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Research Paper

FATIGUE ANALYSIS AND DESIGN OPTIMIZATION OF A DIGGER ARM

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In this project a detailed Fatigue Analysis of the digger arm under the worst loading condition was carried out. 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 parasolid 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.

Keywords: Digger arm, FEA, Fatigue, Goodman curve

INTRODUCTION

A digger arm used in excavator is a typical hydraulic heavy duty human operated machine used in general versatile construction operations, such as digging, ground levelling, carrying loads, dumping loads and straight traction. The digger arm operates in worst working conditions. Due to its worst working conditions, it is subjected to huge loads. This digging task is also repetitive in nature and during the operation the entire link mechanism works under the dynamical condition. Because of this reason the digger arm fails very frequently and the entire system becomes idle and leads to a commercial loss to the owner.

The hydraulic excavator is most commonly used for digging rocks and soil, but with its many attachments it can also be used for cutting steel, breaking concrete, drilling holes in the earth, laying gravel onto the road prior

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to paving, crushing rocks, steel, and concrete, and even mowing landscapes. Hydraulic excavators have an operating weight of 20,000 pounds (9,072 kg) or higher.

The invention of the hydraulic excavator, with its easier operation and cheaper production has replaced the excavator. Excavators are also called diggers, JCBs (a proprietary name, in an example of a generic trade work), mechanical shovels, or 360-degree excavators (sometimes abbreviated simply to 360). Tracked excavators are sometimes called "track hoes" by analogy to the backhoe. In the UK, wheeled excavators are sometimes known as "rubber ducks.

PROBLEM DEFINITION

Digger arm has been designed and optimized for worst loading condition. Initially static Analysis is done by applying the worst loading conditions generated due to static and dynamic conditions. Maximum principle stresses are calculated from the analysis. Fatigue life of the digger arm is estimated by using the Goodman diagram tool by giving the inputs like principle stresses obtained from the static analysis for both static and dynamic load conditions. In this project we will find out the life, safety factor and damage of digger arm by using Goodman diagram tool. S-N curve for the material is given as input for the material used for digger arm. NX-CAD software is used for 3D modelling of the digger arm and ANSYS software is used to do the fatigue analysis of the digger arm.

METHODOLOGY

The methodology followed in the project is as follows:

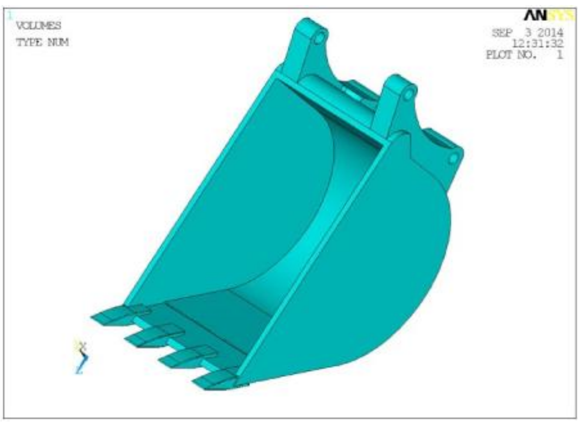
- Perform the Design calculations of the Digger arm.
- Create a 3D model of the digger arm using NX-CAD software.
- Perform static analysis of the digger arm for static and dynamic load conditions using ANSYS software and calculate the maximum principle stresses. Estimate the life, safety factor and damage of digger arm by using Goodman diagram tool.
- Optimize the original model to increase the life of the digger arm.

3D MODELLING

3D model of the digger arm was developed in NX-CAD from the design calculations done. The model was then converted into a parasolid to import into ANSYS. A Finite Element model was developed with solid elements. The elements that are used for idealizing the digger arm were described below.

Initially static Analysis is done by applying the worst loading conditions generated due to static and dynamic conditions. Maximum principle stresses are calculated from the

Figure 1: Shows the 3D Model of Digger Arm



analysis. Fatigue life of the digger arm is estimated by using the Goodman diagram tool by giving the inputs like principle stresses obtained from the static analysis for both static and dynamic load conditions.

