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Modeling and Static Analysis of Backhoe Excavator Bucket

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Abstract- Excavators machines are also called as heavy duty earthmoving equipment which are very important and normally used for excavation task. During the excavation operation unknown resistive forces offered by the terrain to the bucket. Excessive amount of these forces adversely affected on the machine parts and may be failed during excavation operation. Design engineers have great challenge to provide the better robust design of excavator bucket parts which can work against unpredicted forces and under worst working condition. It has been observed that the existing bucket material of backhoe excavator gives the satisfactory results. Also it has been found that deformation and stresses values are safe. In order to increase the life of backhoe excavator bucket other two materials i.e. HORDOX-400 and HORDOX-500 has been analyzed for the similar force and boundary conditions that of the existing bucket. It has been found that the value of deformation, stresses and life for HORDOX-400 is much better than other material. Also the cost of HORDOX-400 is affordable. So the HORDOX-400 can been used in place of EN-8 i.e. existing bucket material. Also Finite Element Analysis (FEA) is the most powerful technique for strength calculations of the structures working under known load and boundary conditions. Thus, In this paper, We will suggested the use Finite Element Analysis (FEA) as a tool for static analysis of backhoe excavator bucket for existing as well as optimized excavator bucket. And to find out the maximum stress point and deformation and the method to minimize it with increasing the life of backhoe excavator bucket.

Keywords: backhoe excavator bucket, FEA, PRO-E and ANSYS software etc.

1. INTRODUCTION

In the era of globalization and tough competition the use of machines is increasing for the earth moving works, considerable attention has been focused on designing of the earth moving equipments. Today hydraulic excavators are widely used in construction, mining, excavation, and forestry applications. The excavator mechanism must work reliably under unpredictable working conditions. Poor strength properties of the excavator parts like boom, arm and bucket limit the life expectancy of the excavator. Therefore, excavator parts must be strong enough to cope with caustic working conditions of the excavator.

The backhoe hydraulic excavator or backhoe loader is by far the most popular construction machine in India. According to 'Equipment analysis: India backhoe loader report backhoe loader accounting for around 45 per cent of the mobile construction machinery market. This market still expected rise as Indian government focuses on developing the country's infrastructure in future.

Bucket is an important attachment used in backhoe excavator machines. There are various types of backhoe excavator buckets used for the different applications as per the requirement, such as digging bucket, rock bucket and the V- bucket.

2. PROBLEM DEFINITION

In this paper, our main emphasis on the complete bucket, in which the teeths are first contact with the ground surface, due to stresses and deformation developed on to it. Also the stresses developed are transformed to the complete bucket structure such as side plate, cutting plate, hinged plate etc. may leads to damage of bucket after a certain period of working cycles.

Thus, to find out solution on to it, further analysis work is being done on to JCB (3D) backhoe excavator model and reducing the stress concentration area with increasing life of excavator bucket.

Parameters Of Backhoe Excavator Bucket

Various dimensions required to model excavator bucket are obtained by Reverse Engineering Process. Excavator bucket parameters are taken for modeling and analysis. Steel rule, Screw gauge, Vernier caliper etc. instruments are used for taking the dimensions from actual excavator bucket. CAD model of excavator bucket is prepared in such a way that it should exactly represent the actual excavator bucket virtually and it can be taken for the further analysis.

2.1 CAD Modelling Of Excavator Bucket

Computer-aided design (**CAD**) is the use of computer systems to assist in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. Part module is most important for modeling of 3D part and it must be user-friendly so that new users can also able to work with software. Here for modeling excavator bucket PART model and its commands are used. As, the excavator bucket consists of basically the complete bucket structure and the teeths. First, each parts are to be made in pro-e software such as the bucket, tooth (4 no.) as shown below. then, all the parts get assembled with each other to form complete assembly.

