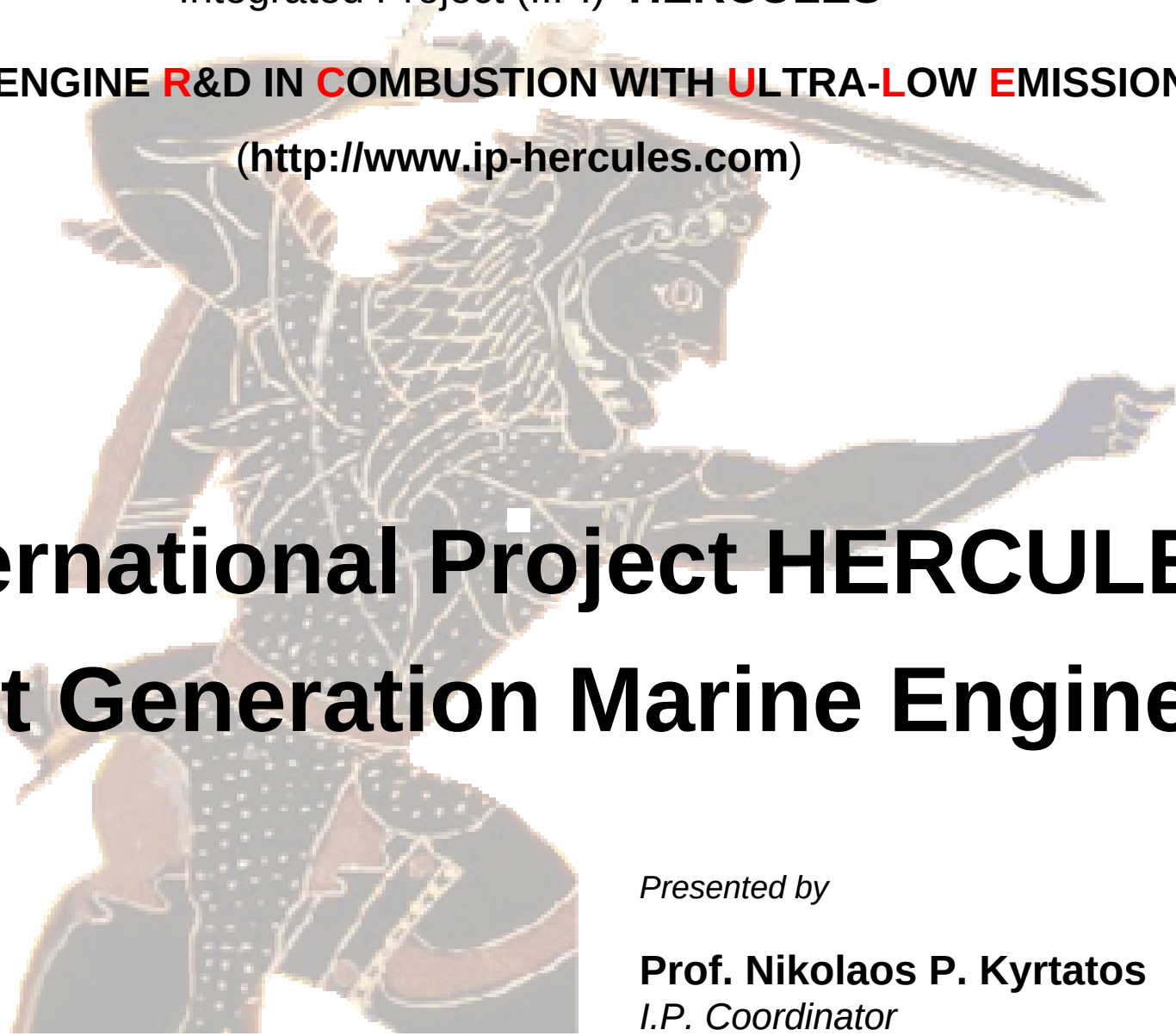
Integrated Project (I.P.) **HERCULES**

HIGH – EFFICIENCY ENGINE R&D IN COMBUSTION WITH ULTRA-LOW EMISSIONS FOR SHIPS

(**http://www.ip-hercules.com**)



The International Project HERCULES for Next Generation Marine Engines

Presented by

Prof. Nikolaos P. Kyrtatos
I.P. Coordinator

HERCULES I.P. will develop **new technologies**:

- To drastically reduce gaseous and particulate emissions from marine engines
- To increase engine efficiency and hereby to reduce specific fuel consumption, CO2 emissions and lifecycle cost
- To increase engine reliability

SCOPE

The **objectives** will be attained through interrelated developments in:

- Thermodynamics and mechanics of “extreme” parameter engines
- Advanced combustion concepts
- Multistage intelligent turbocharging
- “Hot” engines with energy recovery and compounding
- Internal emission reduction methods and advanced aftertreatment techniques
- New sensors for emissions and performance monitoring
- Adaptive control for intelligent engines

Project Budget: 33.3 Million Euro

Project partly funded by:

- The European Commission under Sixth Framework Programme (FP6)
  (Contract # TIP3-CT-2003-506676)
  Funding: 15.0 Million Euro

- The Swiss Government - Bundesamt für Bildung und Wissenschaft (BBW)
  Funding: 2.8 Million Euro

Project Duration: 36 Months

- Start Date: 1/3/2004
- Expected Finish: Mid of 2007

I.P. HERCULES – Consortium

There are 40 participating organisations, from 10 countries:

Austria, Czech Republic, Denmark, Finland, Germany,
Greece, Italy, Sweden, United Kingdom and Switzerland

From the participants:

- 60% are *Industrial partners*
- 19% are *Universities*
- 12% are *Research organisations*
- 9% are *Users / Ship Operator companies*.

The two major partner groups,
MAN-B&W (G), MAN-B&W (DK), WARTSILA (FI), WARTSILA (CH),
cover together about 80% of the world's marine engine market
(medium- and low-speed engines).

