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Transient Analysis on Excavator Bucket with Gray Cast Iron and Vanadium

R. Jagadeesh Kumar[1], P. Kameswara Rao[2], M. Gangadhar Rao[3], R. RamaKrishna[4]
[1, 2, 3, 4]*Assistant Professor, Lendi Institute of Engineering & Technology, Jonnada*

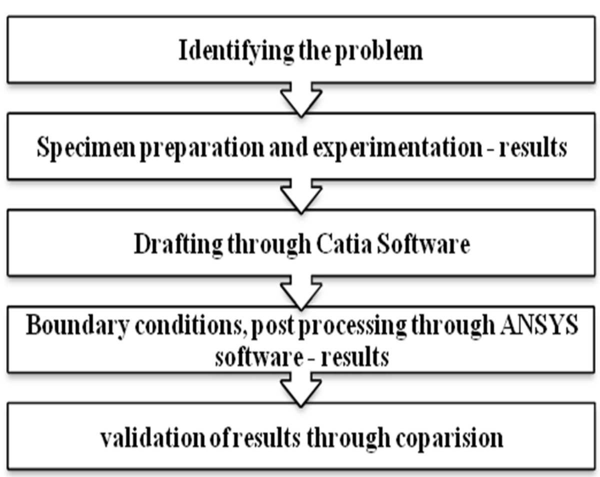
Abstract: The excavator machines are power machines used in the Agricultural, Mining and Construction industry. The main purpose of this excavator is for digging, ground leveling and material transport operations etc. The excavator bucket part is subjected to various load forces. So in this project, the work is carried on the bucket by interchanging the composite materials like gray cast iron and vanadium. Since the bucket experienced so many loads like impact during digging transient analysis is carried out, the standard specimen prepared through stir casting technique and conducted tests on the specimen like tensile, compression, hardness, and impact test to validate the data. The main objective of this project is to design an excavator bucket using CATIA V5 software of 3-D modeling software. Then simulation did through ANSYS 19.2 software by transient analysis technique to know the deformation and stresses etc. And the results of deformation and stress are compared between Gray Cast Iron without Vanadium and Grey Cast Iron with Vanadium for comparing justified result.
Keyword: Excavator Bucket, Gray Cast Iron, Vanadium, Transient analysis, stir casting.

I. INTRODUCTION

The main purpose of excavator machine is for digging the lands or mines, demolition, lifting heavy jobs etc. in this paper analysis carried out digging type excavator and optimized by interchanging the material.
In this paper the material chosen for preparing specimen though stir casting technique. The composition of material is 99.5 % of grey cast and 0.5 % of vanadium to enhance the properties of bucket[6]. The comparative study with the structural steel and ductile cast iron excavator buckets, which are the most commonly used for manufacturing processes for an excavator bucket. In addition, it was preferred to develop an optimized material which will decrease the weight of the component and enhance the properties. The following table indicates enchantment of properties by using vanadium for the bucket material. And also comparison between without addition of vanadium for material for manufacturing bucket [3].

II. METHODOLOGY

This is the procedure that can explain to determining the unknown parameters for the given excavator bucket as boundary conditions and solving the problem through transient analysis technique. The following procedure adopted to validate results[5].
The below flow chart describes the methodology to determining the problem in exiting design, drafting and analyzing the bucket, experimentation and comparison of results for validation.



III. IDENTIFYING THE PROBLEM

For a digging type bucket there is impact force created on teeth of the bucket while digging, so in less duration of time large amount force applied on the teeth. In that case more stress is induced in the teeth part.

The bucket is subjected to various loads but generally failure occurs at the fixed position of the bucket and bushing and this will be at the centre of the bushing or at teeth end of excavator bucket. In such a condition the failure is due to maximum stresses acting when the bucket carries load and also while digging. So the stresses are applicable at the bushing and teeth portion.

