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Design and Analysis of an Excavator Bucket

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ABSTRACT:

Excavator machines are high power machines used in the Mining, Agricultural and Construction industry whose principal functions are Digging (material removing), Ground leveling and material transport operations. Backhoe attachment is rear part of excavator machine. The backhoe attachment is subjected to static as well as dynamic forces. This project work includes static force analysis and design modification of backhoe assembly of excavator.After doing such operation, there is possibility of breaking of pin in tooth adapter assembly as well as bending of tooth point. The objective of this paper is to design an excavator bucket by using CATIA V5 R20 software. Model is exported through ANSYS 13.0 for meshing in analysis software boundary conditions and the forces are applied at the tip of teeth of excavator bucket.

Static analysis is done in ANSYS 13.0 analysis software. In this paper the stresses developed at the tip of excavator bucket teeth are calculated. Structural analysis was carried out on the excavator bucket at different inclinations of teeth such as 25^0,30^0,35^0,40^0,45^0. And the analysis was carried out on three types of materials named Stainless Steel, AISI-1045 and TI Carbide and the action of various stress and strains on the excavator bucket at various loads were investigated. In this research different widths also considered for teeth. The best combination of parameters like Von misses Stress and Equivalent shear stress, Deformation, shear stress and weight reduction for eexcavator bucket were done in ANSYS software. TI carbide has more factor of safety, reduce the weight, increase the stiffness and reduce the stress and stiffer than other material. With Fatigue analysis we can determine the lifetime of the excavator bucket.

1 INTRODUCTION:

Development of any country mainly depends upon Industrial sector, Agriculture, Construction; Transportation etc. Heavy vehicles are the backbone of the entire above sector hence these vehicles should work properly in all working condition. The efficiency of these vehicles depends upon type of loading, operating condition duration of use and maintenance. To increase life of vehicle static as well as dynamic analysis of above condition should be done. These heavy vehicles include multiaxel Trucks, Cranes, Bulldozers, Tractors and Road Rollers etc. Today in the machine age when the use of machines is increasing for the earth moving works, considerable attention has been focused on designing of these earth moving equipments.

Achievement of an ambitious and rapidly growing rate of industry of earth moving machines is assured through the high performance construction machineries with problem is not always ready in the formula’s provided in the standards or the books. Excavator machines are high power machines used in the Mining, Agricultural and Construction industry whose principal functions are Digging (material removing), Ground leveling and material transport operations. Backhoe attachment is rear part of excavator machine. The backhoe attachment is subjected to static as well as dynamic forces. This project work includes static force analysis and design modification of backhoe assembly of excavator.

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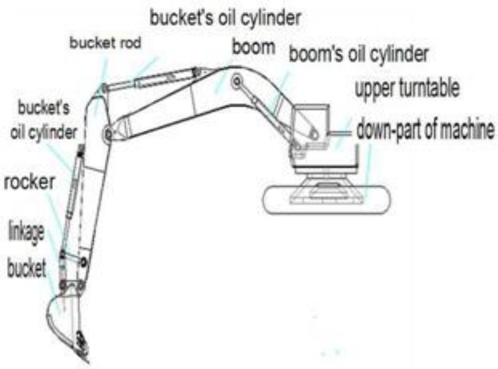

Fig.1.1 A typical diagram of a digging machine

1.1Parts of an excavator

1. Bucket
2. Rivet
3. Tooth

1.1.1 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.

Fig.1.2 Excavator bucket design

1.1.2 Rivet

A Rivet is a permanent mechanical fastener. A Rivet consists of a smooth cylindrical shaft with a head on one end. The end opposite to the head is called Tail.

Fig.1.3 Rivet design

1.1.3 Tooth

The excavator bucket toothhave to bear heavy loads of materials like wet soil and rock andalso subjected to abrasion wear due to the abrasive nature of solidparticles 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 materialof bucket tooth, so that its life will improve against abrasive wear.

