ISSN : 2249-5762 (Online) | ISSN : 2249-5770 (Print)

Excavator Bucket Tooth Failure Analysis

[1]Kalpak. S. Dagwar, [2]R.G. Telrandhe
[1]M-Tech CAD-CAM DMIETR, Wardha, Maharashtra, INDIA
[2]Dept. of Mechanical Engineering, DMIETR, Wardha, Maharashtra, INDIA

Abstract
The Excavator bucket tooth have to bear heavy loads of materials like soil, rock and subjected to abrasion wear due to the abrasive nature of soil particles. Its tooth got damaged due to abrasive wear and impact load. This paper deals with review of Excavators bucket tooth analysis to find out its actual failure.

Keyword
Abrasive Wear, Hard Facing, Digging Force, Tooth Development

I. Introduction

Rapidly growing rate of industry of earth moving machines is assured through the high performance construction machineries with complex mechanism and automation of construction activity. An Excavator bucket is an attachment for heavy equipment which is designed to be used in site excavation. Buckets can be attached to Excavators, tractors, cranes, and similar types of equipment.

Excavator buckets are made of solid steel and generally present tooth protruding from the cutting edge, to disrupt hard material and avoid wear-and-tear of the bucket. The excavator bucket tooth have to bear heavy loads of materials like wet soil and rock and also subjected to abrasion wear due to the abrasive nature of soil particles when tooth acting to break up material Generally alloy steel is used to make an Excavator bucket tooth and hard facing of some wear resistant materials can be applied on the material of bucket tooth, so that its life will improve against abrasive wear [1].

The direct contact of metallic components with the soil constituents requires the employment of alloys that have both good toughness and abrasive resistance. High values of hardness are also needed in those surfaces over which the extracted materials move and even harder materials to manufacture the mineral milling equipment. Due to these reasons. A careful analysis should be preformed to select appropriate materials in this field.

Nowadays, an excavator tooth has to be replaced after approximately a working week, causing an elevated cost which represents an important economic factor in the mining industry [7]

II. Calculation of Excavators Bucket Force

Digging force has a key effect on the dynamic behavior of the bucket wheel drive system [5].
The methodology adopted is to find maximum
Digging force for the given cylinder pressures, and this is done using Design View. The second stage is to find the forces at all pivot points of the attachment, this is done using MathCAD.

- Calculation of Digging and Breakout Force
- Digging Force (RX)

The digging force is the available force at the tip of the bucket tooth created by the stick cylinder(s). Maximum digging force is calculated with dimension “a” at its maximum and with the bucket in a position calculated for maximum Breakout force.

$$F_S = \frac{R_X\ x\ b}{a}$$

F_s -stick cylinder force
a -Perpendicular distance stick cylinder axis - stick pivot
b -Distance stick pivot - tooth tip

The SAE provide the breakout and digging force. For maximum Breakout force condition but for autonomous application it is important to understand. Which are improved bucket geometry for more efficient digging and loading of material and heavy duty robust construction for increased strength and durability [2].

III. Geometric Modeling & Description

In order to investigate the distribution of stresses in the cutting tooth, author set up a finite element model. Consider the solid model shown in fig. 1, consisting of a holder, a part from the cutting edge and an optimized cutting tooth. The cutting tooth is jointed into the holder as a removable piece. The holder is actually a steel rectangular structural tube, and of course it is possible the remaining parts of structure are made of a different kind of steel.

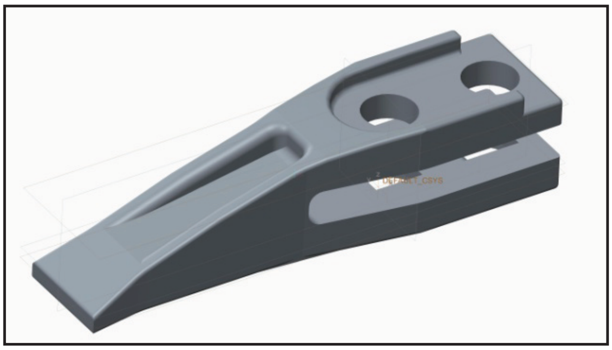

Fig. 1: 3D Solid Models of Excavator Bucket Tooth

The finite element mesh of cutting tooth is of free type using 10-node tetrahedral elements and so this solid structure is divided into 25 937 finite elements. The geometrical model of tooth is illustrated in fig. 2. The mechanical properties of steel used in linear elastic finite element analysis are also taken: Young’s modulus (E) is $205x10^3$ MPa and Poisson’s ratio (v) is 0.29. This material behavior is assumed to be linear elastic until the effective stress reaches proportional limit and in this region the stress-strain relation is represented by Hooke’s law.