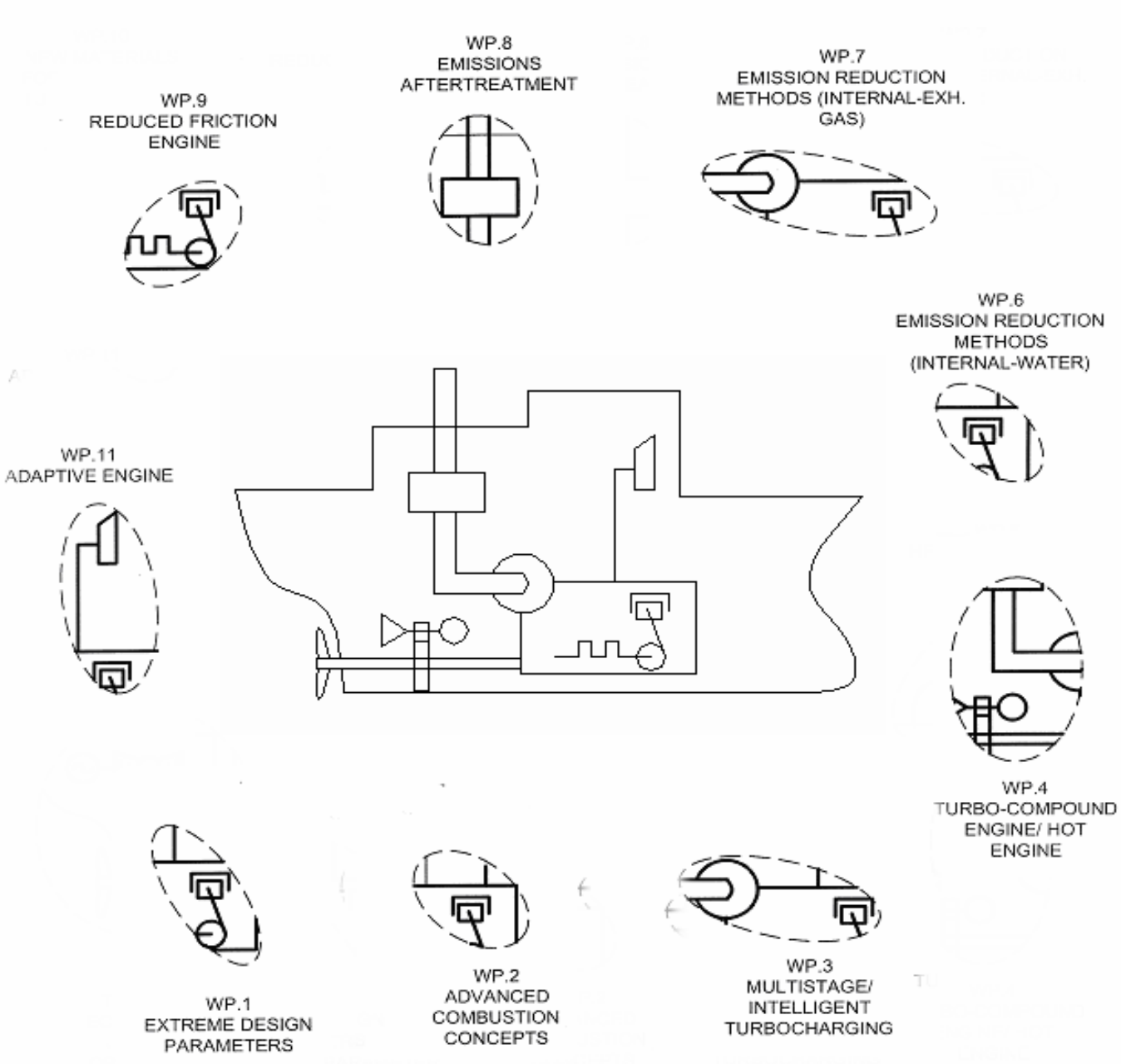
Overview of I.P. HERCULES Workpackages

STRUCTURE OF THE WORK

Nine (9) **Workpackages**

Eighteen (18) **Tasks**

Fifty-four (54) **Subprojects**



I.P. HERCULES INNOVATIONS

Some of the areas where innovations are considered in the I.P. HERCULES are:

- Engines with “extreme” boost, m.e.p. design parameters
- “New” combustion concepts
- “Intelligent” variable flow area, multistage turbochargers
- “Hot”-operating engine with combined steam cycle
- Marine engines with water injection
- Exhaust gas recirculation in heavy-fuel engines
- New aftertreatment methods for heavy fuels (plasma, scrubbers)
- New sensors and emission measurement methods
- “Low-friction” engines
- “Adaptive” control of engines

I.P. HERCULES – Structure

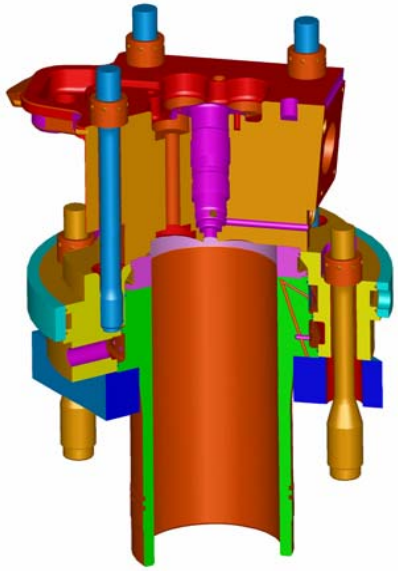
WP1	**Extreme Design Parameters**	Task 1.1: Mechanics of engine with extreme design parameters
		Task 1.2: Thermodynamics of engine with extreme design parameters
WP2	**Advanced Combustion Concepts**	Task 2.1: Combustion process simulation
		Task 2.2: Emission formation simulation
WP3	**Multistage / Intelligent Turbocharging**	Task 3.1: Variable Turbocharging
		Task 3.2: Intelligent Turbocharger
WP4	**Turbo-compound Engine / Hot Engine**	Task 4.1: Combined Cycle
		Task 4.2: Hot engine
WP6	**Emission Reduction Methods (Internal – water)**	Task 6.1: Water Injection Techniques
		Task 6.2: Humidification methods
WP7	**Emission Reduction Methods (Internal – Exhaust Gas)**	Task 7.1: Internal Measures
		Task 7.2: Emission reduction methods (EGR and particulates)
WP8	**Emissions Aftertreatment**	Task 8.1: After-treatment Methods
		Task 8.2: Monitoring of emission
WP9	**Reduced Friction Engine**	Task 9.1: Adaptive Components
		Task 9.2: Tribo-optimisation
WP11	**Adaptive Engine**	Task 11.1: Adaptive Control
		Task 11.2: Intelligent engine
WP13	**Project Management**	

