Development of Backhoe Machine By 3-D Modelling Using CAD Software and Verify The Structural Design By Using Finite Element Method

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Abstract

Present study covers the detailed design, modelling and FE analysis of Backhoe Machine. . Backhoe Loader is the the rear part of the excavator machine. The backhoe loader is used for a wide variety of tasks: construction, small demolitions, light transportation of building materials, powering building equipment and digging holes/excavating, landscaping, breaking asphalt and paving roads. Various loads are applied at the bucket tip and to the boom and digger arm. So it is necessary to analyze the parts assembly to avoid failure while it is in working condition. From static analysis, high stress area can be found out when Backhoe Loader is in different load condition. Also by providing some design changes, stress can be minimized.
Keywords: Backhoe Loader; Stress Analysis; FEM.

I. Introduction

Today in the machine age when the use of machines is increasing for the earth moving works, considerable attention has been focused on designing of these earth moving equipments. Achievement of an ambitious and 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. Bulldozers, scrapers, motor graders, excavators and other machines are widely used for most arduous earth moving work in engineering construction. 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 by careful stress analysis of the machines. This arises a scope for developing some standard methodology to calculate the loads on the machine and carrying out stress analysis of various parts of earth moving machineries.

II. Literature review

Bhaveshkumar P. PATEL et.al[1] suggest that during the excavation operation unknown resistive forces offered by the terrain to the bucket teeth. Excessive amount of these forces adversely affected on the machine parts and may be failed during excavation operation. Design engineers have great challenge to provide the better robust design of excavator parts which can work against unpredicted forces and under worst working condition. Thus, it is very much necessary for the designers to provide not only a better design of parts having maximum reliability but also of minimum weight and cost, keeping design safe under all loading conditions. Finite Element Analysis (FEA) is the most powerful technique for strength calculations of the structures working under known load and boundary conditions. FE analysis of backhoe parts shows that the parts with welding provide higher strength. Structural weight optimization carried out by trial and error method shows the total reduction in weight is of 70.649 kg (24.96%) and weight reduced by applying shape optimization is of 78.977 kg (27.91%). Comparison shows that the variations in results of individual parts are very less and total variation in result is of only 3.93% which reflect that the results of structural weight optimization performed by trial and error method are accurate and acceptable. The differences in results of the Von Mises stresses and the classical theory are very less and we can say that the results are identical and acceptable.

Juber Hussain Qureshi et.al [2]suggest that a Backhoe machine is used to lift tones and ones of load, thus some amount of pressure is to be developed for providing the necessary force by the cylinder to lift this load. FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. Finite element Analysis of the boom is made followed by the results of Dynamic study of the Boom of the machine. In this paper researcher provides the platform to understand the Modeling and FEA of Boom of Backhoe Loader, which was already carried out by other researchers for their related applications and it can be helpful for the development of boom of backhoe loader. With the results obtained from the Finite Element Analysis by Pro-e Mechanica software is are very safe as per the stress values and the deflections As Inertia plays a big effect while performing a dynamic analysis which is completely dependent upon the time in our case which can only be assumed for the cycle to complete. The max effect of inertia can be plotted on the graph especially for new shapes of boom, to get the safe results of stresses resulting in the safe life of the boom.

Juber Hussain Qureshi et.al [3] suggest that 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 modeling for analyzing, testing and validation of backhoe loader parts under high stress zones.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. This study tells the optimization of the Boom for including the strength of welds where welds can be modeled 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.

