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Fatigue Analysis and Design Optimization of Excavator Bucket

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Abstract:*Construction activity is continually rising, and the strong performance of construction equipment ensures rapid expansion in the earth moving machine sectors. This study focuses on the method for calculating the digging forces needed to dig the terrene for minor building work. This approach calculates the force and is also used to perform a fatigue analysis to determine the bucket's fatigue life and failure rate. Because the current excavator arm mechanism is subjected to deformation and bending forces during lifting and digging operations, failure at the bucket end of the arm happens frequently. The excavator arm is analysed using ANSYS workbench software at current digging force and lifting capacity. An analytical approach has also been provided for static force analysis of excavator bucket.*

Keywords: Digging Forces, Fatigue Analysis, Excavator Bucket, Optimization, etc.

I. INTRODUCTION

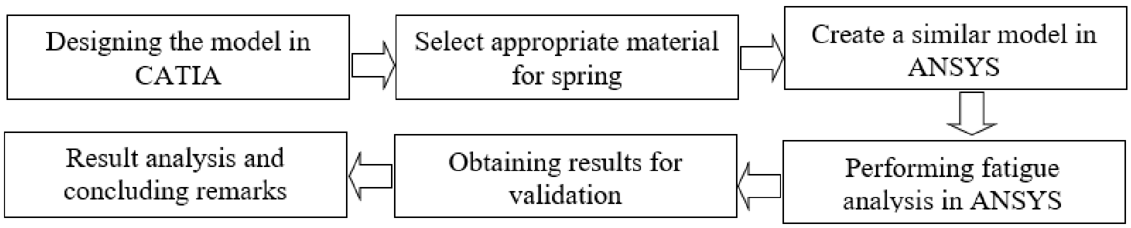
For various earthmoving tasks, such as building, mining, agriculture, forestry, military applications, and notably for cleaning up dangerous areas, earth moving excavation provides a vast potential and a favourable technique. High-performance construction machineries with sophisticated mechanisms and automation of construction activities ensure a rapidly expanding rate of industry for earth moving machines. The machine is operated by a hydraulic system when digging or moving the material. Excavators are typically used to excavate beneath the natural surface of the land on which the machine sits and load the material onto trucks, tractor-drawn wagons, or convey or belt systems. "A ride-on dual purpose self-propelled wheeled machine for on and off-road operation," is the definition of a backhoe excavator. One end has loader arms that can support a full-width bucket or attachment, while the other has a boom and arm combination that can swing half-circle for digging or attachment manipulation. "Backhoe excavators are used as a utility machine on large building sites (such as highways and dams) and urban infrastructure projects in India, as well as for loading hoppers and trucks."

Excavator consists of various parts like bucket, rivet and tooth. Excavator buckets are typically built of solid steel and have teeth emerging from the cutting edge to disturb hard materials and reduce bucket wear.

Figure: a) Excavator Bucket b) Tooth

A rivet is a mechanical fastener that is permanent. A rivet is made up of a smooth cylindrical shaft with a head attached to one end. The tail is the end opposite the head. The excavator bucket teeth must endure heavy loads of materials such as moist soil and rock, as well as abrasion wear caused by the abrasive nature of solid particles when breaking up material. Excavator bucket teeth are typically made of alloy steel, and hard facing of some wear resistant materials can be placed to the material of the bucket tooth to extend its life against abrasive wear.

II. METHODOLOGY



III. LITERATURE REVIEW

Darko Danicic, Stojan Sedmak (2015): Because time estimations based on the crack can provide a time period in which the cracks can be found and corrected to avoid a collapse of the structure, this technique is a direct contribution of new maintenance methods, particularly proactive maintenance. It resulted in a loss of more than ten million euros in this case. Furthermore, the inspection period may be prolonged, lowering maintenance expenditures. Set a time when key elements of the structure should be updated to avoid damage, using proper non-destructive assessment. It means that based on these predictions, a corrected time for steel structure inspection may be applied, resulting in more efficient inspection and maintenance

Ana Petrovic, TaskoManeski (2018): The following methods were taken in this study to solve the problem of a fracture appearing on the gusset plate of the pylon vertical truss of a bucket wheel excavator SchRs630. The excavator SchRs630 pylons, slewing platform, and undercarriage were numerically modelled. Numerical calculations were performed for a variety of load situations that depict the loading of a structure at various points during its operational life. The load that causes gusset plate stress concentration (crack incidence) has been identified.

