1ST IRAN COMPRESSOR CONFERENCE

5 July 2017, Tehran, Iran

Contents

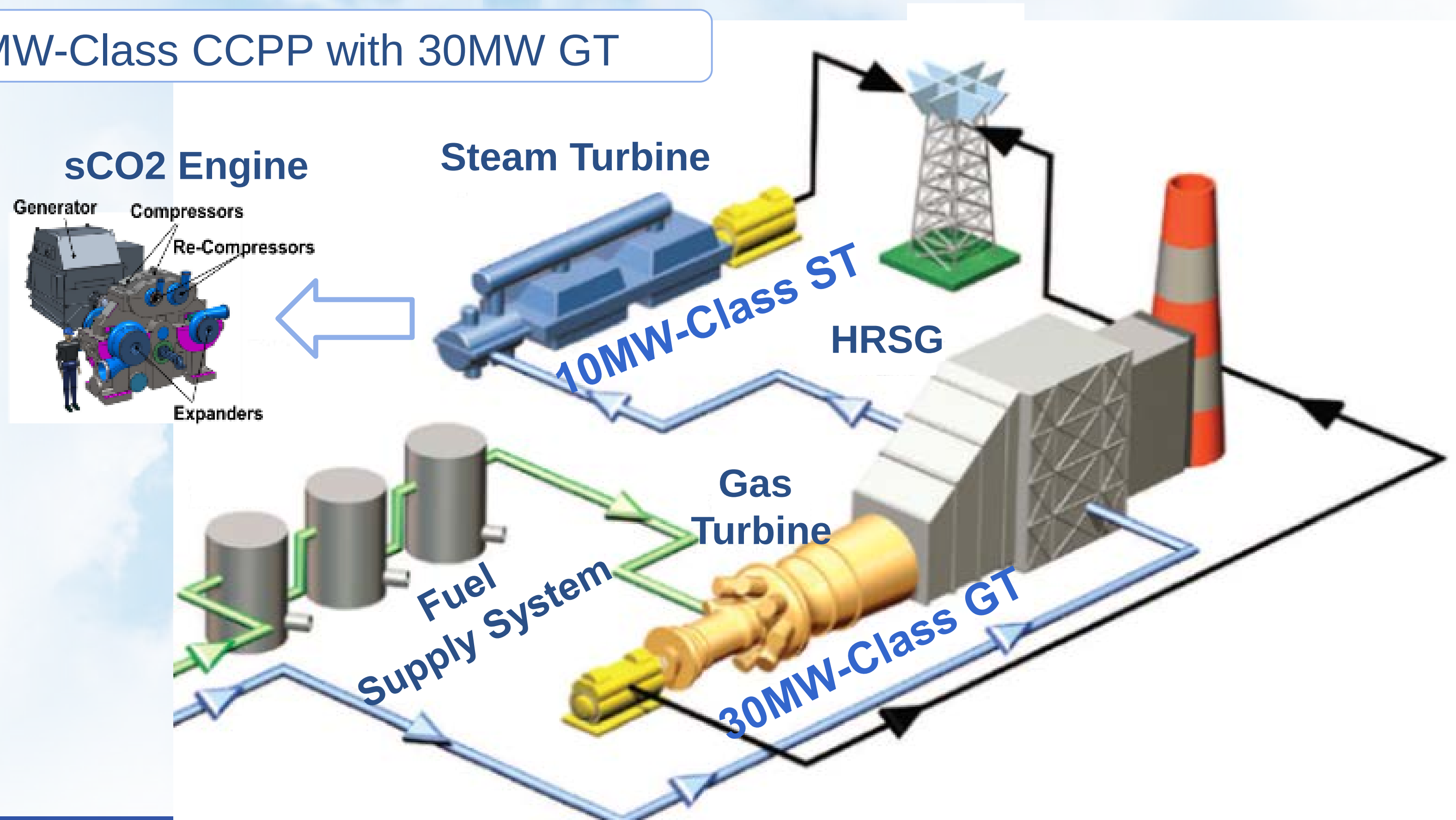
1. sCO_2 (Supercritical CO_2) Engine

New Power Generation System with sCO2 engine

Disruptive Innovation

Innovative power generation system that can replace conventional steam turbines

40MW-Class CCPP with 30MW GT