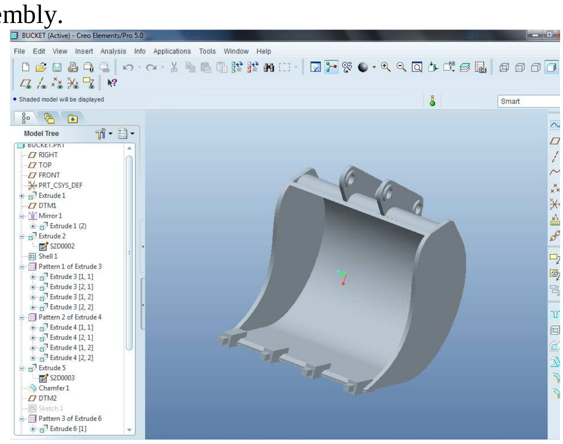

Fig. 1.bucket structure with adapter and hinged plate

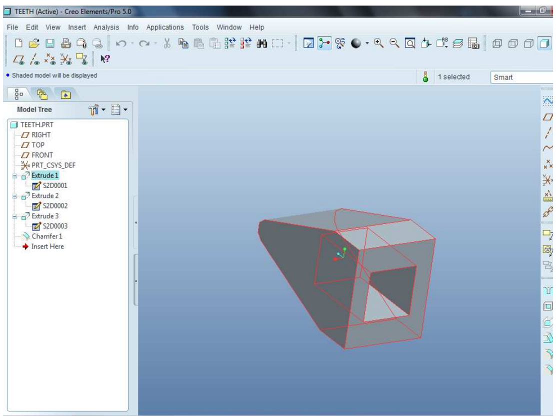

Fig. 2.bucket tooth

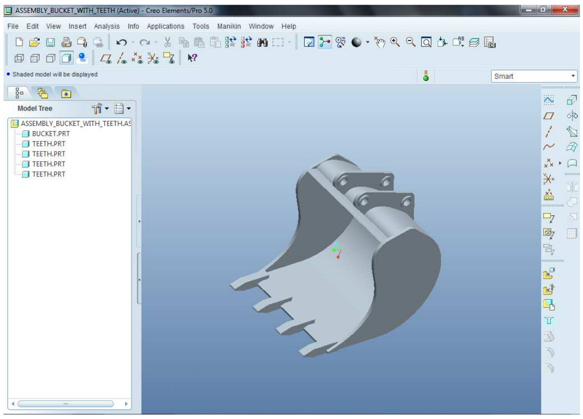

Fig. 3.Assembly of an Existing excavator bucket in Pro-e software

2.2 Conversion of CAD file into IGES (Neutral File) format

After creating model of excavator bucket we need to convert it into suitable Neutral File Format. Because to perform the analysis on excavator bucket it must be imported in FEA software. Because FEA software can't work directly on CAD file. Hence the universal accepted format for exchanging such data is used which is called as neutral file format.

The Initial Graphics Exchange Specification (IGES) is a vendor-neutral standard format used to exchange geometric models between various CAD and CAE systems. The filter can import partial files, so we can generally import at least part of our file. We can also import multiple files into the same model.

3. STRUCTURAL ANALYSIS OF EXISTING BACKHOE EXCAVATOR BUCKET USING ANSYS

Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

The following table 1.shows the Mechanical properties of an existing excavator bucket.

Mechanical properties	**Existing Bucket Material**	
	EN-8 (bucket structure)	HORDOX-400 (tooth)
Young's Modulus (E)	2.03×10^5 MPa	2.1×10^5 MPa

Density (ρ)	7800 kg/m^3	7850 kg/m^3
Poisson's ratio(μ)	0.30	0.29

Table No. 01 Mechanical properties of an existing excavator bucket.

Here, first of all we going to perform (static) structural analysis of existing excavator bucket to find out effect of forces applied on the bucket structure through the digging force applied on to bucket. Also find out deformation, various stresses induced and the life cycle of bucket. After importing CAD file into FEA tool we have to set analysis type as a Structural analysis. And type of element as 3D Tetrahedron element. Meshing of excavator bucket is done with 3D tetrahedron element. Meshed view of excavator bucket is shown as below fig. No.4.

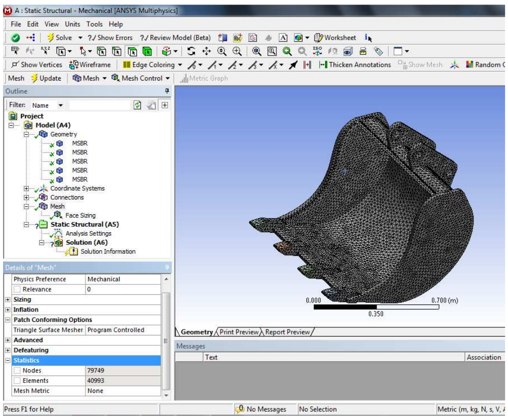

Fig. 4.Meshed view of existing bucket

Details of backhoe excavator bucket meshing are as follows.

