

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

Analysis of Excavator Bucket Teeth Using FEM

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ABSTRACT: 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. It is a bulk material handling component and come in a range of sizes and shapes. The excavator bucket teeth 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 teeth acting to break up material as the bucket are dragged through it. So the teeth of excavator bucket got damaged and wear tear takes place.

The present study is aimed on the influence of Boron carbide and chromium variations on analysis of Bucket Teeth. FEM analysis are carried out and it is observed that best results are found by adding coating of Chromium and boron carbide of coating 2mm. the excavator bucket teeth 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. The excavator bucket teeth have to bear heavy loads of materials like soil, rock and subjected to abrasion wear due to the abrasive nature of soil particles. So, its teeth got damaged due to abrasive wear and impact load. We have used to analyze Excavator bucket teeth using finite element method (FEM). FEM is selected as the component size is complicated and the process is an all-position process, highly versatile and user friendly. The Result of Boron carbide and chromium steel having almost same result on Equivalent stress and deformation. The Result of the same is having higher Than High tensile steel by almost 0-1%. The Process of FEM is being used for Coating and without Coating of Excavator Bucket teeth.

KEYWORDS: Excavator Bucket, finite element method (FEM), ANSYS, Solid Works.

I. INTRODUCTION

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. It is a bulk material handling component and come in a range of sizes and shapes. Excavator buckets are made of solid steel and generally present teeth protruding from the cutting edge, to disrupt hard material and avoid wear-and-tear of the bucket. Typically a material such as steel is used to make an excavator bucket, because the attachment needs to be durable and very strong. The excavator bucket teeth 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 teeth acting to break up material as the bucket are dragged through it. So the teeth of excavator bucket got damaged and wear tear takes place. Generally alloy steel is used to make an excavator bucket teeth and hard facing of some wear resistant materials can be applied on the material of bucket teeth, so that its life will improve against abrasive wear [1]. In the market, there are many companies which are doing business in the earth

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moving equipments. Depending upon the type of the application, the different types of equipments are used. The excavator is also one of them which mostly used for excavation in mines, hills, etc. etc. mainly excavator is nothing but the type of machine which has working boom, arm and bucket for excavation, loading etc. which are interconnected and well controlled by the hydraulic power. The whole engine and body is mounted on the base structure which is very much rigid, strong with maximum load bearing capacity. The boom also mounted on the support structure which well-connected and controlled by operator with joystick from the operator cabin [2].

In the analysis of excavator bucket finite element method (FEM) is used. FEM is selected as the component size is complicated and the process is an all-position process, highly versatile and user friendly. The main attention is focused on the influence of Boron carbide and chromium variations on analysis of Bucket Teeth. The finite element method (FEM) rapidly grew as the most useful numerical analysis tool for engineers and applied mathematicians. The main advantages are that it can be applied to arbitrary shapes in any number of dimensions. The shape can be made of any number of materials. The FEM provides a standard process for converting governing energy principles or governing differential equations in to a system of matrix equations to be solved for an approximate solution. ANSYS software is used to analysis of excavator bucket through FEM and for modelling solid works is used.

II. LITRATURE SURVEY

The excavator bucket teeth 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. Field tests are carried out and it is observed that best results are found by adding the low carbon (4.5%) and high chromium (33%) in the substrate by MMAW process. The excavator bucket teeth have to bear heavy loads of materials like soil, rock and subjected to abrasion wear due to the abrasive nature of soil particles. So, its teeth got damaged due to abrasive wear and impact load [1]. Laboratory wear tests can be designed to meet the criteria but test results generally do not accurately predict wear under field conditions. Field wear testing is needed to optimize the final selection of materials for the given application. The concept of wear gradient is introduced. Wear gradients, with respect to time and location, are small and reproducible in laboratory tests but generally are significant and fluctuate under field conditions. Field tests are classified as sequential series, concurrent series, and concurrent group tests. The use of reference specimens for establishing time-averaged wear gradients is discussed and formulae for correcting the test specimen wear for non-uniform trio conditions over the test area are presented. A field test for abrasive wear of a linear array of specimens is described. The corrected wear values of duplicate specimens agree within 5% of the mean [2].