Fig. 1.4 Tooth design

1.2 Parts of a tooth

1. Lip plate (cutting edge)
2. Adapter
3. Tooth (tip)
4. Cast corner

Fig. 1.5 Excavator bucket design model

2. LITERATURE SURVEY

The following research papers are consulted for obt aining an indepth understanding ofvarious aspects of the project

Manisha.p et.al. [1]:

In this paper he discussed as excavator is a typical hydraulic heavy-duty human operated machine used in general versatile construction operations, such as digging ,ground leveling, carrying loads, dumping loads and straight traction.

Kalpak.Set.al.[2]:
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.

Bhaveshkumaret.al.[3] :
Excavators are used primarily to excavate below the natural surface of the ground on which the machine rests and load it into trucks or tractor. Due to severe working conditions, excavator parts are subjected to high loads.

Yang.Cet.al.[4]:
The hydraulic excavators are widely used in construction, mining, excavation, and forestry applications. Its diversity and convenient operability make it popular. The performance of hydraulic excavator is depending on its performance of the backhoe front attachment.

Jonas Helgessonet.al.[5] :
An optimized bucket design is important for increasing productivity and loading performance for underground loaders. Design theories are today difficult to evaluate due to lack of verification methods. Later year's development of simulation software and computers has made it possible to verify the design by simulating the loading process. The purpose with this thesis has been to both develop and use a simulation model of the loading process for one of Atlas Copco's underground loaders.

Mehul Kumar A Patel et.al.[7]:
The Hydraulic excavator machines are heavy duty earth mover consisting of a boom, arm and bucket. It works on principle of hydraulic fluid with hydraulic cylinder and hydraulic motors.

Mr.BhushanGhodakeet.al.[8] :
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.

SujitLomateet.al.[9] :
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.

AhmetErkliget.al.[10] :
In this study, static structural analysis of backhoe-loader arms has been performed with the finite element method (FEM). The aim of this study is to simulate and strengthen the back and front arms of the backhoe-loader concerning with stress under maximum loading condition and different boundary conditions.

Rahul Mishra1et.al.[11]:
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 atrench or foundation footing to loading a pile of soil.

JaydeepPatil, TejaskumarBharsakaleet.al. [12] :
Excavators are high power machines used in the mining, agricultural and construction industry whose principal functions are digging (material removing), ground leveling and material transport operations. Backhoe attachment is rear part of excavator machine. The backhoe attachment is subjected to static as well as dynamic forces.

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Dr. Sabah Khan, Sheikh Mohashinet.al. [13]:
The Excavator is used for material handling at mining and construction sites. The bucket teeth of the excavator have to bear heavy dynamicExcavators are high power machines used in the mining, agricultural and construction industry whose principal functions are digging (material removing), ground leveling and material transport operations. Backhoe attachment is rear part of excavator machine.

Dr. Sabah Khan et.al. [14]:
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.

3. GEOMETRIC MODELLING:

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Assault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Assault Systems product lifecycle management software suite.