1. Maximum Nodes formed = 79749
2. Maximum Elements created = 40993

Now, We apply the load and boundary condition for static force condition for each tooth and the hinged plate with displacement. [6]

The various forces are:
Force 1: 2542 N
Force 2: 2542 N
Force 3: 2542 N
Force 4: 2542 N
Force 5: 11380 N
Force 6: 11380 N

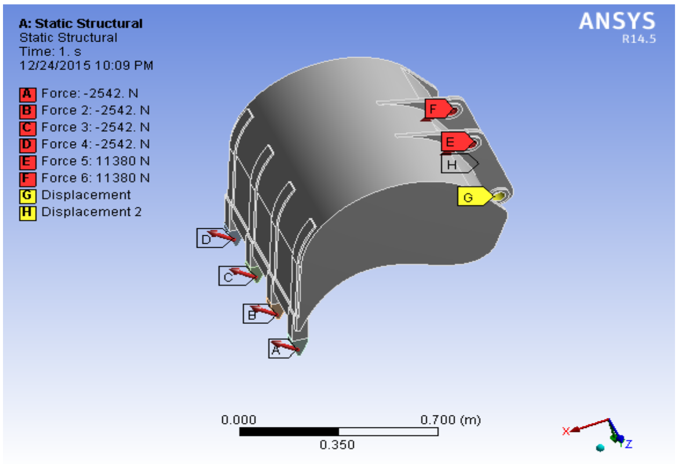

Fig. 5. Boundary condition applied for existing bucket

4. RESULTS OBTAINED BY STRUCTURAL ANALYSIS.

By applying load and boundary conditions by considering static force analysis condition, various results for existing excavator bucket as follows.