Bhaveshkumar P. Patel et.al [4]suggest that the automation of the land excavation machines can find applications in the excavation of soil in both terrestrial and planetary mining and construction. In the process of automating an earthmoving machine, we have utilized a model of soil-tool interaction that predicts resistive forces experienced at the tool during digging. The predicted forces can be used to model the closed loop behavior of a controller that serves the joints of the excavator so as to fill the bucket. Accurately predicting the excavation force that will be encountered by digging tools on the soil surface is a crucial part of designing of mini hydraulic excavator. Based on principles of soil mechanics, this paper focuses on application of an analytical model that is relatively simple and easy to determine required resistive force. Here, soil parameters like soil cohesions, soil density and soil surcharge etc. that can be determined by traditional soil strength tests and taken as reference. The excavation force is investigated and it is helpful in designing of the components of kinematic linkages. This paper emphasize on graphical representation of the relations between excavation force and different parameters like soil density, soil blade friction angle, soil cohesion, internal friction angle and depth of tool. This paper evaluates the digging force based on fixed bucket size of 300 mm length × 300 mm width × 300 mm depth and the minimum digging depth up to 1.5 m especially designed for construction applications. Based on peer review on soil-tool interaction, it is very clear that almost all the related work carried out previously by others is based on the FEE Provided by Reece. For our application based on presented work, as solid blade friction angle, soil friction angle, soil density & soil cohesion increases, the total resistive force experienced at the blade is also increases and As the side friction angle increases, the total resistive force experienced at the blade gets decreased. As rack angle gets minimum (i.e.44º to 45º), the total resistive force exerted at the blade is minimum & changes as it increase or decreases. As the additional rack angle increases up to 25º the total resistive forces increases and onwards it gets reduces. There is a linear relationship between the swept volume and the total resistive force. These relations of variables with total resistive are helpful for design of controller that serves the joints of the excavator so as to fill the bucket. It is also helpful for trajectory planning for digging operation. Based on this study optimum parameters can be selected for better performance of the soil excavation task.

Bhaveshkumar P. PATEL et.al [5] suggest that 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. Design of backhoe link mechanism is critical task in context of digging force developed through actuators during the digging operation. The digging forces developed by actuators must be greater than that of the resistive forces offered by the terrain to be excavated. This paper focuses on the evaluation method of bucket capacity and digging forces required to dig the terrain for light duty construction work. This method provides the prediction of digging forces and can be applied for autonomous operation of excavation task. The evaluated digging forces can be used as boundary condition and loading conditions to carry out Finite Element Analysis of the backhoe mechanism for strength and stress analysis. A generalized breakout force and digging force model also developed using the fundamentals of kinematics of backhoe mechanism in context of robotics. An analytical approach provided for static force analysis of mini hydraulic backhoe excavator attachment. The capacity of the bucket has been calculated according to the standard SAE J296 and comes out to be 0.028 m3. This bucket specification is the most superior when compared to all the other standard mini hydraulic excavator models available in the market. The breakout forces calculated as per SAE J1179 and comes out to be 7626 N. The SAE standard only provide the breakout and digging forces for maximum breakout force condition but for autonomous application it is important to understand and to know to predict the digging forces for all position of bucket configuration , which is presented here by development of the generalized breakout force model. The comparison of the different backhoe excavator models in the context of physical dimensions bucket specification and digging forces shows that by kipping slightly less or same link dimensions the required digging force of proposed backhoe attachment is reduced to 7626 N which are enough and more than resistive forces offered by ground 3916.7 N for light duty construction work.

Bikash Rai et.al [6]

In this paper an attempt has been made to design and analyze the rotating bucket of the excavator along with the stick and the bucket arm. This paper focuses on the joint design by using the geared motor for angular rotation of the bucket arm and studies the effect of digging, torsional force and bending stresses developed on the joint. Study the motion of the bucket. The paper shows that by determining various reaction forces a rotary joint can be designed for the excavator arm, which facilitate the rotation of the arm and increase the productivity. This is very important to analyze all the forces during designing process, selection of material, power of motor.