Weld hard facing techniques are employed mainly to extend or improve the service life of engineering components either by rebuilding or by fabricating in such a way as to produce a composite wall section to combat wear, erosion, corrosion, etc. Five different welding processes including shielded metal arc welding (SMAW), gas metal arc welding (GMAW), gas tungsten arc welding (GTAW), submerged arc welding (SAW), and plasma transferred arc welding (PTAW) have been compared. Based on the quantitative and qualitative factors, the PTAW process is found to be the best method to hardface boiler grade steels [3]. An excavator is a typical hydraulic heavy-duty human operated machine used in general versatile construction operations, such as digging, ground levelling, carrying loads, dumping loads and straight traction. After doing such operation, there is possibility of breaking of pin in tooth adapter assembly as well as bending of tooth point. The stresses developed at the tip of excavator bucket teeth are calculated. Percentage error between stress Analytical result and stress ANSYS result are calculated [4].

A better tool design in the excavation process has been always a challenging task for the engineers. A poorly designed tool always results in poor excavation of the ground, higher wear of the tool, wastage of the time, and power. But proper understanding of the soil mechanics in context of the soil cutting process may help in a better tool design. Moreover it requires the resistive forces offered by the ground on the bucket. The excavation force necessary to cut the soil by the excavator bucket tooth has been analysed in this to improve the design of the bucket teeth [5].

A better design in excavation process has been challenging task for the engineers. Poor design gives always poor result in excavation process. Excavation tasks range from cutting a geometrically described volume of earth for a

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trench or foundation footing to loading a pile of soil. The main objective is to analyze the force calculation of excavator bucket and calculation of excavator bucket capacity, which are failing under the given operating conditions. During operation of excavator at different positions the stresses induced in the bucket [6].

III. METHODOLOGY

The methodology used for the work is as follows; (1) Study about Excavator Bucket.

(2) Data observation and classification.

(3) Analysis of Excavator Bucket by ANSYS.

A. Excavator Bucket

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. An excavator is a piece of heavy equipment that is commonly used in construction work, mining work and work that requires lifting that can be too heavy for humans. An excavator is a vehicle that is engineered and consists of things that can be used such as a backhoe and also has a cab that tends to be mounted to the back pivot near the undercarriage. It also has tracks and wheels that it is running on. As the use of excavator in day to day life is increasing for many purposes but the applicable site is not inspected properly due urgency of work by the owner or the contractor due to which improper handling of it leads to damage of the ground engaging tool i.e. bucket teeth. The teeth of the excavator are main contacting part of it which comes first in contact with the soil while doing excavation at various sites [7].

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 [7].

B. Data Observation and Analysis

The data observation is based on the generally used excavator bucket and 2mm coating of chromium and boron metal as well as we observe the maximum pressure on the surface of bucket can be applied. The excavator is also one of them which mostly used for excavation in mines, hills, etc. mainly excavator is nothing but the type of machine which has working boom, arm and bucket for excavation, loading etc. which are interconnected and well controlled by the hydraulic power. The boom also mounted on the support structure which well-connected and controlled by operator with joystick from the operator cabin. The boom of the excavator consists of two hydraulic cylinders which have to bear maximum load i.e. working load. As the boom is the integral part of the excavator, it has to control the stick movements also. The stick is mounted on boom with connecting cylinder to guide from top for its respective movements. After doing such operation, there is possibility of breaking of pin in tooth adapter assembly as well as the bending of tooth point. For that in this investigation we compare with 2mm coating of boron and chromium and with generally used bucket. Analysis of such investigation is shown in next section. The total capacity of Bucket teeth is 25kN. For safety reason or impact condition in the thesis the factor of safe

