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Excavator Bucket Life Improvement by Means of Weight Optimization Technique and It's Dynamic Balancing for Better Efficiency with the Help of CAD/CAE Tool

[1]Ajinkya Vijay Nardange,[2]Dr. S. P. Trikal,[3]Prof. N. B. Borkar

[1]Student,[2]Head of Mechanical Engineering Department,[3]Assistant Professor
[1]Mechanical Engineering Department,
[1]Shree Sant Gajanan Maharaj College of Engineering, Shegaon, Maharashtra, India

Abstract:Excavator bucket performs heavy duty work as a earth movers. Several high pressure- high impact loads come on the teeth of the bucket. Sudden impact on earth surface, high stresses and shearing loads try to damage bucket every time. But the bucket must overcome from all the forces and loads which are directly and indirectly affect the performance efficiency. After some duration the dynamic stability of bucket also get affected due to heavy duty work. Sometimes the modification is done to improve the life of bucket by means of attaching the extra metal plates. But by this the weight of the bucket gets increased. The dynamic stability of bucket is very important for bucket which may lose by increase in weight.

Excavator bucket life is the very important issue, because it fails to complete its designed life. The major reason behind this failure is its working environment and modes of operations. Excavator buckets are designed to work in worst conditions, situations for long duration of time. During its working bucket undergoes with great amount of stresses, loads, jerks, deformations and it would be very difficult to withstand in such situations.

In this paper the design of bucket is tested in CAE tools. Also, the CAD tool will help for the creation of virtual excavator bucket design. Several tests like, structural analysis, vibration analysis, shape optimization, crash test etc. will give the behavior of excavator bucket during working condition. Also, the change in bucket material may provide the extra dimension to the study. Hence the complete dynamic performance is checked by applying loads with respect to time and cycles. Collective results will give the helpful conclusions which will improve the bucket life. Again, by changing the design and performing all related test will provide the optimized design solution for the excavator bucket life improvement which is the main aim of this project.

***Index Terms* - Excavator Bucket, CAD Tool, CAE Tool.**

I. Introduction

Excavator buckets are digging attachments with teeth that can be fixed to the arm of an excavator. The buckets are controlled by the excavator operator using controls in the cabin. There are different types of excavator buckets that are used depending on where the digging has to be done. Excavator buckets can also be used to move dirt or load dump trucks for transportation to dumping sites. Excavators are used in conventional trenching methods for laying pipelines and also used for digging trial pits for geotechnical investigation.

A bucket (also called a scoop to qualify shallower designs of tools) is a specialized container attached to a machine, as compared to a bucket adapted for manual use by a human being. It is a bulk material handling component. The bucket has an inner volume as compared to other types of machine attachments like blades or shovels. The bucket could be attached to the lifting hook of a crane, at the end of the arm of an excavating machine, to the wires of a dragline excavator, to the arms of a power shovel or a tractor equipped with a backhoe loader or to a loader, or to a dredge. Excavator bucket is the important part which is responsible for work. It is used for digging, trolley felling, Heavy duty work etc.

Fig. 1: Excavator Bucket

II. Aims and Objectives of Study

1) Life improvement of excavator bucket by performing different CAE analysis.
2) Stress Analysis to find the possible deformation and stress concentrated areas.
3) Vibration/modal analysis of bucket for obtaining natural frequency value.
4) Shape optimization of Modified Excavator Bucket.
5) Redesigning of bucket.
6) Comparisons of existing bucket and modified bucket.
7) Analysis of modified and optimized bucket.
8) Tabulated data formation for three different loading conditions.

III. CAD Modeling of Excavator Buckets

To perform the various types of analysis on the excavator bucket we need a CAD model. For this purpose the CATIA V5R19 software is used. Following three buckets are created by using this software. Overall shape is identical but some additional plates are attached or modified to improve the strength.

3.1 Existing Bucket

Figure 2 and 3 are showing the CAD model of Existing Excavator Bucket, which is prepared on CATIA V5R19 software. Some basic commands from part module like Pad, Pocket, Rib, Fillet, Chamfer etc are used to perform modeling of Excavator Bucket.

