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Study & Analysis of Boom of Backhoe Loader with the Help of FE Tool

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ABSTRACT

Construction industry is undoubtedly the backbone and propelling force behind our progress, in response to booming construction industry, utilization of earth moving equipment has increased considerably leading to high rate of failure.The backhoe loader mechanism must work reliably under unpredictable working conditions. Thus it is very much necessary for the designers to provide not only an 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. FEA is the most powerful technique in strength calculations of the structures working under known load and boundary conditions.. In this paper authors, describes its basic structure, stress characteristics and the engineering finite element modelling for analysing, testing and validation of backhoe loader parts under high stress zones.

Keywords:* - Backhoe, *FEA, Bucket

I. INTRODUCTION

Rapidly growing rate of industry of earth moving machines is assured through the high performance construction machineries with complex mechanism and automation of construction activity. Backhoe excavators are widely used for most arduous earth moving work in engineering construction to excavate below the natural surface of the ground on which the machine rests. Hydraulic system is used for operation of the machine while digging or moving the material. An excavator is comprised of three planar implements connected through revolute joints known as the boom, arm, and bucket, and one vertical revolute joint known as the swing joint. Kinematics is the science of motion which treats motion without regard to the forces that cause it. Within the science of kinematics one studies the position, velocity, acceleration, and all higher order derivatives of the position variables (with respect to time or any other variables) . The excavator linkage, however, is a complex link mechanism whose motion is controlled by hydraulic cylinders and actuators. To program the bucket motion anoint-link motion, mathematical model of the link mechanism is required to refer to all geometrical and/or time-based properties of the motion. Kinematic model describes the spatial position of joints and links, and position and orientation of the bucket. The derivatives of kinematics deal with the mechanics of motion with considering the forces that cause it.

Figure 1 The Backhoe

The basic problem in the study of mechanical link mechanism is of computing the position and orientation of
Bucket of the backhoe attachment when the joint angles are known, which is referred to as forward kinematics. The inverse kinematics problem is, thus to calculate all possible sets of joint angles, which could be used to attain a given position and orientation of the bucket tip of the backhoe attachment. The problem of link mechanism control requires both the direct and inverse kinematic models of the backhoe attachment of the Excavator. The kinematic modeling helpful to follow the defined trajectory as well as digging operation can be carried out successfully at required location of the terrain using proper positioning and orientation of the bucket and ultimately digging task can be automated.

The Backhoe is essentially, soil digging machine. The working tools off the Backhoe are actuated by the Hydraulic Cylinders. The required motion for digging operation is controlled by controlling the hydraulic cylinders. Each component is actuated by a hydraulic cylinder.

A combination of extensions and retractions of the hydraulic cylinders generates the required motion of the components for digging. The hydraulic cylinder simultaneously provides the digging forces to be generated at the bucket tip. The pressure to be developed is generated by

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the hydraulic pump coupled to the engine. Fig. describes the working volume of such a backhoe.

Figure 2 Working Volume of Backhoe

II. LITERATURE REVIEW

i. 3D Modelling of Boom

The Boom is the most stressed part of the backhoe loader. The boom of L&T CASE 770 is made of fabricated plates bended and welded to make one side of the boom; the two opposite parallel sub-assembly are welded with stiffener plates inside. The drawing for the Boom with sectional width is shown in the figure. All the plates welded are of 16 mm thickness, the fillet weld can be measured to be 8 to 10 mm strong.

The drawing for the Boom with sectional width is shown in the figure. All the plates welded are of 16 mm thickness, the fillet weld can be measured to be 8 to 10 mm strong.

The consideration that the weld is stronger than the base metal is kept in mind and thus the weld is not modelled in 3D software and also is not considered for any type of Finite element analysis done in the project.

ii. Kinematic Analysis

The Figure below shows the connections of Pin joint to different parts, to facilitate the motion of the system. While the linear motion of cylinders is done via use of slider mechanism constraint in the assembly mode of Pro-engineer standard module. The closed setting for cylinders is done in the mechanism to exteriorize the dependencies of motion constraint to facilitate the constraint of motions.

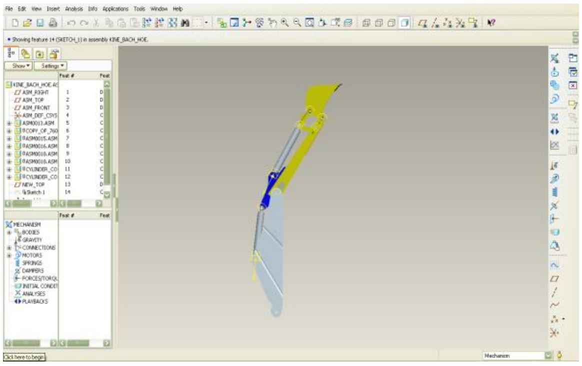

Figure 3 Connection of pin joint to different parts

iii. Dynamic Analysis

Since for dynamic analysis the mass (centre of gravity) and the time play important two inputs required to solve any dynamic analysis.