1. **Total deformation**
   Maximum: 2.677 mm
   Minimum: 0 mm

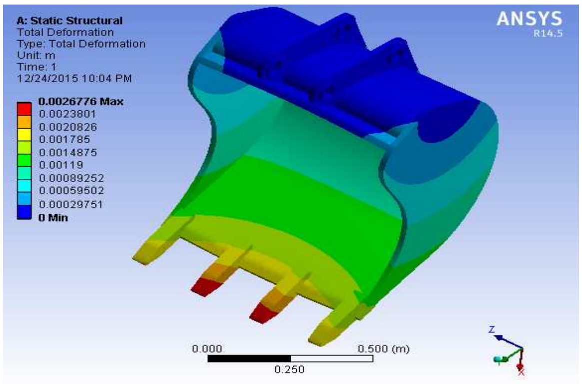

Fig. 6. Total deformation for existing bucket

2. **Equivalent stress or von mises stress**
   Maximum: 191.1 MPa

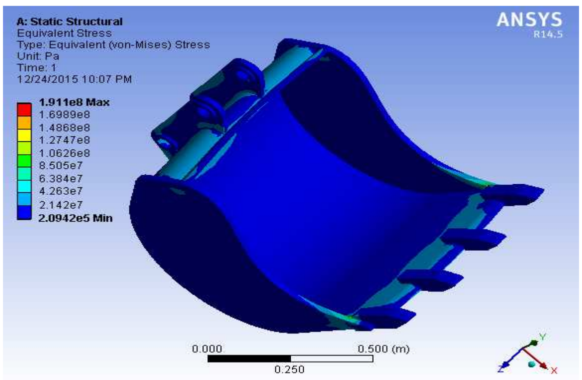

Fig. 7. von-mises stresses for existing bucket

3. Normal stress

Maximum: 81.9 MPa

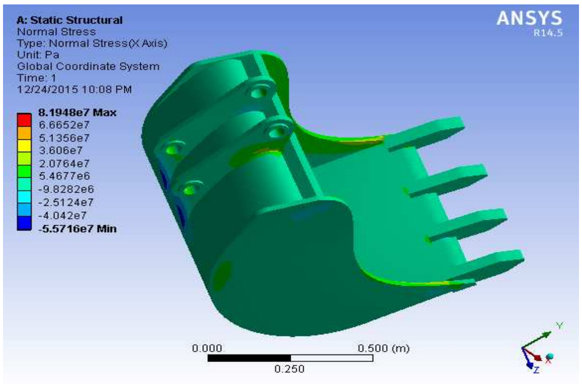

Fig.8. normal stress for existing bucket

4. Stress intensity

Maximum: 206 MPa

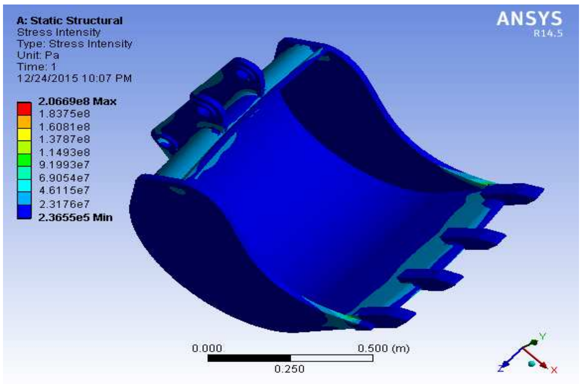

Fig.9. stress intensity for existing bucket

5. Shear Stress

Maximum: 67.31 MPa

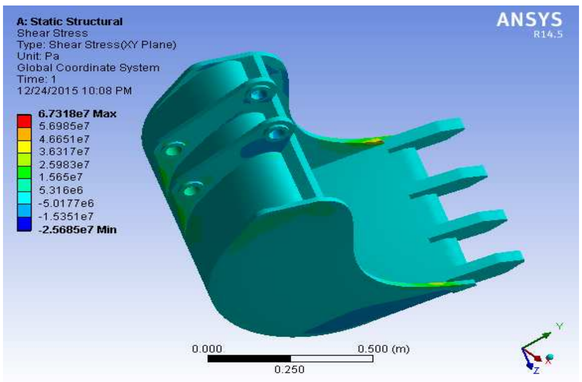

Fig. 10. Shear stress for existing bucket

6. Life cycle

Life of an existing bucket can be calculated by using ANSYS software

Maximum: 1000000

Minimum: 22760

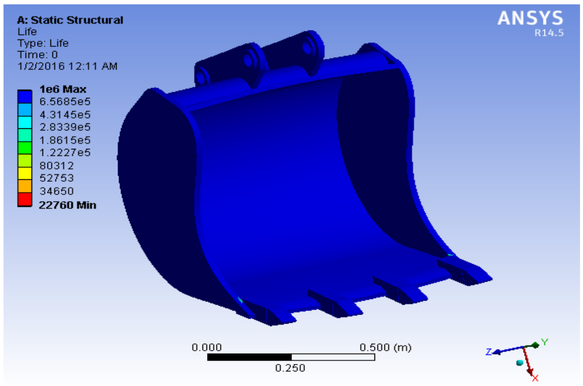

Fig.11. life cycle for existing bucket

Results of existing excavator bucket

From above analysis we can find out the results of the existing excavator bucket. It is tabulated as follows.

Result	Existing Bucket EN-8 & HORDOX-400
Total deformation	2.677 mm
Equivalent stress	191.1 MPa
Normal stress	81.9 MPa
Stress intensity	206 MPa
Shear stress	67.3 MPa
Life cycle	22760 min

Table No .2 Results of existing excavator bucket

Above table No. 2 shows the results of various mechanical properties and life for existing excavator bucket. The value of total deformation is 2.677 mm which is less. Also equivalent or von-mises stresses becomes 191.1 MPa which is also within permissible limit and it is safe. The minimum life cycle becomes 22760 min and maximum 1000000 cycles.

So, in this, in order to achieve the better results for all mechanical properties and to increase life cycles, the further analysis was carried out on an optimized excavator bucket.

5. OPTIMIZED EXCAVATOR BUCKET

The optimization in existing excavator bucket is basically carried out with increasing the thickness at the hinged plate. i.e. incorporating the weld plate at the each side of hinge plate. As, on site, it is observed that the failure of bucket starts from the hinged plate which ultimately affects digging operation.

The modeled weld plate made in pro- engg. Software as shown below in Fig. 12 weld plate (left side) and Fig. 13 weld plate (right side).

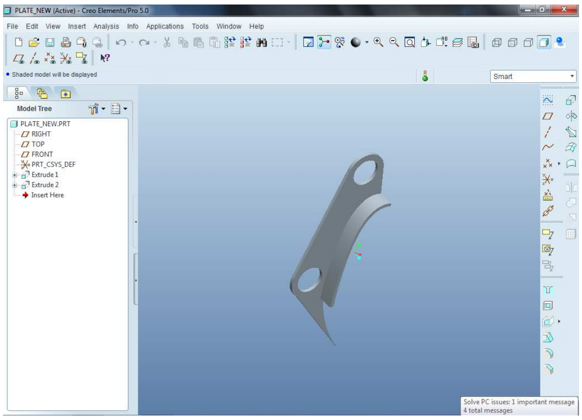

Fig. 12 weld plate (left side)