IV. EXPERIMENTATION

A. *Specimen Preparation*

Stir casting is the method employed to prepare the specimens. Gray cast iron (ASTM 40) which has excellent casting performance and vanadium (99.5% & 0.5%) of weight to volume ratio have been taken into the consideration to prepare the specimen. Results show that the weight percentage of material exhibits better results1. The specimen was casted at 1204^{o}C and at a stirring speed ranging in between 600-700 RPM for 15 minutes. Results implicate that the 0.5% inclusion of vanadium in raw grey cast iron has shown improvement of properties that are listed in the above table1. The standard specimen size mentioned below.

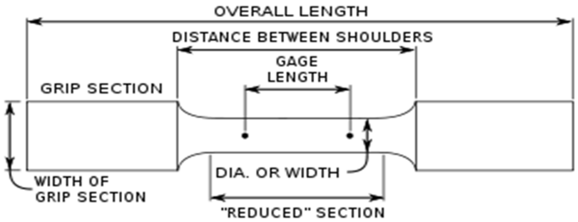


Figure 1. Standard specimen size

B. *Testing*

1) *Tensile and Compressive Tests:* A universal testing machine is use to conduct tensile and compression test conducted for given specimen showed in figure 1. And results listed below. The specimen fixed between two jaws of the UTM machine where load is increased gradually and readings are substituted in the given formula to determine maximum ultimate strength of the given specimen.

i) Tensile strength = ultimate load (P) / Area (A)

Where,

P = 133.831 KN

A = $\pi d^2/4$ d=20mm

= 314.159 mm^2

Then,

Tensile strength = 133.831/314.159

= 0.4259969 KN/ mm2 (or) 425.996 N/ mm^2

ii) Compression strength = ultimate load (P) / Area (A)

Where,

P = 447.91 KN

A = $\pi d^2/4$ d=20mm

= 314.159 mm2

Then,

Compression strength

= 447.91/314.159

= 1.4257 KN/ mm2

2) *Hardness Test*

A Brinell hardness testing machine is used to measure the hardness number for given specimen. An indentation is used to determine hardness using this machine and results explained below. Here ball diameter (d) of the indenter (D) and load applied on the specimen surface and values are substituted on given formula

3) *Hardness Tester*

$BHN = 2P/\pi D(D - \sqrt{(D^2 - d^2)})$.

Where,

Diameter of the indenter (D) =3 mm

Load P = 876.8 Kgf

D = is the diameter of impression on the work piece = 1.7mm

Then,

Brinell hardness number

$= 2*(876.8) / \pi*(3)(3 - \sqrt{(3^2 - 1.7^2)})$.

$= 1753.6/4.985$

$= 35.177$

4) *Properties Obtained*

S.No	Properties	Grey Cast Iron without Vanadium	Grey Cast Iron with Vanadium
1	Density	7200 Kg/m^3	7109 Kg/m^3
2	Tensile strength	276 Mpa	426 Mpa
3	Compression strength	1200 Mpa	1425.75 Mpa
4	Elongation	1%	1%
5	Hardness (Brinell)	180-302 HB	352
6	Young's Modulus	$110*10^9$ GPa	$110*10^9$ GPa
7	Poission ratio	0.28	0.28

Table .1 – Properties of materials

By using above experiment results, the boundary conditions of given bucket can be applied in ANSYS workbench

V. DRAFTING 3D MODEL

Using CATIA V5 software modeling of excavator bucket done which is useful to export in .igs format to ANSYS v19.2 software for further preprocessing and determining stresses and deformations under various cases. The following figure.2 shows that 3D model of digging type bucket. The type of application is taken from standard paper[1].