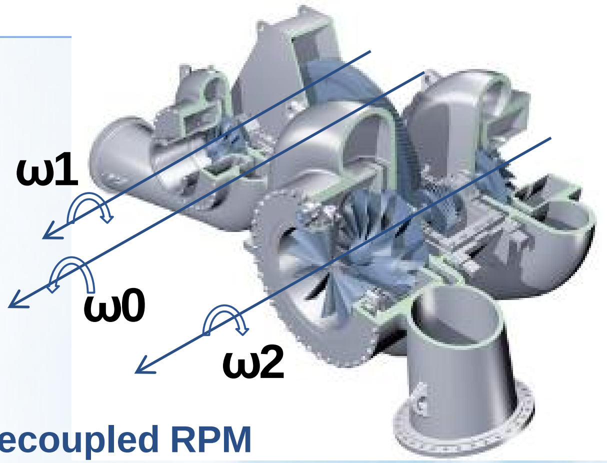


Key Features of sCO2 Engine

DOE[1] : "Thinking Out of the Box" Concept !!

Integrally geared type: High efficiency, Compact Size, Flexible, Modular

Integrally Geared Concept



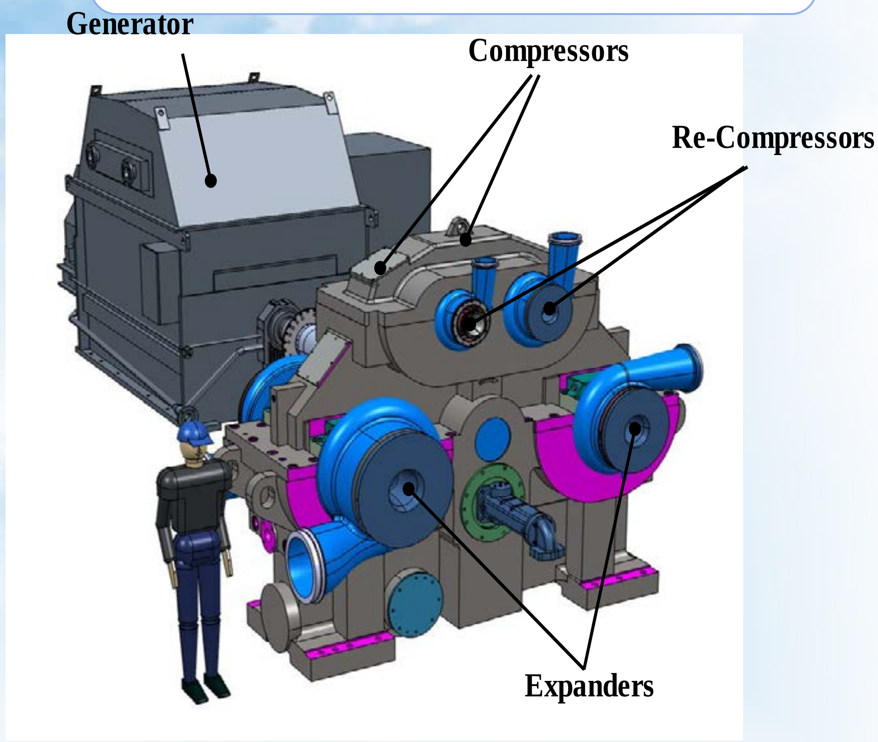
Decoupled RPM
Higher Component Efficiency

