CST
Compression Service Technology

MACHINERY MAINTENANCE CONSULTANCY SERVICES

CST MAINTENANCE CONSULTANCY APPROACH

Dedicated team of experienced engineers to:

- support end users
- improve machinery performance
- maximize productivity

Best three-party co-operation team:

- CST specialized Maintenance Engineering Group
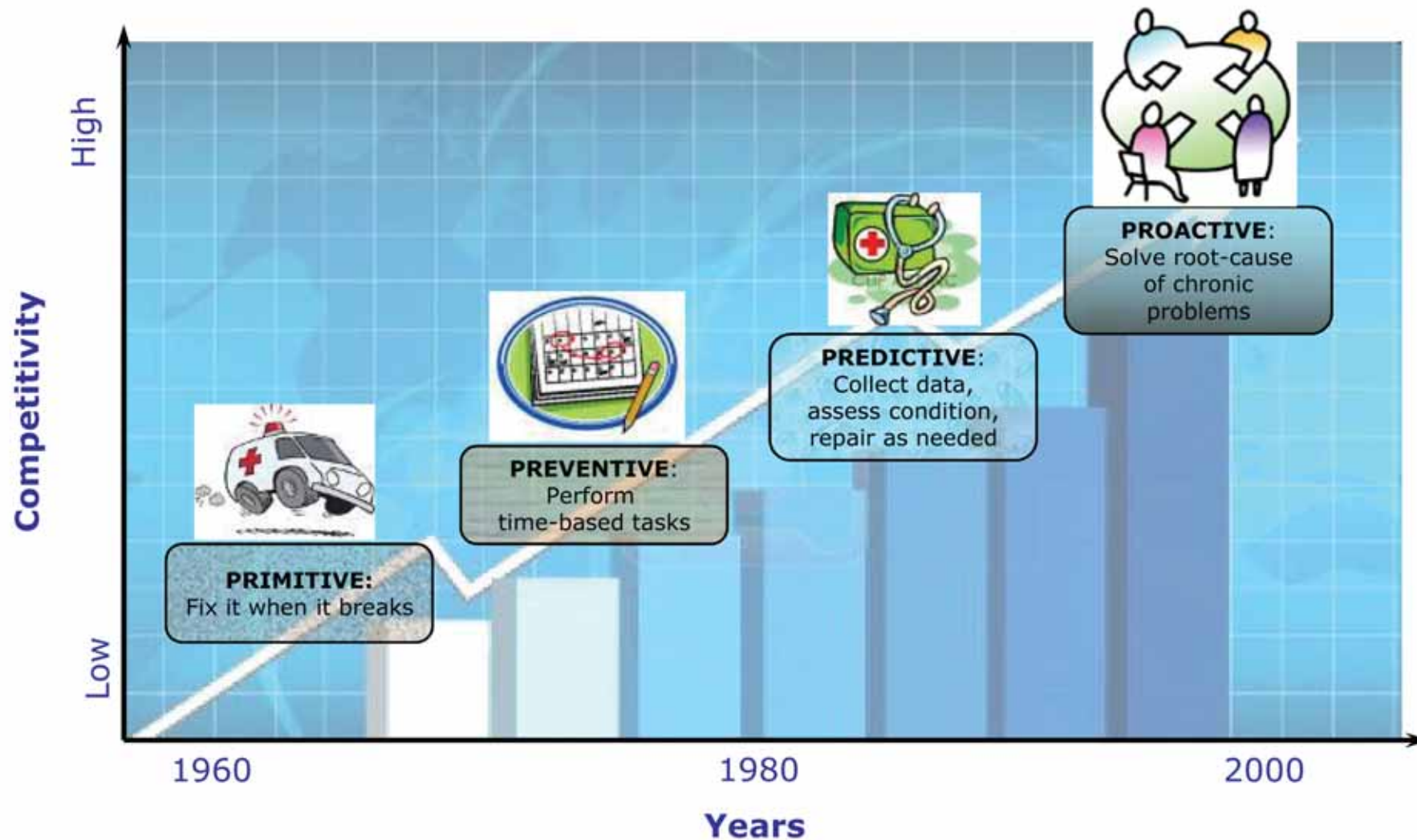- User's engineers
- OEM / Packager

Impact of Poor Maintenance on Plant Operation

➢ "U.S. Industry spends more than $200 billion each year on maintenance of plant equipment"

➢ "The results of ineffective maintenance management represent a loss of more than $60 billion each year in the U.S."