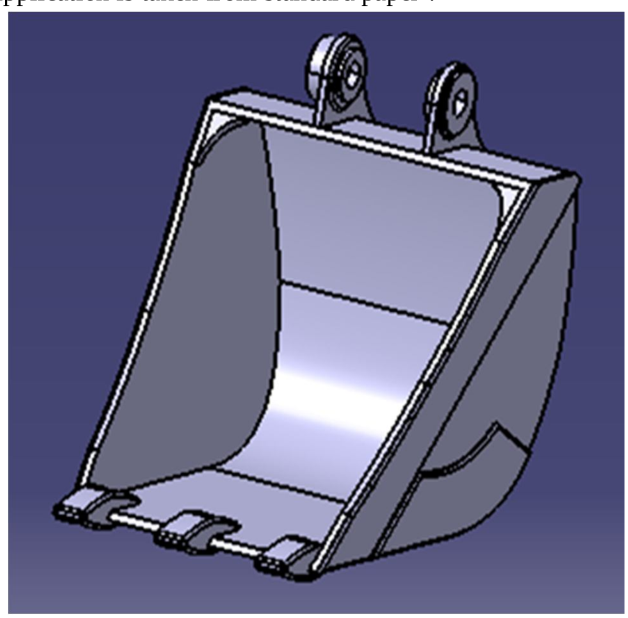


Figure.2 3D Model of Excavator bucket through CATIA V5 software

VI. ANALYZING

The ANSYS 19.2 software is used to analyze bucket under various boundary conditions which is explained below.

These are the results are obtained through the ANSYS software. The solution can be obtained by dividing into 3 cases.

1) *Case I:* At 15696N (standard load) the results are obtained for Excavator bucket made of Gray Cast Iron without Vanadium and with Vanadium.
2) *Case II:* At 18000N load the results are obtained for Excavator bucket made of Gray Cast Iron without Vanadium and with Vanadium.
3) *Case III:* At 20000N load the results are obtained for Excavator bucket made of Gray Cast Iron without Vanadium and with Vanadium.

A. Case I

The following working conditions are considered to obtain ANSYS results. By placing the excavator bucket in standard load condition we can observe the following ANSYS results.

1) *Gray Cast Iron*
a) *Total Deformation Plot.*

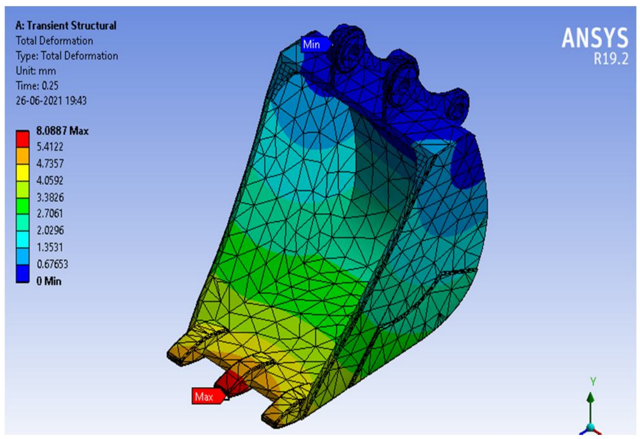


Figure 3. Total deformation plot

The Maximum deformation observed is 8.0887 mm at 0.25 s at standard load (15696N).

b) *Von Mises Stress Plot.*

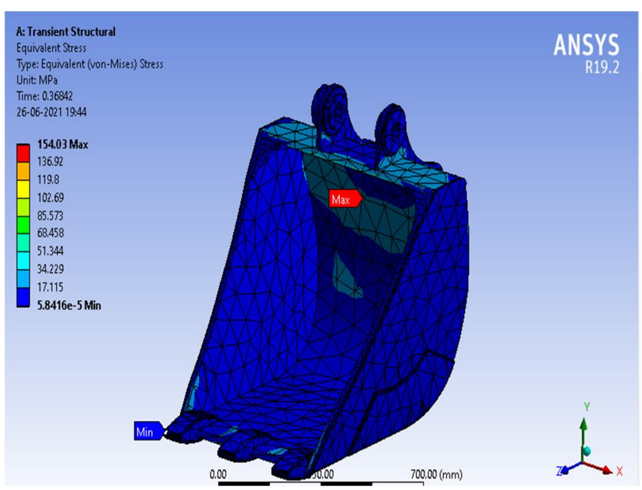


Figure 4. Von Mises Stress

The Maximum Von-Mises stress observed is 1540.3 MPa at 0.25 s at standard load (15696N).

