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# Using Additive Manufacturing Technique for Topological Optimization of JCB ARM

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***Abstract:*** The JCB arm is one of the vital components used for lifting of heavy materials. The mass reduction is one of the important criteria for improving design of components. The objective of current research is to reduce the mass of JCB arm using topology optimization technique of additive manufacturing. The JCB design is developed in Creo design software and FE simulation on arm is conducted using ANSYS software. With reduction of JCB arm mass, the equivalent stress increased by nearly 140MPa. There is slight reduction in deformation with topology optimized design of JCB arm. The topology optimized design of arm has .01mm lower deformation value as compared to generic design.

**Keywords:** JCB arm, FEA, Topological Optimization

## I. INTRODUCTION

The first form of creating layer by layer a three-dimensional object using computer-aided design (CAD) was rapid prototyping, developed in the 1980's for creating models and prototype parts. This technology was created to help the realization of what engineers have in mind. Rapid prototyping is one of the earlier additive manufacturing (AM) processes. It allows for the creation of printed parts, not just models. Among the major advances that this process presented to product development are the time and cost reduction, human interaction, and consequently the product development cycle [1], also the possibility to create almost any shape that could be very difficult to machine. However, at the present time it is not yet adopted in the manufacturing sector, but scientists, medical doctors, students and professors, market researchers, and artists use it [2–4]. With rapid prototyping, scientists and students can rapidly build and analyze models for theoretical comprehension and studies. Doctors can build a model of a damaged body to analyze it and plan better the procedure, market researchers can see what people think of a particular new product, and rapid prototyping makes it easier for artists to explore their creativity.

## II. LITERATURE REVIEW

Bhaveshkumar P. Patel, Jagdish M. Prajapati[5] have conducted numerical investigation on Backhoe loader using techniques of Finite Element Analysis. The shape of loader is optimized for mass reduction. The research findings have shown that 3.9% of weight can be reduced while keeping the stress within the safe limits.

Bhaveshkumar P. Patel and J. M. Prajapati[6] have conducted design optimization of backhoe excavator attachment. The research findings would pave the way for future research is design and material optimization of JCB arm attachment.

Sachin B. Bende, Nilesh P. Awate[7] have conducted FE simulation studies on JCB excavator. The problems of lifting and digging identified using CAD/CAE system. The critical regions of high torsional and bending stresses are determined along with digging force.

Gaurav K Mehta, V.R.Iyer, Jatin Dave[8] have conducted static structural analysis of excavator arm subjected to different operating conditions. The stresses generated on arm under maximum diffing force are evaluated using techniques of FEA. The simulation results have shown that the stresses generated on bucket, arm, and boom are well within safe limits.

R M Dhawale and S R Wagh[9] have conducted numerical investigation of excavator arm subjected to 3 dimensional loading conditions. The analysis is conducted with increased bucket volume to increase amount of material fed in the bucket.

Shilpa D. Chumbale Prasad P. Mahajan[10] have conducted ANSYS FEA simulation on excavator arm linkage to evaluate stresses and deformation at existing digging force and also at newly calculated digging force. The second case of analysis is conducted on bucket fully filled with material and comparison is made with first case.

Gui Ju-Zhang, Cai Yuan-Xiao, Qing-Tan and You Yu-Mo [11] have conducted static structural analysis of excavator boom using ANSYS FEA simulation software. The stress and strain values are determined for 3 different loading/working conditions. The study results are of certain guiding significance for working device's optimization design.

## III. PROPOSED WORK

The objective of current research is to reduce the mass of JCB arm using topology optimization technique of additive manufacturing. The JCB design is developed in Creo design software and FE simulation on arm is conducted using ANSYS software.

## IV. METHODOLOGY

The JCB arm design is developed in Creo software using sketch and extrude tool. The 3D parametric model of JCB arm is fully solid structure which is subjected to static structural analysis. The JCB design is shown in figure 1 below.

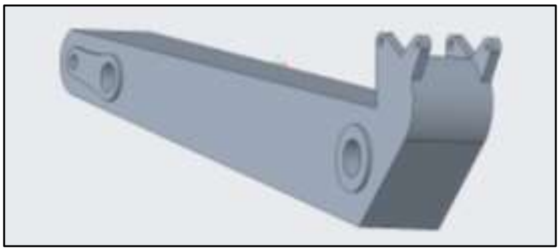

Figure 1: JCB design in Creo

The JCB design is discretized with medium sizing and normal inflation. The growth rate is set to 1.2 and smoothing set to medium. The JCB model is discretized using tetrahedral element type as shown in figure 2 below.