➢ "The dominant reason for this ineffective management is the lack of factual data"

by Keith Mobley (President and CEO of Integrated Systems Inc.)
"An Introduction to Predictive Maintenance"

EVOLUTION OF MAINTENANCE

PRIMITIVE: Fix it when it breaks

PREVENTIVE: Perform time-based tasks

PREDICTIVE: Collect data, assess condition, repair as needed

PROACTIVE: Solve root-cause of chronic problems

Competitivity — High / Low

Years — 1960 1980 2000

C.S.T. Proprietary information

CST SERVICE PROGRAMS

Recurring problem solving

➤ Asset lifecycle management
➤ Machinery "Healthcare Packages"
➤ Revamping, Rehabilitation and Modernization of existing machinery

Routine diagnostics

➤ Remote Monitoring & Diagnostics through Tele-Assistance
➤ On board advanced diagnostic systems

Failure analysis

➤ Field support for machinery operation analysis and troubleshooting
➤ Vibration integrity design services: acoustic, torsional, stress and dynamics

FIELD SUPPORT & TROUBLESHOOTING
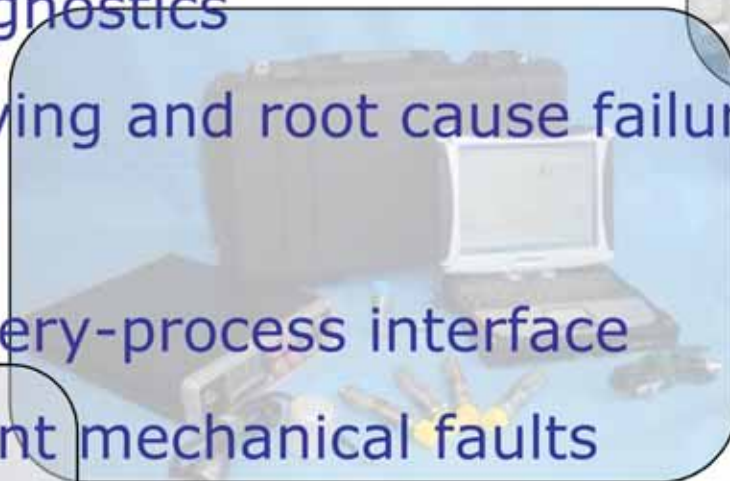
➢ Field inspections and measurements (vibrations, pulsations, power, throughput, telemetry, thermography, acoustic emissions, experimental modal analysis, etc.)

