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Prediction of Fatigue Life of Boom Nose End Casting Using Linear Elastic Fracture Mechanics

Nitin D.Ghongade[1] , Rajesh.M. Metkar[2] , Subhash D.Hiwase[3]

Abstract
The main objective of this study is to get the life estimation of Boom nose end casting using theoretical approach and compaired it with finite element method. Therefore, this study consists of three major sections : (1) dynamic load analysis (2) FEM and stress analysis (3) prediction of fatigue life for Boom nose end casting. In this study a dynamic loads were obtained from cyclic loading at different time. Finite element analysis was performed to obtain the variation of stress magnitude at the crack locations. This loads and boundary condition were applied to the FE model in ANSYS. The analysis was carried out for different crack length on the surface area of circle of Boom Nose End Casting. As a result, fatigue life for different crack length on the Boom Nose End Casting is obtained. The main objective of this study is to investigate the fatigue life of Boom Nose End Casting under complex loading conditions. Due to the repeated bending and tensile loading acting, Boom Nose End Casting fails, as cracks forms in surface area of circle. Hence, fatigue plays an important role in Boom Nose End Casting development. Accurate prediction of fatigue life is very important to insure safety of components and its reliability. The Linear Elastic Fracture Mechanics approach is used to predict the fatigue life of Boom Nose End Casting.
Keywords— Boom Nose End Casting, Dynamic Loading, Fatigue Failure, Finite Element Method.

I. Introduction

Boom nose end casting is the part of excavator which is welded to the big arm or dipper. Boom is connected to the Boom Nose End Casting using steel pin shaft. The sudden failure of Boom Nose End Casting is due to overload, complex loading, geometry problem, temperature, improper handling etc. It is subjected to several forces which vary in magnitude and direction. Most of the time Boom nose end casting fails in the surface area of circle due to tensile and bending load. Initially small crack are occurs on the surface area of circle. Boom Nose End Casting experiences a large number of fluctuating / cyclic load cycles during its service life, fatigue performance and durability of this component has to be considered in the design process due to fatigue failure. The finite element analysis was performed on Boom Nose End Casting using ANSYS software. Stresses from these analyses were used to compair the Stresses obtained from Linear Elastic Fracture Mechanics. Figure 1.1 shows different parts of excavator with Boom Nose End Casting. Three methods which are used to predict fatigue life include stress life(S-N), strain Life (E-N) and Linear Elastic Fracture Mechanics (LEFM). In this study, Linear Elastic Fracture Mechanics approach is used to predict fatigue life for Boom Nose End Casting. In first step the forces acting on Boom Nose End Casting was found out, after obtaining the forces on the Boom Nose End Casting , the stresses for given forces were obtained and the life of Boom Nose End Casting was predicted using Linear Elastic Fracture Mechanics approach.

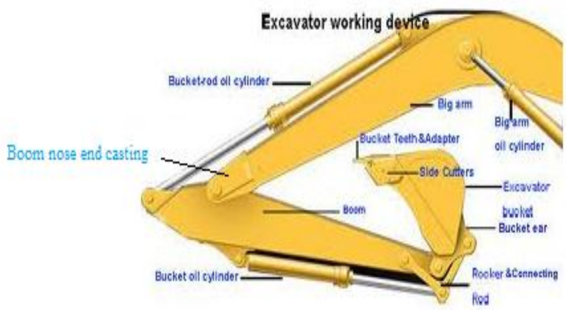

Figure I.1: Excavator with different parts

II. Dynamic Load Analysis of The Boom Nose End Casting

The main objective of this study is to obtain accurate magnitude of the loading on Boom Nose End Casting that consists of bending and tension. An analytical approach is used to find forces acting on Boom Nose End Casting is that some forces is given in excavator manual also weight of the bucket ,capacity of the bucket, dipper weight are given in manual which is helpful to findout forces . These forces are vary with time i.e the action performed by JCB during the working this can be obtained by doing experimentation.

