DESIGN-INFORMED STRUCTURAL OPTIMISATION

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Structural optimisation has become an important tool in the field of Civil Engineering, but there is limited research done on structural optimisation of specific structures and components, especially for large construction machinery. By optimising construction machinery components, it is possible to reduce the material usage and decrease the cost of the machine, without compromising its strength.

This research study looks at a case study of optimising a wheel loader arm. Initially, the critical load calculation and the static force analysis of the wheel loader arm were conducted and the forces and reactions acting on the arm were obtained. Then a finite element analysis was conducted by assigning the relevant loads and boundary conditions and the results obtained deemed that the stresses and displacements of the arm were within the acceptable limits.

The Solid Isotropic Microstructure with Penalisation (SIMP) for intermediate densities method is used for the topology optimisation process considering the minimum compliance as the objective function and the volume fraction as the constraint. Using the Abaqus FEA software, topology optimisation models were obtained for different volume fractions and the most optimum geometry comparing maximum von Mises stress, displacement, and mass with the original design. After the completion of the topology optimisation process, Computer-Aided Design models are generated by exporting the mesh into SOLIDWORKS. Subsequently, shape optimisation is conducted considering the different manufacturing constraints.

The final optimised model has a 20.3% reduction of mass compared to the original structure, while stresses, displacement and strains are kept within the allowable limits in accordance with codes of practice.

This case study demonstrates on how structural optimisation can be integrated into the designs of different structures and components. By using a similar method, it is possible to optimise different components of the wheel loader arm and other construction machinery components. These optimisations will reduce the weight and material usage of these components, which can help reduce the overall cost of the machines significantly.

Keywords: Topology optimisation, Shape optimisation, Finite Element Analysis, SIMPmethod, Wheel loader arm

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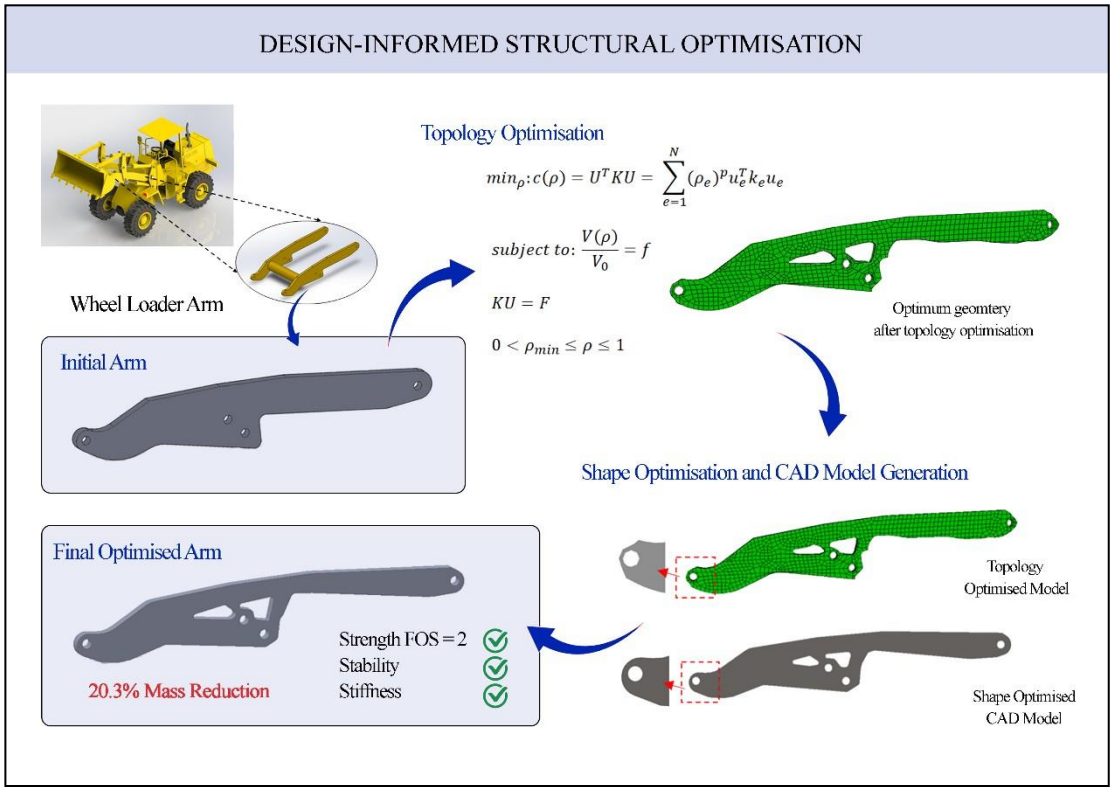
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Wheel Loader Arm
Topology Optimisation
$min_\rho: c(\rho) = U^T KU = \sum_{e=1}^{N} (\rho_e)^p u_e^T k_e u_e$
$subject\ to: \frac{V(\rho)}{V_0} = f$
$KU = F$
$0 < \rho_{min} \leq \rho \leq 1$
Optimum geomtery after topology optimisation
Initial Arm
Shape Optimisation and CAD Model Generation
Topology Optimised Model
Shape Optimised CAD Model
Final Optimised Arm
20.3% Mass Reduction
Strength FOS = 2
Stability
Stiffness