Rosen Mitrev, Dragan Marinkovic (2019): In this investigation was done on the dynamic stability of a hydraulic excavator while executing lifting operations in this research. The created six-degree-of-freedom dynamic model takes into account the base body's elastic relationship to the terrain, as well as the front digging manipulator connections. Using the Lagrange formalism, a set of nonlinear differential equations characterising the dynamic behaviour is generated. The excavator dynamic overturning is studied using numerical experiments. Finally, a small-scale experimental model was used to validate the mechanical system concept.

Sumar HadiSuryo, Athanasius Priharyoto (2018): The largest stress of a bucket tooth is located in its terminal section, which is in direct contact with the earth, according to simulation results. During use, it can cause wear, bend, crack, and fracture in the bucket teeth end. The finite element method was discovered to be effective in improving the quality of in geometry forms. Calculation of bucket curling force yielded the largest force value from the excavator. The greatest force value that may be obtained has a magnitude of 8285.06 N.

IV. DESIGN OF EXCAVATOR ARM

The UK standards "FOS=5 should also be applied with better-known materials that are to be used in unpredictable environments or under to uncertain stressors." Because the backhoe is subjected to varying stresses depending on the angle of digging, for example, if the bucket angle is about 45^0, the digging force experienced by the bucket will be less, and if the bucket angle is moved away from 45^0, the force required will be larger.

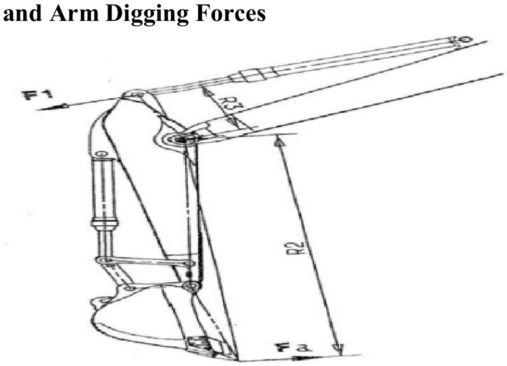
Table 1: Properties of medium strength alloy steel

Sr.No.	Property Name	Value
1	Ultimate Strength	690 MPa
2	Yield Strength	450 Mpa
3	Poisons ratio	0.29
4	Density	7.85g/cm^3
5	Tensile Strength	850 Mpa
6	Shear Modulus	80 Mpa
7	Bulk Modulus	140 Mpa

Assumptions Made in Calculation

The boom cross section is idealized to channel section, 175*133, plate thickness = 6mm. The stick cross section is idealized to box cross section, 142*117, plate thickness = 6mm. The maximum bending stress does not exceed the allowable yield strength 138N/mm^2

Calculation of Bucket Digging and Arm Digging Forces



Bucket digging force is defined as maximum digging force due to bucket cylinder in tangential direction at bucket tooth. Pressure of Bucket Cylinder: It is the pressure of bucket cylinder according to the operation pressure of hydraulic oil, depending on the next formulation: $F_2 = (\pi/4)\, D_b$^2 * P_b. Bucket digging force: $F_b = (F_2 * A * C) / (R_1 * B)$.

Values Found by Actual Practical Observation:

A= 600 mm B= 800 mm C= 470 mm R_1= 1300 mm D_b= 115mm P_b= 0.049Mpa

Calculations:

$F_2 = (\pi/4)\, D_b$^2 * P_b = 138 kN.

Arm Digging Force

Arm digging force is defined as maximum digging force due to arm cylinder in tangential direction at bucket tooth in position where bucket tooth force due to bucket cylinder is maximized.

Values Found by Actual Practical Observation:

R_2= 3700mm R_3= 650mm D_a= 135mm P_a= 0.049Mpa

$F_2 = (\pi/4)\, D_a$^2 * P_a = 123.21 kN

V. MODELLING OF EXCAVATOR ARM

The approach for modelling EXCAVTOR ARM in CATIS V5 is as follows. The dimensions are added to a basic-2D design of the base for support, which is subsequently developed into 3D using the pad command. Then go to generative form design and give volume extrude to the 2D sketch of the boom. Then, after exiting the workbench, construct the arm D sketch and use the pad and shell command. After that, make a 2D sketch of the bucket side, followed by a pad and shell command.