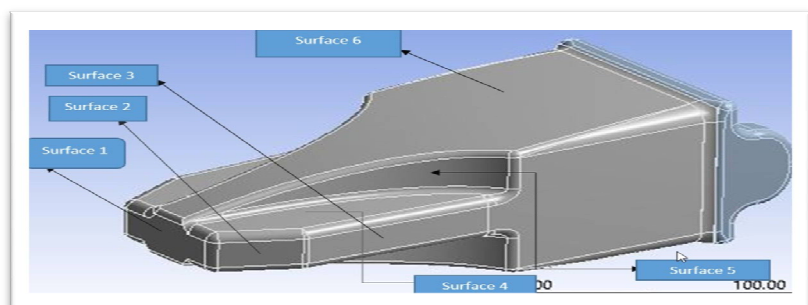


Fig 1 Excavator Bucket teeth numbefring

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for loading condition is taken as 2. So the maximum allowable working Capacity of teeth is taken as 12.5kN and in all surface of the bucket teeth is given pressure as per load maximum pressure of 12.5kN. This is the figure of excavator bucket teeth that generally used in construction work, mining work and work that impossible for human. The loading condition of excavation bucket teeth with 2mm chromium coating and 2mm boron coating. In this bucket teeth the back portion will be the fixed surface.

Table.1. loading Condition as per surface basis

Surface	Area in mm ²	Allowable force/area	Pressure in MPa
Surface 1	1491	(12.5/1491.48)	8.38
Surface 2	768	(12.5/768.78)	16.25
Surface 3	1907	(12.5/1907.95)	6.55
Surface 4	2747	(12.5/2747.31)	4.54
Surface 5	2063	(12.5/2063.23)	6.05
Surface 6	16545	(12.5/16545.68)	0.754

There are 6 surfaces in excavator bucket teeth and we applied the pressure in all six faces. The all six faces have a maximum pressure the can be applied on it. This is the loading condition that will be analyze by finite element method (FEM). In the next section for finite element method analysis ANSYS package is used. 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. 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. 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.

IV. FEM ANALYSIS OF EXCAVATOR BUCKET

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. It is a bulk material handling component and come in a range of sizes and shapes. The excavator bucket teeth 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 teeth acting to break up material as the bucket are dragged through it. So the teeth of excavator bucket got damaged and wear tear takes place.

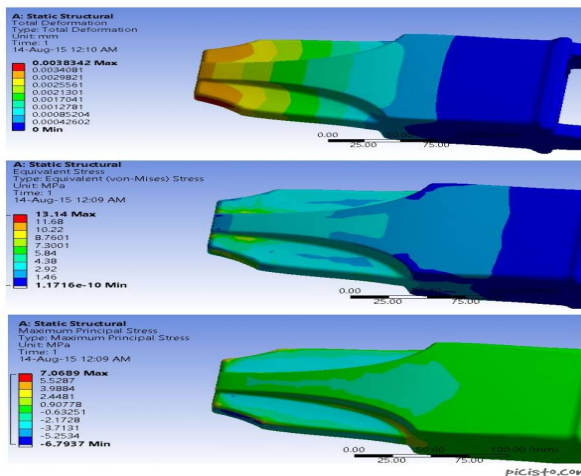
In the analysis of excavator bucket finite element method (FEM) is used. FEM is selected as the component size is complicated and the process is an all-position process, highly versatile and user friendly. The main attention is focused on the influence of Boron carbide and chromium variations on analysis of Bucket Teeth. The finite element method (FEM) rapidly grew as the most useful numerical analysis tool for engineers and applied mathematicians. The main advantages are that it can be applied to arbitrary shapes in any number of dimensions. The shape can be made of

any number of materials. The FEM provides a standard process for converting governing energy principles or governing differential equations in to a system of matrix equations to be solved for an approximate solution. ANSYS software is used to analysis of excavator bucket through FEM.

Analysis of Excavator Bucket By ANSYS

The Coating and base material are analysed using FEM with different combination. Firstly the High tension Steel and Hardox 450 is analysed alone using FEM. Then a coating or layer of chromium and boron carbide of 2mm is used over base material. The coated material is showing abrupt high stress and deformation whereas base material showing very low.