Shiva Soni et.al [7] suggest that an excavator is a typical hydraulic heavy-duty human-operated machine used in general versatile construction operations, such as digging, ground leveling, carrying loads, dumping loads and straight traction. Normally backhoe excavators are working under worst working conditions. Due to severe working conditions, excavator parts are subjected to high loads and must work reliably under unpredictable working conditions. The objective of this paper is to analyze the existing design and redesign the excavator boom which is suitable for side digging and also for digging over hanged part of wall. Modeling of excavator attachment like boom, long arm, small arm, cylinder, bucket & coupling is done by using INVENTOR software. Model is exported through IGES file format for MESHING in Altair Hyper mesh Analysis Software. Meshing is done using suitable type of elements. Material property is assigned; Boundary conditions and the forces are applied. Static analysis is done in INVERTOR software which is being supported by ANSYS software. During operation of excavator at different positions the stresses induced in the attachments varies. The forces applied in the analysis were calculated by using INVENTOR software, and reported that the Arm, Boom and Bucket shows stress in the attachment are coming under allowable limit. For reducing stresses and for optimum weight of the excavator parts, thickness of the material is reduced in the modeling. software.

P Mahesh Babu1 et.al [8]performed a detailed Fatigue Analysis of the digger arm under the worst loading condition . During the part of project a static and fatigue analysis of digger arm was carried out using finite element analysis package. The 3 dimensional model of the digger arm was designed using NX-CAD. Then the 3D model is imported into ANSYS using the Para solid format. The finite element idealization of this model was then produced using the 10 node tetrahedron solid element. The analysis was performed in a static condition. From the analysis results total deformation, alternative stress and shear stresses are documented by using FEA software. In this project we will also find out the life, safety factor and damage of digger arm by using Goodman tool. S-N curve is given as input for the material used for digger arm. Finally design optimization of the digger arm was done to increase the life of the digger arm component. NX-CAD software was used for 3D modeling of the digger arm and ANSYS software was used to do the fatigue analysis of the digger arm. The digger arm is developed to perform excavation task for light duty construction work. Based on static force and dynamic force loads, finite element analysis is carried out for digger arm. It is clearly depicted that the stresses produced in the component of the digger arm are within the safe limit of the material stresses for the case of static and dynamic load conditions. It is also clearly depicted that the fatigue life cycle of the digger arm is more by 42.6% for modified digger arm compared to original digger arm. Based on results we can conclude that optimization can help to reduce the initial cost of the digger arm as well as to improve the functionality and life cycle as the digger arm operates in worst working conditions. The optimization also helps to avoid frequent failure of digger arm which may cause the entire system become idle and lead to a commercial loss to the owner

Gui Ju-Zhang et.al [9] suggest that according to the type of YC225LC-8 hydraulic backhoe excavator, mechanical analysis was carried out in three typical work condition of the working device by using the mechanical theory and method. The static strength finite element analysis of excavator boom was carried through by using ANSYS, from which, the stress and strain deformation contour diagrams of three typical work condition were obtained so that the hardness can be checked. The results of finite element analysis showed that the static intensity of the boom is enough. The maximum stress mainly occurred in the hinge point connected the boom cylinder with the boom and the hinge point connected the boom with the base, which played an important part in controlling the strength of the excavator working device. The study results are of certain guiding significance for working device's optimization design. Finite element modeling analysis showed that: the maximum stress does not exceed the material's yield and tensile strength, the boom of design is reasonable and does not need to be improved. Finite element analysis has great significance for the actual production process not only to study the excavator's specific conditions using the actual data to simulate the working condition, which are close to the actual production results, but also to save the cost of research and development.

III. CONCLUSION

From linear static analysis, maximum deformation of the component and maximum stress can be k nown and from that the material can be changed if required to meet the loading condition. If the component is failing, either the plate thickness can be changed or the curvature can be increased and again check for the loading conditions. After redesign of components, the stress is under the allowable limit. Earth moving equipments have been known well for more then fifty years. Backhoe works well in the digging below ground level. The life of components of backhoe depends on the density of the earth, whether it is a soil digging, rock digging or it is used for mines. Higher stress region can be minimized by removing sharp corners, by providing smooth fillet.

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