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Comparative Analysis of Wear for Excavator Bucket Tooth Using Different Materials

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Abstract: ***The Excavator is used for material handling at mining and construction sites. The bucket teeth of the excavator have to bear heavy dynamic loads of materials like soil, rock, etc. The bucket teeth are subjected to abrasive wear due to the abrasive nature of soil particles. This phenomenon reduces the life of the excavator bucket tooth to 72 -120 working hours. This paper deals with comparative analysis of wear on the basis of volume loss using, for the excavator bucket. The purpose of work is to improve the service life of bucket tooth by decreasing the wear.***

Keywords: excavator, wear

1. Introduction

Mining is the extraction of valuable minerals or other geological materials from the earth from an ore body, lode, vein, seam, reef or placer deposits which forms the mineralized package of economic interest to the miner. The Mining industry in India is a major economic activity which contributes significantly to the economy of India. The GDP contribution of the mining industry varies from 2.2% to 2.5% only but going by the GDP of the total industrial sector it contributes around 10% to 11%. Even mining done on small scale contributes 6% to the entire cost of mineral production. Indian mining industry provides job opportunities to around 700,000 individuals (1).

Ministry of Mines is responsible for survey, exploration and mining of all minerals, other than natural gas, petroleum, atomic minerals and Coal. Ores extracted during mining include metals, coal, oil shale, gemstones, limestone, dimension stone, rock salt, potash, gravel, and clay. Mining is required to obtain any material that cannot be grown through agricultural processes, or created artificially in a laboratory or factory. Mining in a wider sense includes extraction of any non-renewable resource such as petroleum, natural gas, or even water.Wear related failure in industry can be summarized as (2)-:

Type of wear	Abrasive wear	Adhesive wear	Erosive wear	Fretting wear	Corrosive wear	Other
failure	50%	15%	8%	8%	5%	14%

2. Theoretical Analysis

The excavation force required to cut the soil by the excavator bucket tooth has been analyzed in this work to improve the design of the bucket teeth, for different materials. The existing excavator bucket tooth assembly was analyzed for the operational loading conditions for its failure during working.

Calculations:

Material Properties of Tooth (3): **AISI 1045**	Material properties of tooth: **AISI 1035**
Modulus of elasticity = 205 GPa	Modulus of elasticity = 190-210 GPa
Poisson's Ratio = 0.29	Poisson's Ratio = 0.27-0.29
Ultimate Tensile Strength = 670 MPa	Ultimate Tensile Strength = 585 MPa
Yield Tensile Strength = 435 MPa	Yield Tensile Strength = 370 MPa
Hardness =210 BHN	Hardness =183 BHN
Material Properties of Tooth: **AISI 304**	Material properties of tooth: **AISI 4130**
Modulus of elasticity = 190 GPa	Modulus of elasticity = 205 GPa
Poisson's Ratio = 0.29	Poisson's Ratio = 0.285
Ultimate Tensile Strength = 517 MPa	Ultimate Tensile Strength = 560 MPa
Yield Tensile Strength = 206 MPa	Yield Tensile Strength = 460 MPa
Hardness =123 BHN	Hardness =197 BHN

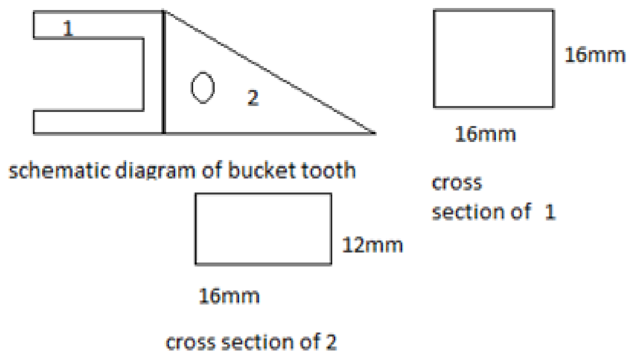

Figure 1: Tooth geometry

Theoretical Stress Analysis for the tooth

h = 18mm, y = 52/2 = 26 mm,

M = Force x Eccentricity

= 31900 x 200 = 6380000 N.mm

$I_{xx1} = \frac{bd^3}{12} + Ah^2$ Here b =16 mm, h=12 mm

I_{xx1} = 2*(16*$\frac{12^3}{12}$+16*12*20^2)

