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Design and Analysis of Tooth of Excavator Bucket Using Different Materials at Different Widths

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Abstract
Excavators (hydraulic) are heavy construction equipment consisting of a boom, dipper (or stick), bucket and cab on a rotating platform known as the house. The house sits atop an undercarriage with tracks or wheels. They are a natural progression from the steam shovels and often mistakenly called power shovels. All movement and functions of a hydraulic excavator are accomplished through the use of hydraulic fluid, with hydraulic cylinders and hydraulic motors. Due to the linear actuation of hydraulic cylinders, their mode of operation is fundamentally different from cable-operated excavators which use winches and steel ropes to accomplish the movements. The objective of this paper is to design an excavator bucket by using CATIA V5 R20 software.Model is exported through ANSYS 15.0 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 15.0 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 widths of teeth such as 25 mm, 30 mm, 35 mm, 40 mm and 45 mm. 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. The best combination of parameters like Von misses Stress and Equivalent shear stress, Deformation, shear stress and weight reduction for excavator bucket were done in ANSYS software. TI carbide with 25mm width 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.

Key words:
Excavator bucket, Static analysis, Stainless Steel, AISI-1045 and TI Carbide

1. Introduction
A hydraulic excavator (digger) is an outsized vehicle that is build up for demolition and excavation purposes. A conventional hydraulic excavator consists of various parts but the basic prime parts are boom, chassis, and bucket, and move using wheels or tracks. They are available in a wide range in size and function, an instance of which is the comparable but smaller “mini excavator.” All versions are usually designed for the same intentions. Hydraulic excavators weigh lying 3,000 and 2 million pounds and their speed varies between 19 HP and 5,000 HP. Conventionally, Hydraulic excavator bucket is made up of selling steel and normally tooth present, which is protruding from the cutting edge, is to disrupt hard material and prevents from wearing-and-tearing of the bucket. The excavator bucket tooth has to stand heavy loads of materials, for example, wet soil and rock furthermore,

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it also subjected to abrasion wear because of the abrasive nature of soil particles when tooth acting to disintegrate material. Generally, for making tooth of excavator bucket alloy steel is used along with the addition of some other wear resistant materials so that its life will improve against abrasive wear. Using alloy along with solid steel is basically due to having both good toughness and abrasive resistance as of having direct contact of metallic components with the soil constituents. Therefore, better selection of tooth material and tooth design should be undertaken in order to prevent from bucket tooth failure.

Literature Survey

Bhaveshkumaret.al.[1]:

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. The excavator mechanism must work reliably under unpredictable working conditions. Thus it is very much necessary for the designers to provide not only a equipment of maximum reliability but also of minimum weight and cost, keeping design safe under all loading conditions. It can be concluded that, force analysis and strength analysis is an important step in the design of excavator parts. Finite Element Analysis (FEA) is the most powerful technique in strength calculations of the structures working under known load and boundary conditions. In general, computer aided drawing model of the parts to be analyzed must be prepared prior to the FEA. It is also possible to reduce the weight of the mechanism by performing optimization task in FEA. This paper provides the platform to understand the Modeling, FEA and Optimization of backhoe excavator attachment, which was already carried out by other researchers for their related applications and it can be helpful for development of new excavator attachment.

Manisha.p et.al. [2]:

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. 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 CREO-parametric 2.0software. Model is exported through IGES file format 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 ANSYS13.0 analysis software. In this paper the stresses developed at the tip of excavator bucket teeth are calculated. Percentage error between stress Analytical result and stress ANSYS result are calculated.

Kalpak.Set.al. [3]:

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.

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. This paper focuses on the research work of excavator attachment, which mainly includes those aspects, such as the kinematic analysis, dynamic analysis, structural analysis, trajectory planning and control, fatigue life analysis and structural optimization design. and the development trends of excavator attachment, in the near future, are forecasted.