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c) Shear Stress.

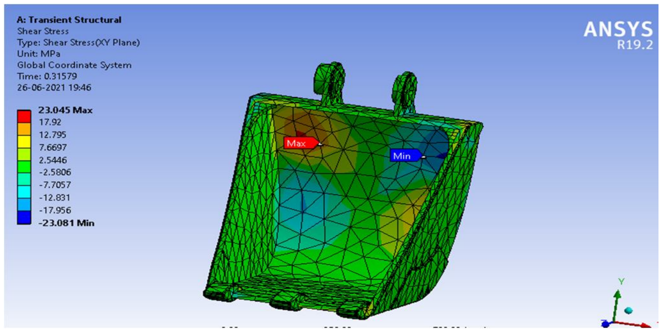


Figure 5. Shear Stress Plot

The Maximum Shear stress observed is 23.045 MPa at 0.25 s at standard load (15696N).

d) Maximum Principal Stress.

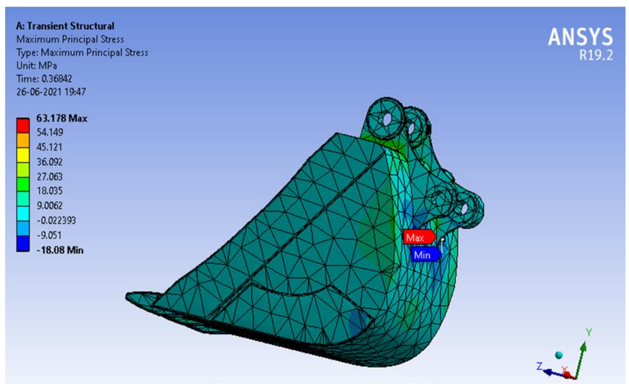


Figure 6. Maximum principal stress

The Maximum principal stress observed is 63.178 MPa at 0.25 s at standard load (15696N).

2) Gray Cast Iron with vanadium:

a) Total Deformation Plot.

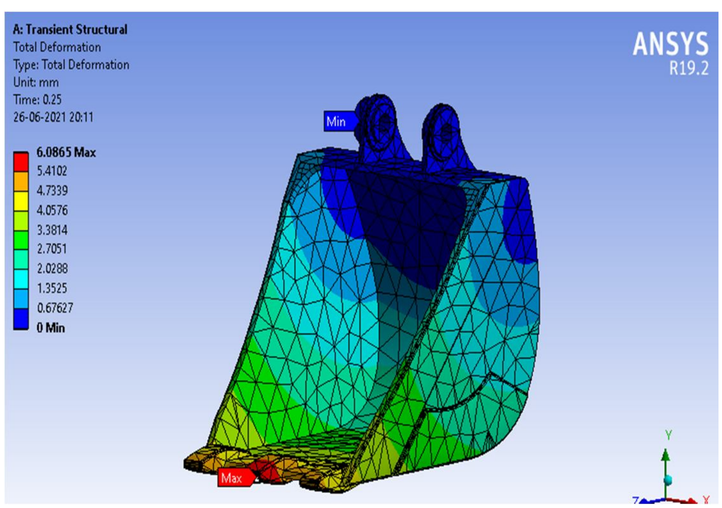


Figure 7. Total deformation

The Maximum deformation observed is 6.0865 mm at 0.25 s at standard load (15696N).

b) Von Mises Stress Plot.