Hardox 450



High tensile Steel

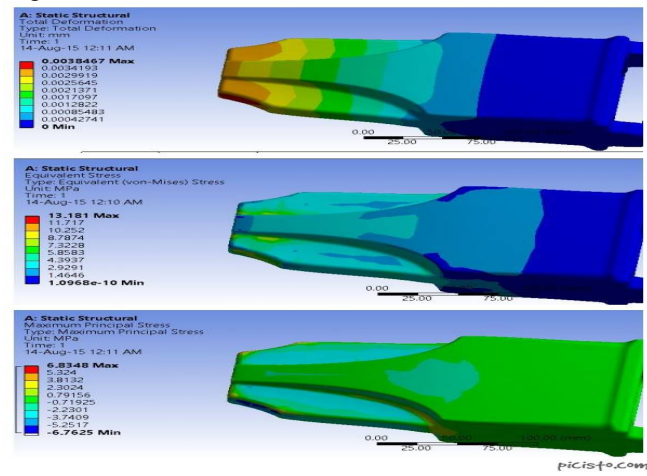


Fig.2. Deformation, Eq. Stress, maximum principal Stress without coating

Table 2 Result of hardox and High tensile Steel without Coating

Force	Hardox 450		High tensile Steel	
	Max.	Min.	Max.	Min.
Equivalent stress (Von Mises) in MPa	13.181	1.09×10^{-10}	13.14	1.1716×10^{-10}
Maximum Principal Stress in MPa	6.8348	-6.7625	7.0689	-6.7937
Deformation in mm	0.0038	0	0.003842	0
Factor of safety	15	15	15	15

2mm coating in excavator bucket teeth with boron carbide and chromium carbide and the properties of boron carbide and chromium carbide are, Boron carbide is characterized by a unique combination of properties that make it a material of choice for a wide range of engineering applications. Boron carbide is used in refractory applications due to its high melting point and thermal stability. Boron carbide is a high temperature semiconductor that can potentially be used for novel electronic applications. Chromium carbide-based cermets are materials of interest in different application areas due to their unique properties. The hardness of Cr₃C₂-Ni cermets is high and they exhibit excellent corrosion, oxidation, abrasion, and erosion resistance.

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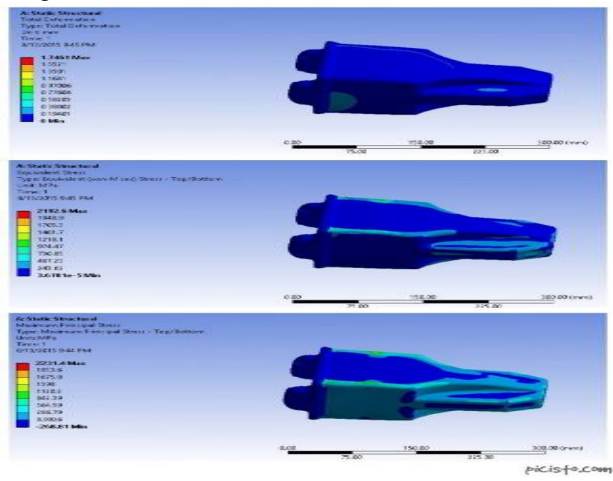
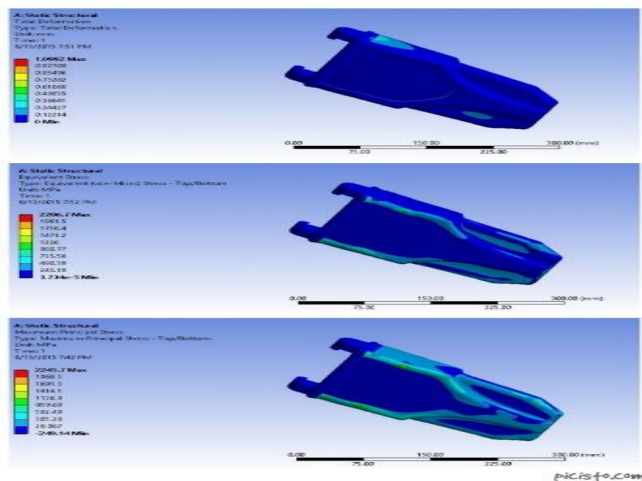
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Table 2 Result of hardox and High tensile Steel without Coating