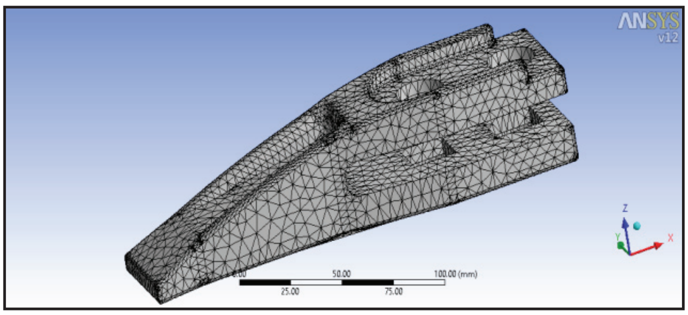

Fig. 2: Geometrical Model of Tooth of Meshing in Finite Element Analysis

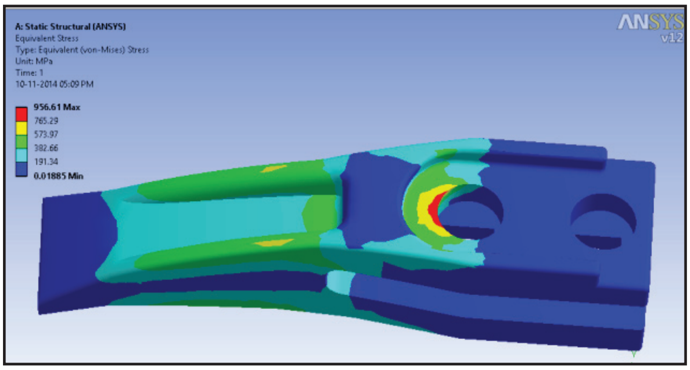

Fig. 3: Tooth for Finite Element Analysis

It is established that the development of cutting tooth could be improved by using finite element analysis. This technique is applicable to compare different types of tooth easily. It leads to an assessment of the effect of the main parameters on the behavior of the geometric configuration of the tooth. Consequently the results of finite element analysis show that the head of tooth is the most critical point and so we conclude that high strength steel will be adequate because of the extreme loads. The obtained results can be useful in practice.

IV. Bucket Tooth Development

The objective was to elaborate a testing and planning methodology ensuring the verification of the new components (buckets, tooth) developed [4]. Following the review of the excavators' cutting structures used until then having more advantageous features than those of the earlier ones.
The most important features among these are listed below.