III. Stress Analysis of Boom Nose End Casting Using Finite Element Method

In order to carry out Finite Element Analysis appropriate boundary conditions and loading situation are identified and discussed as below.

III.1 Finite Element Modeling

Finite element modeling of any solid component consists of geometry generation, applying material properties, meshing the component, defining the boundary constraints, and applying the proper load type. These steps will lead to the stresses and fatigue life calculation of component. In this study, similar analysis procedure is performed for Boom Nose End Casting.

III.2 Generation Of The Geometry Of Boom Nose End Casting

According to the drawing, the dimensions of Boom Nose End Casting, solid model is generated using CATIA V5 modeling software. Figure III.2.1 shows the solid model of the Boom Nose End Casting.

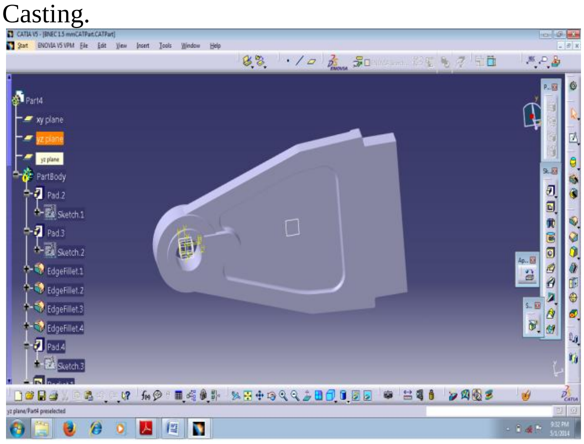

Figure III.2.1: Generated geometry of the Boom Nose End Casting

III.3 Mesh Generation

FE analysis is performed on Boom Nose End Casting to obtain the maximum principal stress, minimum principal stress, equivalent von-mises stress etc. Figure III.3 shows mesh model and Material properties were used for model is tabulated in Table III.3.1

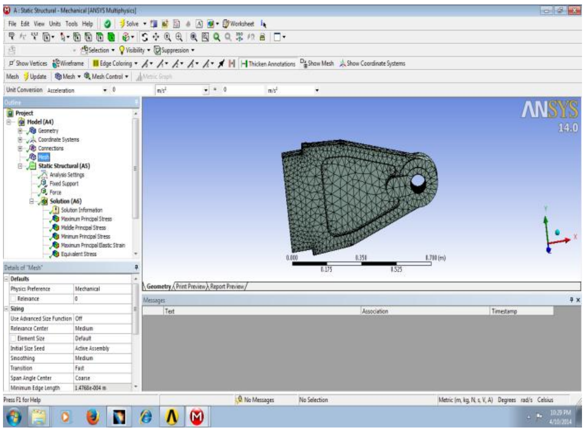

Figure III.3: Meshed geometry of the Boom Nose End Casting

TABLE III.3.1
MATERIAL PROPERTIES FOR BOOM NOSE END CASTING

Grade- EN10025 steel	
Compressive Ultimate Strength	520 MPa
Compressive Yield Strength	320 MPa
Tensile Ultimate Strength	690 MPa
Tensile Yield Strength	480 MPa
Youngs Modulus	206 MPa
Poisson's Ratio	0.3

III.4: Finite Element Analysis Results And Discussion

In the ANSYS software two type of forces are applied one is tensile force and other is bending force, also fixed support is given according to the actual situations. In this way, finite analysis was performed for Boom Nose End Casting and results are obtained. The crack length varies from 1.5mm to 30mm, maximum principal stress obtained varies from 62 MPa to 49 MPa, minimum principal stress obtained varies from 18 MPa to 10 MPa, Equivalent von-mises stress obtained varies from 45 MPa to 43 MPa.

IV. Fatigue Behavior and Life Predictions

This topic focuses on the prediction of fatigue life for Boom Nose End Casting. Results coming from theoretical approach are used to obtain life estimation of Boom Nose End Casting. Linear Elastic Fracture Mechanics approach are used to obtain fatigue life of Boom Nose End Casting.