Force	Hardox 450		High tensile Steel	
	Max.	Min.	Max.	Min.
Equivalent stress (Von Mises) in MPa	2206.7	3.734×10^{-5}	2207.5	3.6836×10^{-5}
Maximum Principal Stress in MPa	2245.7	-249.14	2246.5	-262.07
Deformation in mm	1.0992	0	1.0998	0
Factor of safety	15	0.4354	15	0.4354

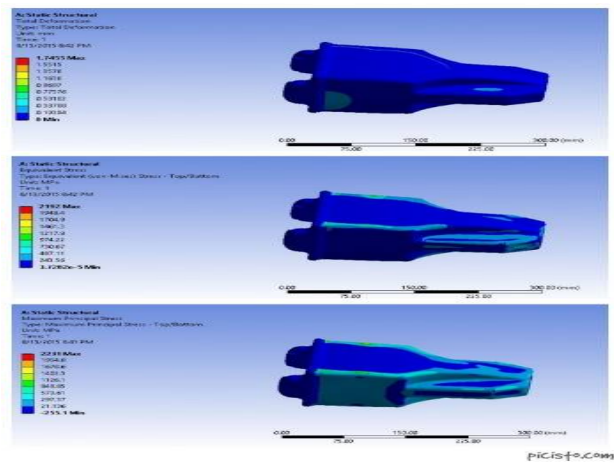
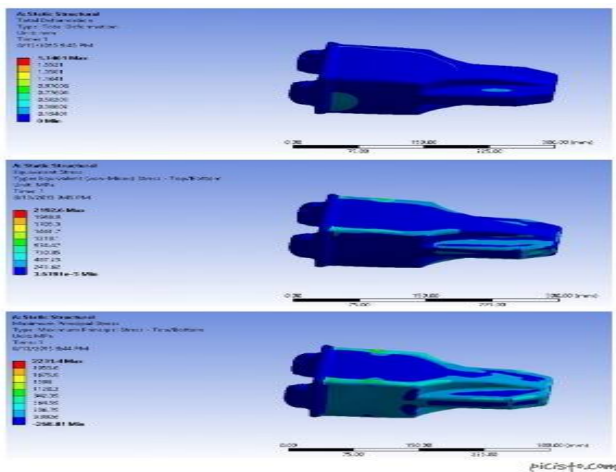
Hardox 450

High tensile Steel



**Fig.3. Deformation, Eq. Stress, maximum principal Stress with Boron Carbide coating
Hardox 450 High tensile Steel**

Hardox 450



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Table 3 Result of hardox and High tensile Steel with Coating of Boron Carbide of 2mm

Force	Hardox 450		High tensile Steel	
	Max.	Min.	Max.	Min.
Equivalent stress (Von Mises) in MPa	2206.7	3.734×10^{-5}	2207.5	3.6836×10^{-5}
Maximum Principal Stress in MPa	2245.7	-249.14	2246.5	-262.07
Deformation in mm	1.0992	0	1.0998	0
Factor of safety	15	0.4354	15	0.4354

Table 4 : Result of hardox and High tensile Steel with Coating of Chromium of 2mm

Force	Hardox 450		High tensile Steel	
	Max.	Min.	Max.	Min.
Equivalent stress (Von Mises) in MPa	2192	3.7282×10^{-5}	2192.6	3.6781×10^{-5}
Maximum Principal Stress in MPa	2231	-255.1	2231.4	-268.81
Deformation in mm	1.7455	0	1.7461	0
Factor of safety	15	0.44334	15	0.44334

The result of FOS and deformation between coating of chromium and boron carbide for 2mm. Boron Carbide will be having more better result than chromium coating. The minimum FOS for both are 0.4354 and 0.4433.

V. CONCLUSIONS

The main criteria to take Boron carbide and chromium to take in this thesis is Boron carbide is the second hardest material known in world and chromium is the highly wear resistive material. But the both material didn't show positive result with the bare material. The following conclusion came out with the thesis which are listed below:

1. High tensile steel and hardox 450 has almost same result on Stress and deformation.
2. Coating used of 2mm does not show any positive material which give a negative result.
3. A single material without coat of material give better result than coating of bucket teeth.

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