Design and analysis of trapezoidal bucket excavator for backhoe

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Abstract. Excavator is the most multifunction heavy tool because it can handle other heavy tool such as sloping, dumptruck loading, and breaker. Usually, when doing excavation there is always possibility of breaking of pin in tooth adapter. The aim of this paper is designing bucket excavator using SOLIDWORK 2016 software and doing analysis with ANSYS R15.0 software using finite element analysis (FEA) method. This paper emphasize about the development that is done in the tip of excavator bucket teeth based on the calculation and ANSYS simulation with maximum shear stress result which is in the amount of 50,437 Mpa with maximum deformation level is being found at the part of excavator bucket head.

Keywords: Excavator Bucket, Trapezoidal Bucket Design, FEA approach

1. Introduction

Excavator is heavy tool consisting of arm, boom (shoulder), and bucket which is pushed by hydrolyzed strength of the handled diesel machine and trackshoe. Excavator has multifunction ability because it can handle various of other heavy tool works. As the name implies (excavation), an excavator is a piece of heavy equipment that is commonly used in mining work, construction work and work that requires lifting that can be too heavy for humans [1]. But not limited to that alone, excavators can also do construction work such as making a slope (sloping), loading dump truck (loading), breaker (breaker), etc.

The teeth of excavator is a part that gets the first contact with soil while doing excavation works in various situations [1]. Using excavator can increase some necessities in the daily life, but in its application, there is no checking works of the emergency possibilities while it is used, so that the damage of teeth bucket excavator can occur when excavation process. So, in this case explains that sometimes the damage of teeth excavator part because of some handling is not appropriate by operator. Therefore, it is necessary of doing pressure calculation at the tip of part the bucket excavator teeth using finite element method which aims to decrease the damage.

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2. Theory of Force Calculations

Penetration of a bucket of the material is determined by the arm crowd force (Fs) and bucket curling force (Fb). These is set by SAE J1179 standard "Hydraulic Excavator and Backhoe: Digging Forces" [2].

These rated digging forces are the forces that can be exerted at the most outside cutting point (that is the tip of part the bucket teeth). Forces calculate by applying relief hydraulic pressure to the cylinders providing the digging force.

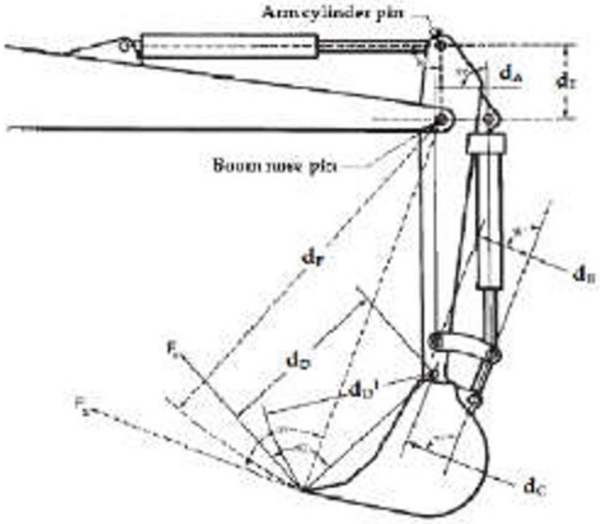

Fig.1. Determination of Digging Forces [2]

According to SAE J1179: Maximum radial tooth force through bucket cylinder (bucket retraction force) F_B is the digging force that occur by the bucket cylinder that hits the arc or radius d_D [3].

$$F_B = \frac{p\times(\pi/4)D_B{}^2}{d_D}\left(\frac{d_A \times d_C}{d_B}\right)$$

(1)

Arm crowd force (Fs) is force that occurs at the tip of part the bucket teeth due to the arm cylinder is the digging force generated by the arm cylinder and which touches the radius of the beam d_F.

$$F_S = \frac{p * \frac{\pi}{4} * D_A{}^2}{d_F}(d_E)$$

(2)

Breakout Force (L): as shown in fig. 2, forces at the tip of the teeth created by the bucket cylinder. Maximum breakout force (L) is reached when tooth force reaches maximum.

$$F1 := \frac{d}{C \times e} \times \frac{r}{L}$$

(3)

F 1 = Bucket cylinder force

C = Distance between bucket cylinder axis - lever pivot

D = Distance between connecting link axis - lever pivot

e = Distance between connecting link axis - bucket pivot

r = Radius bucket pivot - tooth lip

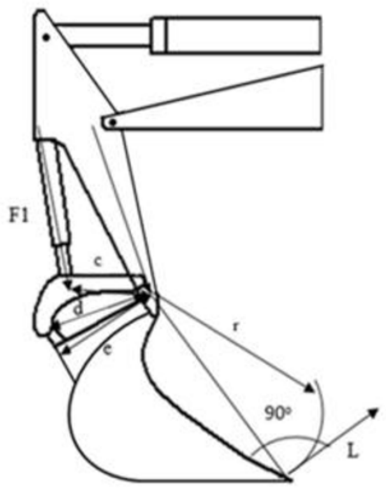

Fig.2. Determination of Breakout Force [4]

3. Methodology

This paper based on two main methods. There are geometric modelling of trapezoidal bucket and analysis methode using finite element (FEA) approach.