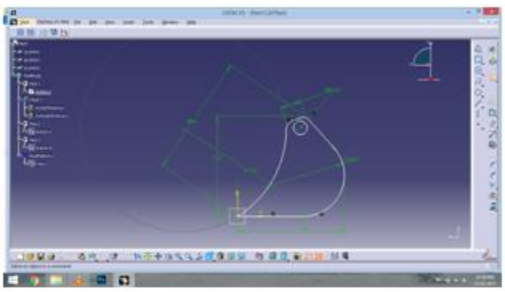

Fig.3.1 CATIA model of excavator bucket

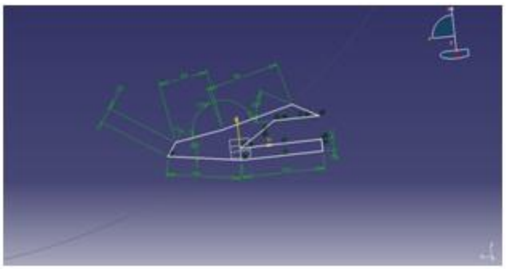

Fig.3.2 Model of Excavator bucket

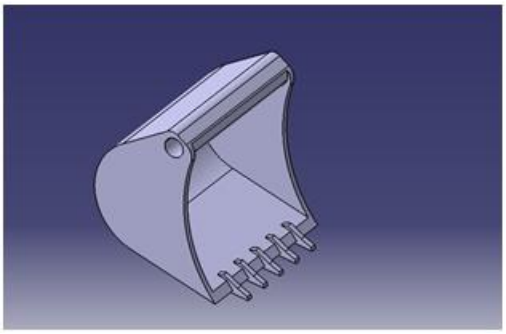

Fig.3.3 Designed CATIA model of excavator bucket with teeth

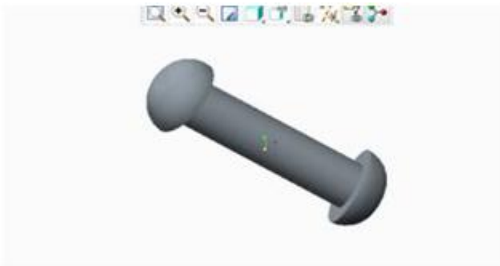

Fig.3.4 Designed CATIA model of rivet

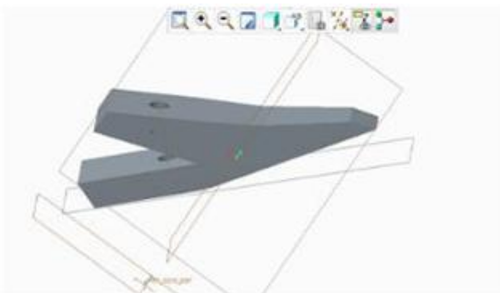

Fig.3.5 Designed Catia model of teeth

4. STEPS INVOLVED IN ANALYSIS USING ANSYS

The ANSYS program has many finite element analysis capabilities, ranging from a simple, linear, static

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analysis to a complex, nonlinear, transient dynamic analysis. A typical ANSYS analysis consists of the following steps:

Build the model using key points, lines, areas and volume commands.

- Giving material properties.
- Choosing proper element.
- Meshing the model to discrete elements.
- Applying the given loads.
- Applying the boundary conditions.
- Running the solution phase.
- Review the results using the post processor.

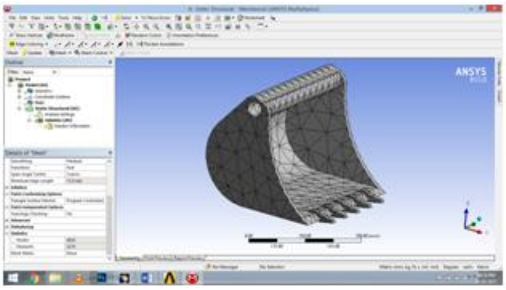

Fig.4.1 Excavator bucket after meshing

5 RESULTS AND DISCUSSIONS:

The main objective of this investigation is to do the Structural analysis on excavator bucket with different materials at various loads and find out the behaviour of the excavator bucket at various inclinations and widths. Here in this analysis various factors were calculated by applying loads at appropriate sections of the excavator bucket. Structural analysis was carried out on the excavator bucket at different inclinations 25^0,30^0,35^0,40^0,45^0 on three types of materials Stainless Steel, AISI-1045 and TI Carbide and the action of various stress and strains on the excavator bucket at various loads were investigated. In this research different widths also considered for teeth.