AhmetErkliget.al.[5]:

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

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and strengthen the back and front arms of the backhoe-loader concerning with stress under maximum loading condition and different boundary conditions. According to analysis result, back and front arms of the backhoe-loader are strengthened with the use of reinforcements. As a result of the study, strength of the arms has been increased by nearly 20%.

2. Methodologies

In his paper the tooth of excavator bucket is designed in catia by using different materials by varying widths as per SAE standards later it is imported to ANSYS and discretized into 13335 elements with 26058 nodes for structural analysis. The materials used are Stainless Steel, AISI-1045 and TI Carbide.

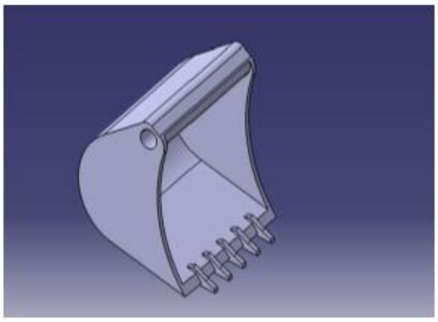

Fig 1 Catia Model of excavator bucket

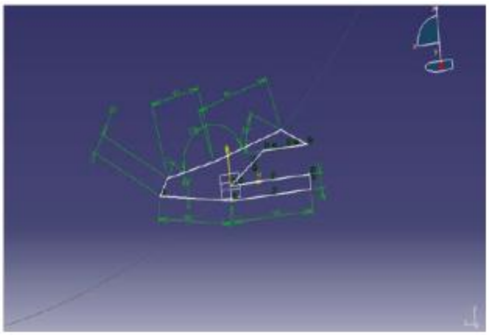

Fig 2 Catia Model teeth of excavator bucket

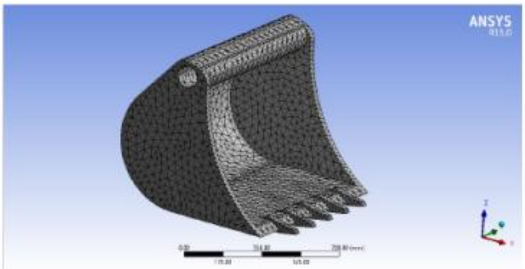

Fig 3 Meshing model of excavator Bucket

3. 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 tooth at different widths 25, 30, 35, 40, 45mm 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.

Analysis of Stress in Different Materials at 25mm Width

For stainless steel

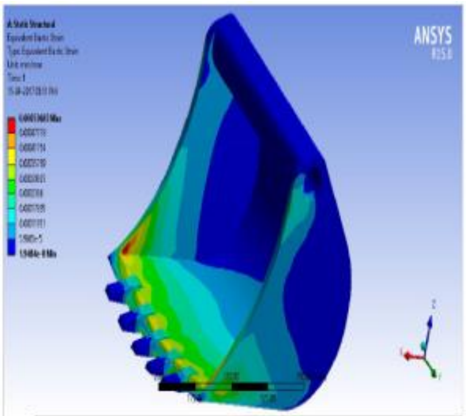

Fig.4 Equivalent stress of stainless steel

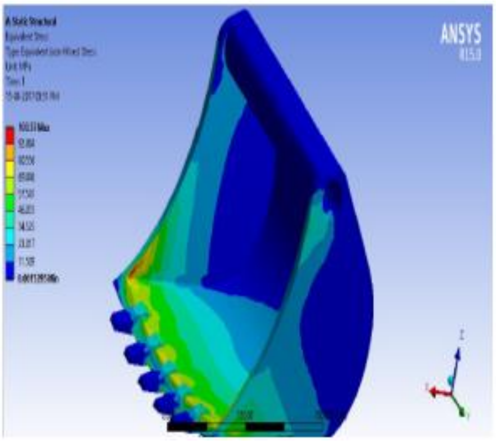

Fig.5Equivalent Von-Mises stress of stainless steel]