3.1 Material Selection

The bucket material for bucket excavator were taken as of Alloy Steel Hardox 500 standard and have the following properties as shown in Table 1.

3.2 Geometric Modelling Methode

The geometry of the trapezoidal bucket excavator has been obtained by an extrusion in SOLIDWORK 2016. First generates an trapezoidal bucket excavator then teeth-rivet, as shown in Fig. 3. Bucket and teeth-rivet are assembled together in assembly in SOLIDWORK 2016. The geometry is ready for preprocessing on next step.

Table 1. Material Properties [5]

Modulus Elasticity	210 GPa
Yield Tensile Strenght	1000 MPa

Ultimate Tensile Strenght	1250 MPa
Impact Toughness	30 J
Poisson's Ratio	0.29
Density	7850 kg/m^3
Brinell Hardness	370 - 500

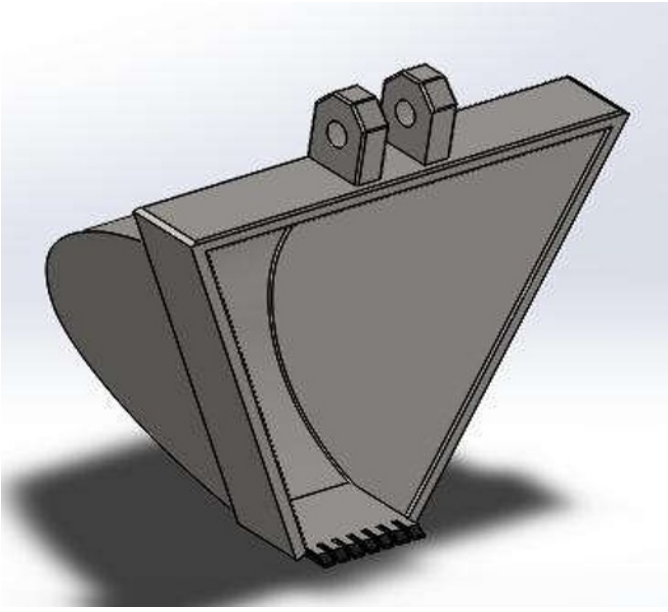

Fig.3. Excavator Trapezoidal Bucket

3.3 Finite Element Analysis (FEA) Methode

The model was developed in the SOLIDWORK 2016. The element analysis method is usually used to improve the design and optimization a product of heavy tool equipment. My main discussion is on the trapezoidal bucket that comes first in contact with the soil for its contact deformation as well as the stress generation to perform various types of operations. To achieve this, trapezoidal bucket excavator have been analyzed under different boundary conditions and maximum loads.

Table 2. Mesh Statistics

Statistics	
Nodes	15641
Elements	8205

It is the imitation of the operation of a realistic process or system over time. To simulate something first, a model must be developed; this model represents the most important characteristics or behaviors / functions selected or abstract system or process. ANSYS offers various kinds of affordable technologies and services to meet the diverse and evolving design needs. In ANSYS R15.0 Stress element or solution is displayed as a different color based on the stress value to distinguish parts have a high value down to a low value. These Steps are Main Menu > Project > Model > Static Structural > Solution.

The reports generated by ANSYS R15.0 on solving bucket excavator are as shown in Fig. 5.