Easy Inter-cooling, Re-heating Power
Better Cycle Efficiency generation

IGV, DGV
Flexible Operation

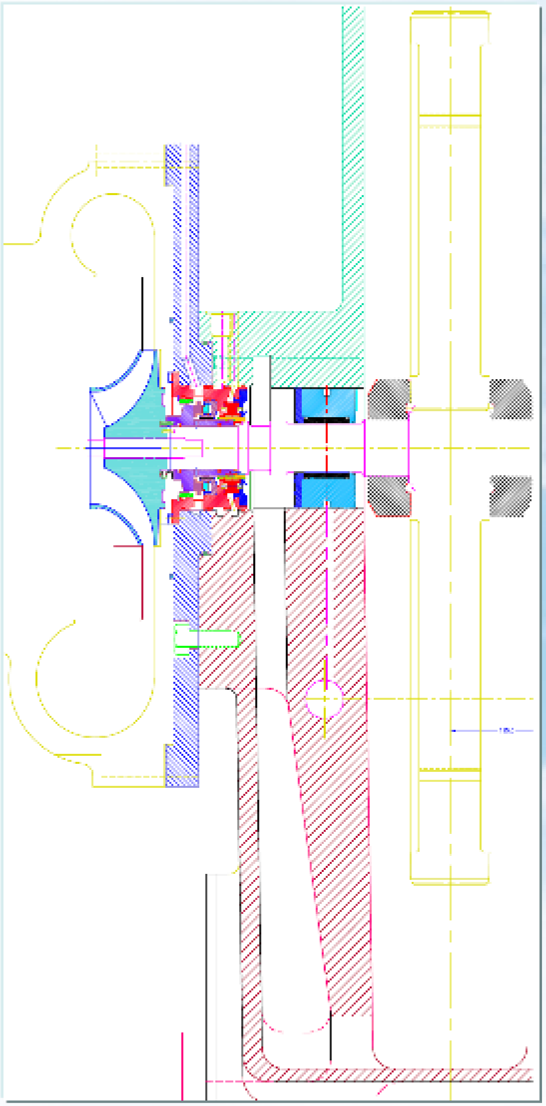
1) DOE: Department of Energy

Proposed Concept
for DOE Sunshot Project



2. Compressor Design Process

Engineered Compressor Design Process



1 – Selection Tool

Aero-structural design begins with proven designs that are scaled to meet each application.

Tested design reduces risk of low performance

2 - Parts Bin

Limits are defined to reduce risk.

Standard: gear box, pinion, bearing, shaft, seals, gears,… reduce development time and iteration

3 – Detailed Analysis

Detailed analyses confirm design integrity

Parametric models used to decrease Manufacturing drawing effort

4 – Manufacturing Drawings

Engineered Compressor Design Philosophy

Master Set of Components

- Flow path components.
- Allows for scaling design over range of size and applications.
- Allows ability to ensure excellent performance without extensive testing.