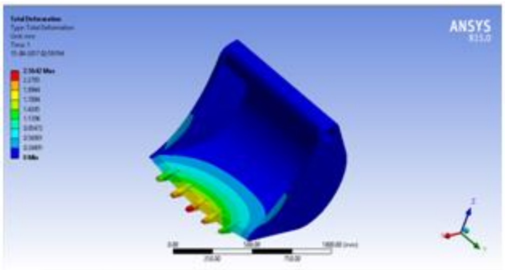

Fig.5.1.1 Structural analysis of stainless steel

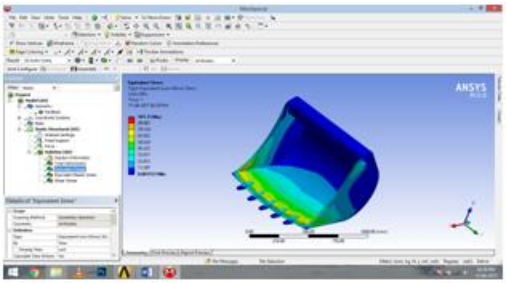

Fig.5.1.2 Equivalent stress of stainless steel

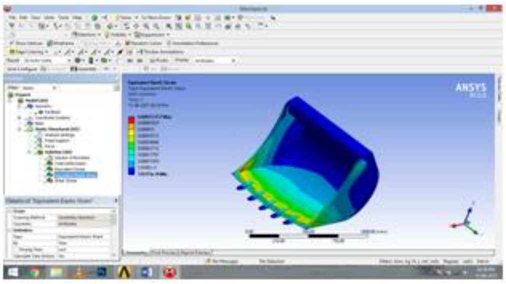

Fig.5.1.3 Equivalent elastic strain of stainless steel

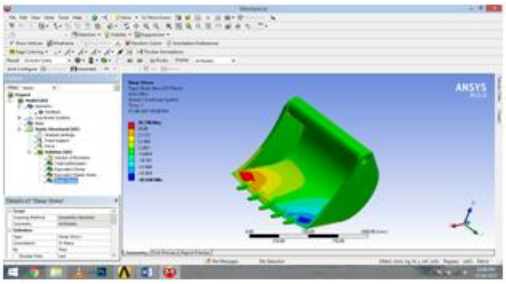

Fig.5.1.4 Shear stresses developed in stainless steel bucket

Here in this case the material used is Stainless Steel and the load acted upon excavator bucket and the Structural analysis is done in order to find out total deformation, equivalent Von-Mises stresses, equivalent shear stress and shear stress in the

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excavator bucket. And the results were clearly shown in the figure. The above analysis was conducted on all parts of the excavator bucket, the distance between the teeth of the excavator bucket was maintained same along the length of the analysis the results explains the same. We found that on doing Structural analysis on the excavator bucket the maximum values and minimum values were listed in below table.

Table.5.1 Maximum stresses developed

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	2.5642	0
2.	Equivalent Von-Mises Stresses	101.75	0.001537
3.	Equivalent Shear Stress	0.00053357	1.9721e-8
4.	Shear Stress	39.748	-42.046

For AISI-1045

Table 5.2 Deformations for AISI 1045

		Obtained Value	
S.No	Type of Stress	Maximum	Minimum
1.	Total Deformation	2.3925	0
2.	Equivalent Von-MisesStresses	101.6	0.0014474
3.	Equivalent Shear Stress	0.00050168	1.7542e-8
4.	Shear Stress	39.815	-42.197

TI Carbide

Table 5.3 Deformations in TI carbide

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	1.0346	0
2.	Equivalent Von-MisesStresses	100.4	0.0010993
3.	Equivalent Shear Stress	0.00022561	5.9912e-9
4.	Shear Stress	39.955	-42.628

5.1 Structural analysis of stress in different materials at 25^{0}inclination

Table 5.4 structural analysis of TI-carbide

		obtained value	
s.no	type of stress	maximum	minimum
1.	total deformation	2.5416	0
2.	equivalent Von-Mises stresses	101.25	0.0013511
3.	equivalent shear stress	0.00052944	1.9493e-8
4.	shear stress	39.587	-39.241