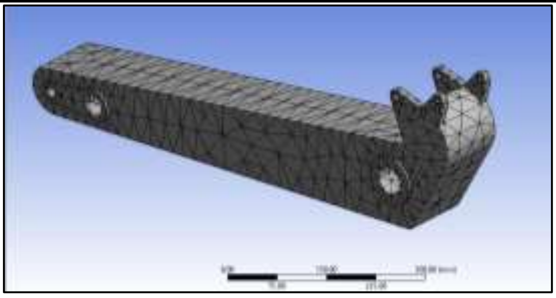

Figure 2: JCB discretized model

The structural loads and boundary conditions are applied on JCB model as shown in figure 3 below. The displacement support and loads are applied as shown in red colored region.

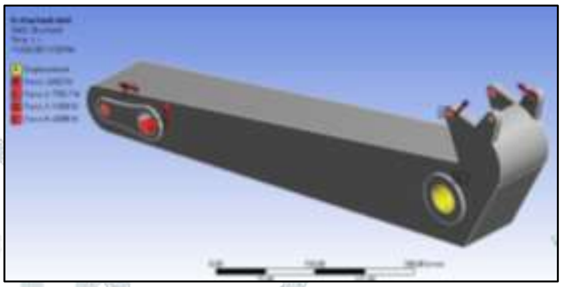

Figure 3: Loads and boundary condition

The topological optimization of JCB arm is conducted. The mass density plot is generated with 50% mass retention as shown in figure 4 below.

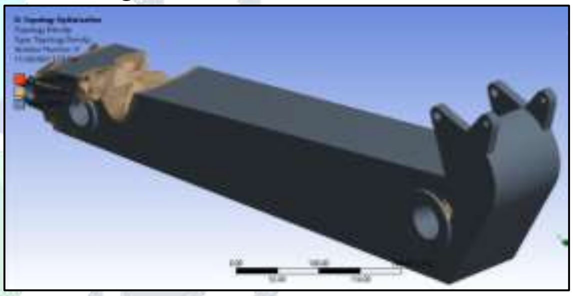

Figure 4: Topology Optimized design

The mass removal zone of JCB arm is observed near the frontal displacement support cylindrical region. The mass removal region is shown in dark brown colour. The structural analysis is conducted on JCB arm topologically optimized design is then conducted.

## V. RESULTS AND DISCUSSION

The static structural analysis results are obtained from the FE simulation of generic and topologically optimized design of JCB arm. The equivalent stress plot of generic design is shown in figure 5 below.

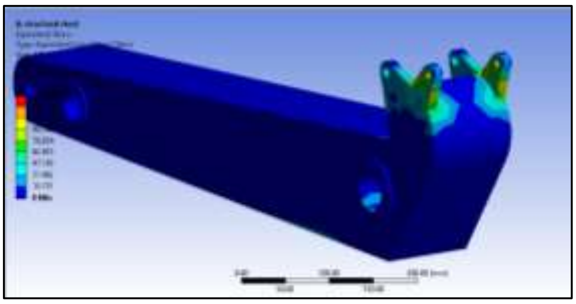

Figure 5: Eq. stress plot of generic design

The equivalent stress plot shows maximum value at the support regions of the arm. The equivalent stress obtained from the analysis is more than 125.8 MPa. The stress on other regions is minimal. The deformation plot is also obtained from the analysis as shown in figure 6 below.

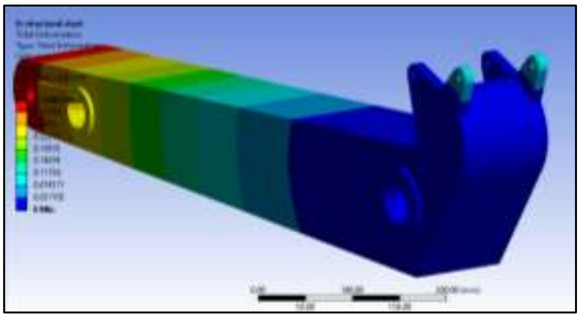

Figure 6: Total deformation plot of generic design

The maximum deformation is observed at the free end of JCB arm. The magnitude of maximum deformation obtained from the analysis is more than .29mm.

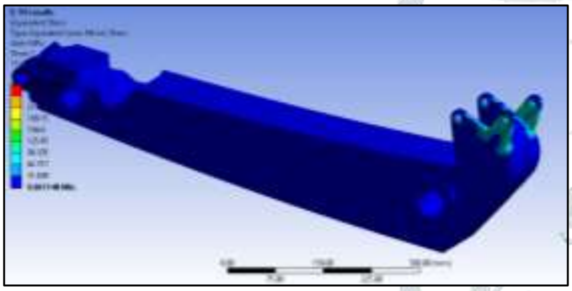

Figure 7: Eq. stress plot of topology optimized design

The equivalent stress plot is generated for topologically optimized design as shown in figure 7 above. The plot shows higher stress at the support region of topologically optimized design with magnitude of more than 250.8MPa.