I_{xx2} = 2* (16*$\frac{16^3}{12}$+16*16*20^2)

I_{xx2} =215.72*$10^3 mm^4$

Now I_{XX}=I_{xx1} +I_{xx2}

I_{xx} ==374*$10^3 mm^4$

By bending equation

$\frac{M}{I_{xx}} = \frac{\sigma}{y}$

$\frac{6380000}{374*10^3} = \frac{\sigma}{30} = \sigma = 511.76MPa$

F= 31900N and A=708mm^2

Then shear stress = $\frac{force}{area}$

$\tau = \frac{31900}{708} = \tau = 45.05MPa$

Wear analysis the analytical wear analysis is carried out for two materials used for fabricating excavator bucket tooth based on Archard's Modified equation for abrasive wear. The amount of volume loss is then compared with the simulation using ANSYS based on creep strain (4)

Consider a modified form of the Archard equation:

W = K* S C2 * R C3

Wear strain as the change in volume divided by the original volume and rewrite the wear equation as

ewr = C1 * S C2 * R C3 eq 1

Where C1 is equal to K divided by the volume. This strain is similar to volumetric strain which has the form

On the basis of contact stress

Contact stress is taken half of the ultimate tensile strength

Material I AISI 1045Material II AISI 304

Contact stress = 0.5*670 =335MPa

ewr =$\frac{10^{-4}}{0.473}$*335*1*1 = ewr = 70.83*10^{-3}

Contact stress =0.5*517=258.5MPa

ewr= $\frac{10^{-4}}{0.473}$*258.5*1*1 =54.65* 10^{-3}

Material III AISI 1035Material IV AISI 4130

Contact stress =0.5*585 =292.5MPa

Contact stress =0.5*560=280MPa

Then Wear strain

ewr =$\frac{10^{-4}}{0.473}$*292.5*1*1 = ewr = 61.83*10^{-3}ewr =$\frac{10^{-4}}{0.473}$*280*1*1 = 59.19*10^{-3}

Where S induced stress, R repetition of load, C2&C3 are constant

Simulation

Statistics	
Nodes	42353
Elements	24256
Mesh Metric	None
Suppressed	No
Refinement	1

It is the imitation of the operation of a real-world process or system over time. The act of simulating something first requires that a model be developed; this model represents the key characteristics or behaviors/functions of the selected physical or abstract system or process (5).

In this work, I have simulated failure based on bending stress and wear of the standard teeth of excavator bucket using ANSYS. ANSYS provides a wide range of affordable technologies and services to help meet the diverse and evolving needs for design. The reports generated by ANSYS on working excavator bucket are as follows:

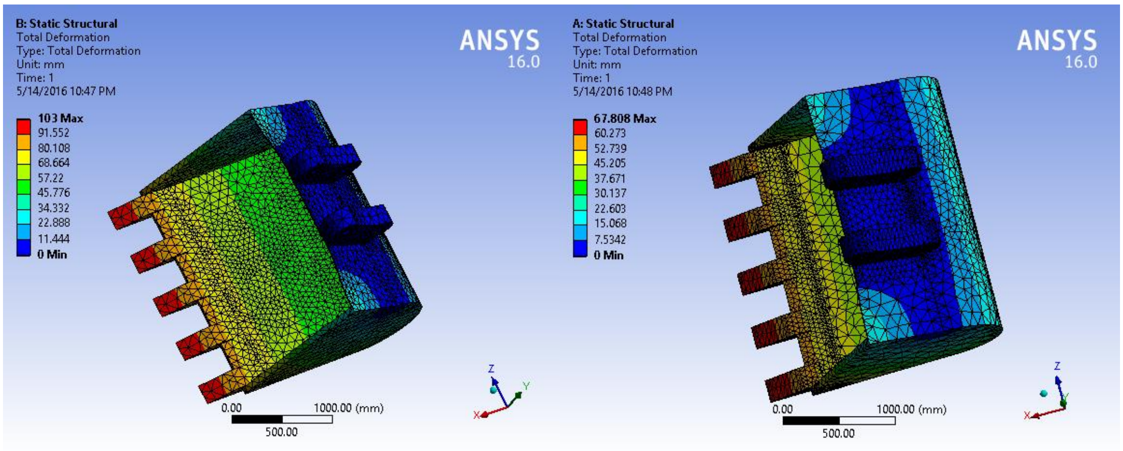

Figure 2: Total Deformation

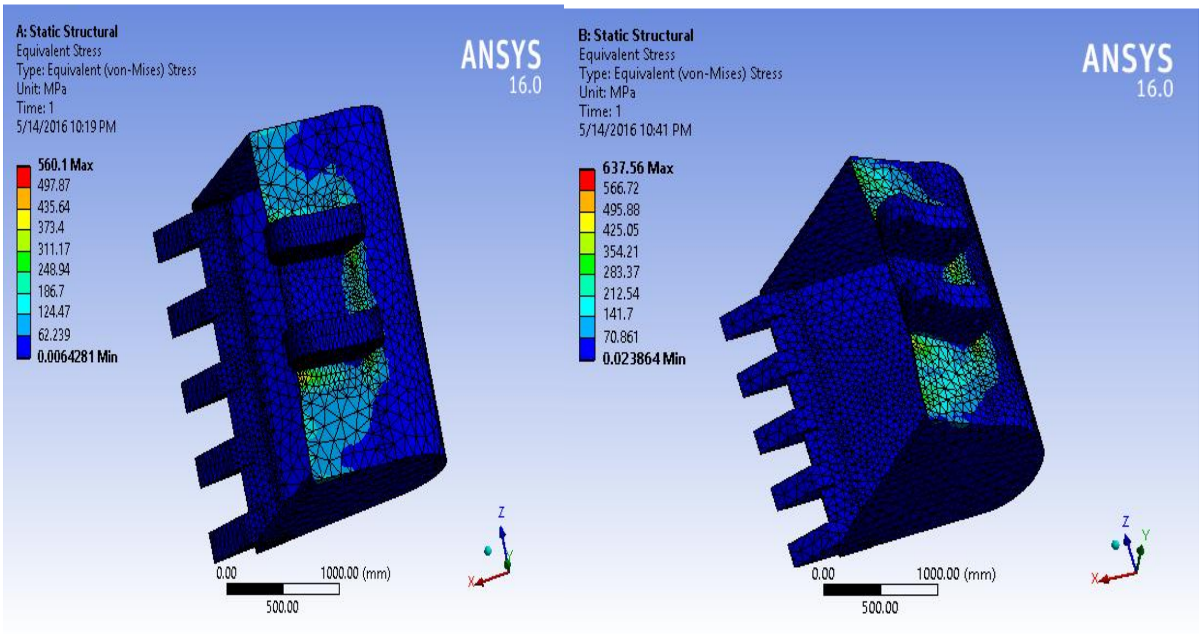

Figure 3: Equivalent Stress

Fig 2 represents the bending stress acting on excavator bucket tooth under 31900N force.it is clear that maximum bending stress is acting in between the joint and bucket . Red portion represents the maximum bending stress which is equal to 560MPa for AISI1045 and 673.56MPa for AISI1035.

Sno.	Material	Analysis	Analytical Result	Ansys Result	% of Error
1	AISI1035	Bending stress	511.76MPa	497.87MPa	2.72
2	AISI1045	Bending stress	511.76MPa	495.88MPa	3.10

3. Conclusion

1) It is observed that the region near the bush and teeth are having high value of stress and hence they are more prone to failure.
2) Material will be separated if applied stress exceeds ultimate tensile stress.
3) Total deformation for AISI 1035 and AISI 1045 are 103 mm &63.08 mm respectively.it is clear that material AISI 1045 is stronger than material AISI 1035.
4) In field trial it was observed that teeth number 2, 3&4 wear at faster rate than teeth 1 and 5 which is consistent with more material flowing over and around the outside teeth.
5) It is clear that **percentage error of bending stress** for AISI 1045 is approx. 3.10 % and for AISI 1035, it is 2.72 % which is less than 5 % hence our analysis is correct.
6) The position of middle tooth must be changed periodically so that uniform wear occur on each tooth.
7) The viability of the use the creep strain to model the wear coefficient for abraded materials was demonstrated. Previous models were developed taking into account only the Young's modulus of worn surface, discarding the properties of abrasive material. These cases work only for pairs where the abrasive particle is harder than the abraded material and it was demonstrated that they fail when the abrasive hardness is relatively low.

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