For TI Carbide

Table 5.5 excavator bucket minimum and maximum values

		obtained value	
s.no	type of stress	maximum	minimum
1.	total deformation	1.026	0
2.	equivalent Von-Mises stresses	99.188	0.00096682
3.	equivalent shear stress	0.00022231	5.9631e-9
4.	shear stress	39.747	-39.61

For AISI-1045

Table 5.6 structural analysis of For AISI-1045

		obtained value	
s.no	type of stress	maximum	minimum
1.	total deformation	2.3716	0
2.	equivalent Von-Mises stresses	100.96	0.12691
3.	equivalent shear stress	0.00047912	1.7364e-8
4.	shear stress	39.63	-39.323

Case-2.1: Structural analysis of stress in different materials at 30^{0}inclination

- **AISI-1045**

Table 5.7 structural analysis of excavator bucket

		Obtained Value	
S.No	Type Of Stress	Max	Min
1.	Total Deformation	2.3513	0
2.	Equivalent Von-Mises Stresses	101.19	0.0014008
3.	Equivalent Shear Stress	0.0004937	1.7587e-8
4.	Shear Stress	39.349	-39.062

❖ **For Stainless Steel**

Table 5.8 structural analysis of stainless steel

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	2.5196	0
2.	Equivalent Von-Mises Stresses	101.29	0.0014727
3.	Equivalent Shear Stress	0.00052497	1.9775e-8
4.	Shear Stress	39.299	-39.146

For TI Carbon

Table 5.9 structural analysis of TI-carbon

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	1.0176	0
2.	Equivalent Von-MisesStresses	100.45	0.0010952
3.	Equivalent Shear Stress	0.00022282	6.0085e-8
4.	Shear Stress	39.493	-39.308

Case-2.2: Structural Analysis of Stress in Different Materials at 35^{0}Inclination

Table 5.10 structural analysis of TI-carbide

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	1.0097	0
2.	Equivalent Von-MisesStresses	100.22	0.0010792
3.	Equivalent Shear Stress	0.00022389	5.9353e-9
4.	Shear Stress	39.193	-38.828

For Stainless Steel

Table 5.11 structural analysis of stainless steel

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	2.4987	0
2.	Equivalent Von-MisesStresses	101.99	0.0015094
3.	Equivalent Shear Stress	0.00053196	1.9621e-8
4.	Shear Stress	38.995	-39.705

For AISI-1045Table 5.12 structural analysis for AISI-1045

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	2.3321	0
2.	Equivalent Von-MisesStresses	101.75	0.0014162
3.	Equivalent Shear Stress	0.0004997	1.7437e-8
4.	Shear Stress	39.046	-39.757

Case-2.3: Structural Analysis of Stress in Different Materials at 40^{0}Inclination

Table 5.13 structural analysis of AISI-1045

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	2.313	0
2.	Equivalent Von-MisesStresses	100.98	0.0013942
3.	Equivalent Shear Stress	0.000496	1.7425e-8
4.	Shear Stress	38.765	-39.047

❖ **For Stainless Steel**

Table 5.14 structural analysis of stainless steel

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	2.4781	0
2.	Equivalent Von-MisesStresses	101.22	0.0014629

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3.	Equivalent Shear Stress	0.00052803	1.9602e-6
4.	Shear Stress	38.712	-38.956

❖ **For TI Carbide**

Table 5.15 structural analysis of for TI-carbide

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	1.0017	0
2.	Equivalent Von-MisesStresses	99.459	0.001101
3.	Equivalent Shear Stress	0.0002222	5.9397e-9
4.	Shear Stress	38.918	-39.254