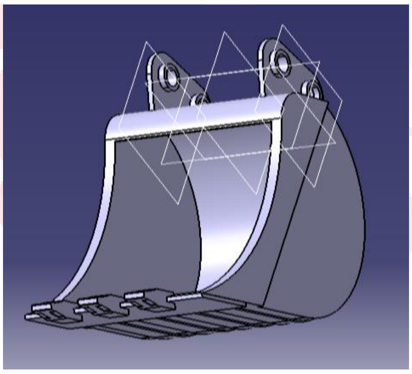

Fig. 2: CAD model of Bucket

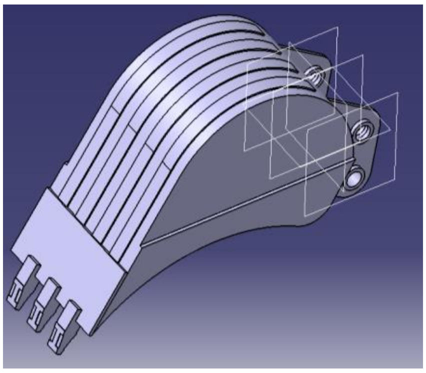

Fig. 3: CAD model of Bucket

3.2 Modified Bucket

Figure 4 and 5 shows the modified bucket. This type of modification is usually done in workshops after some definite period of time or after failure of bucket. The additional metal plates are attached on existing bucket to improve the strength. But weight of the bucket also increases in this process. Such bucket may not have longer life on excavator or it may create hydraulic failure problems.

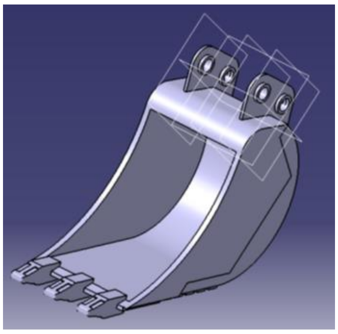

Fig.4: CAD model of Bucket

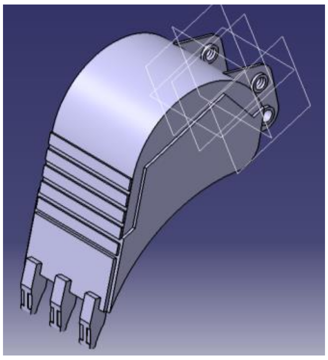

Fig.5: CAD model of Bucket

3.3 Optimized Bucket

This is well balanced bucket with reduced weight as compare to modified bucket. It is designed to improve the life of excavator bucket. Metal plates are attached only on the required places. Unwanted strength improvement by attaching metal plates is avoided.

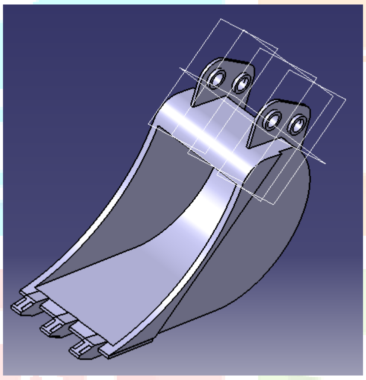

Fig.6: CAD model of Bucket

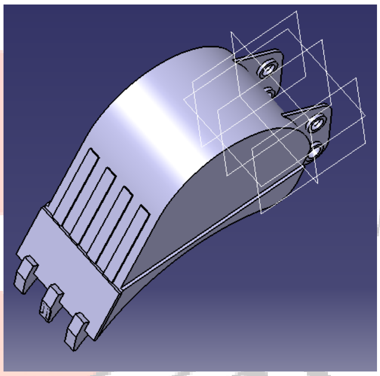

Fig.7: CAD model of Bucket

IV. BOUNDARY CONDITIONS

These are the analysis conditions which are applied as a input to perform any analysis. It mainly contains metal properties, number of nodes and elements, meshing and forces applied etc.

Table 1: Properties of Medium Carbon Steel for Structural Analysis.