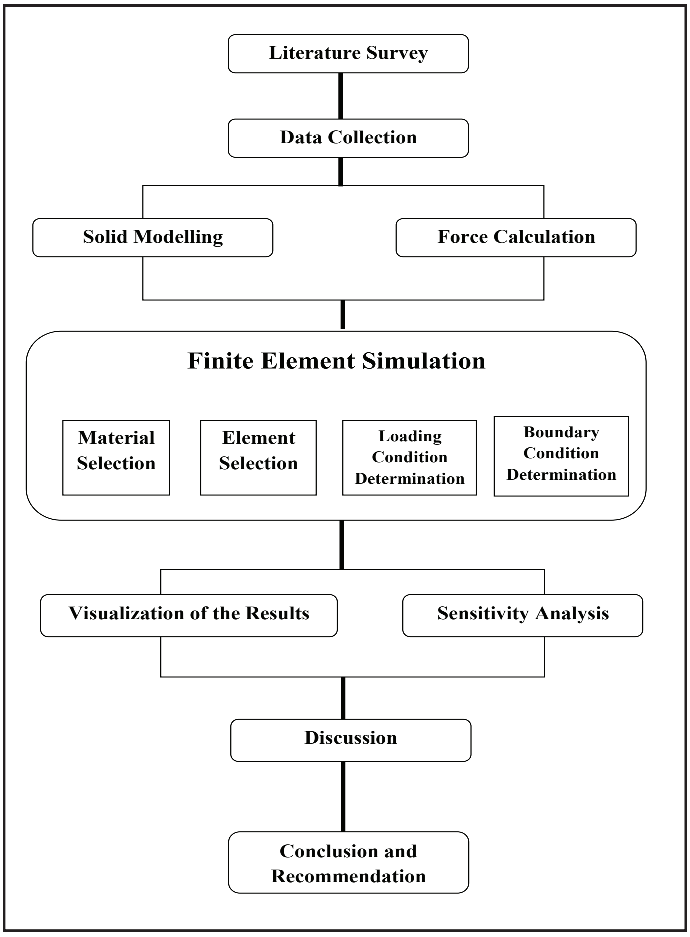

Fig. 4:

V. Failure of Bucket Tooth

The excavator bucket tooth which fail due to abrasive wear and impact load is protected against abrasive wear by using four different types of hard facing materials using manual metal arc welding process [6].
A tooth of a Digging of an excavators is working member which is subjected to an intensive abrasive were during operation and to heavy impact and static loads which determine its service life. A tooth of excavators buckets performance two main functions: It plunges into rock; it brakes-up the rock and guide the broken particles of rock into the excavators bucket. When a tooth of an excavator digging bucket plunges into the rock, a flow of particulate rock moves along its top surface, the flow of particulate rock at the starting portion of the tooth of a comparatively short length being of laminar nature [3]. The flow of particulate rock then leaves the tooth surface which results in a material increase, from twenty to forty times, in resistance to penetration of the tooth in the rock. To lower this resistance, the portion of the tooth surface adjacent to the portion where the laminar flow of particulate rock leaves the tooth is made concave. The flow of particulate rock at this portion changes from laminar to turbulent so as to determine a positive formation of vortices in the boundary layer of particulate rock which is adjacent to the top surface of the tooth at the concave portions. The major part of coarser particulate rock moves over the vertices of the boundary layer. Therefore, intensity of abrasive wear of the tooth is determined by the character of movement of particulate rock in the boundary layer. [8]

VI. Analytical Calculation

A. Material Properties

Tooth: AISI 1040

Modulus of elasticity = 205×10^3
Poisson's Ratio = 0.29
Ultimate Tensile Strength = 670 MPa
Yield Tensile Strength = 435 Mpa

B. Bending Stress Calculation

h = 18mm
y = 52/2 = 26 mm
M = Force x Eccentricity
= 57000 x 150
= 85.50×10^5 N.MM

$$Ixx\ 1 = \frac{bd^3}{12} + (Ah^2)$$

$$=2\{\frac{16*14^3}{12} + (16*14*18^2)\}$$

$$=2\{\frac{43904}{12} + (72576)\}$$

$$=2\{3658.667 + (72576)\}$$

$$= 2(76234.667)$$

$$= 152469.33mm^2$$

$$= 152.469X10^3mm^2$$

$$Ixx\ 2 = \frac{bd^3}{12} + (Ah^2)$$

$$=2\{\frac{16*16^3}{12} + (16*16*18^2)\}$$

$$=2\{\frac{65536}{12} + (82944)\}$$

$$=2\{5461.33 + (82944)\}$$

$$= 2(88405.33)$$

$$= 176810.66 mm^2$$

$$= 176.810x10^3 mm^2$$

Ixx = Ixx 1 + Ixx 2

Ixx = $152.469X10^3 + 176.810x10^3$

Ixx = 329306

Ixx = $329.306x10^3$

$$\frac{M}{I} = \frac{\delta b}{y}$$

$$\frac{85.50x10^5}{329.30X10^3} = \frac{\delta b}{26}$$

25.9641 x 26

$$\delta b = 675.06\ N/mm^2$$

Bending Stress = 675.06 MPa

C. Shear Stress Calculation

Force = 57000 N

Area = $1311.83mm^2$

$$\delta s = \frac{57000}{1311.83}$$

δs = 43.45 MPa.