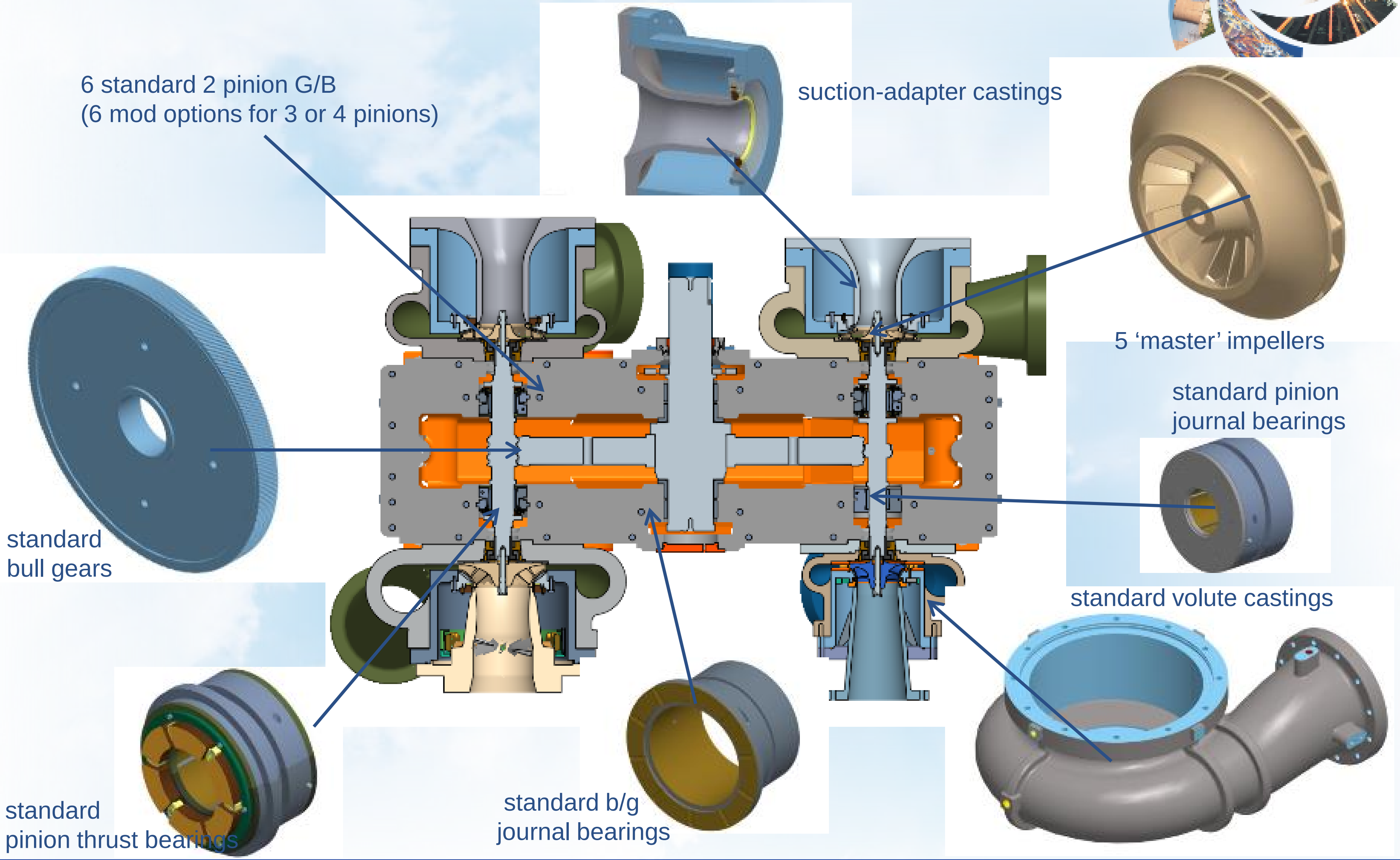
Standardized Set of Components

- Mechanical Components.
- Allows for an expedited design process.
- Allows ability to adapt in service machinery for changing operational needs.

Custom Integration between ‘Master’ and ‘Standard’ Parts

- Allows for ability to match wide range of applications.
- Requires engineering effort to ‘match’ appropriately.
- Yields best design and offers an approach where proven new technologies can be integrated in products.