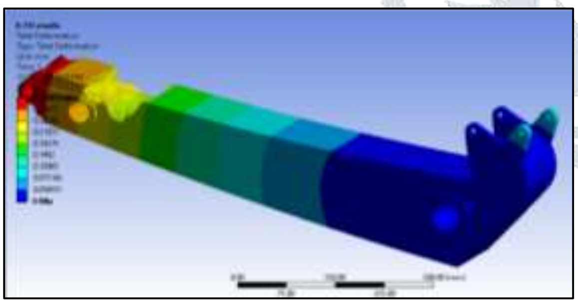

Figure 8: Total deformation plot of topology optimized design

The maximum deformation plot is obtained for topology optimization design of JCB arm as shown in figure 8 above. The plot shows maximum deformation at the free end of arm. The deformation obtained is higher than .292mm.

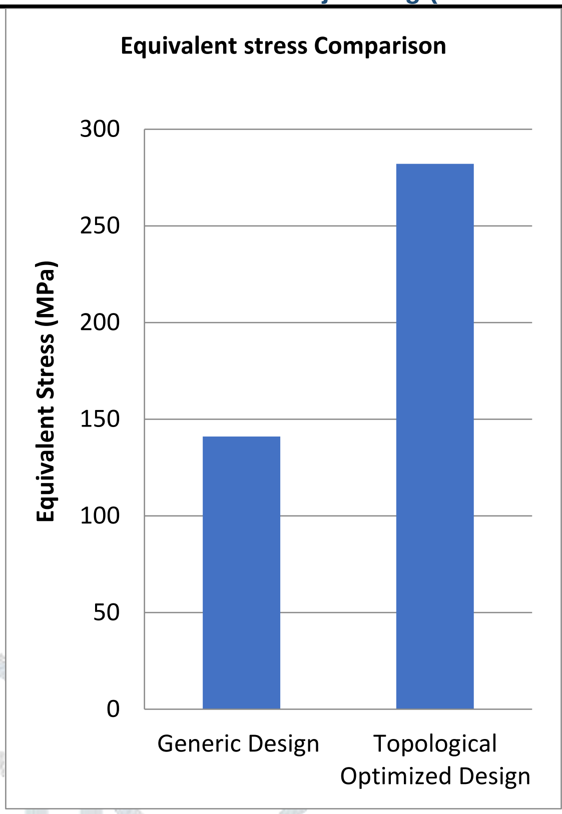


Figure 9: Equivalent Stress Comparison

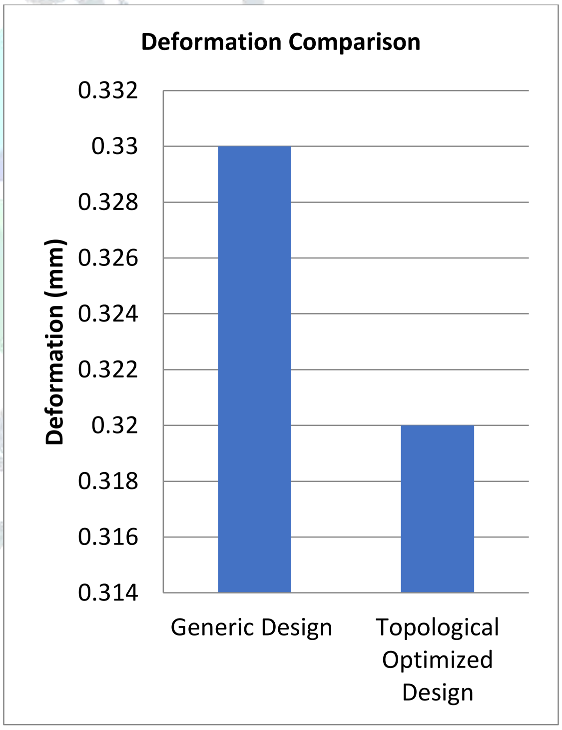


Figure 10: Deformation Comparison plot

The equivalent stress comparison plot and deformation comparison plot is shown in figure 9 and figure 10 above. With reduction of JCB arm mass, the equivalent stress increased by nearly 140MPa. There is slight reduction in deformation with topology optimized design of JCB arm. The topology optimized design of arm has .01mm lower deformation value as compared to generic design.

## VI. CONCLUSION

The use of topology optimization technique of additive manufacturing can significantly reduce the mass of JCB arm. With reduction of JCB arm mass, the equivalent stress increased by nearly 140MPa. There is slight reduction in deformation with topology optimized design of JCB arm. The topology optimized design of arm has .01mm lower deformation value as compared to generic design.

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