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Weight reduction of Robotic Arm using topology optimization and Lattice Structure Technique in additive manufacturing

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Abstract: Robots are becoming essential for automation in every sector i.e. automobile, industrial and bio-medical applications. The current research is intended to optimize the mass of robotic arm component using techniques of lattice structure technique of additive manufacturing. The design and FEA analysis of robotic arm component is conducted using ANSYS simulation package. The incorporation of beam lattice structure has significantly reduced the mass of robotic arm component without much compromise in its strength. The percentage of mass reduction obtained from lattice structure design of robotic arm is 20.11%. The increase in equivalent stress with beam lattice design is 18.54%.

Key Words: Robots, Optimization, FEA

1. INTRODUCTION

In automobile industries, construction and many different manufacturing sectors, different types of robots are used having many human beings like functioning. These robots have a robotic arm that is different in shape, size, and function according to our needs. These robotics arms are very often like a human arm and operate in a different production piece of function. A robot is a structure that includes sensors, control systems, manipulators, power supplies and software's all working jointly to accomplish a work. Designing, building, programming and doing analysis of a robot is a combination of physics, engineering, mathematics, and computing. It's anthropomorphic or human-like functioning embraces few sensory pieces of equipment that are used to the interface and connect the device with the other part of devices to take effortless or essential judgment to run adequately.

2. LITERATURE REVIEW

D. Bassily et. al. [1] have worked on development of leap motion controller JACO robot arm having 6 DOF. The human machine interaction was improved using Leap Motion control algorithm. The use of this "interactive human robot has been discussed in relation to Ambient Assisted Living, where other operating conditions have been introduced"[1].

P. Adeeb Ahammed et. al. [2] have worked on the development of ATmega32 robotic arm using accelerometer. The robot was designed for picking of hazardous materials and relocating it. An upgraded design of robotic arm was also produced having 6 DOF's.

Mohammad Javed et. al. [3] have worked on the development of AT mega microcontroller robotic arm. The robotic arm developed was programmable to move along straight line and perform specific functions. The motion of user's arm is captured and repeated by the robot arm. The inbuilt potentiometers controlled the motion of servo motors driving the arm.

Piotr Kopniak et. al. [4] have worked on development of robotic arm with hydra controller. The tracker used in the analysis was Xsens Xbus Kit tracker and the tracker used to determine the precise location of robot to ensure proper arm movement.

Pedro Neto et. al. [5] have worked on development of industrial robot which was accelerometer based and incorporated the ANN algorithm. The ANN algorithm is used to detect arm movements and posture. The performance of robotic arm with ANN enhanced by 92%.

Matthew Finnie et. al. [6] have proposed the design of anthropomorphic arm arm control over LAN or online. The user can control the robot's arm remotely and access its sensory response signals. A robotic arm camera captures images and transmits them to the control station. The robot arm is controlled using a slave control system.

Shilpa Mehta et. al. [7] have worked on development of anthropomorphic 6-DOF robot arm which is easy to use and has visual-control. Single rotating axis was used with man machine interface system (MMI). The motion capture algorithm of MMI translated movement in to electric motor of arm.

Yasutaka Nishioka et. al. [8] have worked on development of rotating robot to be used for medical applications having 4 DOF's. The robotic arm was made of "breathable connectors, air bag actuators, and acrylonitrile butadiene styrene (ABS) joints" [8]. These materials are lighter in weight as compared to steel robots.

4. OBJECTIVE

The current research is intended to optimize the mass of robotic arm component using techniques of lattice structure of additive manufacturing. The design and FEA analysis of robotic arm component is conducted using ANSYS simulation package. The stresses, deformation are evaluated for each design type.

4. METHODOLOGY

The design of robotic assembly is imported in ANSYS design modeller as shown in figure 1 below. The initial design of robotic arm assembly was converted in .iges file format and then imported where it is checked for hard edges and surface imperfections.