Basic Design Premise – Starts from Parts



3. Compressor Core Development

- Efficiency & Reliability

Core Development Technology

Improvement of On-Design Performance

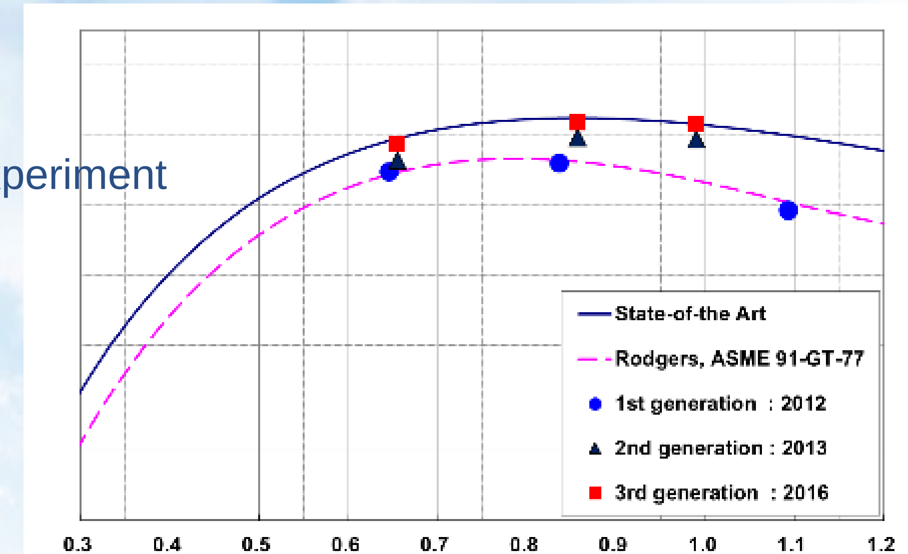
□ Improvement of Master Impeller

- Continuous effort to increase efficiency of master impeller

[Master Impellers]

□ Methodology

- Improved by numerical analysis and experiment
- Completed test for new design



[Improved efficiency of Master Impellers]

Core Technology Development

Air-End Component Test rig

- Dedicated component test facility
- Rig design and instrumentation designed to be ASME PTC-10 compliant
- Measurements of a full range of internal pressures and temperatures are possible
- Performance test of full stages and individual components
  - Vaned and vaneless diffusers
  - IGV performance
  - Volutes

Core Technology Development

Improvement of Off-Design Performance (1)

□ Issue for Off-design performance

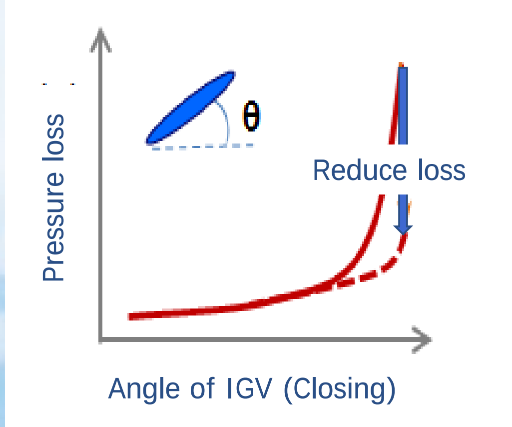
- Off-design performance was recommended to be improved by customer.

□ Performed CFD Optimization

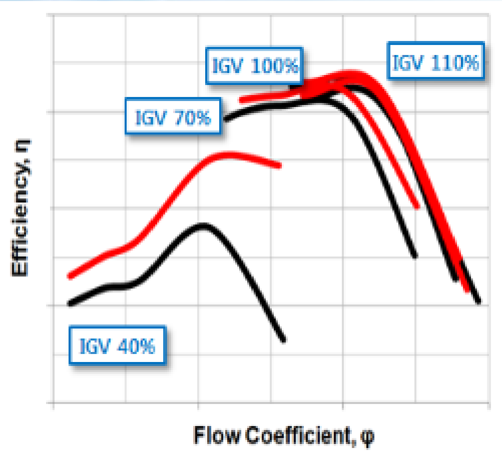
- Cost function was set to minimize pressure loss.

□ Technical Improvement

- Define losses generated at IGV
- Introduce the optimization design process
  . Optimize IGV vane shape
  . Minimize tip clearance
- on going IGV test



- Optimal Model - Base Model



[Optimized IGV Performance - CFD]

Core Technology Development

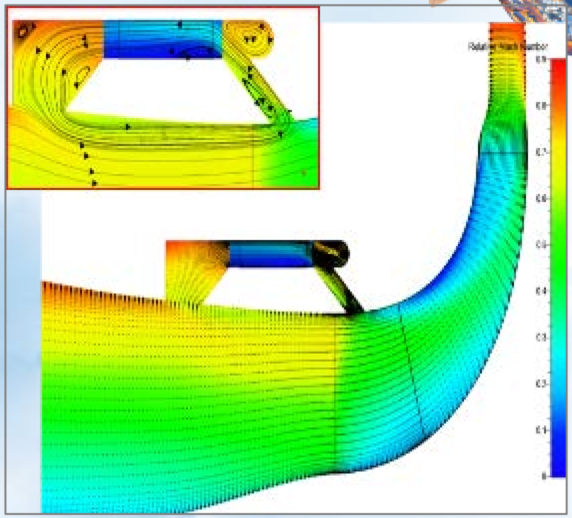
- Improvement of Off-Design Performance (2)