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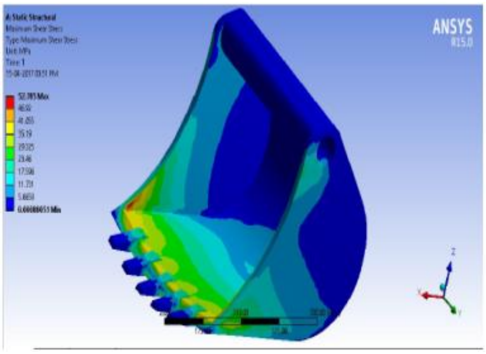

Fig.6Shear stress of stainless steel

Table1 Maximum stresses developed

		Obtained values	
S.No	Type of stress	Maximum	Minimum
1	Total Deformation	2.4325	0
2	Equivalent Von-Mises Stress	103.5	0.0015395
3	Equivalent Shear Stress	39.577	-40.388
4	Shear Stress	52.8785	0.00088051

For AISI-1045

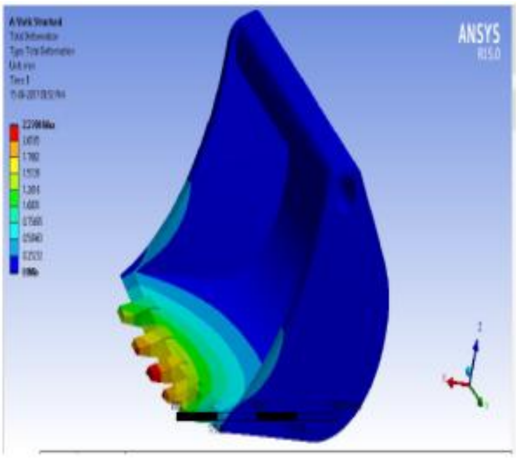

Fig.7 Equivalent stress

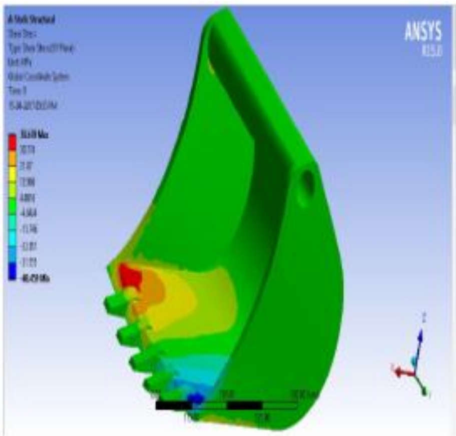

Fig.8Equivalent Von-Mises stress

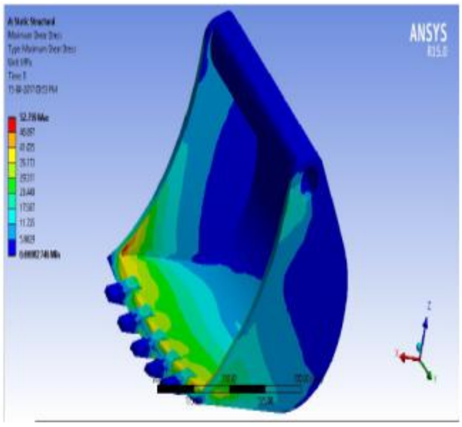

Fig.9Shear stress

Table 2 Maximum stresses developed For TI Carbide

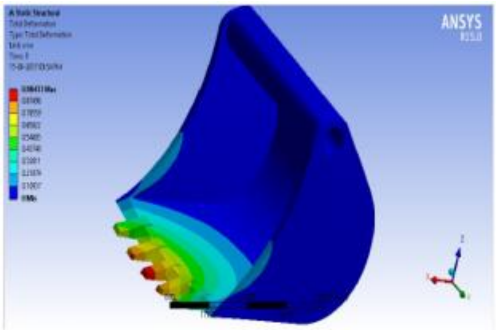

Fig.10 Equivalent stress

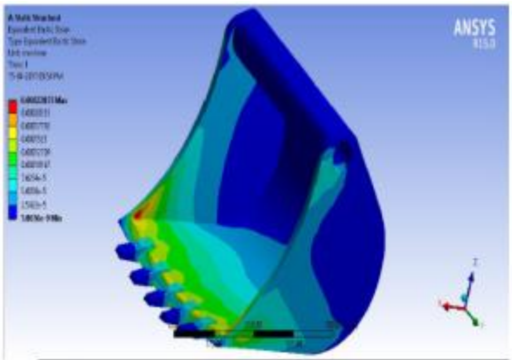

Fig.11 Equivalent Von-Mises stress

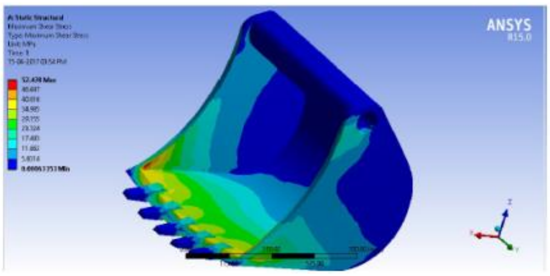

Fig. 12Shear stress

Table 3 Maximum stresses developed

		Obtained values	
S.No	Type of stress	Maximum	Minimum
1	Total Deformation	0.98433	0
2	Equivalent Von-Mises Stress	103.12	0.0010977
3	Equivalent Shear Stress	40.043	-40.688
4	Shear Stress	52.478	0.00063353

Analysis of stress in different materials at different inclinations at 25^0, 35^0, 45^0

At 25^0

Table 4 Maximum stresses developedAt 25^0

		Obtained values for Stainless steel		Obtained values for AISI-1045		Obtained values for TI CARBIDE	
S.No	Type of stress	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
1	Total Deformation	2.3716	0	1.026	0	2.3716	0
2	Equivalent Von-Mises Stress	100.96	0.12691	99.188	0.00096682	100.96	0.12691
3	Equivalent Shear Stress	0.00047912	1.73648e-8	0.00022231	5.9631e-9	0.00047912	1.73642e-8
4	Shear Stress	39.63	-39.323	39.747	-39.61	39.63	-39.323

At 35^0

Table 5 Maximum stresses developedAt 35^0