Property	Value
Young's Modulus (E)	2e5 MPA
Poisson's Ratio	0.29
Density	7870 kg/m^3

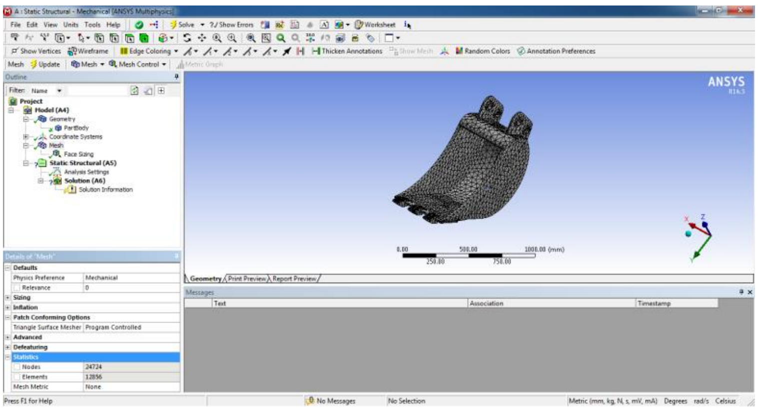

Fig. 8: Meshed View of Existing Excavator Bucket

Table 2: FEM Properties of Meshed Bucket

Type of Element	3D Tetragonal
No. of Elements	12856
No. of Nodes	24724

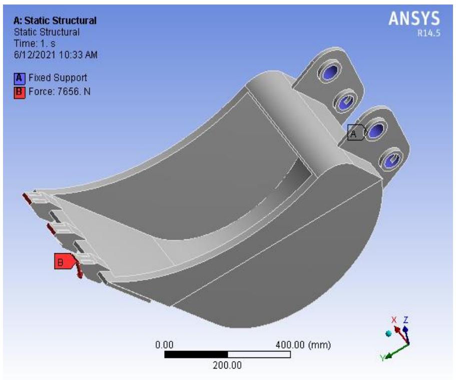

Fig.9: Forces Applied on Excavator Bucket

V. STRUCTURAL ANALYSIS RESULTS

5.1 Results for Existing Bucket

By performing Structural Analysis on existing bucket following results are obtained. Figure 10 shows the total deformation by the application of structural load as shown in boundary conditions. It is observed that the maximum deformation is 0.8479 mm only. This deformation is having acceptable range. Maximum deformation accursed at the teeth which is not the integral part of the excavator bucket remains un-deformed or it has negligible deformation.

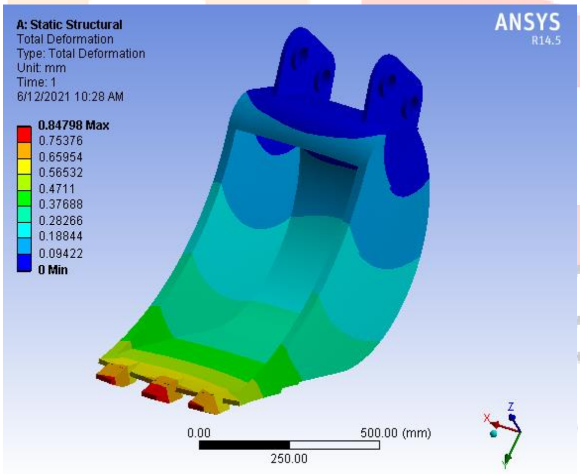

Fig. 10: Total Deformation in excavator bucket

Figure 11 shows the shear stresses due to the loading. If we observe maximum shear stress value which is 19.76 MPa only. Hence the loads acted on the bucket will not affect the performance. Also entire bucket appears in the green color which has only 6.55 MPa stress value. Therefore, the bucket is safe for this loading.

