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Vibrational Analysis of an Excavator Arm

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Abstract- **Excavators are intended for excavating rocks and soils. Excavator may have a mechanical or hydraulic drive. Hydraulic excavators are the most important group of excavators. It consists of four link members: the bucket, the stick, the boom and the revolving superstructure (upper carriage). There is an almost limitless range of sizes of backhoe, from hoes mounted on small agricultural tractors used in residential construction all the way to huge crawler-mounted hoes capable of handling some of the heaviest work in industrial jobs. These excavators are also operated with other attachments such as clamshell, dragline, drilling equipments, scarifies for breaking pavements and frozen soils. On the other hand, the work functions of the backhoe often overlap those of other machines such as front-end loaders, tractor shovel, scrapers, clamshells and draglines. For light duty construction work, generally mini hydraulic backhoe excavators are used and mostly there are soil surfaces for excavation. So, design of backhoe excavator is critical task in context of digging force developed through actuators during the digging operation. The important criteria for the design to be safe is that, the digging forces developed by actuators must be greater than that of the resistive forces offered by the surface to be excavated. The two important factors considered during designing an excavator arm are productivity and fuel consumption. As the present mechanism used in excavator arm is subjected to torsional and bending stresses during lifting and digging operation respectively, because of which failure occurs frequently at the bucket end of the arm. So, the new mechanism of excavator arm is designed and the Pro-e software is used for making the 3D model of the excavator arm linkage. By using ANSYS workbench software vibrational analysis of the excavator arm assembly is done by considering various frequencies of vibrations occur during its working.**

Index Terms- **Excavator arm, lifting, digging, actuators, productivity, CAD-CAE systems.**

I. INTRODUCTION

An excavator is heavy equipment consisting of an articulated arm (backhoe), bucket and cab mounted on a pivot (a rotating platform, like a Lazy Susan) a top and undercarriage with tracks or wheels. Their design is a natural progression from the steam shovel. Excavators are intended for excavating rocks and soils. Excavators may have a mechanical or hydraulic drive. Hydraulic excavators are the most important group of excavators. The typical hydraulic excavator of VOLVO is shown in the fig.1.

Fig.1. A typical hydraulic excavator of VOLVO.

II. DESIGN OF EXCAVATOR ARM

Calculation of pin diameter:
F = 10,300N, r = 391mm, L = 315mm, P = 15.69N/mm2, A = 66836mm2,
Shear stress = 42N/mm2, Bending stress = 84N/mm2.
Let, d = diameter of pin
Torque, T=F × r=10300×391=4027300N-mm, Load, W=P×A=15.69×66836=1048656.8N
Now, Max. bending moment = M = WL/4 = (1048656.8 × 315)/4 = 82581723N-mm
Since, pin is subjected to suddenly applied load. Considering Km = 1.5, Kt = 2
We know that, equivalent twisting moment
Te = √(Kt × T)2 + (Km × M)2 = √(2 × 4027300)2 + (1.5 × 82581723)2
Te = 124134176.5 N-mm
But, Te = π/16 × d3 × shear stress
124134176.5 = π/16 × d3 × 42
Therefore, d = 246.9mm
we know that, equivalent bending moment

Me = 1/2[Km × M + Te] = ½[1.5 × 82581723 + 124134176.5]

Me = 124003380.5N-mm

But, Me = π/32 × d3 × bending stress

124003380.5 = π/32 × d3 × 84

Therefore, d = 246.86mm

Taking larger of the two values, we have diameter of pin = d = 246.9mm

III. MODELING

3.1 CAD modeling

CAD technology is very important while designing Excavator Mechanism. Following are advantages of CAD technology :

1) To increase the productivity of the designer

2) To improve the quality of the design

3.2 CAD/CAE softwares for Excavator mechanism design

- PRO/E – For 3D Component Design.
- PRO/Mechanism – For Mechanism

Pro/ENGINEER is a parametric, feature based, solid modeling System. It is the only menu driven higher end software. Pro/ENGINEER provides mechanical engineers with an approach to mechanical design automation based on solid modeling technology and the features such as 3D modeling, parametric design, feature-based modeling, associativity, capturing design intent, combining features into parts, and assembly. The three dimensional model of the assembly of Excavator arm is shown in the fig.2.