➢ Portable diagnostics

➢ Problem solving and root cause failure analysis

➢ Analysis of

- machinery-process interface
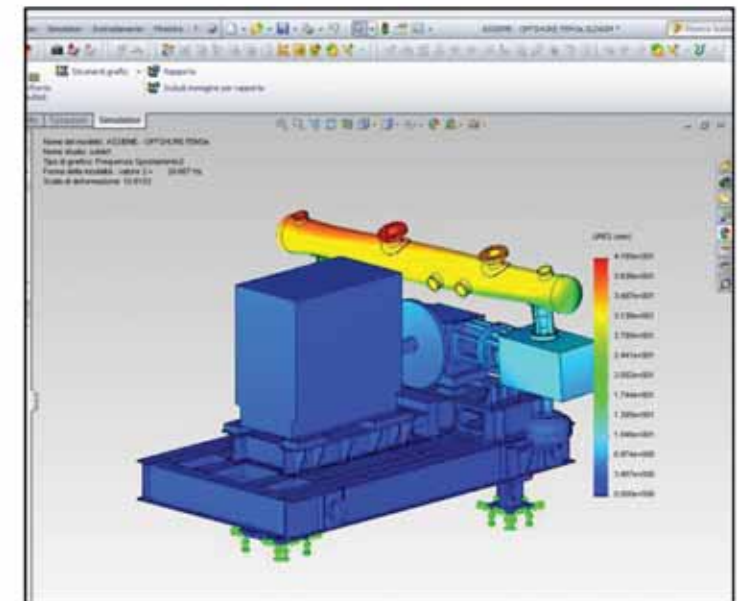- recurrent mechanical faults
- performance problems
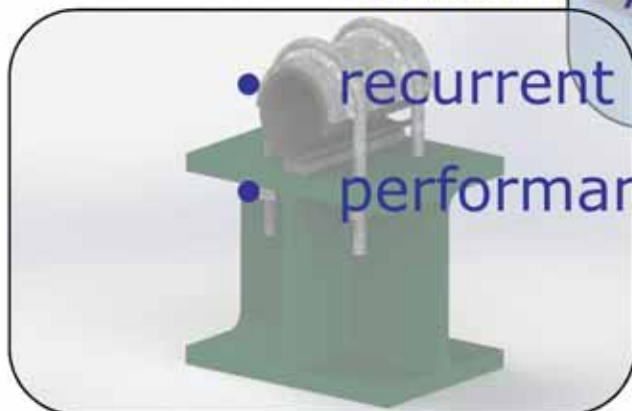
PULSATION ANALYSIS

➢ Simulation of pressure pulsation effects generated by reciprocating piston motion

➢ Three-dimensional finite element modeling
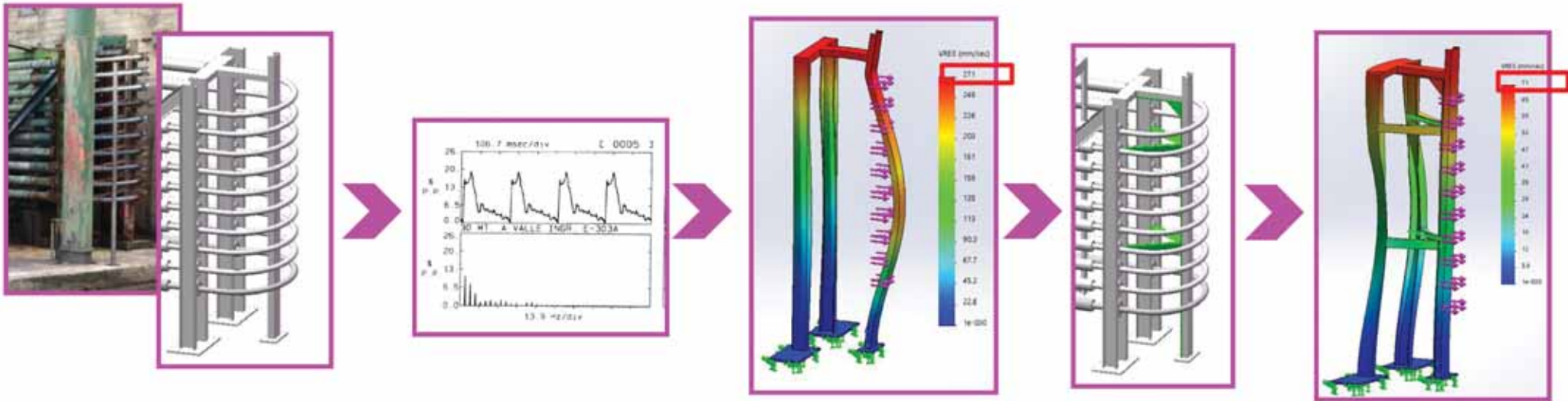
➢ Prediction of acoustic resonances