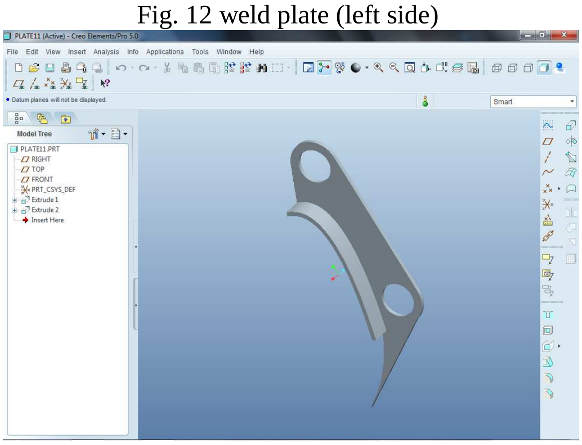

Fig. 13 weld plate (right side)

Following Fig.no.14 shows the assembly of an optimized excavator bucket, in this weld plate i.e. four no. are welded to each side of hinged plate, thus the strength of hinged plate form which the forces are applied on is increases considerably. Also by changing the material properties the stresses are reduced with increase in life cycles.

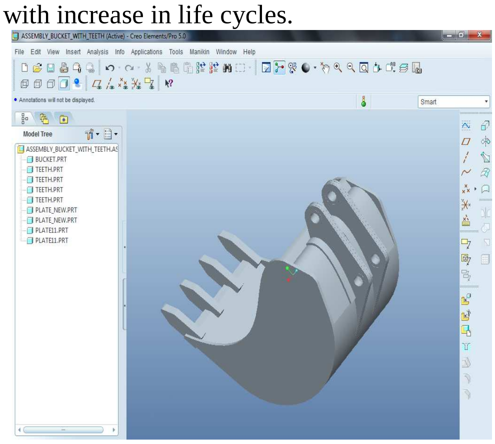

Fig. 14. Optimized excavator bucket

6. ANALYSIS OF MODIFIED EXCAVATOR BUCKET WITH DIFFERENT MATERIALS

Existing excavator bucket made up of the two different materials. i.e. for complete bucket structure EN-8 material and the teeth's are of HORDOX – 400 material properties. To improve the performance of bucket and to reduce the stress concentration areas, we can analyze some other materials for better results. Also it helps to increase the life of bucket to considerable woking cycles. The different materials are analyze are

1. HARDOX – 400
2. HARDOX – 500

Following table shows the material properties

Material	**Mechanical properties**		
	Young's Modulus (E)	Density (ρ)	Poisson's ratio(μ)
HARDOX 400	2.1*10^5 MPa	7850 kg/m^3	0.29
HARDOX 500	2.1×10^5 MPa	8050 kg/m^3	0.29

Table No. 3: Properties of different materials.

7. RESULT AND DISCUSSION

In this paper as we decided in the objectives, CAD model were modeled as per specified dimension by using Pro/E software.

As stated earlier, the existing bucket was made with the two different materials. i.e. The complete bucket structure made with the EN-8 material and teeth's are of HORDOX-400. And the optimized bucket structure with the complete HORDOX-400 and HORDOX-500 material properties. After that Finite element analysis was carried out with the help of Ansys software, similarly as that of existing excavator bucket and the various results are calculated as shown below in tabular format.

Materials	**Existing**	**Optimized**	
	EN-8 & HORDOX-400	HORDOX 400	HORDOX 500
Total deformation	2.677 mm	2.138 mm	2.413 mm
Equivalent stress	191.1 MPa	191. MPa	195 MPa

Normal stress	81.9 MPa	80.0 MPa	82.2 MPa
Stress intensity	206 MPa	201 MPa	211 MPa
Shear stress	67.318 MPa	67.125 MPa	68.80 MPa
Life cycle	22760 min	66102 min	54764 min

Table No. 4: Results for different materials.

8. CONCLUSION

By modeling and analysis of backhoe excavator bucket it has been observed that, although, the values of von-mises or equivalent stresses for existing and optimized bucket become less difference, but the area of stress in optimized backhoe excavator bucket is reduced as compared to existing one.

Also, the value of deformation and stress intensity optimized HORDOX-400 excavator bucket becomes 2.138mm & 201MPa respectively, are less as compared to other materials.

The life of existing bucket material is of 22760 min cycles. but by analyzing and comparing with different materials, it has been found that the life of optimized HORDOX-400 excavator bucket 66102 min. which is better than existing & optimized – 500 material. Also the cost of HARDOX-400 material is less and affordable. So, the complete bucket structure material with HORDOX-400 is more feasible.

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