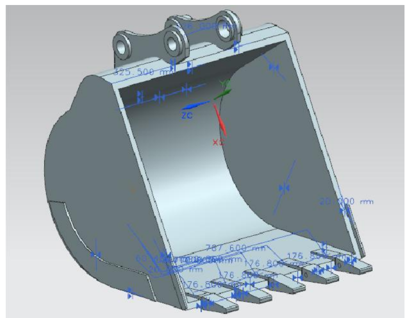


Figure: 3D – Model of bucket

VI. ANALYSIS OF EXCAVATOR BUCKET

The software requires all three dimensions to be defined in order to do analysis. It won't be able to perform calculations unless the geometry is completely described. As a result, the Excavator arm's CAD model is transformed to a STEP file, which can be used to import the geometry of the excavator arm model into ANSYS 16.0's design modeller. After you've finished importing the geometry for the excavator arm, you'll need to apply the materials. Physical preferences in Ansys meshing technology serve to automate the meshing process. A mesh can typically be built in batch with an initial solution run to discover regions of interest for an initial design. After then, the mesh can be fine-tuned to improve the accuracy of the solution. Default The model is meshed, and the resulting mesh is shown in the picture.

Material Properties Required for Analysis

1. **SM50A:** This steel material is used for all the plates or sheets of bucket.
   Mechanical Properties: Young's Modulus: 2*105 MPa, Tensile Strength: 800 MPa, Yield Strength: 450 MPa, Elongation: 8-25%, Physical Properties: Density: 7700 kg/m3

2. **SCNCrM2B:** This is low alloy steel used for the tooth of the bucket.
   It contains proportion of materials as C=0.25-.35%, Si=0.08%, Mn=1.00%, Ni=1.6-2% Cr=0.3-0.9%, Mo=0.15-0.35. Mechanical Properties: Young's Modulus: 2*105 MPa, Tensile Strength: 880 MPa, Yield Strength: 685MPa, Elongation: 9% Physical PropertiesDensity: 7700 kg/m3

Static structural analysis

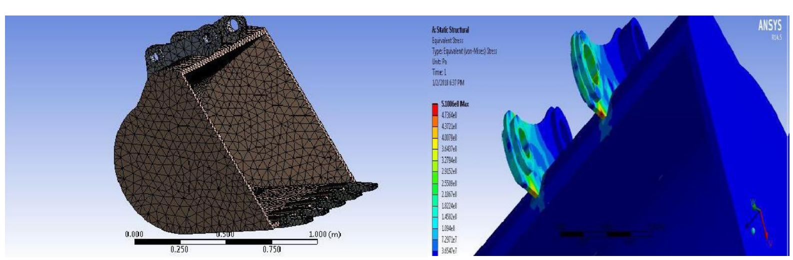


Figure: Excavator Bucket a) meshing b) Analysis

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Fatigue Life Calculation:

From the given results we can calculate fatigue life of excavator bucket. Fatigue life calculation: By using Goodman's Fatigue life calculation method prediction of fatigue life as: Mean Stress(X) = σmax+σmin2 = 510.06+36.542 = 273.27 MPa, Alternating Stress(Y) = σmax−σmin2 = 510.06−36.542 = 236.73 MPa Now, Slope (m) = σ alternate$\sigma mean$ = 236.73273.27 = 0.86 , Coordinate (Y1) = Endurance limit-mX=400-(0.86*273.27) = 164.98 MPa, Margin of Safety = Y1Y =164.98236.73 = 0.69 Margin of Safety < 1 so that design is not safe Fatigue Life = (1-(1/Margin of safety)) = 449259 cycles **= 121.30hrs**

We discovered that the bucket's life is significantly less than 200 hours based on the calculations and results above. This state of the bucket is undesirable, so it must be optimised in order to provide a life of at least 1000 hours. Optimization is the process of identifying the areas of the system that fail when under stress and re-designing those areas in a way that will provide us with the best possible results. By analysing the above data, we discovered that the most stress is applied to the bucket's lugs, which is the cause of the bucket's failure. We're now optimising that bucket by widening or thickening the bucket lugs. by 4mm apiece, as well as some radial alterations at the lug's end and a reduction in chamfer. In order to achieve the best result, we will also raise the welding thickness for improved strength.