STAGE I – delivery volume bottle analysis
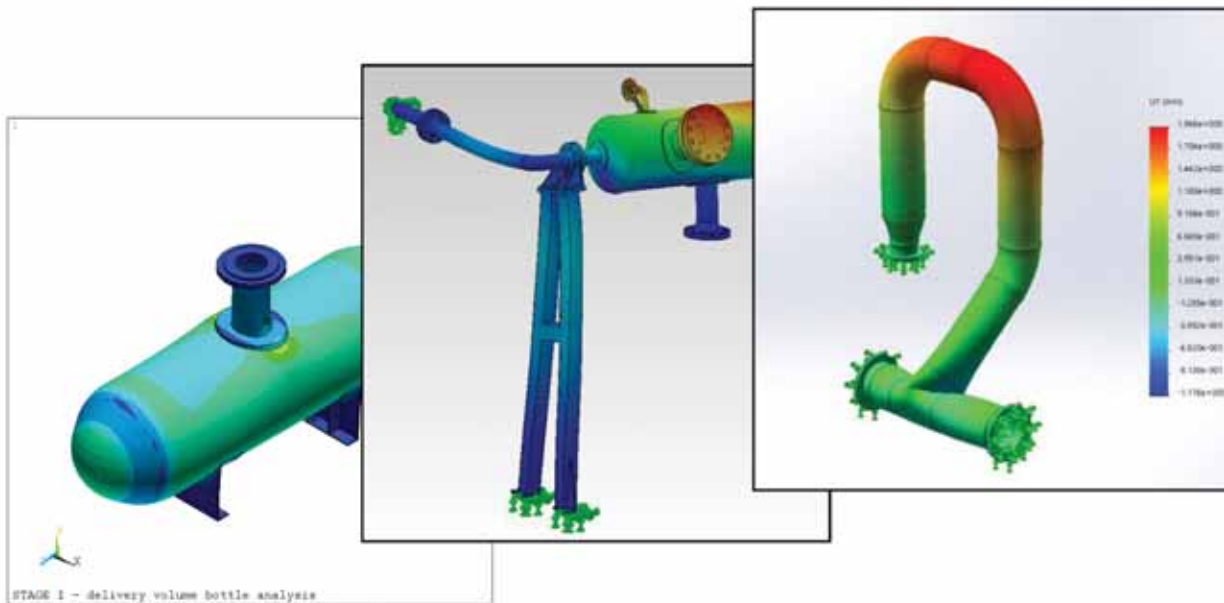
PIPING AND EQUIPMENT STRESS ANALYSIS

CYLINDER/MANIFOLD MODAL ANALYSIS

MECHANICAL ANALYSIS

- ➤ Dynamic analysis focused on structure stiffening
- ➤ Forced response simulation
- ➤ Best structure design to minimize vibrations
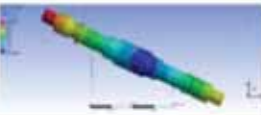- ➤ On-site surveys to perform RCAs and confirm resolution
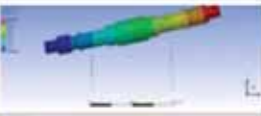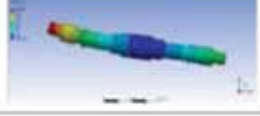
ROTORDYNAMIC ANALYSIS

➤ Modal analysis to determine Torsional Natural Frequencies (TNFs)