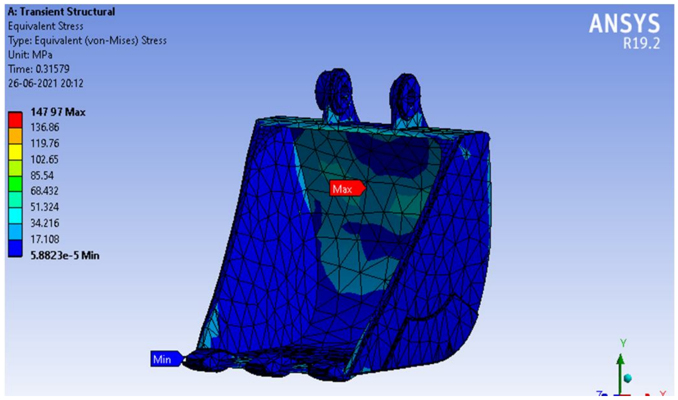


Figure 8. Von Mises Stress Plot

The Maximum Von-Mises stress observed is 147.97 MPa at 0.25 s at standard load (15696N).

c) Shear Stress.

The Maximum Shear stress observed is 21.034 MPa at 0.25 s at standard load (15696N).

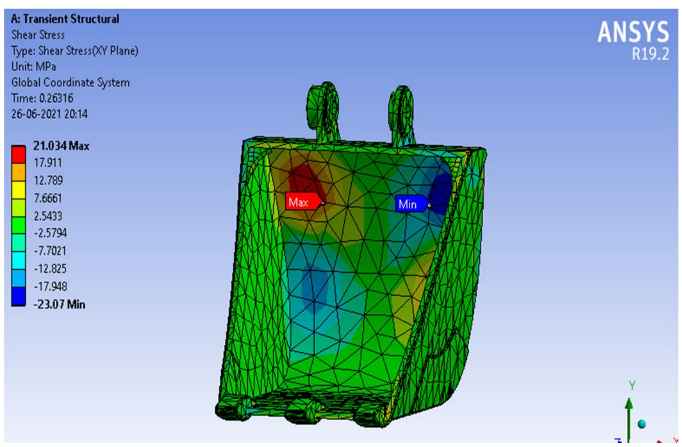


Figure 9. shear Stress Plot

d) Maximum Principal Stress.

The Maximum principal stress observed is 63.178 MPa at 0.25 s at standard load (15696N)

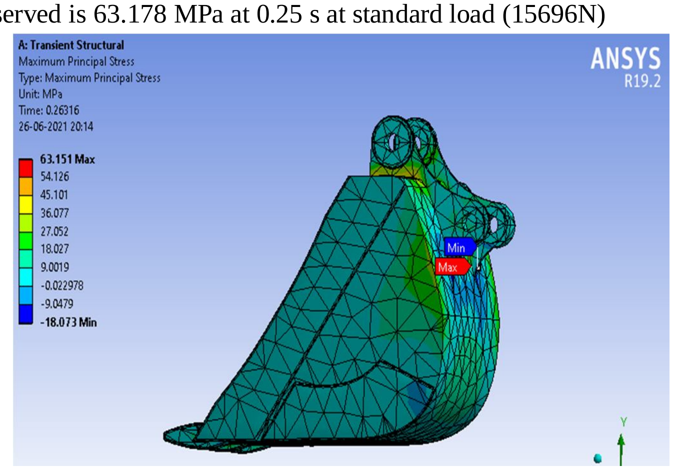


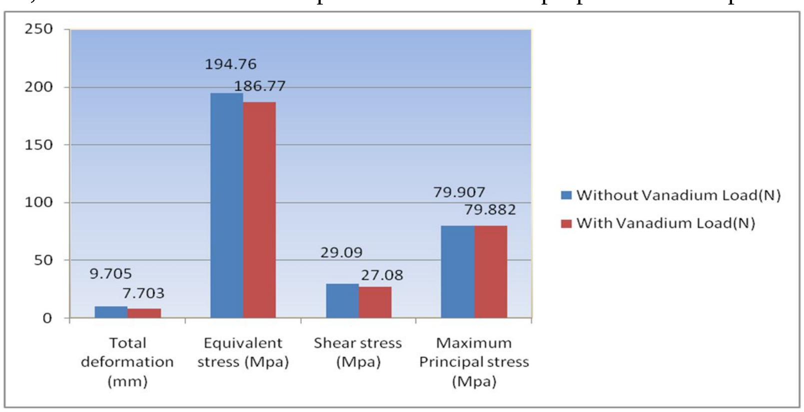
Figure 10. Maximum principal Stress Plot

Similarly other cases results are obtained and listed below table2.

