•Expansion of the thermal-mechanical AM analysis framework to accommodate multi-material additive manufacturing processes.

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Mechanical CAD Design for Next-generation Aerospace Structural Systems Using Advanced Material Additive Manufacturing Technology

Helal Uddin[1(a)] , Md. Nur Alam Mondal[2(a)]

[a] Department of Mechanical Engineering, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh.

INTRODUCTION & AIM

The next-generation aerospace platforms require structural systems with very high strength-to-weight ratios and a reduced number of parts. The Traditional subtractive manufacturing constrains the geometrical complexity. Although additive manufacturing (AM) proposes solutions with the help of new materials (titanium alloys), the existing trends in mechanical CAD do not fully utilize the potential of AM. The result of this disconnect can frequently be uncontrolled thermal distortion, anisotropic characteristics, and non-economical component costs. To create an original, combined CAD-based Design for Additive manufacture (DFAM) framework that directly correlates the functional demands of a component with the material behavior and machine condition.

METHOD

This approach combines design intent, material science, and AM physics via a continuous digital throughput:

Topology Optimization: Topology Optimization Aerospace load cases are then used with AM-specific constraints, including minimum feature size and optimal build orientation.

Structural Validation: To verify that the optimized geometry has aerospace functional requirements, Finite Element Analysis (FEA) can be used.

FEA and Mechanical Analysis: A pre-fabrication simulation is run to predict thermal distortion as well as to reduce residual stresses.

Direct CAD Mitigation: Intelligent precautionary defect-reduction measures are hard-coded in the finished CAD models before manufacture.