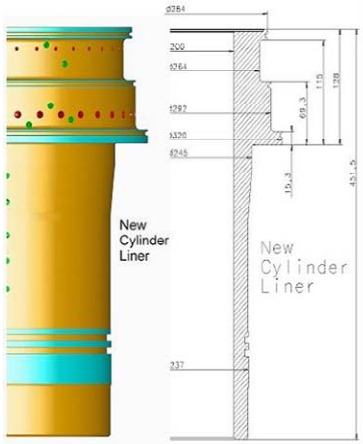
TASK 1.1: Mechanics of engine with extreme design parameters

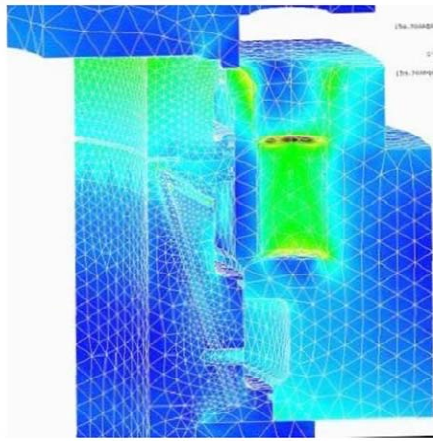
Objectives: To study the operation of engine under extreme conditions, design new components and test them on a research extreme value engine (EVE)

Progress Highlights:

- CDF / Cycle Simulations completed
- New components (cylinder head, valves hydraulic actuators) for EVE designed
- Cylinder liner materials mechanical limits study
- Tests with CR fuel injection system performed
- Rig testing of bearings materials / geometry
- Reference tests with EVE to be done end of 2005







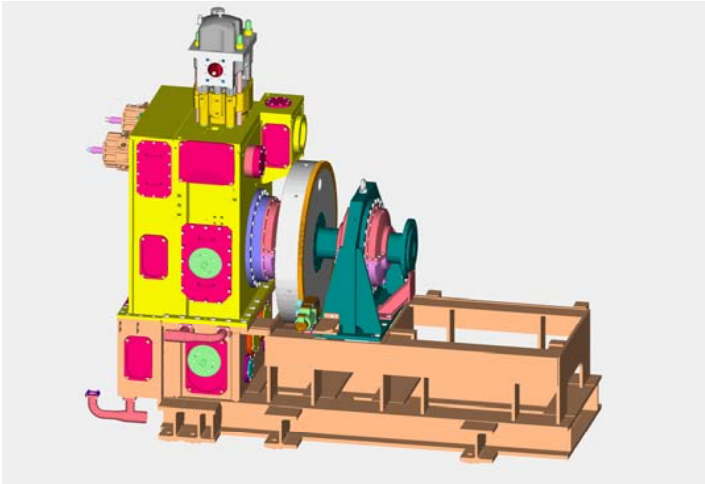
Partners: Miba, Helsinki University of Technology Department of Mechanical Engineering, WÄRTSILÄ, M.JÜRGENSEN FLENSBURG, TAMPERE UNIVERSITY OF TECHNOLOGY

TASK 1.2: Thermodynamics of engine with extreme design parameters

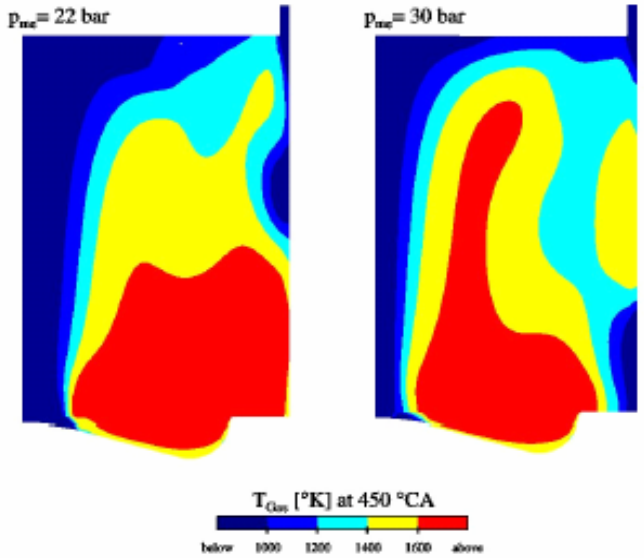
Objectives: To investigate operation of 2-S and 4-S engines under extreme thermal and mechanical load, design new components and test them full-scale

Progress Highlights:

- Thermodynamic layout completed
- CFD pre-calculations complete
- New components (bearing shells, piston rings, fuel valves) design complete
- Engine design and FEM models (combustion chamber components) nearly complete
- Production of test items and prototype components in progress



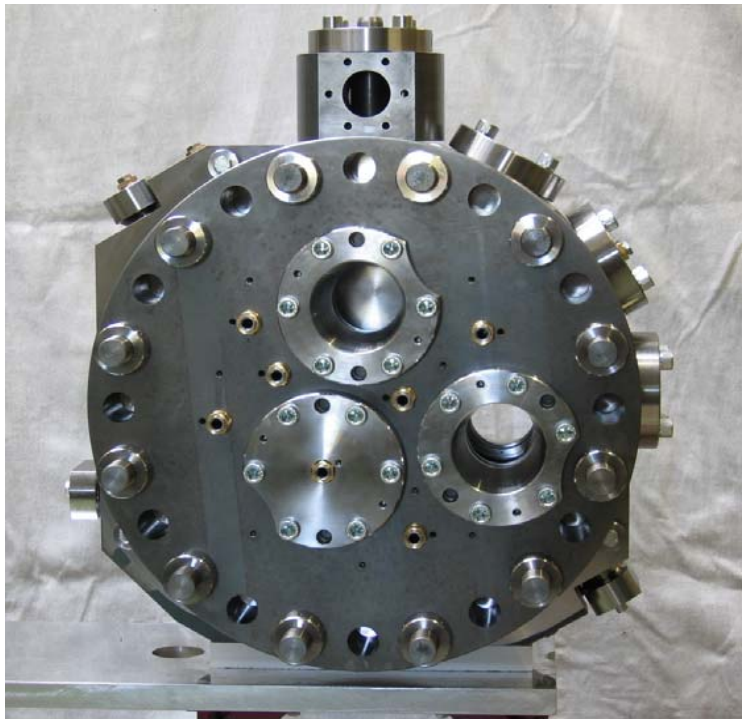
Model of the test engine for experiments



Partners:

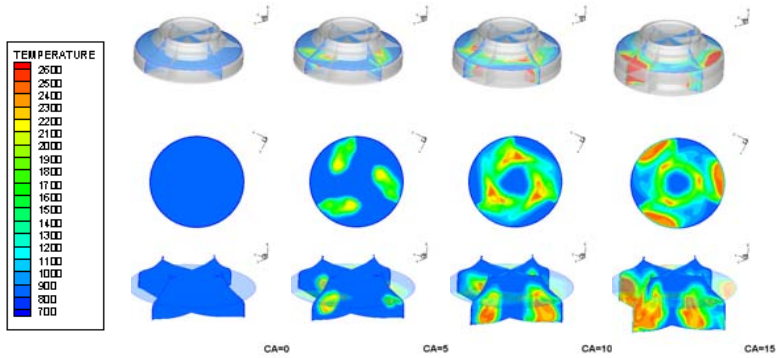
TASK 2.1: Combustion process simulation

Objectives: To perform specialised experiments, to develop advanced models of in-cylinder processes, to perform engine optimisation studies



Progress Highlights:

- Development of a spray combustion chamber
- Validation of spray, combustion and emission formation models
- Simulation studies of 2-stroke and 4-stroke in-cylinder engine processes
- Engine tests for generating validation data



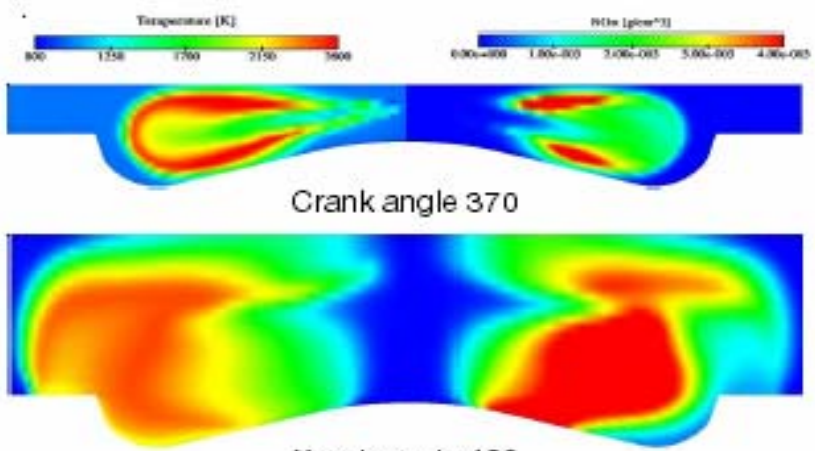
Partners:

TASK 2.2: Emission formation simulation

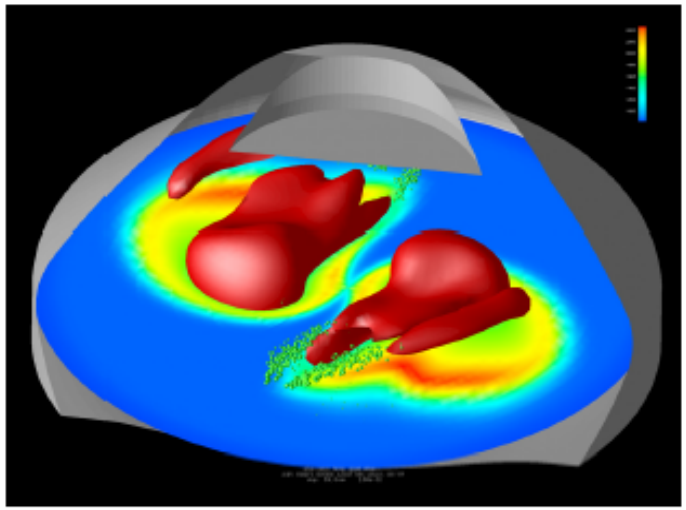
Objectives: To apply 3-D CFD tools to the simulation of in-cylinder processes, to extend and adapt existing physical models, to validate models against experimental data

Progress Highlights:

- Data mining of engine measurements (1200 test runs)
- Evaluation of physical models embedded in 3-D CFD codes for 2-stroke and 4-stroke engines
- Improved chemical description (modelling) of combustion in 2-stroke engines



Kiva 3D simulation of combustion in four-stroke MAN B&W marine diesel engine

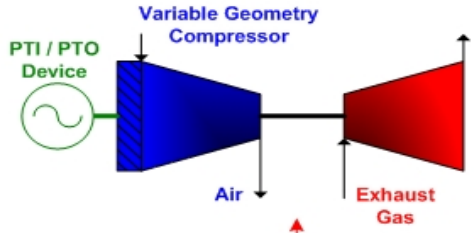


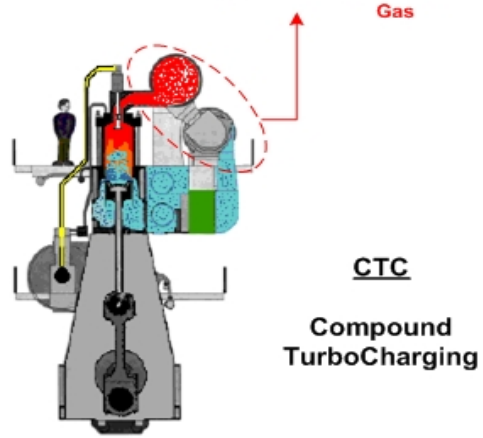
Partners: MAN | Lunds Universitet | Institut für Technische Verbrennung

TASK 3.1: Variable turbocharging

Objectives:

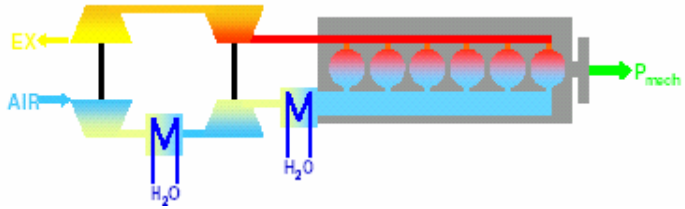
- High pressure turbocharging concepts for two and four stroke diesel engines
- Variable geometry turbocharger components for two stroke diesel engines
- Investigation of electrically assisted turbo (PTI/PTO) for two stroke engines