S.No	Properties	Without Vanadium			With Vanadium		
		Load(N)			Load(N)		
		15696	18000	20000	15696	18000	20000
1	Total deformation (mm)	8.088	8.954	9.705	6.086	6.951	7.703
2	Equivalent stress (Mpa)	154.03	175.83	194.76	147.97	167.97	186.77
3	Shear stress (Mpa)	23.045	26.281	29.09	21.034	24.271	27.08
4	Maximum Principal stress (Mpa)	63.178	72.128	79.907	63.151	72.102	79.882

Table .2 – ANSYS results

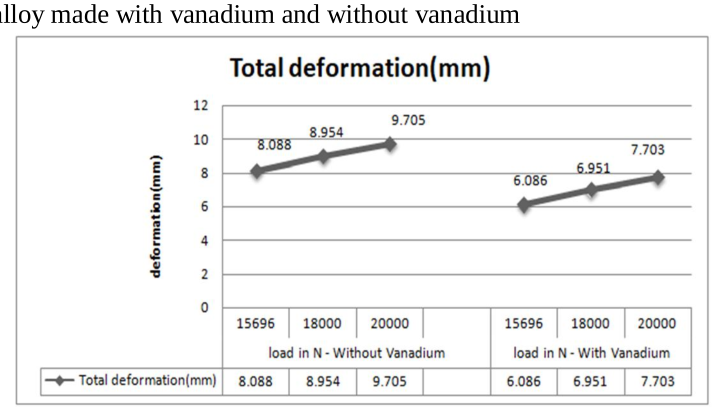
At maximum loading condition, inclusion of vanadium improves the structural properties of composite material shown in below.



VII. RESULTS AND DISCUSSIONS

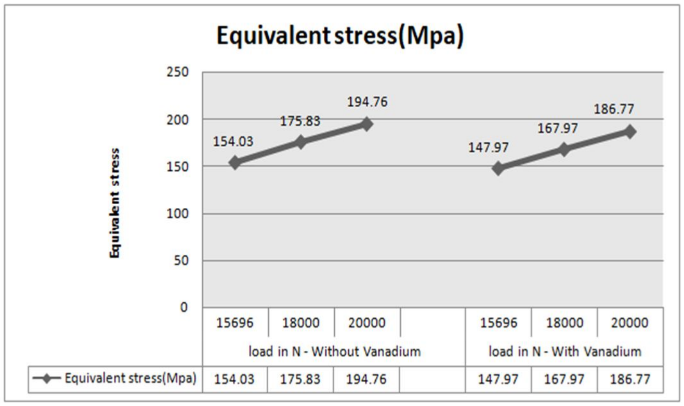
A. Comparisons

The following graph shows the results summary of the Case I, Case II and Case III. And also below graph 1, 2, 3 and 4 indicates the comparison between specimen alloy made with vanadium and without vanadium



