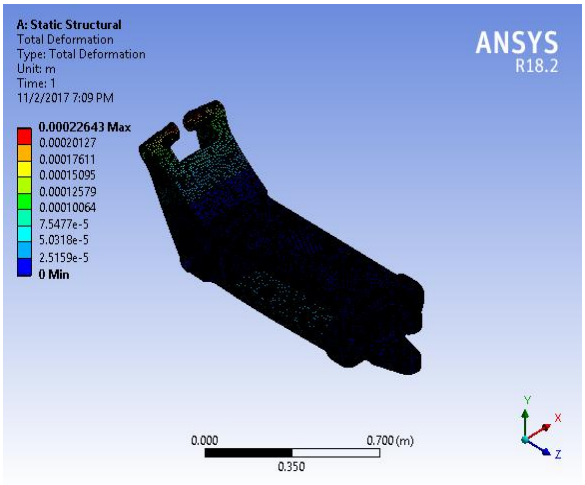

Fig.10 Total deformation – offset boom carriage

4) Von- Mises Stress

The maximum von mises stress was found to be 93.87 MPa.

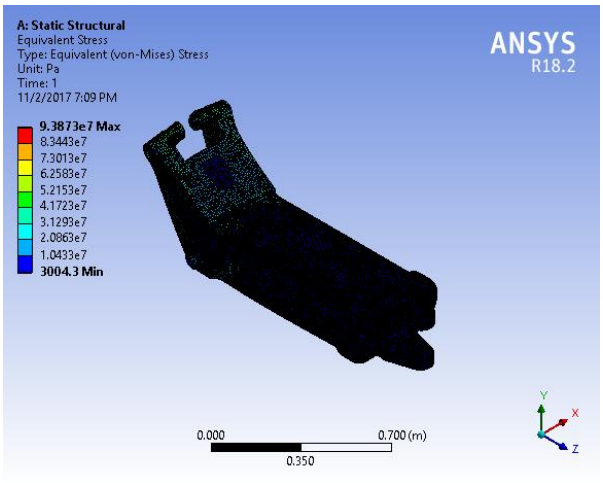

Fig.11 Von mises stress – offset boom carriage

B. Analysis Of The Offset Boom Kingpost

The material considered for the offset boom carriage is HARDOX 400. The material properties of the HARDOX 400 is given below in table

Table Iii - Material Properties Of Hardox 400

S.no	Property	Value
1.	Density	7473.57 kg / m^3
2.	Poisson's ratio	0.29
3.	Yield Strength	1000 MPa

1) Meshing

Size of mesh elements = 0.01 m

Type = fine

Mesh Statistics

No. of nodes = 449541

No. of elements = 306041

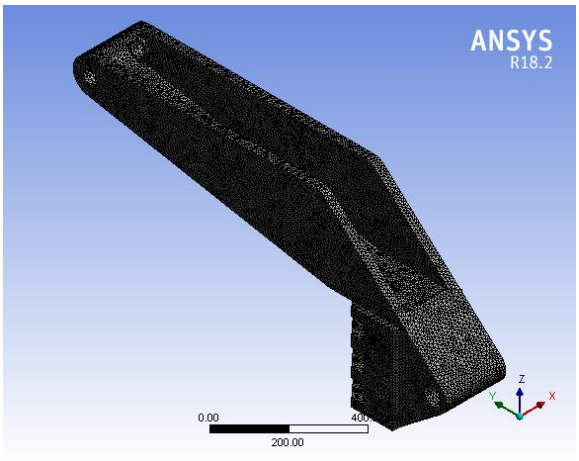

Fig.12 Mesh – offset boom carriage

*2) **Load Action***

The forces are considered based on the calculation done is last chapter.