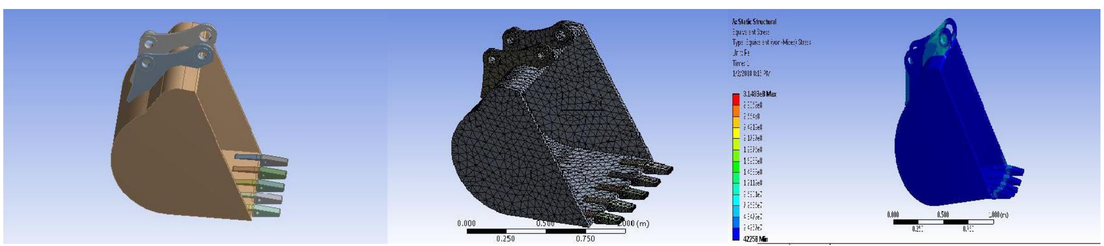

Figure: Optimised Bucket a) Model b) Meshing c) Analysis

From the Analysis following results were carried out σmax = 314.83 MPa 2) σmin = 0.0422 Mpa, Using Goodman's Fatigue life calculation method, Mean Stress(X) = (σmax+σmin)/2 = (314.83 + 0.0422)/2 = 157.43 MPa Alternating Stress(Y) = (σmax−σmin)/2 = (314.83 − 0.0422)/2 = 157.39 MPaSlope (m) = σalternate/$\sigma mean$ = 157.39/157.43 = 0.99 Coordinate (Y1) = Endurance limit-mX=450-(0.99*157.43) = 294.14 MPa Margin of Safety = Y1/Y =294.14 / 157.39 = 1.86

Result: Margin of Safety > 1 so that design is safe Fatigue Life= (1-(1/Margin of safety)) = 4623655 cycles = 1248hrs.

VII. CONCLUSION

Excavator buckets are designed to undertake excavation tasks in light construction projects. Calculations are used to determine the bucket and arm digging forces. CATIA software is used to produce the model, which is then analysed in Ansys. The safety factor, breakout force, and maximum lifting capacity are all significant aspects to consider while building an excavator arm. Excavator buckets are designed to undertake excavation tasks in light construction projects. The excavator bucket is subjected to finite element analysis using various material characteristics and static force loads. The fatigue life is calculated using stress values, and the cycle time life is converted to hours. The stress points are carried out and the optimum bucket is created using the results model is created.

REFERENCES

[1] S. M. Metev and V. P. Veiko, Laser Assisted Microtechnology, 2nd ed., R. M. Osgood, Jr., Ed. Berlin, Germany: Springer-Verlag, 1998.

[2] J. Breckling, Ed., The Analysis of Directional Time Series: Applications to Wind Speed and Direction, ser. Lecture Notes in Statistics. Berlin, Germany: Springer, 1989, vol. 61.

[3] S. Zhang, C. Zhu, J. K. O. Sin, and P. K. T. Mok, "A novel ultrathin elevated channel low-temperature poly-Si TFT," IEEE Electron Device Lett., vol. 20, pp. 569–571, Nov. 1999.

[4] M. Wegmuller, J. P. von der Weid, P. Oberson, and N. Gisin, "High resolution fiber distributed measurements with coherent OFDR," in Proc. ECOC'00, 2000, paper 11.3.4, p. 109.

[5] R. E. Sorace, V. S. Reinhardt, and S. A. Vaughn, "High-speed digital-to-RF converter," U.S. Patent 5 668 842, Sept. 16, 1997.

[6] (2002) The IEEE website. [Online]. Available: http://www.ieee.org/

[7] M. Shell. (2002) IEEEtran homepage on CTAN. [Online]. Available: http://www.ctan.org/tex-archive/macros/latex/ contrib. /supported/ IEEEtran/

[8] FLEXChip Signal Processor (MC68175/D), Motorola, 1996.

[9] "PDCA12-70 data sheet," Opto Speed SA, Mezzovico, Switzerland.

[10] A. Karnik, "Performance of TCP congestion control with rate feedback: TCP/ABR and rate adaptive TCP/IP," M. Eng. thesis, Indian Institute of Science, Bangalore, India, Jan. 1999.

[11] J. Padhye, V. Firoiu, and D. Towsley, "A stochastic model of TCP Reno congestion avoidance and control," Univ. of Massachusetts, Amherst, MA, CMPSCI Tech. Rep. 99-02, 1999.

[12] Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification, IEEE Std. 802.11, 1997.