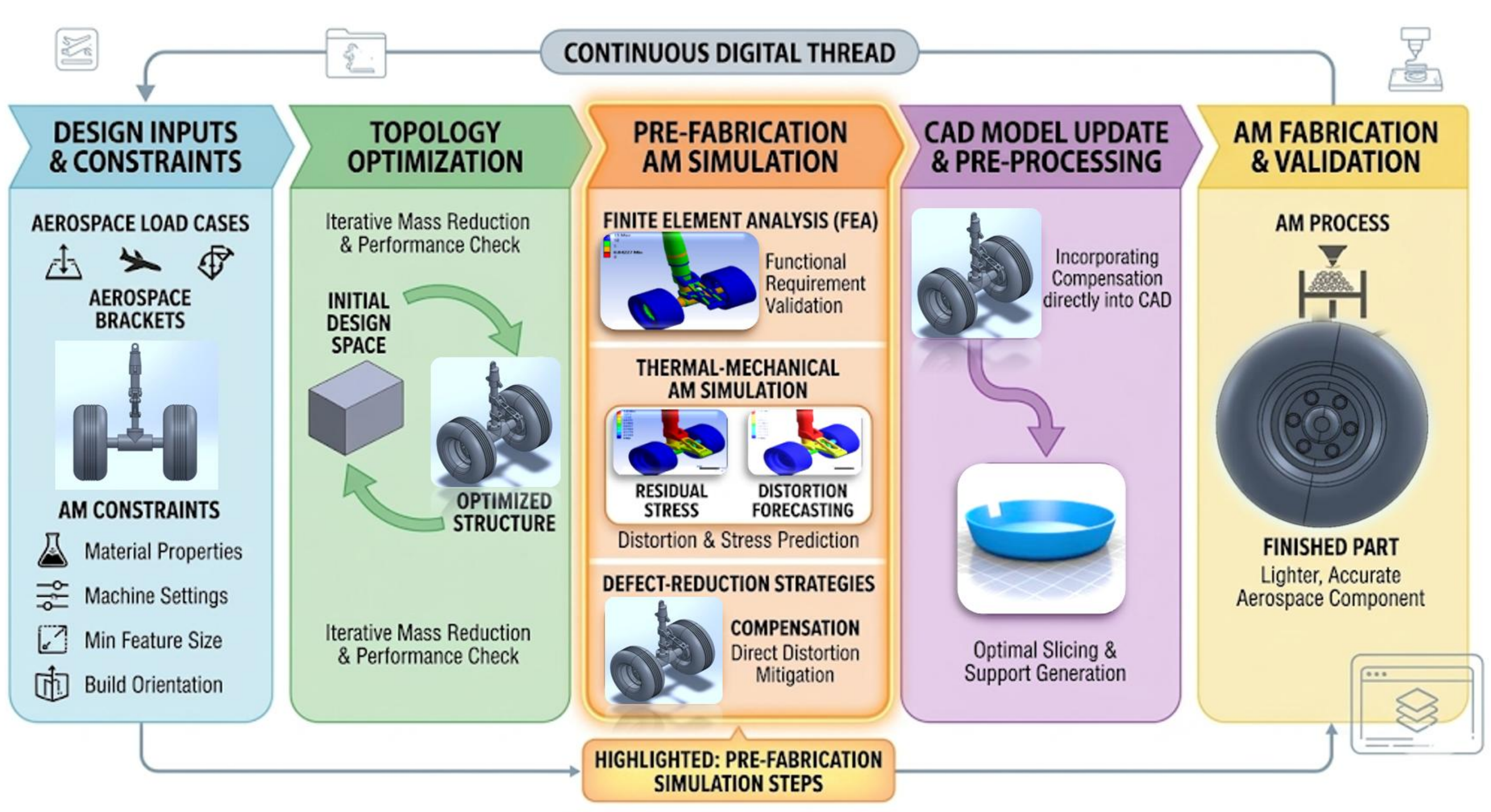

Fig.1. Proposed integrated CAD-DFAM workflow highlighting the pre-fabrication simulation steps.

RESULTS & DISCUSSION

Aerospace demonstration parts applied to the CAD-DFAM framework achieved significant performance and manufacturability improvements.

Mass Reduction: Mass reduction was (on average) **34-38%** of that of a fresh set of initial baseline designs, optimized based on topology.
Distortion Mitigation: Third, post-build thermal distortion was eliminated by **82%** by including the compensation plans in the CAD models.

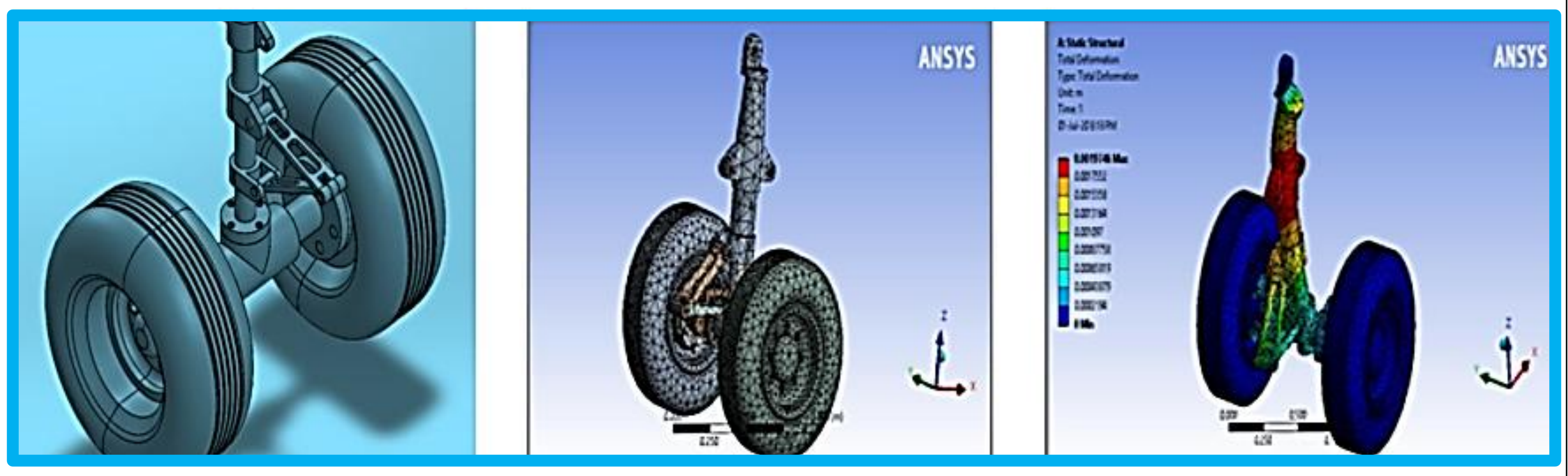

Fig.2. Thermal-mechanical simulation forecasting residual stress and distortion in the aerospace component.

Table 1. Performance and Manufacturing Metrics of the CAD-DFAM Framework.

Evaluation Metric	Baseline CAD Design	DFAM Optimized Design	Net Improvement
Component Mass	100% (Reference)	62% - 66%	34% - 38% Reduction
Post-Build Distortion	High (Unmitigated)	Low (Compensated)	82% Reduction

CONCLUSION

This study effectively created a complete set of CAD-based DFAM frameworks, correlating functional requirements to the Additive Manufacturing process physics. With pre-fabrication simulation and topology optimization, the average component mass was reduced by **34-38%,** and post-build distortion was minimized by **82%.** The method offers a tested and proven weight-reduction/precision technique for aerospace structural systems.

FUTURE WORK / REFERENCES

Physical construction and mechanical test of the optimized aerospace components under simulated flight loads. A thermal-mechanical AM Analysis Framework Expansion The thermal-mechanical AM analysis framework to support multi-material additive manufacturing processes.

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[2]. Misiun, G., van de Ven, E., Langelaar, M., Geijselaers, H., van Keulen, F., van den Boogaard, T., & Ayas, C. (2021). Topology optimization for additive manufacturing with distortion constraints. *Computer methods in applied mechanics and engineering*, *386*, 114095.