		Obtained values for Stainless steel		Obtained values for AISI-1045		Obtained values for TI CARBIDE	
S.No	Type of stress	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
1	Total Deformation	2.4781	0	2.313	0	1.0017	0
2	Equivalent Von-Mises Stress	101.22	0.0014629	100.987	0.0013942	99.459	0.001101
3	Equivalent Shear Stress	0.00052809	1.9602e-6	0.00496	1.7425e-8	0.0002222	5.9397e-9
4	Shear Stress	38.712	-38.969	38.765	-39.047	38.918	-39.254

At 45^0

Table 6 Maximum stresses developedAt 45^0

		Obtained values for Stainless steel		Obtained values for AISI-1045		Obtained values for TI CARBIDE	
S.No	Type of stress	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
1	Total Deformation			2.2959	0	0.99303	0
2	Equivalent Von-Mises Stress			99.6666	0.0014416	99.092	0.001098
3	Equivalent Shear Stress			0.00048637	1.7146e-8	0.00021982	5.822e-9
4	Shear Stress			38.4	38.238	38.55	-38.113

4. 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 86.39 MPA and stress due to shearing of rivet is calculated 187.67 MPA by analytically. The stress at the tip of the teeth is calculated 112.98 MPA and stress due to shearing of rivet 157.47 is calculated. Percentage error between analytical result and Ansys result are 13.69 % and 6.72 %.

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. Structural analysis was carried out on the excavator bucket at different widths of teeth such as 25 mm, 30 mm, 35 mm, 40 mm and 45 mm. 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. The best combination of parameters like Von misses Stress and Equivalent shear stress, Deformation, shear stress and weight reduction for excavator bucket were done in ANSYS software. TI carbide with 25mm width 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.

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