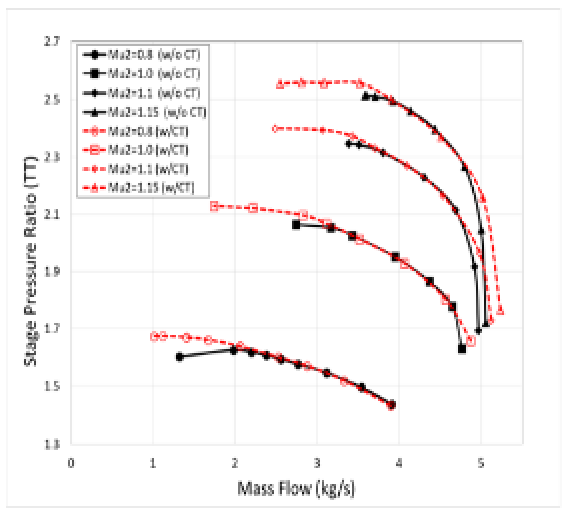
  □ Operating Range Enhancement

  - Recirculation passage
  - The high pressure fluid energizes the low momentum fluid near endwall

  □ Technical Improvement

  - Completed component test
  - Both chock and stall margin extended

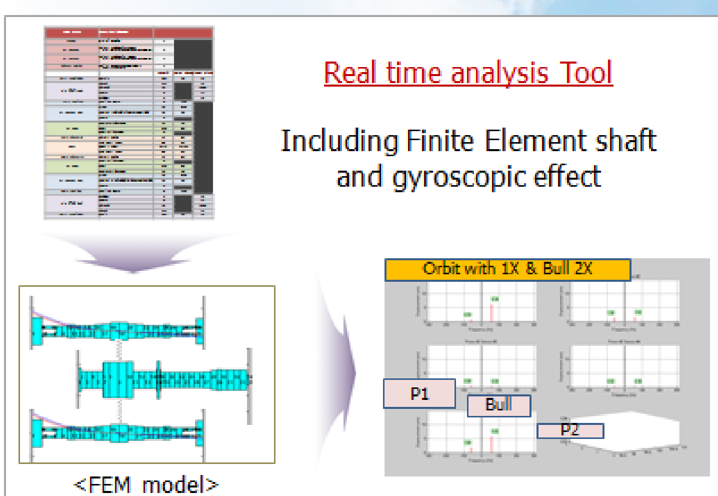




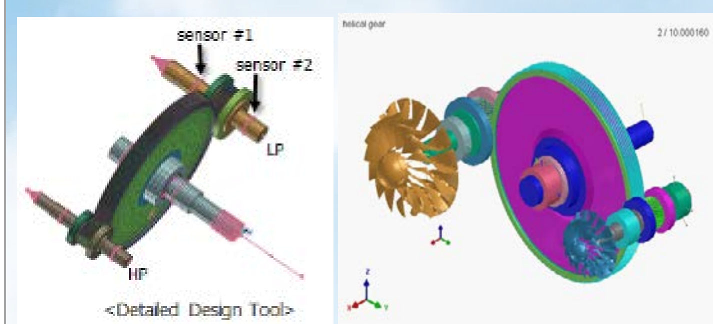
Core Technology Development

Vibration Classification and Corresponding Approach

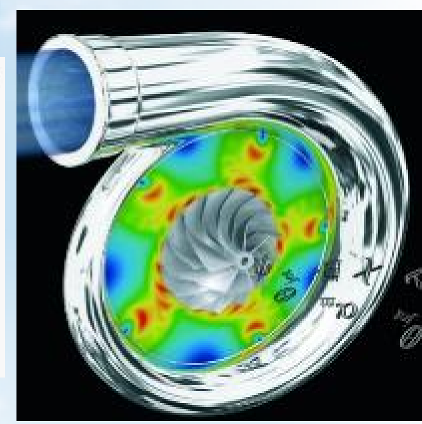
Vibration type	Shaft interaction	Source of Vib.	Simulation
Lateral Vibration	Single shaft Vibration	Unbalance	Unbalance response analysis (in-phase, out phase)