IV.1: Linear Elastic Fracture Mechanics approach Used To Predict Fatigue Life

Linear elastic fracture mechanics describe the fracture behavior of material and component that respond elastically under loading. Linear Elastic Fracture Mechanics assume that the crack has been already available and detected and predict crack growth by considering stress intensity factor. It is the basic theory of fracture that deals with sharp cracks in elastic bodies. Linear elastic fracture mechanics methodology are as follows

- Decide the mode of fracture.
- Evaluate the stress intensity factor considering initial crack length.
- Evaluate Fracture toughness considering critical crack length
- Obtain crack propagation rate using Paris law

$$\frac{da}{dN} = C(\Delta K)^n \qquad \text{Equation 4.1}$$

- Integrating the Equation 4.1 we get the fatigue life of component in no. of cycle

$$[N]_{N_i}^{N_f} = \frac{1}{C\,[(S_{max} - S_{min})\pi^{1/2}]^n} \left[\frac{a^{[1-(n/2)]}}{1-(n/2)}\right]_{a_i}^{a_f}$$

Where,
N- Number of cycle
C=1.35e-12 and n=2.25 are constant value depend on material
a_i =1.5 and $a_f = 5$ are the initial and final crack length
$S_{max} = 57.14$ MPa and $S_{min} = 15.795$ MPa are the maximum and minimum applied stress
The life obtained by propogating a crack from 1.5mm to 5mm is 190002585 cycles.

V. Conclusion

Boom nose end casting is a part of JCB, failure of the part requires costly procurement and replacement. FEA is very efficient and simple method for achieving stresses at different loading condition according to forces applied to the Boom nose end casting. Finite element analysis has been performed to obtained the different stresses. The crack length varies from 1.5mm to 30mm, maximum principal stress obtained varies from 62 MPa to 49 MPa, minimum principal stress obtained varies from 18 MPa to 10 MPa, Equivalent von-mises stress obtained varies from 45 MPa to 43 MPa and using theoretical approach result are maximum principal stress obtained varies from 30 MPa to 36 MPa, minimum principal stress obtained varies from 5 MPa to 9 MPa, Equivalent von-mises stress obtained varies from 28 MPa to 32 MPa for different crack length and the number of cycle is 190002585 cycles. The result obtained using theoretical approach are within the limit of result obtained from software.

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Authors' information

[1]M.Tech.Student, Production Engineering, Govt. College of Engineering, Amravati, India
[2]Assistant Professor, Department of Mechanical Engineering, Govt. College of Engineering, Amravati, India
[3]Managing Director , Samrachana Software Solution , Hyderabad

Nitin D. Ghongade is M.Tech Scholar of Production Engineering at Government College of Engineering, Amravati, Maharashtra India. His Research Interest is in Fracture Mechanics.

Dr. Rajesh M. Metkar, PhD, was born at Amravati in the Maharashtra state of India on 11th February 1976. He has 15 year of Industrial and Teaching Experience. Currently he is an Assistant Professor in Department of Mechanical Engineering, Government College of Engineering Amravati. He has several research paper in his credit. His area of interest is Finite Element Analysis, Fatigue Life Estimation.

Dr. Subhash D. Hiwase, PhD, is a 41 year old, result oriented, professional technocrat, having Ph.D. degree in Mechanical Engineering and 17 year of rich experience as CEO/MD/Director/Senior Management in Engineering,IT, ERP and Manufacturing domain. He is Currently Vice President of Axis AT& T Bangalore. His expertise includes, Business System Development: Planning, Strategy, Channel, Resourcing, Venture, Partnerships, Alliances, Merger, Costing, R&D,Tech Infra Development, Technology Commercialization, Internatinal, New Economy & New Tech Business. Project Management: Conception to Completion, On time and Every Time, Scientific Project Management Techniques, International Projects.