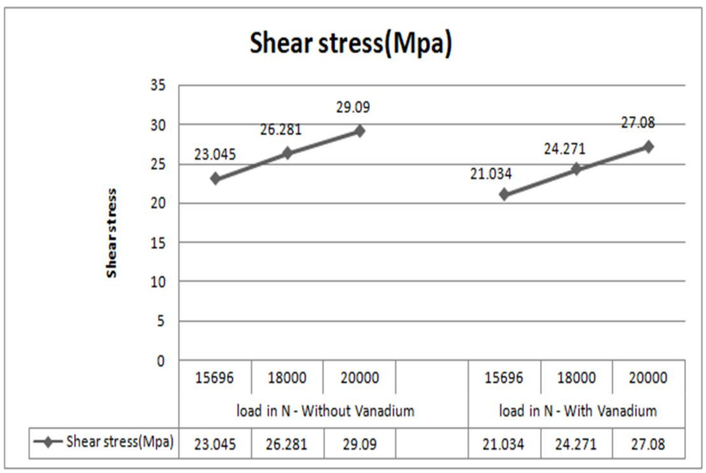
Graph 1. Total deformation

By observing the above total deformation graph.1, we can see that the deformation of the Gray Cast Iron with Vanadium is less when compare with Gray Cast iron.



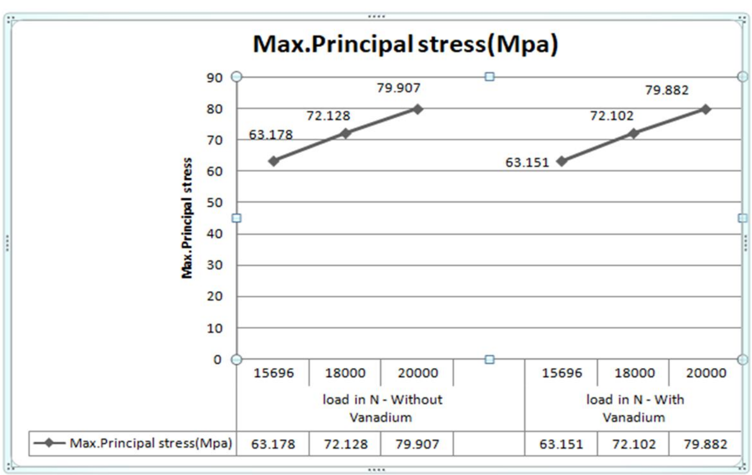
Graph 2. Equivalent Stress

By observing the above Von Mises stress graph.2, we can see that the stress values of the Gray Cast Iron with Vanadium is less when compare with Gray Cast iron. Therefore Gray Cast Iron with Vanadium can carry more load the Gray Cast iron.



Graph 3. Equivalent Stress

By observing the above Shear stress graph.3, we can see that the stress values of the Gray Cast Iron with Vanadium is less when compare with Gray Cast iron.



Graph 4. Max.principal stress

B. Results and Discussions

1) Experimental analysis is done on excavator bucket by comparing with and without inclusion of vanadium, under this conditions the behavior bucket is observed to know the critical loading conditions.
2) Under maximum loading condition, by the inclusion of vanadium in the material which improves the Total deformation, Equivalent stress, Shear stress, Maximum Principal stress compared with normal conditions.
3) Experimental testing like tensile test, compression test, impact test and hardness tests are done on the both materials i.e. Gray Cast Iron with Vanadium and Gray Cast Iron without Vanadium. In which we observed that Gray Cast Iron with Vanadium has better results than the Gray Cast Iron without Vanadium.
4) We would like to conclude that at 15696N, 18000N, and 20000N load conditions will gives satisfactory results while choosing the Gray Cast Iron with vanadium as excavator bucket material while considering stress by maintain adequate structural strength and stability. And compare with Gray cast iron without vanadium results are very much satisfactory.
5) We would like to conclude also that at 15696N, 18000N, and 20000N load conditions will gives satisfactory results while choosing the Gray Cast Iron with vanadium as excavator bucket material while considering deformation factor. Gary cast iron with vanadium has less deformation then the normal gray cast iron.
6) By adding 0.5g of vanadium to the Gray cast iron we got 0.638% reduction in weight while comparing with Gray Cast Iron without Vanadium. Also the deformation or displacement by adding 0.5g of vanadium to the Gray Cast Iron, we got 14.124% reduction while compare with Gray Cast Iron without Vanadium at standard load condition.