FINITE ELEMENT ANALYSIS

Material Properties

Steel properties (A36)

Young's Modulus (Ex) = 2e5N/mm^2

Poisson's Ratio = 0.3

Density = 7850 Kg/mm^3

Yield Strength – 240 N/mm^2

Ultimate strength – 475 N/mm^2

Endurance Limit = 0.5 of ultimate strength = 475/2 = 237.5 N/mm^2

Element Type Used

Element type: Solid92

No. of nodes: 10

Degrees of freedom: 3 (UX, UY, UZ)

Boundary Conditions

1. Bucket cylinder (F_b) load is applied on arm teeth in X-Direction.
2. Arm cylinder (F_s) load is applied on arm teeth with cylindrical angle in X-Direction.
3. Digger arm is arrested in all Dof at hydraulic cylinder joints.

ANSYS RESULTS

Table 1: Max. Deflection and Von Mises Stress

S. No.	Deflection (mm)	VonMises Stress (Mpa)	Principle Stress (Mpa)
1.	1.9	153	124

Figure 2: Total Deflection of Digger Arm

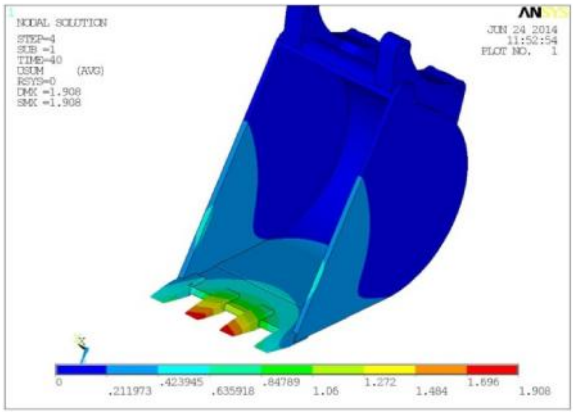
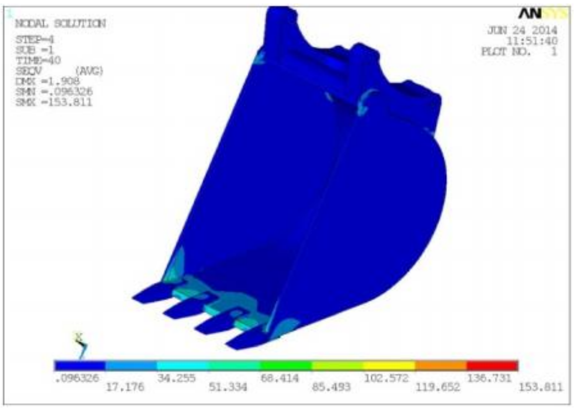
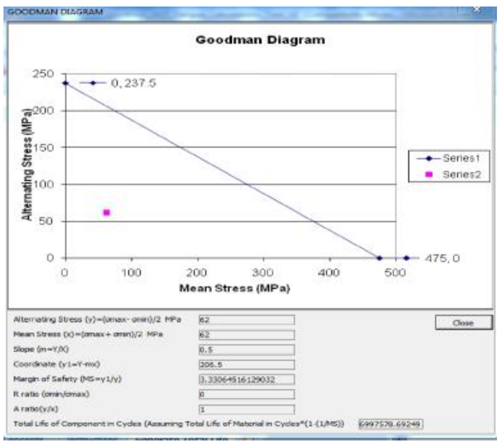