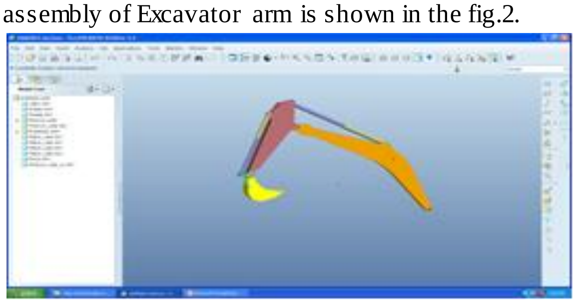


Fig.2 Excavator arm assembly

IV. FINITE ELEMENT ANALYSIS

The finite element method (FEM), sometimes referred to as finite element analysis(FEA), is a computational technique used to obtain approximate solutions of boundary value problems in engineering. Simply stated, a boundary value problem is a mathematical problem in which one or more dependent variables must satisfy a differential equation everywhere within a known domain of independent variables and satisfy specific conditions on the boundary of the domain. Boundary value problems are also sometimes called field problems. The field is the domain of interest and most often represents a physical structure.

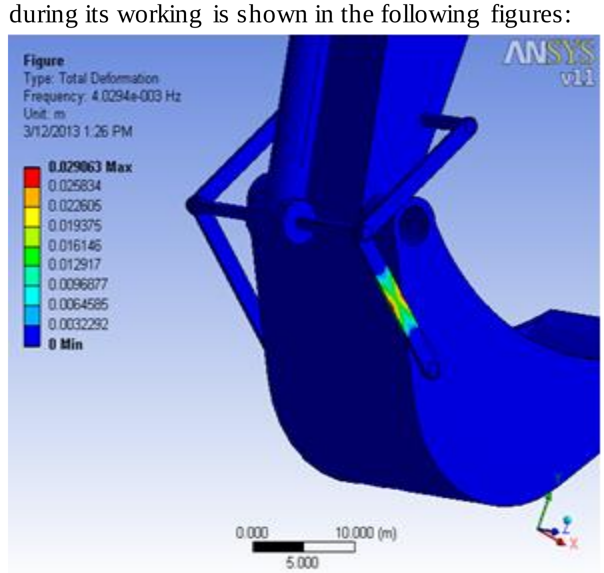
The field variables are the dependent variables of interest governed by the differential equation. The boundary conditionsare the specified values of the field variables (or related variables such as derivatives) on the boundaries of the field. Depending on the type of physical problem being analyzed, the field variables may include physical displacement, temperature, heat flux, and fluid velocity to name only a few.

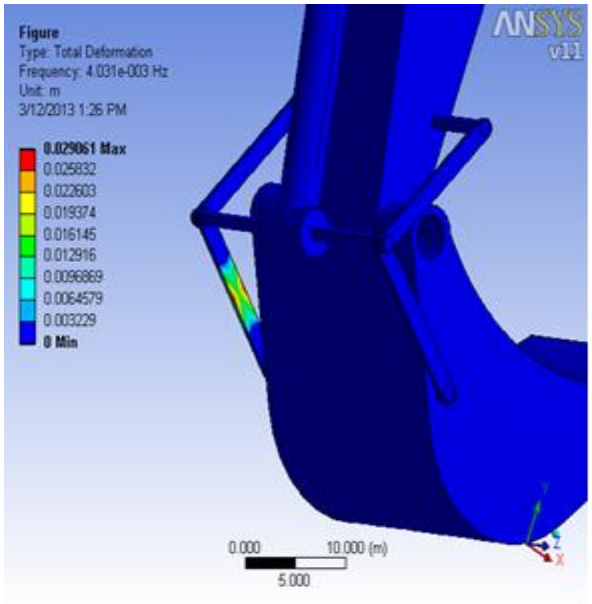
4.1 Vibrational analysis of Excavator arm

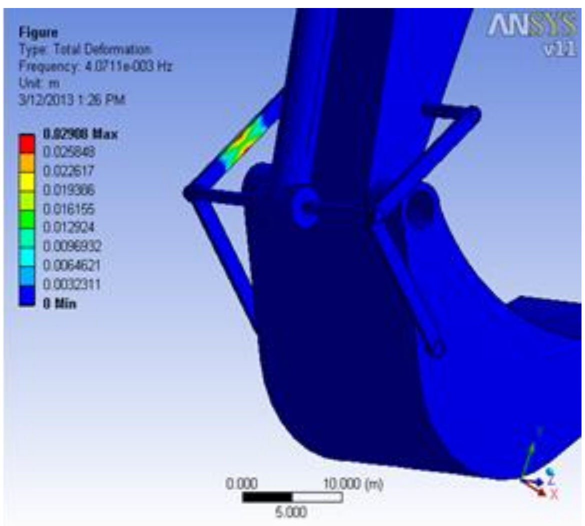
The steps involved in static structural analysis are as follows:

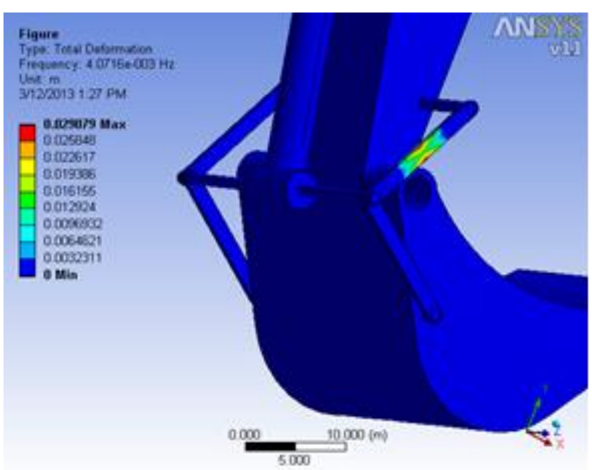
- The IGES file of the Excavator arm is imported and geometry is generated.
- The joint connection type used in the Mechanism Design to place a component in an assembly is specified.
- Meshing of the model is done.
- Fixed support is provided to the mechanism.
- Solution of the problem is done in which the deformation occurred due to the induced stresses at various frequencies of vibration is found.

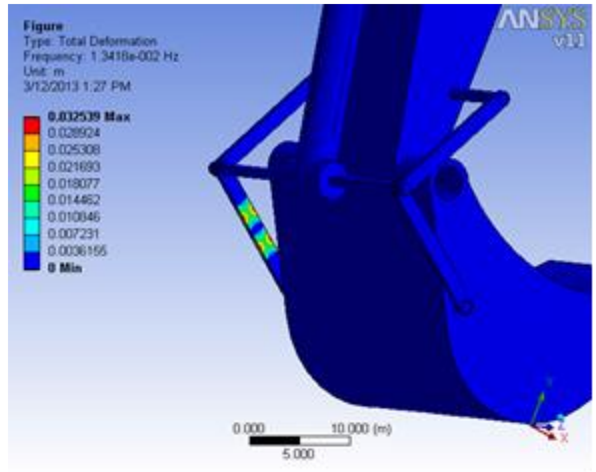
Total deformation occurring due to the stress concentration at different frequencies of vibrations during its working is shown in the following figures:

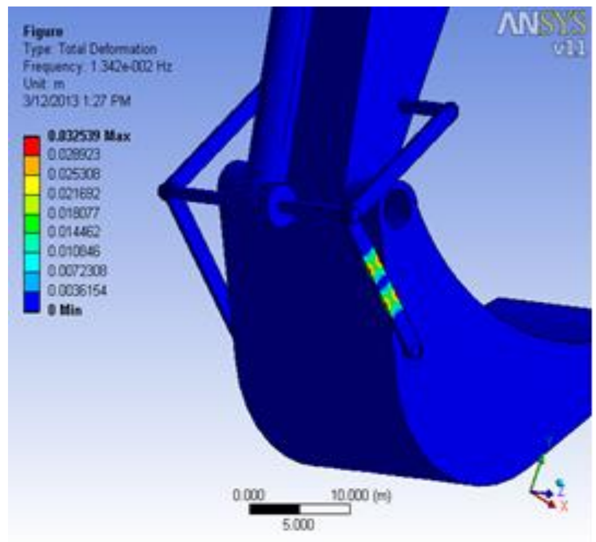












V. RESULTS AND DISCUSSIONS

The vibrational analysis of an excavator arm is done and the areas where the deformation is occurring in the excavator arm due to the stress concentration had been found. The values of total deformation occurring at different areas of excavator arm with respect to various frequencies of vibrations during its working are given in the following table:

Sr. No.	Frequency (Hz)	Total Deformation(m)
1	4.0294e-003	0.029063
2	4.031e-003	0.029061
3	4.0711e-003	0.02908
4	4.0716e-003	0.029079
5	1.3418e-002	0.032539
6	1.342e-002	0.032539

VI. CONCLUSION

In order to eliminate the problem of dislocation due to the play in pin at the bucket end of the excavator arm, the analysis of the problem occurring is done to find out the reasons behind the failure of excavator arm. For this purpose, the complete study of excavator arm is done first by reviewing various literatures on the excavator. Then by considering all the dimensions of excavator arm digging force required for performing various operations is calculated. Three dimensional model of the excavator arm assembly is made by using Pro-e software. For doing analysis of this 3D model of an excavator arm an ANSYS workbench software is used, in which vibrational analysis of an excavator arm assembly is done. While performing various operations, excavator arm is subjected to various stresses because of the force acting on it. Due to this all the parts of excavator arm gets deformed and when deformation exceeds a certain limit failure takes place. During working a large amount of vibration is always occurs in an excavator arm assembly and the frequency of this vibration is always changing at different moments during operation. Due to this vibration, stresses are getting developed in the excavator arm which leads to the deformation of parts and which causes failure of excavator arm. In the vibrational analysis, deformation occurring at different frequencies of vibrations is found. So, after doing the vibrational analysis of an excavator arm assembly, it is found that the stresses and deformation are the main causes of failure of an excavator arm.

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