➤ Forced response analysis to accurately predict vibration and stress

➤ Oil film instability of rotor-bearing system

TORSIONAL
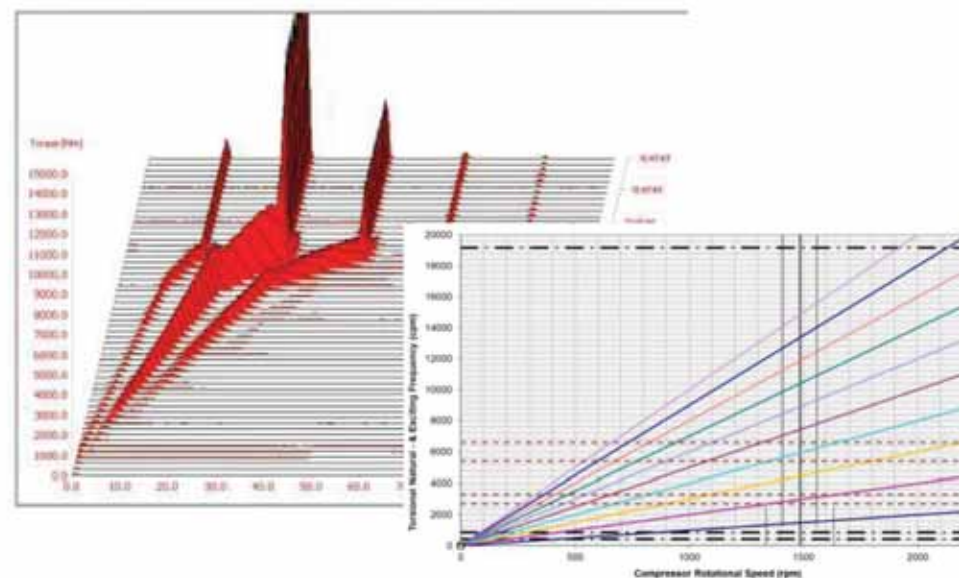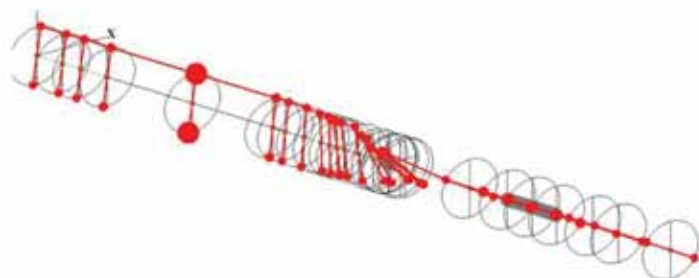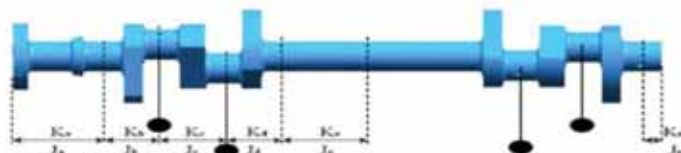
LATERAL

Item	Mode shape	U N L F (CPM)			
		A	B	C	D
1		10255	4579	4643	4594
2		/	6548	/	6840
3		10774	7462	7565	7605

BEARING
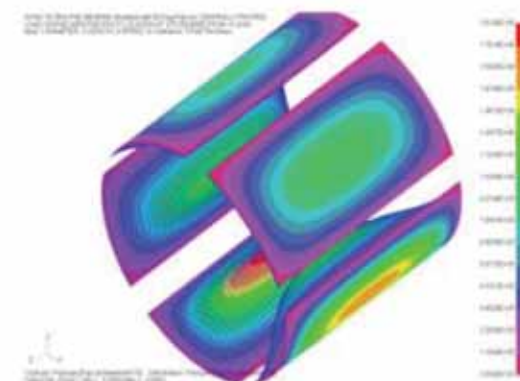
PLANT OPTIMIZATION ACTIVITY

➤ AspenONE suite of products (Hysys, Flare.net)

➤ Heat and material balance

➤ Dynamic simulation for transient analysis (blow down, PSV opening, startup and shutdown)