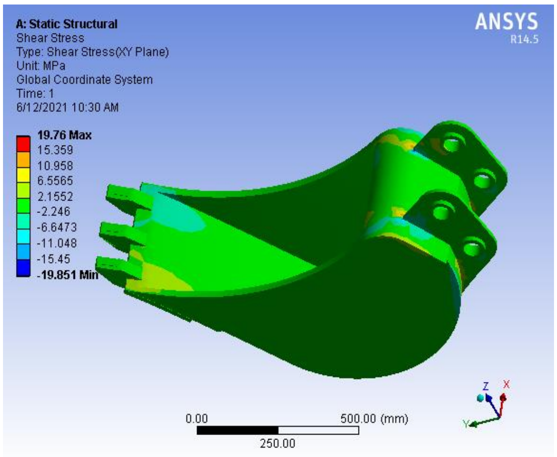

Fig.11: Shear Stress due to loading on Excavator Bucket

Figure 12 shows the Equivalent stresses obtained in structural analysis of the Excavator Bucket. We have used Medium Carbon Steel material and maximum stresses found at the bracket. 60.50 MPa stresses are in acceptable range. Also the remaining Excavator Bucket body portion is in blue colour which shows the minimum stress value.

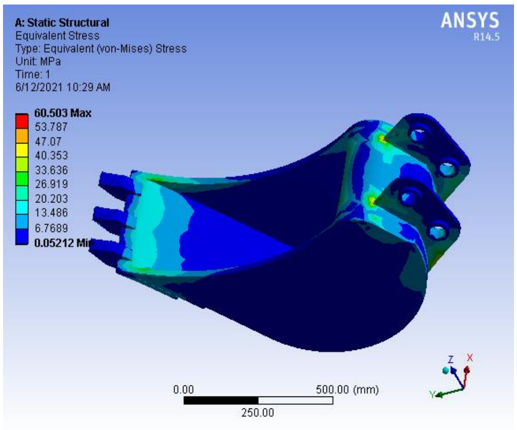

Fig.12: Equivalent Stresses of Excavator Bucket

Figure 13 shows the Normal stresses in structural analysis. The maximum stresses and minimum stresses are at the bracket side of bucket where it is connected to movable hydraulic arm. It has 49.98 MPa value. This value also has a safe limit.

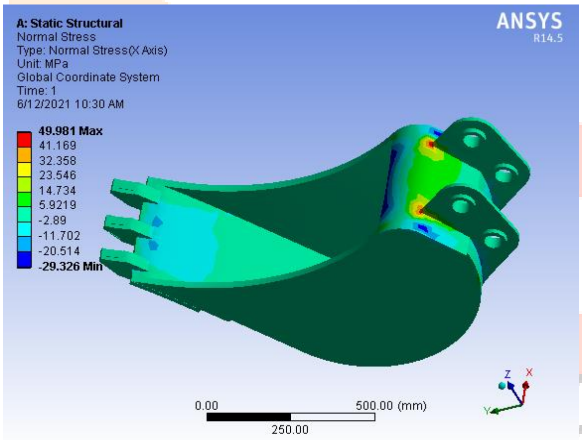

Fig.13: Normal Stress Value obtained for Excavator Bucket

Table 3: Tabulated Result from structural analysis of excavator bucket for **7656 N Load**.

Sr. No.	Result Type	Existing Bucket	Modified Bucket	Optimized Bucket
1	Total Deformation	0.847 mm	1.1709 mm	**0.89 mm**
2	Equivalent Stress	60.53 MPA	85.063 MPA	**78.817 MPA**
3	Shear Stress	19.76 MPA	25.785 MPA	**25 MPA**
4	Normal Stress	50 MPA	73.819 MPA	**62.21 MPA**
5	Stress Intensity	63.25 MPA	90.291 MPA	**81.625 MPA**

VI. Conclusion

By observing the results obtained by stress analysis in existing, modified and optimized bucket following conclusive statements can be given.

1) Results obtained in case of optimized bucket are better than the modified bucket.
2) Existing bucket results are the best results as compared with modified bucket and optimized bucket.
3) As modification on bucket is done after damage during working, hence the weight of bucket increased extensively which cause the dynamic unbalancing as well as overweighting. Optimized bucket will be a solution to this problem.
4) In entire analysis process it is observed that the weight of bucket after modification increases.
5) **Hence the expected life after modification may not be achieved. Hence the reduction of weight by optimizing the shape of modified bucket, we can reduce the weight which tends to improve the life of bucket.**
6) Stresses induced in existing and optimized bucket are approximately same. Hence the dynamic stability and deformation will be in acceptable range in both cases.
7) **By observing all results it is clear that the life of bucket can be improved by performing optimization on modified bucket.**

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