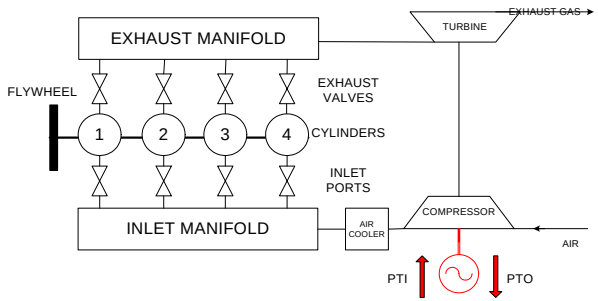




Progress Highlights:

- Feasibility studies of PTI/PTO devices, in progress
- Simulation studies of high pressure charging solutions
- Air / exhaust wastegate investigations tests, completed
- Air assist load pick up capability evaluation, completed
- VGT service tests onboard 2-stroke diesel engines, in progress





Partners:

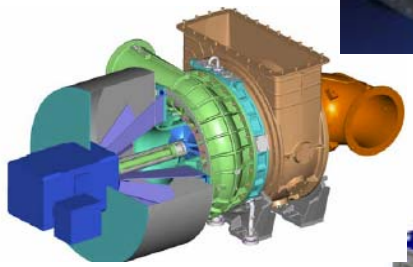
TASK 3.2: Intelligent turbocharging

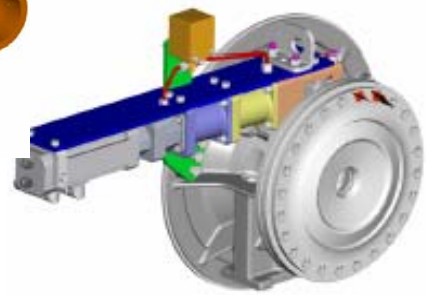
Objectives:

• Variable flow area turbocharger components for two and four stroke diesel engines

• Investigation of electrically assisted turbocharger (PTI/PTO) for two stroke diesel engines

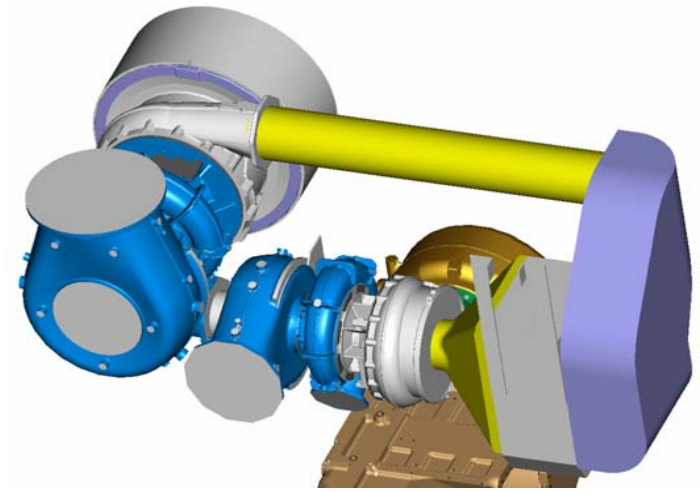
• Multistage turbocharging investigations





Progress Highlights:

- Variable flow area components simulations (1D, CFD), completed
- Conceptual study of variable compressor area component, in progress
- PTI / PTO test unit design and manufacturing complete
- Special bearing configurations
- Electric or hydraulic actuators studies, in progress

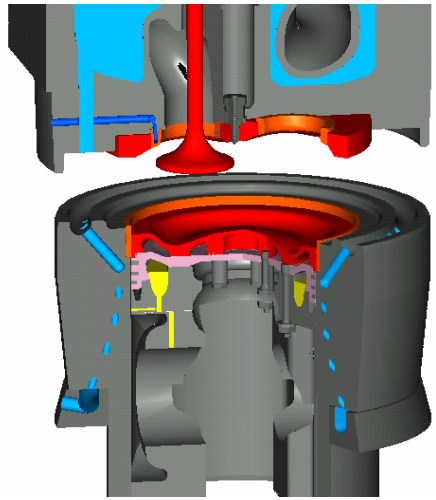


Partners: MAN, KE GU EL, PBS turbo TURBOCHARGERS

TASK 4.1: Combined Cycle

Objectives:

- Development of the “Hot Engine” combined cycle concept
- Prototype tests of concept and components



Progress Highlights:

- Combined cycle concept evaluation, in progress
- Design of suitable engine components, in progress
- Turbocompounded Engine cycle simulations completed
- New generation piston with limited cooling tested
- Cylinder liner development in progress
- New materials resisting hot corrosion/oxidation under testing

Partners: ABB, M.JÜRGENSEN FLENSBURG, MAHLE, WÄRTSILÄ

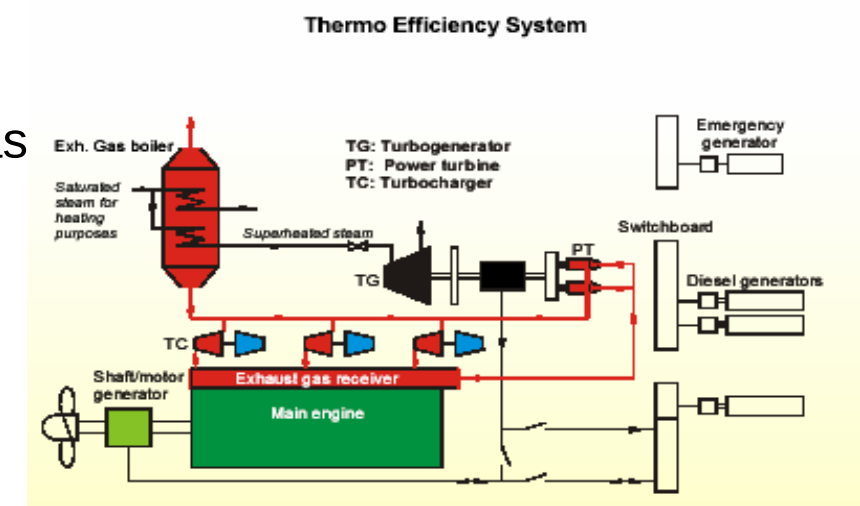
TASK 4.2: Hot Engine

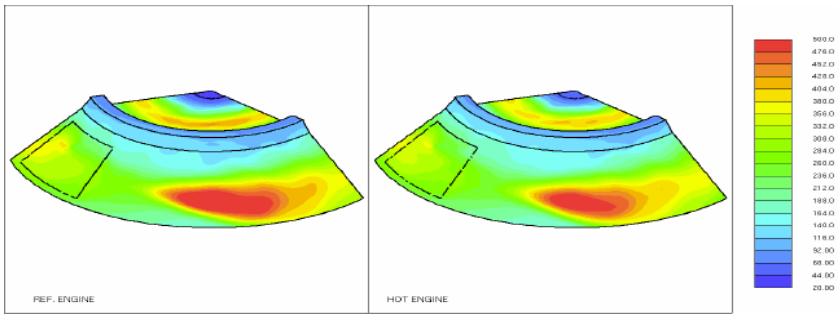
Objectives:

- Development of an optimized combined cycle concept
- Simulation and development of prototype engine components
- Development of suitable boiler and power turbine technologies
- Onboard tests in an ocean-going vessel

Progress Highlights:

- CFD pre-calculations of 2-stroke engine operation as "hot" engine completed
- Basic calculation routines for exhaust gas data generation for steam turbine and boiler optimization completed
- Simulated "Hot engine" test completed
- System optimization calculations nearly completed
- Design of suitable boiler and turbine components, in progress

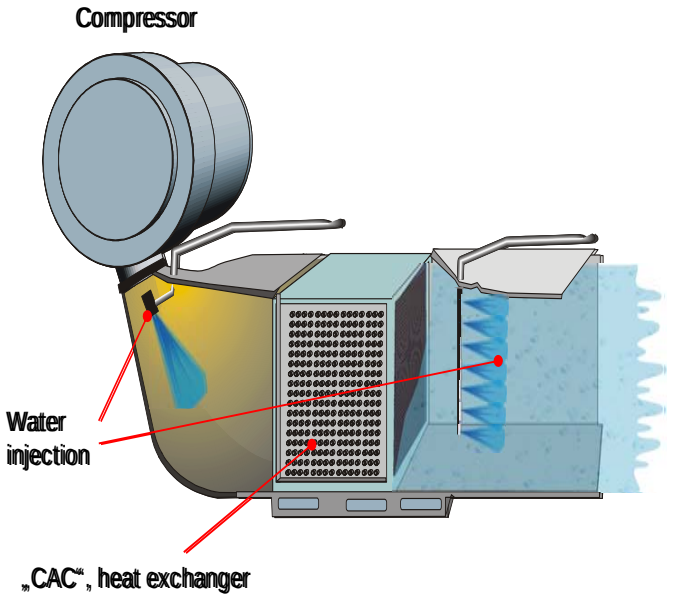




Partners: MAN, AALBORG INDUSTRIES, Hapag-Lloyd Container Line, Peter Brotherhood Ltd

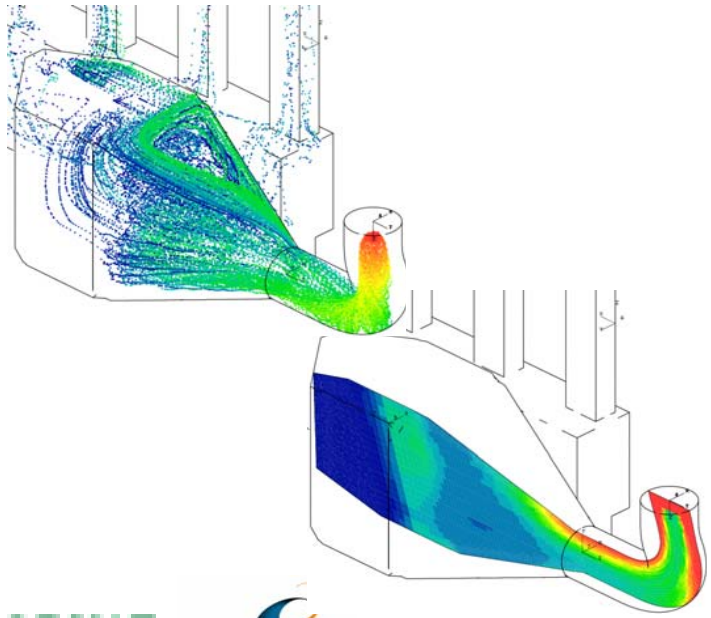
TASK 6.1: Water injection techniques

Objectives: To confirm and quantify the NOx reduction potential of water injection, to model water injection processes, to develop water injection systems and test them on-board



Progress Highlights:

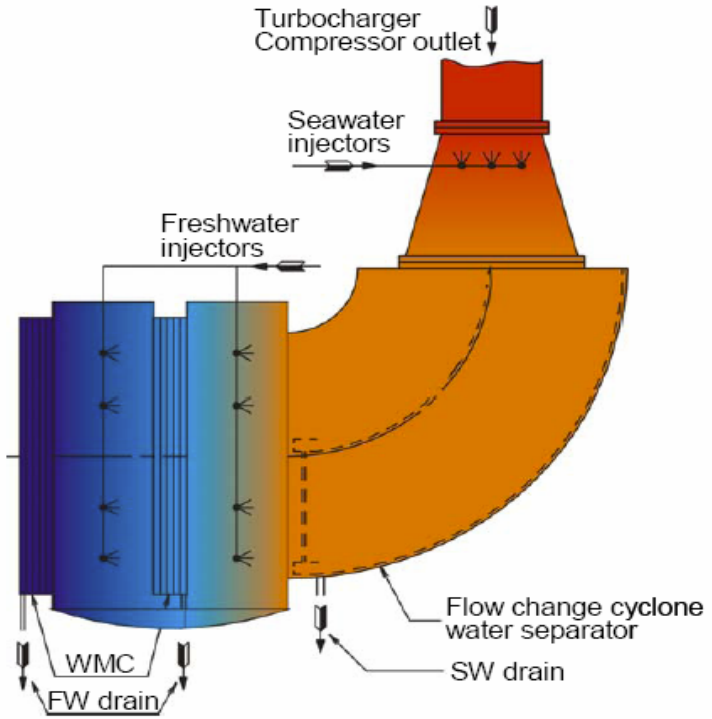
- 2-stroke engines: simulation studies of Direct Water Injection
- 4-stroke engines: simulation studies of a system for saturation of charge air with water vapour
- Component development and manufacturing in progress
- Shipboard integration layout and installation in preparation