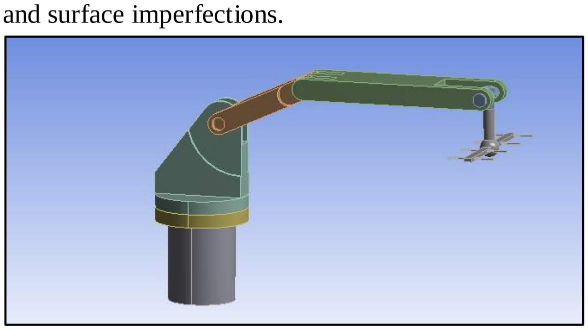

Figure 1: Robotic arm assembly design with arms

The robotic arm assembly is discretized using tetrahedral elements with adaptive shape function, normal inflation and 1.2 growth rate. The meshed model of robot assembly is shown in figure 2 below.

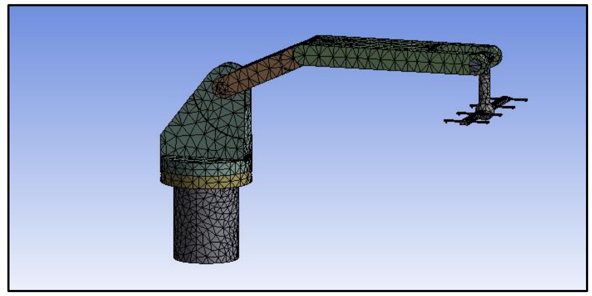

Figure 2: Meshed model of robotic arm assembly design with arms

The robotic arm assembly is applied with static loads and boundary conditions as shown in figure 3. The bottom face of cylinder is applied with fixed support and force of 40.507N is applied on arm manipulator. The standard earth gravity is also applied on the entire assembly.

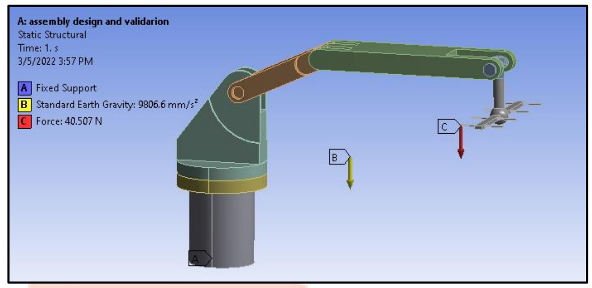

Figure 3: Loading conditions on robotic arm assembly design with arms

The robotic arm is independently analyzed from the reaction load determined in earlier step. The imported robotic arm is shown in figure 4 below and meshed model of robotic arm is shown in figure 5 below.

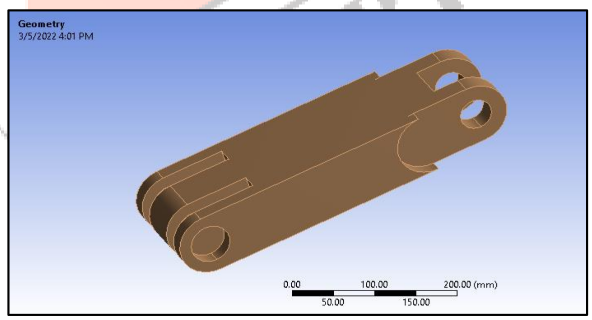

Figure 4: Robotic arm generic design

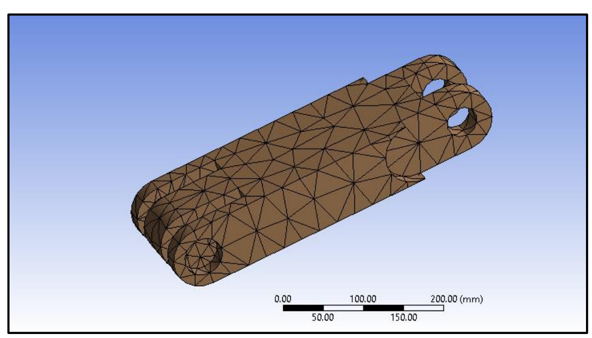

Figure 4: Robotic arm meshed model

The model is discretized with adaptive shape function, fine sizing and normal inflation. The number of elements generated is 2655 and number of nodes generated is 1348. The left face of robotic arm is applied with fixed support on cylindrical face and right face is applied with 328N load as shown in figure 5 below.