FLARE HEADER VERIFICATION

wells | degassing area | compression area | pipeline

FROM WELL TO PIPELINE SIMULATION
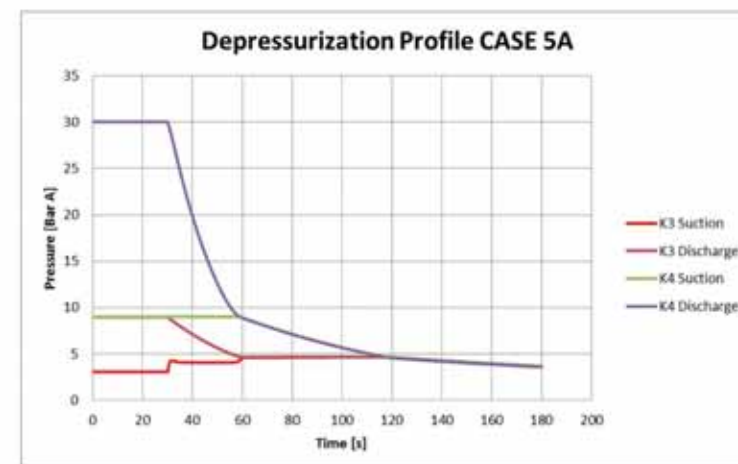
BLOWDOWN PRESSURE SIMULATION

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ASSET HEALTHCARE PROGRAMS

HEALTHCARE PACKAGES

Remote monitoring and diagnostics

Asset management
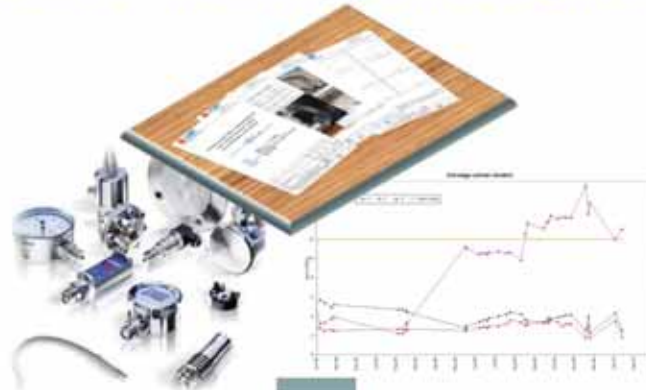
Equipment and maintenance optimization

➢ Maintenance cost reduction
➢ Overcoming recurrent failures
➢ Machinery and process optimization
➢ KPI improvements

C.S.T. Proprietary information

ASSET LIFECYCLE MANAGEMENT

➢ Machine component lifetime assessment and comparison with "best in class"

➢ Updating of machine instrumentation and supervision system

➢ Machine component redesign and modernization

➢ Installation of diagnostic systems

➢ Predictive maintenance consultancy

➢ Data driven maintenance management (DM2)
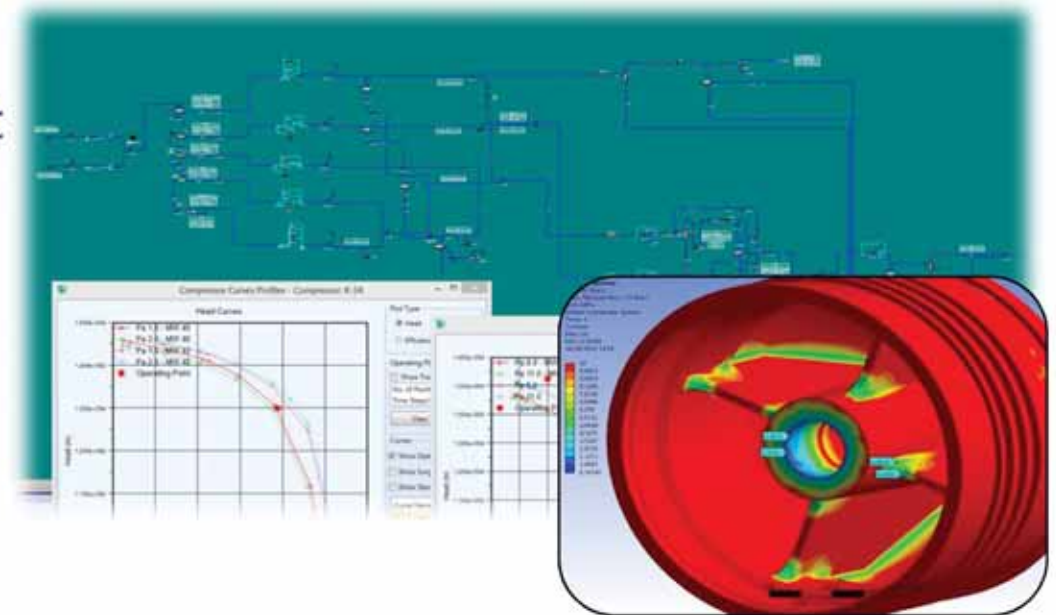
EQUIPMENT OPTIMIZATION