Shear Stress = 43.45 MP

VII. Result and Discussion

From the above analytical as well as Ansys software analysis it has found that the maximum stresses are generating on tooth due to this maximum contact with soil. This stress can be avoided when redesign excavators bucket tooth increasing the thickness and redesign of the excavators bucket tooth.

The following table shows compression between analytical result and Ansys result and percentage of error.

Table 1:

Sr.No.	Analysis	Analytical Result	Ansys Result	% of Error
1	δb	675.60 MPa	705.71 MPa	4.45%

VIII. Conclusion

This paper discussed about failure of bucket tooth is due to abrasive wear and impact loading. The failure can be minimize by improving redesign tooth, discussed force calculation which improved bucket tooth geometry for more efficient digging and loading of material.

References

[1] Shivali Singla, Vineet Shibe, J.S. Grewal,"Performance Evaluation of Hard Faced Excavator Bucket Tooth against Abrasive Wear Using MMAW Process", International Journal of Mechanical Engineering Applications Research, Vol. 02, Issue 02, pp. 74-77, August-December 2011.

[2] Rahul Mishra, Vaibhav Dewangan,"Optimization of Component of Excavator Bucket", IJSRET, Vol. 2, Issue 2 pp. 076-078, May 2013.

[3] Zoltan Virag, Sandor Szirbik,"Examination of an Optimized Replaceable Cutting Tooth of Excavators", Geosciences and Engineering, Vol. 1, No. 2, pp. 337-342, 2012.

[4] GÁBOR LADÁNYI, ISTVÁN SÜMEGI,"Bucket and Cutting Tooth Developments for the Bucket Wheel Excavators of Mátra Power Station LLC", Annals of the University of Petroşani, Mechanical Engineering, pp. 151-162, Dec (2012).

[5] Jevtić, V.; Golubović., Z.; Lekić, Z.,"Mathematical modeling of resistance moment as the basic component for the dynamic behavior of the BWE", XIV international conference on material handling and warehousing, Belgrade, 1996.

[6] Bhaveshkumar P. Patel, Dr. J. M. Prajapati,"Soil-Tool Interaction as a Review for Digging Operation of Mini Hydraulic Excavator", International Journal of Engineering Science and Technology, Vol. 3, No. 2, 894-901, February 2011.

[7] J.E. Fernandez, R. Vijande, R. Tucho, J. Rodriguez, A.Martin "Material selection to excavators tooth in mining industry", Elsevier 2001.

[8] Mr. Bhushan Ghodake, Prof.Sunil More,"Analytical Method To Calculate Tooth Pin Failure of Bucket Tooth of Excavators In Shearing And Bending", International Journal of Research in Engineering & Advance Technology, Vol. 2, Issue 6, Dec-Jan, 2015.

[9] Manisha P. Tupkar, Prof. S.R. Zaveri,"Design and Analysis of an Excavator Bucket", International Journal of Scientific Research Engineering & Technology, Vol. 4, Issue 3, March 2015.

Mr. Kalpak S. Dagwar received his B.E. degree in Mechanical from Shree Tuljabhavani College of engineering, Tuljapur, under Dr. Babashead Aambedkar Marathvada University, Aurangabad in 2011. And he his final student of M-Tech (CAD/CAM) of Datta Meghe Institute of Engieering Technology and Research, Wardha, Maharashtra, INDIA.

Prof. Rupesh G. Telrandhe received his B.E. degree in Mechanical from Babasaheb Naik College of Engineering, Pusad, Maharashtra, India in 2010, and the M.Tech. Degree in CAD/ CAM from Rajiv Gandhi College of Engineering Research and Technology, in 2013. He is an assistant professor in Department of Mechanical Engineering at Datta Meghe Institute of Engieering Technology and Research Wardha. His research interests include Computational Fluid dynamics (CFD), Heat Transfer and CAD/ CAM.