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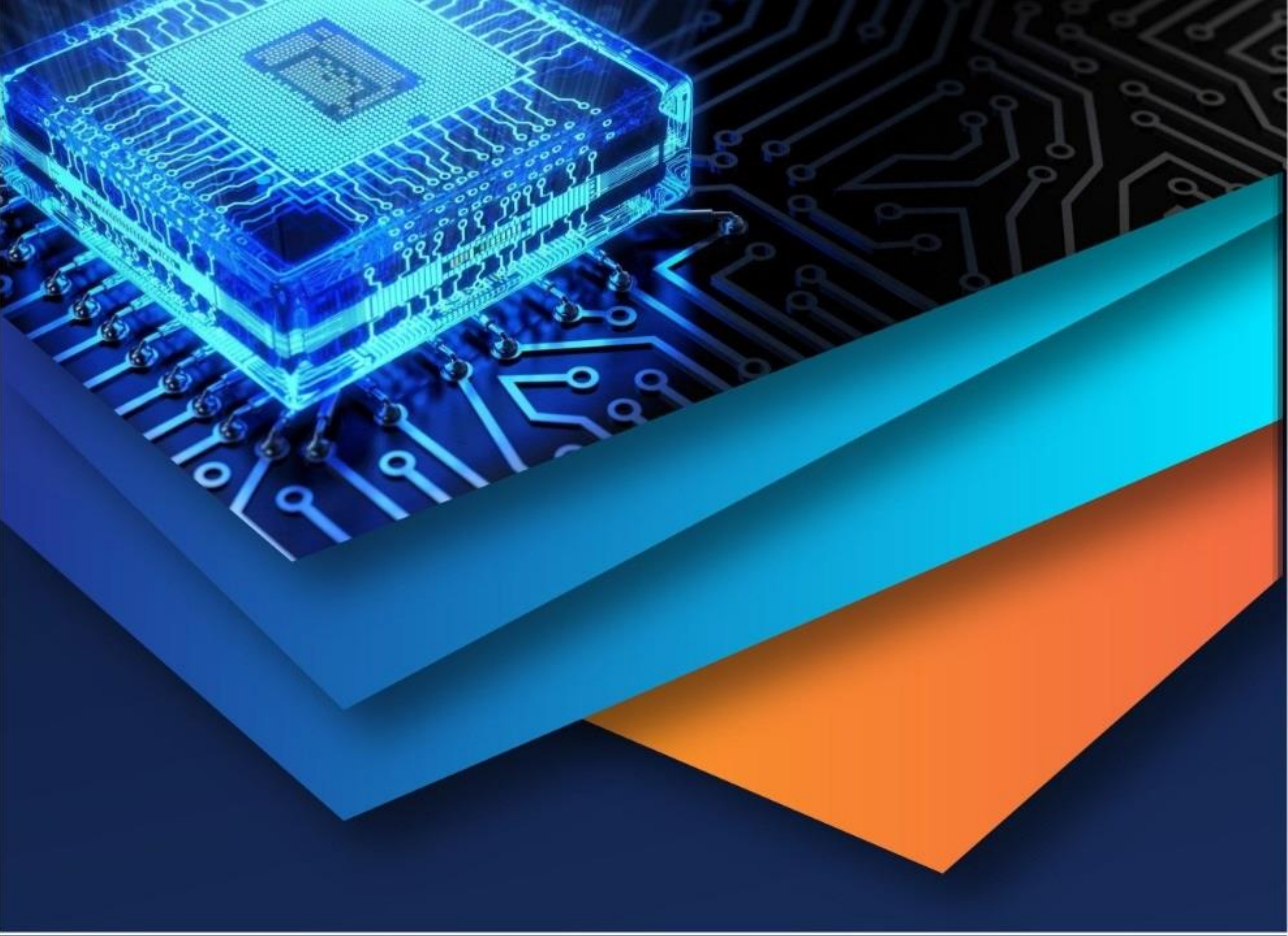

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