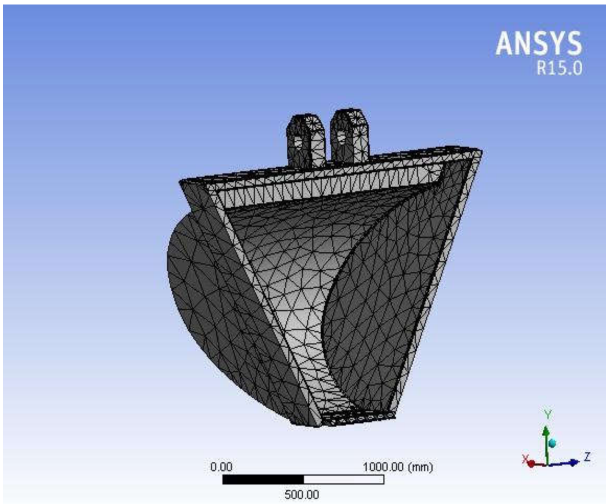

Fig.4. Meshing Trapezoidal Bucket

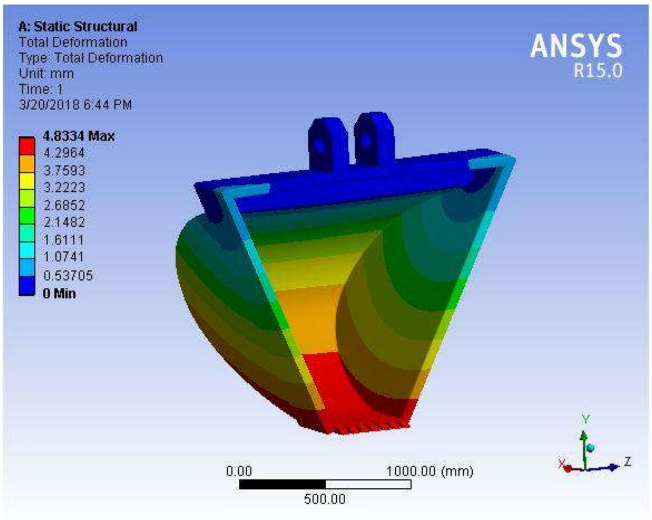

Fig.5. Total Deformation

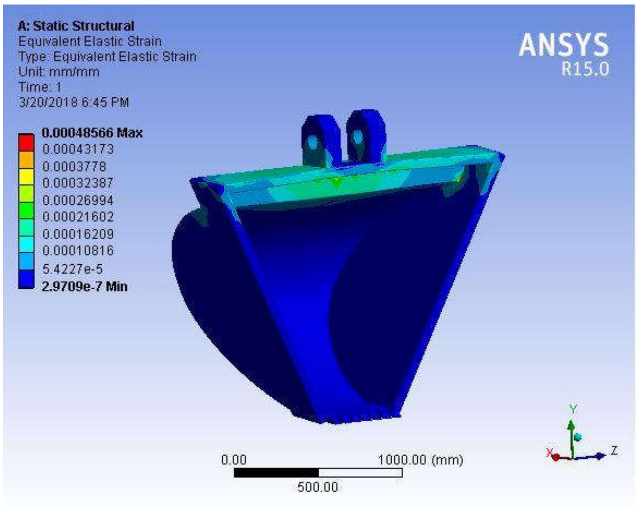

Fig.6. Von Mises Strain

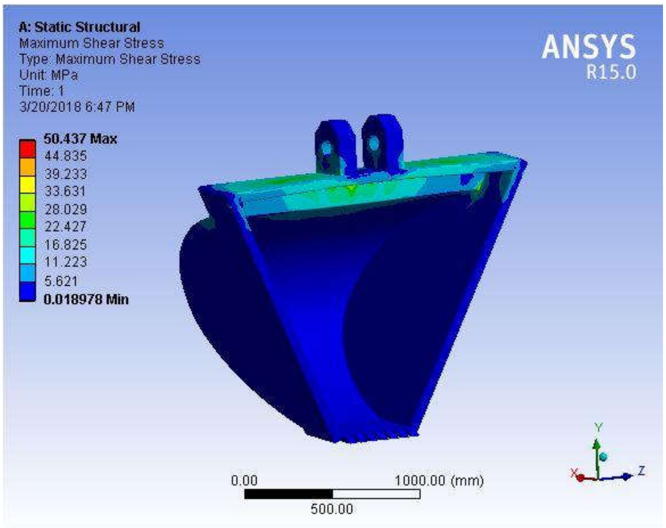

Fig.7. Maximum Shear Stress

4. Result and Discussion

The mechanical properties of steel used in linear elastic finite element analysis are also taken: Young's modulus is 210 GPa and Poisson's ratio is 0.29. This material properties assumption to be linear elastic and the region strain relation is represented by Hooke's law. Maximum Shear stress is calculated 50.437 MPa. Maximum strain using von-misses stress theory as shown in fig.6 is calculated 0.0004857 where it shows maximum strain is at the fixed part. Maximum deformation is is calculated 4.8334 mm at the tip of part the bucket teeth shown in fig.5 and thus wear of teeth occurs from tip to the entire body. It was observed that the head of tooth is the most critical point and so it could be concluded that steel with a high strength will be suitable because of the extreme loads..

5. Conclusion

This paper design and analyze a Trapezoidal bucket excavator by using ANSYS R15.0. Following conclusion can be drawn from the above analysis:

1. Maximum strain that display in a fixed position of top the bucket.
2. Maximum deformation will occur at the end of the tooth to the entire body.

As per it is recommended that buckets used for excavation purposes should be checked properly for their application based on soil. Also geometry is one of the parameters and effects of deformation during the lifetime a bucket. Given the failure of the tooth and rivet due to impact loading, it is economical to change the rivet rather than change the entire assembly of the tooth.

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