Figure 3: Von Mises Stress on the Digger Arm



FATIGUE ANALYSIS

Figure 4: Goodman Diagram with Details



FOR DYNAMIC LOAD CONDITIONS

Figure 5: Von Mises Stress of Digger Arm for Dynamic Loading

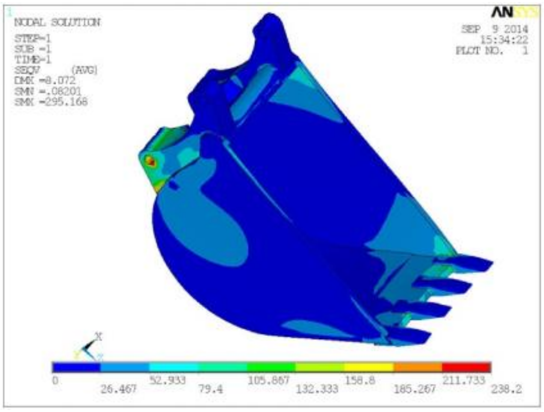
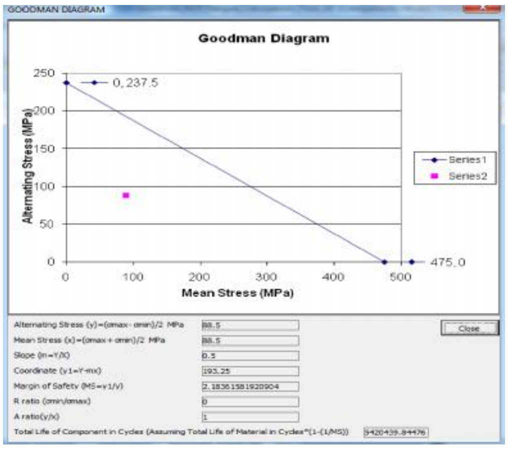
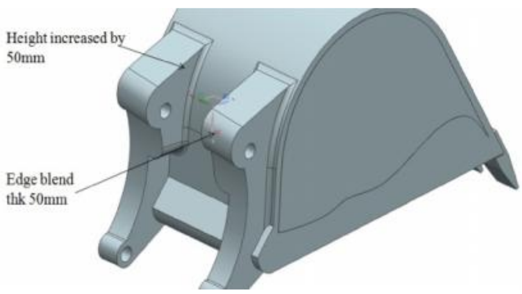


Figure 6: Goodman Diagram with Details



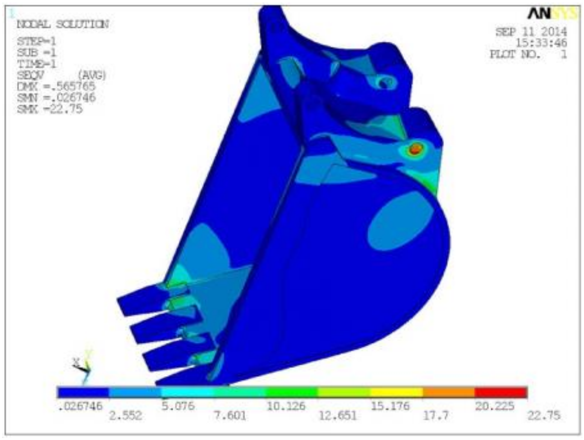
MODIFIED MODEL

Figure 7: Change#1 Made on the Digger Arm



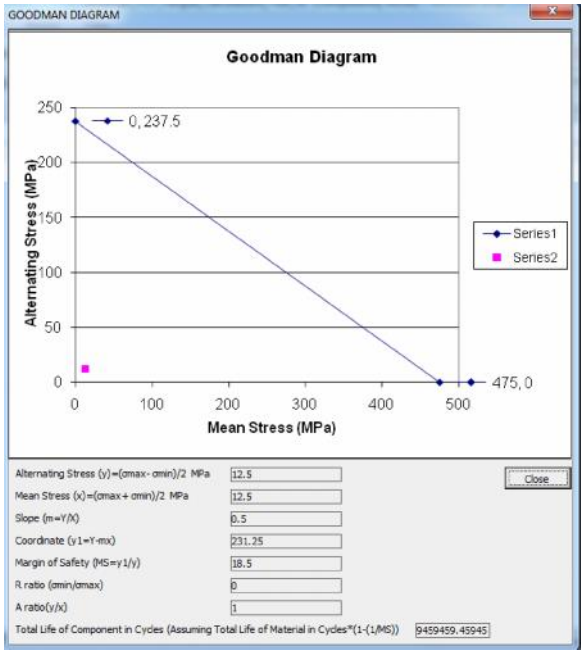
RESULTS

Figure 8: Von Mises of Modified Digger Arm for Dynamic Loading



FATIGUE LIFE CYCLE

Figure 9: Goodman Diagram with Modified Model



RESULTS AND DISCUSSION

Digger arm has been designed and optimized for worst loading condition. Initially static Analysis is done by applying the worst loading conditions generated due to static and dynamic conditions. Maximum principle stresses are calculated from the analysis. Fatigue life of the digger arm is estimated by using the Goodman diagram tool by giving the inputs like principle stresses obtained from the static analysis for both static and dynamic load conditions. After finding the fatigue life cycle of the original digger arm, design changes were implemented to increase the fatigue life cycle. The following observations were made from the analysis.

- The fatigue life cycle of the digger arm observed for the original model of the digger arm from Goodman tool is 5420439 cycles.
- The fatigue life cycle of the digger arm observed for the modified model of the digger arm from Goodman tool is 9459459 cycles.
- It is observed that the fatigue life cycle is increased by 42.6% by implementing the design changes as mentioned above.

CONCLUSION

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.

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