Engineering for revamping, rehabilitation
& modernization of existing units:

➢ Adapting the machine to new operating conditions

➢ Restoring after damage

➢ Technology upgrade

➢ Unit uprate to achieve higher throughput

Before rehabilitation

After rehabilitation

REMOTE MONITORING & DIAGNOSTICS

➢ Simple and reliable performance monitoring

➢ Use of onboard instrumentation

➢ KPI monitoring

➢ Proactive maintenance approach

➢ MTBF and reliability analysis

➢ Reduction of machine downtime and maintenance costs

RM&D: Analysis flow diagram

Primary measurements
- inlet gas pressures and temperatures
- final gas pressure
- inlet cooling oil temperature
- inlet cooling water temperature

Mathematical Model

Expected Calculated Secondary Values

Secondary measurements
- interstage pressures
- discharge temperatures
- outlet cooling oil temperature
- outlet cooling water temperature
- valve cover temperatures
- vibrations

Comparison

Machine health status

RM&D: How the program works

➢ Weekly batch e-mail transmission from user to CST of onboard instrumentation readings (through a preset electronic form)

➢ Data analysis:
- Algorithms with diagnostic rules and performance estimation routines
- Immediate highlights of possible critical situations
- Weekly/Monthly report including trend analyses and maintenance suggestions
- Proposal for troubleshooting intervention if necessary

➢ Reliability improvement plans proposal within a Proactive Maintenance Program

HEALTHCARE PACKAGES: BENEFITS FOR THE END USER

➤ Reliability and efficiency audits to combine

- data collecting and analysis
- investment suggestions

➤ Improve equipment performance through

- MTBF reduction
- KPI improvement

➤ Maintenance rationalization and costs reduction

SOFTWARE TOOLS

COMMERCIAL

- **SOLID WORKS** ®
  3D Modeling
- **SIMULATION** ®
  Finite Element Analysis
- **MOTION** ®
  Rigid Body Dynamic Analysis
- **ANSYS** ®
  Fluid Structure Interaction (FSI)
- **ANSYS MECHANICAL** ®
  Finite Element Analysis
- **FE-SAFE** ®
  Fatigue Strength Analysis
- **AMESIM** ®
  1-D Multi-Physics Simulation
- **MATLAB** ®
  Numerical Analysis Environment
- **XLRotor** ®
  Rotor Dynamic Analysis
- **Hysys** ®
  Process Plant Optimization Software

PROPRIETARY

- **ReciPerf**
  Compressor Performance Simulator
- **CSThermo**
  Gas mixtures physical properties
- **BearingPerf**
  Bearing Design
- **DamPerf**
  API618 5th ed.
  Preliminary Design of Pulsation Dampers
- **CSTors**
  Shaft line Torsional Analysis
- **CylOpt**
  Cylinder Fluid Dynamic Optimization
- Sizing
- **SCAT**
  Design Point Performance
- **Casey**
  Operability Range Definition
- **TM Pulse**
  API 618 Damper Performance Verification
- **CFD Pulse**
  CFD 1-D Pressure Pulsation Analysis of Compression Units
- **TurboPerf**
  Multistage Performance Curves Verification

Competence at work for Service and Innovation

Compression Service Technology

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