Partners: MAERSK OMT WALLENIUS OW MARINE WÄRTSILÄ

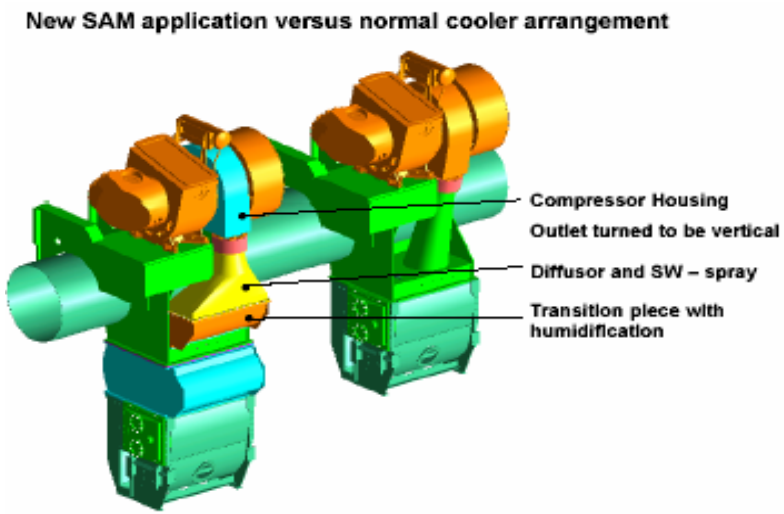
TASK 6.2: Humidification Methods

Objectives: To confirm and quantify the NOx reduction potential of humidification systems, to develop humidification systems, to perform field tests of systems developed



Progress Highlights:

- 2-stroke engines
  - Analysis of a Scavenging Air Moistening system
  - Scale test completed
  - Full-scale tests and implementation of the system on a sea-going vessel planned for Autumn 2005
- 4-stroke engines
  - Analysis and test of a Fuel Water Emulsification system



Partners: MAN WALLENIUS WILHELMSEN MARINE

TASK 7.1: Internal measures

Objectives

- Chemical and physical characterization of the particulate emission of a 2-stroke engine.
- Instrument setup for particulate matter sampling of a 4-stroke engine.

Highlights

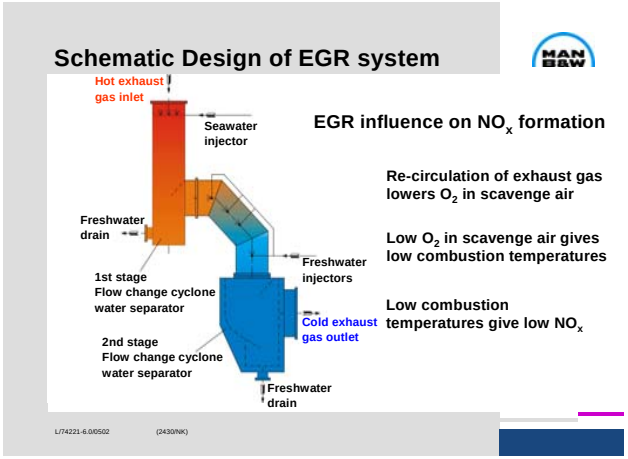
- **Particulate emission sampling was completed on Wärtsilä 4RTflex58T-B.**
- **Evaluation of number size distributions and chemical analyses finished. Second set of measurements planned.**
- **Instrumentation of WFI lab with particulate matter sampling finished, measurements started , first results**
- **Sampling exhaust gas from 4-stoke engines showed similar particle characteristics to 2-stroke engines**.

Partners: WÄRTSILÄ EMPA

TASK 7.2: Emission reduction methods (internal – external – EGR)

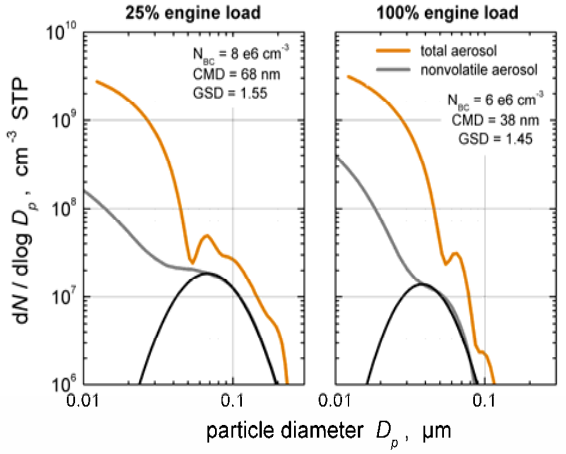
Objectives

- EGR prototype system for 2-stroke marine diesel engine applicable to residual fuel oils
- Reduction of the NO_x emission of at least 50% with out increasing other emissions especially CO_2 (fuel oil consumption)
- Characterization of particulate emission from marine engines
- Identification of influences of fuel oil quality on particulates



Highlights

- Design and manufacturing of various prototype EGR and Combustion Gas Re-circulation (CGR) systems for marine engines
- Measurements with different EGR and CGR setups were made on MAN-B7W 4T50ME-X
- Sampling of reference particulate matter (PM) complete
- Measurements of PM number size distribution complete



PM number size distribution with volatility analysis for two different loads for HFO

Partners:

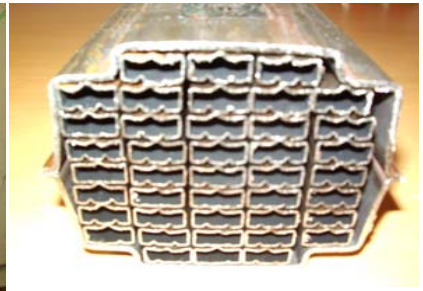
TASK 8.1: After-treatment methods

Objectives

- Development of practical and reliable methods for emissions monitoring in service.
- Extension of emissions measuring technologies for single cylinder measurements.
- Further development of Non Thermal Plasma (NTP) and Wet Scrubber (WS) technologies, including lab tests and under real engine exhaust conditions.

Highlights

- Experimental optimisation of lab-scale wet scrubbing system in progress.
- Study of emission measurement equipment under on-board tilt and rolling conditions finished.
- Testing of equipment while operating the engine on heavy fuel oil ongoing on WCH test bed.
- Evaluation of equipment for gaseous emission measurement from a single cylinder started.
- Preparations of fitting the NTP system to the engine test bed started.