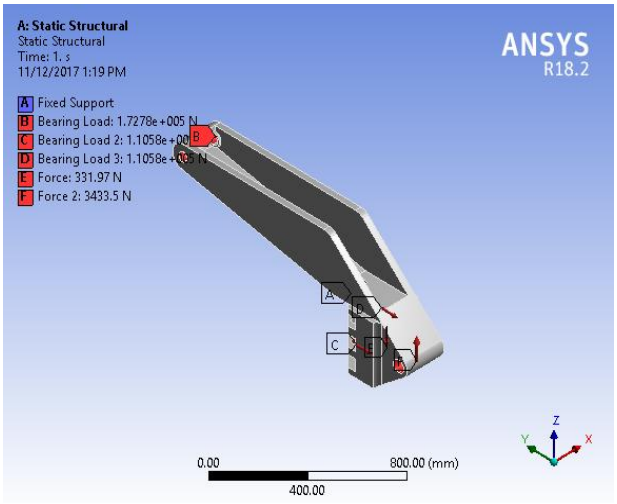

Fig.13 Load action - offset boom kingpost

*3) **Total Deformation***

The max deformation of the offset boom carriage was 1.38 mm.

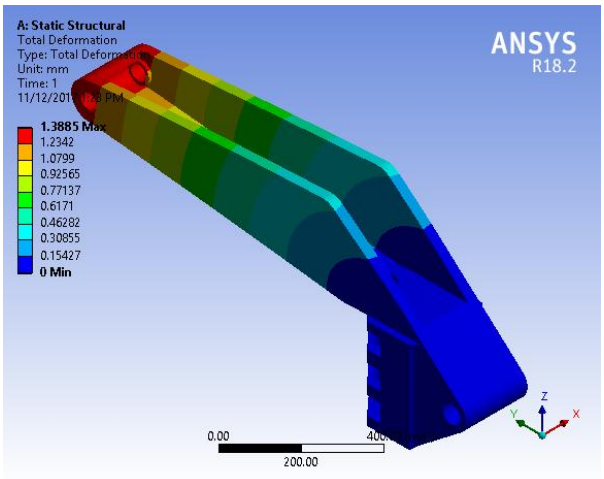

Fig.14 Total deformation – offset boom kingpost

*4) **Von - Mises Stress***

The maximum von - mises stress was found to be 191.86 MPa.

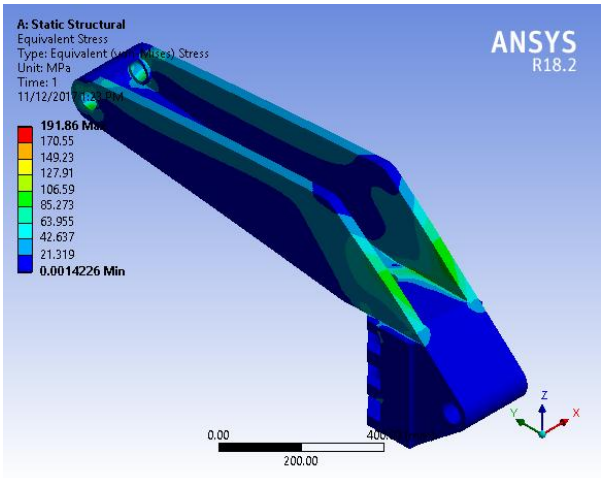

Fig.15 Von mises stress – offset boom kingpost

V. RESULTS

Table Iv - Result Of Offset Boom Attachment

Parts	Total deformation (mm)	Von -mises Stress (MPa)
Offset boom carriage	0.2	93.87
Offset boom kingpost	1.38	191.86

From the result,

1. It can seen that the stresses developed are fewer than the yield stress of the material.
2. The total deformation is fewer than the thickness of the offset boom parts.

VI. CONCLUSION

The offset boom attachment is developed to perform excavation task for light duty construction work like trenches and pipe laying work. Based on static force analysis finite element analysis is carried out for individual parts. The analysis results indicate that the stresses produced in the parts of the attachment are very less equal to limiting (safe) stress of the parts material. The total deformation is also found to be negligible when compared to thickness of the attachment part.In future, there is a scope to perform the structural optimization of the boom attachment for weight reduction. Optimization can help to reduce the initial cost of the attachment as well as to improve the functionality in context of controlling of the excavation operation. Using a swing set cylinder with trunnion mounting can be used.

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