Case-2.4: Structural Analysis of Stress in Different Materials at 45⁰Inclination

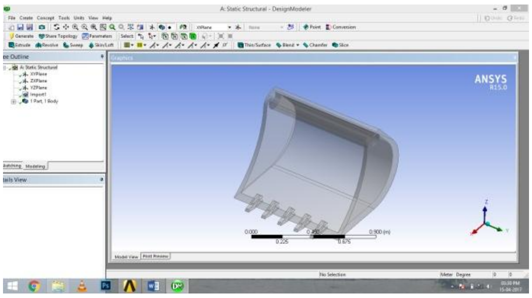

Fig 5.13.4 structural analysis of for TI-carbide

❖ **For AISI-1045**

Table 5.16 structural anbalysis of of AISI-1045

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	2.2921	0
2.	Equivalent Von-MisesStresses	99.666	0.0014416
3.	Equivalent Shear Stress	0.00048637	1.7164e-8
4.	Shear Stress	38.4	38.239

❖ **For TI Carbide**

Table 5.17 structural analysis of for TI-carbide

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	0.99303	0
2.	Equivalent Von-Misses Stresses	99.092	0.001098
3.	Equivalent Shear Stress	0.00021982	5.8226e-9
4.	Shear Stress	38.55	-38.113

❖ **For Stainless Steel**

Table 5.17 structural analysis of of stainless steel

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	2.4555	0
2.	Equivalent Von-MisesStresses	99.71	0.0015152
3.	Equivalent Shear Stress	0.00051684	1.9335e-8
4.	Shear Stress	38.348	-38.291

Width Based Analysis

Case-3: Structural Analysis of Stress in Different Materials at 25mm Width

❖ **For Stainless Steel**

Table 5.18 structural analysis of stainless steel

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	2.4325	0
2.	Equivalent Von-MisesStresses	103.5	0.0015395
3.	Equivalent Shear Stress	39.577	-40.388
4.	Shear Stress	52.785	0.00088051

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Table 5.19 analysis of AISI-1045

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	2.2708	0
2.	Equivalent Von-Misses Stresses	103.57	0.0014436
3.	Equivalent Shear Stress	39.678	-40.459
4.	Shear Stress	52.759	0.00082746

❖ **For TI Carbide**

Table 5.20 analysis of TI-carbide

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	0.98433	0
2.	Equivalent Von-MisesStresses	103.12	0.0010977
3.	Equivalent Shear Stress	40.043	-40.688
4.	Shear Stress	52.478	0.00063353

Case-3.1: Structural Analysis of Stress in Different Materials at 40mm Width

❖ **For TI Carbide**

Table 5.21 analysis of For TI Carbide

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	0.90772	0
2.	Equivalent Von-MisesStresses	101.09	0.00094807
3.	Equivalent Shear Stress	41.588	-40.067
4.	Shear Stress	51.821	0.00054526

❖ **For Stainless Steel**

Table 5.22 analysis of stainless steel

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	2.233	0
2.	Equivalent Von-MisesStresses	103.62	0.0013166
3.	Equivalent Shear Stress	41.041	-39.38
4.	Shear Stress	54.591	0.00075555

❖ **For AISI 1045**

Table 5.23 analysis of stainless steel

		Obtained Value	
S.No	Type Of Stress	Maximum	Minimum
1.	Total Deformation	2.0862	0
2.	Equivalent Von-MisesStresses	102.88	0.0012385
3.	Equivalent Shear Stress	41.121	-39.51
4.	Shear Stress	53.875	0.00071072

6. CONCLUSION:

We designed an Excavator bucket by using CATIA V5 software and analysis is done by ANSYS 15.0 software. The stress at the Tip of teeth of an Excavator bucket is calculated 96.39 MPA and stress due to shearing of rivet is calculated 157.67 MPA by analytically. The stress at the tip of the teeth is calculated 112.98 MPA and stress due to shearing of rivet 167.42 is calculated. Percentage error between analytical result and Ansys result are 14.69 % and 5.82 %. As per the above analysis, it is suggested that the bucket used for the excavation purpose should be properly checked for its application on the basis of the soil strata. And considering the failure of the tooth and rivet due the impact loading, it is very much economical to change the tooth assembly and also the inclination and thickness of the tooth.

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