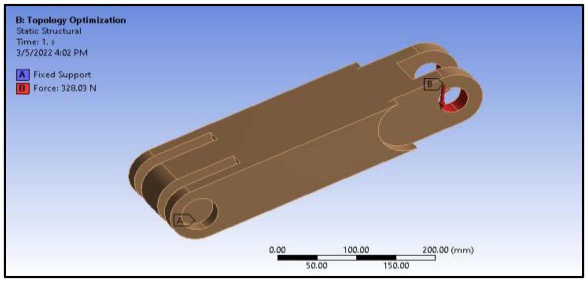

Figure 5: Loads and boundary condition on robotic arm

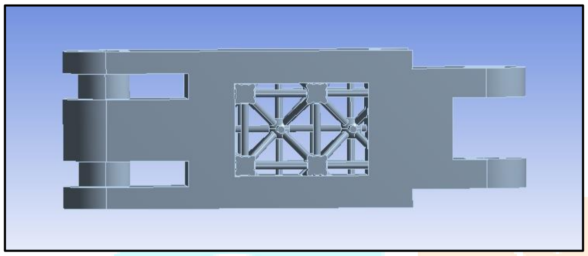

Figure 6: Beam lattice design of robotic arm

The beam lattice deign of robotic arm is developed in Creo design software. This design is imported in ANSYS design modeler as shown in figure 6 above. The lattice structure is developed at the center zone of arm. The lattice structure reduces the mass of robotic arm and is incorporated in location of center region.

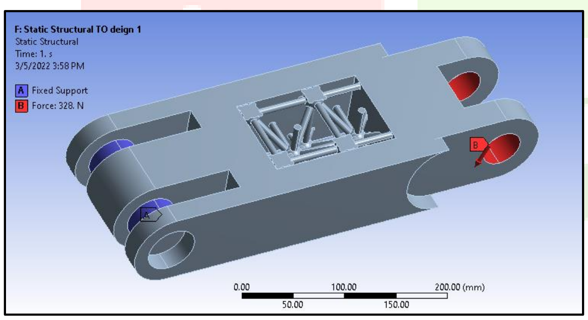

Figure 7: Applied boundary condition on robotic arm

The robotic arm is applied with fixed support on left cylindrical face and right end cylindrical face is applied with downward force of 328N as shown in figure 7 above.

5. RESULTS AND DISCUSSION

The FEA analysis is conducted on robotic arm assembly to determine stresses, deformation. The maximum equivalent stress is observed on arm 1 as shown in figure 8 below. The equivalent stress observed at this region is 1.0665MPa.

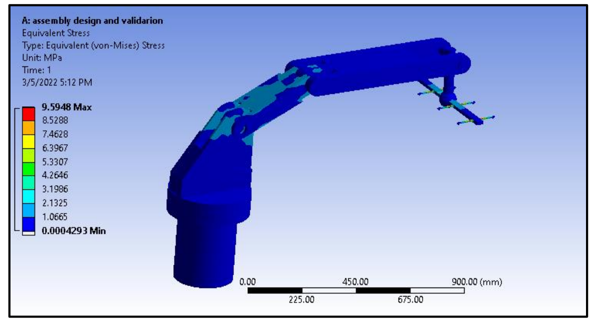

Figure 8: Equivalent stress on robotic arm assembly

As the center region of robotic arm has minimal stress and therefore it can be replaced with lattice structure in order to reduce the mass. The equivalent stress plot on robotic arm 1 is shown in figure 9 below.