		Flow-Induced	Multi-Dynamic Simulation (Unsteady Flow – Vibration)
	Multi-shaft Vibration	Vibration Transmission	Multi-Axis(Shaft) Dyn. Simulation



[Automated Analysis Process]



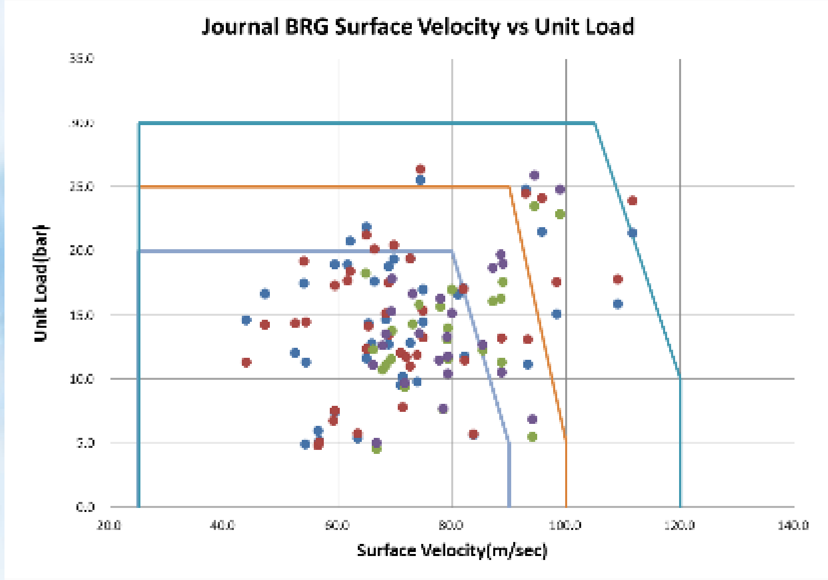
[Multi-Axis Dynamic Simulation]



[Multi-Dynamic Simulation]

Core Technology Development

- Enhanced Reliability for Rotor system (Bearing)
  - □ Special Purpose Bearing
    - - High oil temperature
    - - High circumferential velocity



  - □ Key Technology

Special Bearing

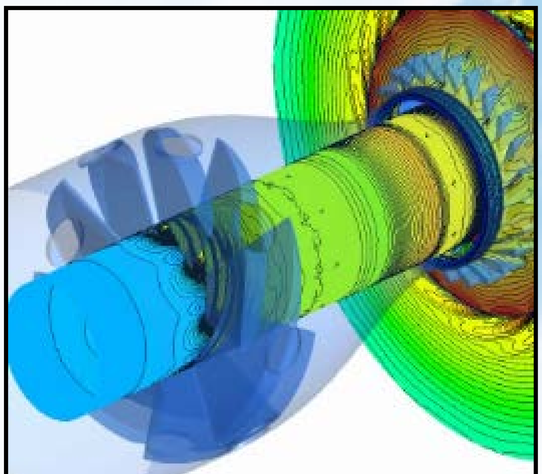
[Copper Pad]

[Direct Nozzle]

