Integrated Turbopump Thermo-Mechanical Design and Analysis Tools

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Summary

- Steady and transient thermo-mechanical effects drive life, reliability, and cost
- Design cycle needs upfront consideration of:
  - fits, clearance, preload
  - cooling requirements
  - stress levels, LCF limits, HCF margin
- Data synthesis is needed from component design tools
Turbomachinery Designers and Test Engineers

Compressor, Pump, and Turbine Meanline (Quasi-2D) Design Optimization:
- COMPAL, PUMPAL, RITAL, AXIAL

3D Geometry Generation and Throughflow Analysis
- CCAD
- AXCAD

Product Development System
- "Virtual Laboratory":
  - CFD Studies Supporting the Physical Lab

Laboratory Testing for Component Development
- Pneumatic
- Laser
- Hot Film
- Thermal
- Structural
- Time Dependent

Rapid Prototyping
- Stereo Lithography
- Sintered Casting Cores

Numerical Machining
- Ruled Surfaces
- Strip Milling
- Arbitrary Surface

Computer Aided Drafting (CAD) and Solid Modeling (SM)
- Solid Edge
- AutoCAD Mechanical Desktop
- Pro-Engineer
- SDRC I-DEAS
- Catia, and Others

System Issues
- Gears
- Motors
- Generators
- Cooling

Rotor Dynamics
- Seals
- Bearings
- Critical Speeds
- Unbalance Response
- Forced Response

CFD Preprocessing
- Pushbutton CFD FINE/TURBO

CFD Postprocessing
- Pushbutton CFD FINE/TURBO

CFD Postprocessing
- Pushbutton CFD FINE/TURBO

Computational Fluid Dynamics (CFD) Design Optimization
- Pushbutton CFD FINE/TURBO

Finite Element Analysis (FEA) Preprocessor
- STRESSPREP
- AXISTRESS

3D FEA for Stress and Vibration Analysis
- COSMOS™
- ANSYS™
- NASTRAN™

Rapid Prototyping
- Stereo Lithography
- Sintered Casting Cores

Semi-Automated Comparison of Design Intent to Tested Design

"Synthesis":
- "Virtual Laboratory":
  - CFD Studies Supporting the Physical Lab

Supporting the Laboratory:
- ”Virtual CFD Studies”

Design Optimization:
- Full Performance Curves
- Data Reduction and Comparison

Pushbutton CFD FINE/TURBO
- Life Evaluation
- Campbell Diagram
- Interference Diagram
- Critical Speeds
- Seals
- Bearings
- Critical Speeds
- Unbalance Response
- Forced Response

Rapid Loading Calculations
- Quasi 3D Flow Calculations

Ruled Surfaces Development
- Hot Film Dependent
- Thermal Structural Time

“Synthesis”:
- CFD Studies Supporting the Physical Lab

Existing Designs
- Reverse Engineer
- Existing Designs

“Synthesis”:
- Semi-Automated Comparison of Design Intent to Tested Design

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Semi-Automated Comparison of Design Intent to Tested Design

"Synthesis":
- "Virtual CFD Studies"
SBIR Tool Development

- Use LNG turbopump design during feasibility study
  - 630 gpm at 29.6 krpm
  - 37 lbm/s

- Utilize existing component analysis tools to drive assembly models

- Integration into collaborative environment, not just interfacing separate tools
Current Design System

- Meanline
- 3D Blading & CFD
- Stress & Vibration

- Captures blade and disk stress, vibration, thermals
- Misses radial and axial preload effects, thermal conduction through bore
Current Design System

Meanline

3D Blading & CFD

Stress & Vibration

- Captures blade and disk stress, vibration, thermals
- Misses radial and axial preload effects, seal interaction, bore conduction
Current Design System

• Captures nominal bearing, seal, and shaft design
• Misses radial and axial preload effects
Thermo-Mechanical Design Tools

- Utilize data from component design tools
  - Rotor, shaft, housing geometry
  - Primary flow from pump and turbine
  - Internal cooling flow
  - Bearing, seal, and shaft design
Thermo-Mechanical Design Tools

- Temperature, stress, deflection
- Blade clearance, seal clearance, bearing race interference
- Thrust load, bearing preload
- Rotor clamp loads, shaft torque
- Stress results feed probabilistic models
Life & Confidence Goals

Fixed Confidence Level

Fixed Number of Cycles
Typical Transient Results
Goals for Design Tool Integration

• Collaborative working environment
• Integrate with existing component design and analysis tools
• Direct data sharing, including CAD files
• Extensible to other solvers and applications
• Preserve intellectual property
Integration with CAD Kernel

• Consistent and open data format
• Combine geometry and analytical results
• Direct support for native CAD files
Design Tool Integration

Parasolid Database
- Flow Options
- Fluid Type
- Geometry
- Blades
- Disks
- Shaft
- Bearings
- Materials
- Cost Options
- Life Options
- Machining

OLE

Meanline

OLE

Blading & throughflow

OLE

CFD

OLE

Stress & vibration

OLE

Assembly thermo-mechanics

OLE

Application X

OLE

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

TFAWS 01 Integrated Thermo-Mechanical Tools Concepts NREC
Integration with Parasolid Data

Parasolid Database

DLL

CNREC Parasolid geometry and attributes

Shared data structure or POD

3rd Party routines to work with application

3rd Party Application

access geometry directly

Parasolid geometry and attributes

Shared data structure or POD

3rd Party routines to work with application

access geometry directly

Parasolid Database

DLL
Integration with Design Framework

OLE
- File open
- File save
- Refresh from file
- Manufacturability metrics
- Cost metrics
- Weight

Application X

Agile Framework

TFAWS 01 Integrated Thermo-Mechanical Tools Concepts NREC
Conclusions

• Thermo-mechanical analysis tool provides upfront design capability
• Existing component design tools are effectively leveraged
• Dual-use capability will give a broad user base
• Parasolid kernel allows collaboration with a wide applications base