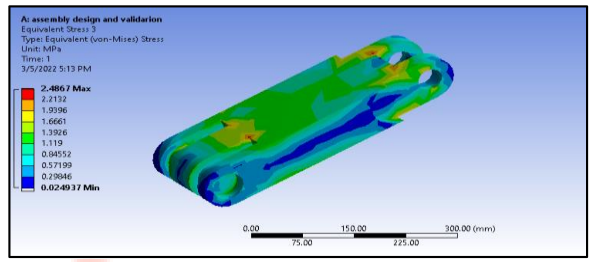

Figure 9: Equivalent stress on robotic arm (from assembly result)

The equivalent stress generated on robotic arm is shown in figure 9 above. The maximum equivalent stress is observed at the corners of arm and is shown in red colored zone with maximum magnitude of 2.48MPa.

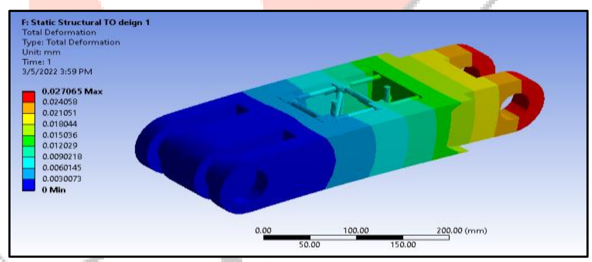

Figure 10: Total deformation of robotic arm with beam lattice

The maximum deformation in robotic arm is observed at the free end as shown in figure 10 above. The maximum deformation obtained for beam lattice design is .027mm.

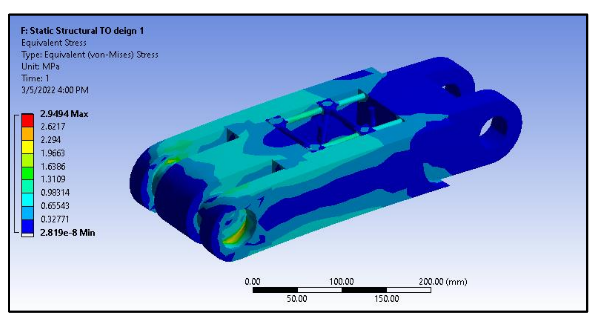

Figure 11: Equivalent stress of robotic arm with beam lattice

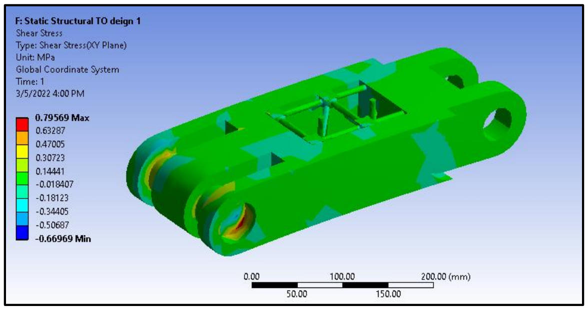

Figure 12: Shear stress of robotic arm with beam lattice

The equivalent stress and shear stress generated on robotic arm with beam lattice is shown in figure 11 and figure 12 above. The maximum equivalent stress is obtained on circular cut out region of robotic arm with magnitude of more than 2.62MPa. The maximum shear stress obtained from the analysis of robotic arm with beam lattice is .632MPa.

Generic design of arm = 2.48

Beam lattice design mass = 2.94

6. CONCLUSION

The use of computer simulation FEA package is viable tool in determining structural characteristics of robotic arm assembly and robotic arm component. The incorporation of beam lattice structure can significantly reduce the mass of robotic arm component without much compromise in its strength. The percentage of mass reduction obtained from lattice structure design of robotic arm is 20.11%. The increase in equivalent stress with beam lattice design is 18.54%.

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