Core Technology Development

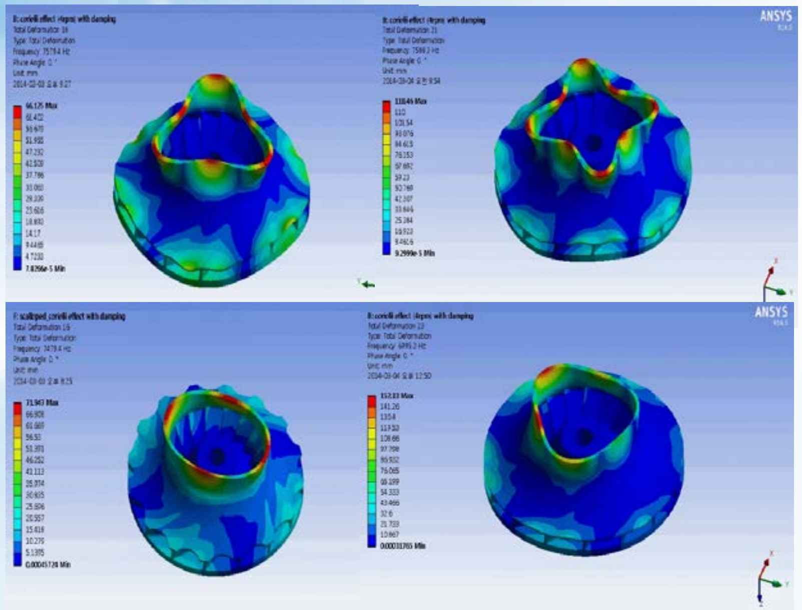
- Enhanced Reliability for Rotor system (Structure)
  - □ Robust design of impeller
    - FSI(fluid-structure interaction) is used for impeller design
    - Considered by steady/unsteady condition
    - Evaluation of strength/resonance/life cycle

      → Design reliability ↑



[Unsteady Fluid Analysis]

Interaction



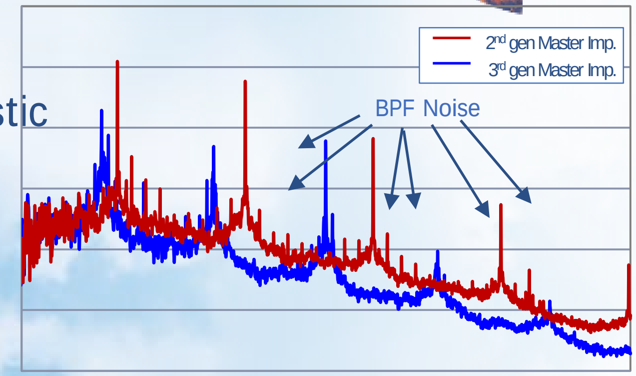
[Structure/Resonance Analysis]

Core Technology Development

- Advance and Competitive Technology : Low Noise Technology

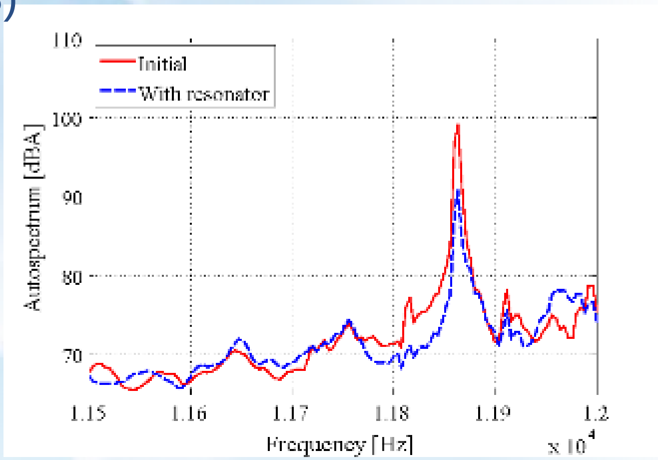
□ Passive Noise Control Methods (Completed)

- To reduce compressor noise radiation by applying acoustic insulation on inter-stage pipes (3~5dB)
- Pipe flow improvement
  → Broadband noise reduction (1~2dB)
- Impeller performance improvement
  → BPF (Blade Passing Frequency) noise reduction (1~2dB)



□ Active Noise Control Methods (On going)

- Non-splitter
- Resonator



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