Thermo-Mechanical Modeling and Analysis for Turbopump Assemblies

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Concepts NREC

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Outline

- Technical Need
- Project Goals
- Technical Approach
- Development Status
- Conclusion
Project Support

- NASA SBIR, through TD61
- Spin-off to IHPRPT
- Spin-off to industry
Technical Need

- Life, reliability, and cost are strongly impacted by steady and transient thermo-mechanical effects
- Design cycle can suffer big setbacks when working a transient stress / deflection issue
- Balance between objectives and constraints is always difficult
- Requires assembly-level analysis early in the design cycle
Technical Need – Operating Point

Temperature
Absolute temperature limits and thermal gradient limitations

Displacement
Critical clearances, fits, and gaps

Stress
Stress margins, LCF life, HCF margin, preloads

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Technical Need - Transient

Graph showing stress and temperature over time for different elements and nodes.
Project Goals

- Develop thermo-mechanical modeling software tools
  - Push thermo-mechanical modeling earlier in the design process
  - Reduce cost and risk of designs
  - Improve life and reliability of propulsion systems
- Integrate existing tools
  - Improve the design process
  - Open system for 3rd party software
Technical Approach

- Design data and results flow from component analysis tools to the assembly model
- Software operates in a collaborative environment
  - Data-centric approach to multi-disciplinary analysis
  - XML provides flexible open data format
- Integrate with CAD data
  - Parasolid kernel
- Integrate with multi-disciplinary optimizer
Data Flow to Assembly

Meanline

3D Blading & CFD

Stress & Vibration

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Data-Centric Organization

Native CAD Files

XML Data Set
- Flow Options
- Fluid Type
- Geometry
- Blades
- Disks
- Shaft
- Bearings
- Materials
- Cost Options
- Life Options
- Machining

Measline

Blading & throughflow

CFD

Stress & vibration

Assembly thermo-mechanics

3rd Party Applications

DFM-DFA-DFE

Engineous

Agile Framework
- Coordination between analysis codes
- Assembly & System Optimization

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Flexible, recursive data tree stores geometry, modeling parameters, and results from different disciplines.

XML provides robust open technology for data sharing.

- Format is self-descriptive and self-checking
- Growing supply of XML tools for C++, Java, Perl, Python
CAD Integration

- Import/export of CAD files can be time consuming and error prone.
- Individual tools can become segregated from design data flow (more time lost in the design cycle).
- Using Parasolid geometry kernel from EDS Unigraphics:
  - Robust geometry functions for curves, surfaces, volumes
  - Read native files from Unigraphics
  - Use IGES for other CAD systems
Multi-Disciplinary Optimization

Quasi-3D aero model

Solid FEA model

MDO Loop 1

Initial Geometry

MDO Loop 2

Optimized results

Stress

Weight

Optimal Design Boundary

Unachievable

Streamline curvature

Aero performance

Meshing

Cosmos

Blade stress & frequency

Back-face shape

Meshing

Cosmos

Bore stress

Quasi-3D FEA model
Conclusion

- Software tool integration will push thermo-mechanical modeling upstream in the design process
- Open format data-centric approach has many advantages for sharing design data and results
- CAD integration provides a crucial link the the design process
- Software integration enables automated multi-disciplinary design trades