It is most difficult to predict the time of the motion. But by an average taken from viewing many cycles performed in-front of eyes by the driver driving the vehicle, we concluded the timing required to perform the operation shown in the complete video is performed in nearly 15-18 seconds of the time .

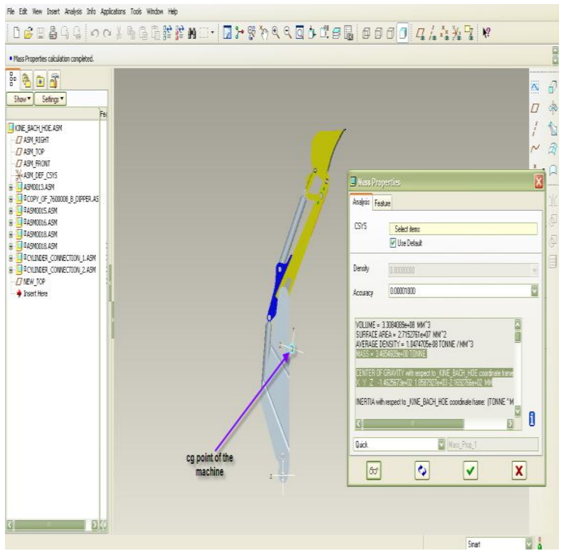

Figure 4 CG of complete machine

III. EXPERIMENTAL DATA

Finite element modelling is one of the major subjects of Computer Aided Engineering where the importance of Finite element method is sub-divided in following rules of problem solving methodologies.

i. Pre-processing

ii. Defining correct loads and correct Boundary conditions.

iii. Solution and Post-processing

FEA consists of a computer model of a material or design that is stressed and analysed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

FEA has become a solution to the task of predicting failure due to unknown stresses by showing problem areas in a material and allowing designers to see all of the theoretical

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stresses within. This method of product design and testing is far superior to the manufacturing costs which would accrue if each sample was actually built and tested.

The use of Finite element is the second step considered in the Finite element analysis which falls after modelling of the part/assembly to be analysed. It is important to take decision before starting the Finite element modelling to ensure the results are correct and your model behaves properly as thought based on engineering principles.

The very basic decision to be taken by the FE analyst is to take the decision in the type of modelling to be done in FEA package. The Few types of modelling used are illustrated below:

i. Shell Modelling
ii. Solid Modelling
iii. Beam Modelling

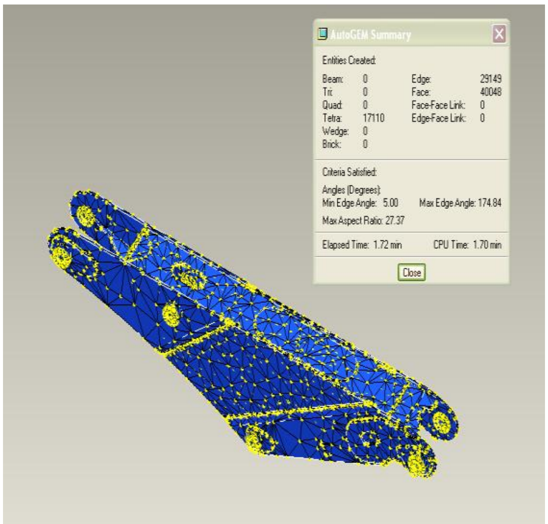

Figure 5 Showing the tetrahedral meshed model of boom

The figure above shows the no. of elements created during the analysis are 17110 in no.'s each element will create an equation to be solved for displacement which will be further used to make the assembly stiffness matrix combining the equation from all the elements. This assembly matrix will result in the values of displacements which further be solved to result in Stresses.

The different parts of the boom which are connected in assembly are also given a weld constraint in Pro-Mechanica to simulate the actual weld with 6 DOF fixed with each the two connected nodes to each other. Surface to surface weld known as perimeter weld and end weld commands are used in Pro-Mechanica.

IV. RESULT

The working operation condition will result in the machine life of **10^6 cycles** with no effect and then the machine wear as said in the book of machine design by the formulation of Modified Goodman Line & Soderberg Line. The comparative chart shows the result.

V. CONCLUSION

This study tells the optimization of the Boom for including the strength of welds where welds can be modelled with shell elements along with the boom to take moments can be done to predict the failure stresses of the welds. Localization and stress linearization of the weld can be simulated for calculating the factor of safety for weld strength.

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