Partners: CHALMERS Chalmers University of Technology, Sweden; SICK MAIHAK; WÄRTSILÄ

TASK 8.2: New measurement methods

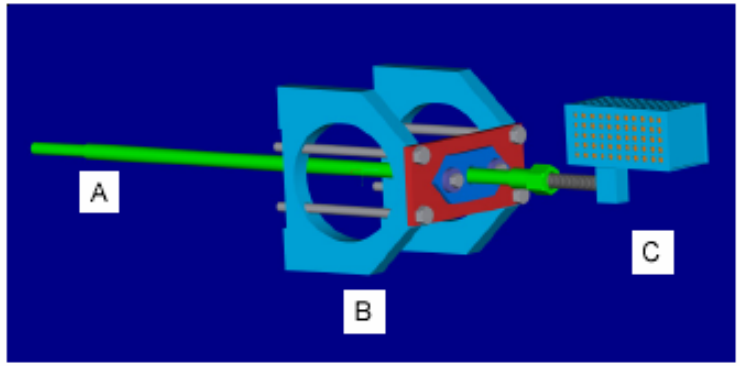
Objectives

- Extension of emissions measuring technologies for individual cylinder measurements of a multi-cylinder marine diesel engine
- Development of practical and reliable methods for emission monitoring

Test set-up for on-board measurements

Highlights

- Identification of emission measurement equipment for on-board use complying with IMO Annex VI requirements complete
- Prototyping, construction and setup procedure for on-board measurement equipment complete
- A special sample transfer tube was designed for ultra-fast (<10ms) individual cylinder NO measurement, tests performed on engine

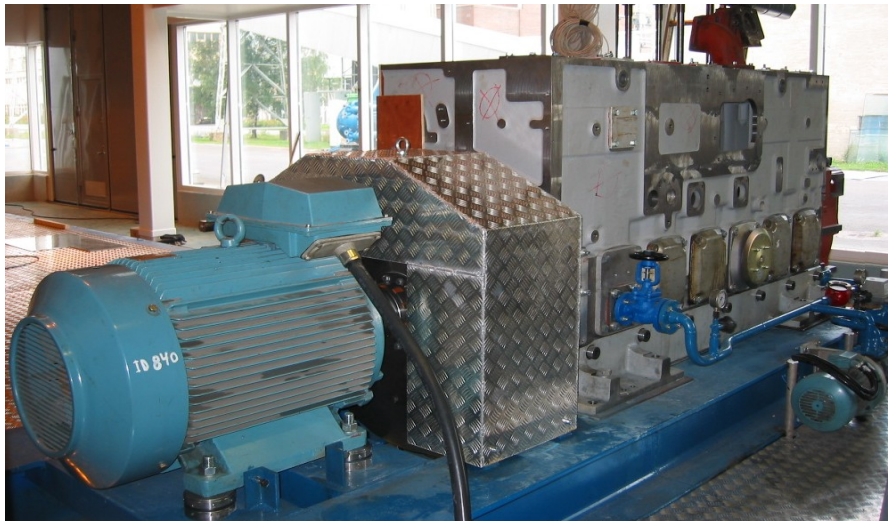


Schematic of sample probe installation for individual cylinder measurement on large diesel engines
A Sample probe
B Connector system for MAN B&W 5L16/24 diesel engine
C NOx Detector (CLD)

Partners:

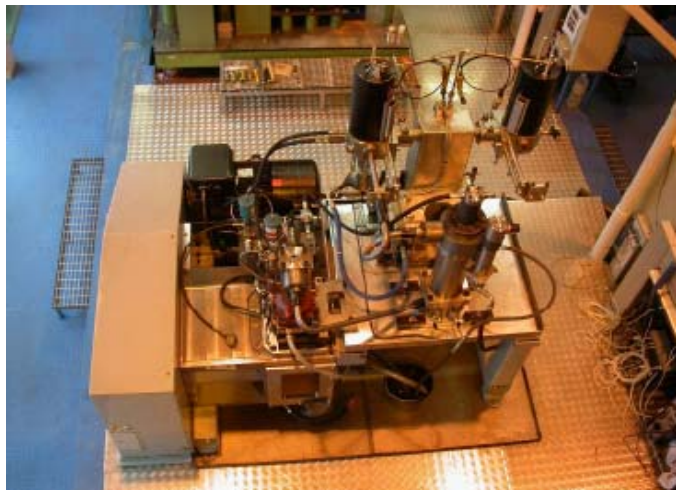
TASK 9.1: Adaptive components

Objectives: Development of engine components with reduced friction and development of adaptive components – full scale tests



Progress Highlights:

- Friction loss mapping of W20 – full scale engine test rig complete
- Bearing technologies – rig measurements and parameters / materials investigations in progress
- Low friction engine components designed - produced – rig tested
- Development of Injection Rate Shaping (RS) Methods ongoing
- Adaptive Components: Magnetic Shape Memory (MSM) actuator for fuel flow control designed – produced – bench tested



Injection quantity, shot-to-shot measurement

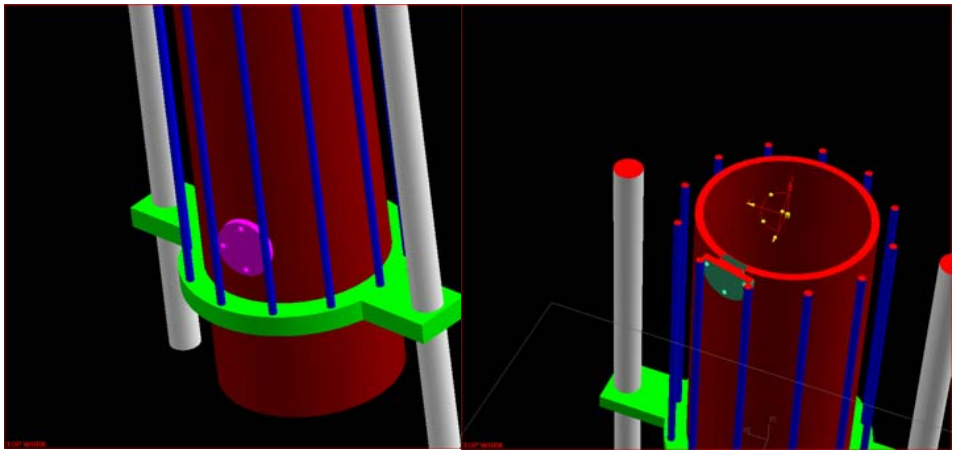
Partners: AdaptaMat, Federal Mogul, M.Jürgensen Flensburg, Miba, Woodward, VTT, Wärtsilä

TASK 9.2: Tribo-optimisation

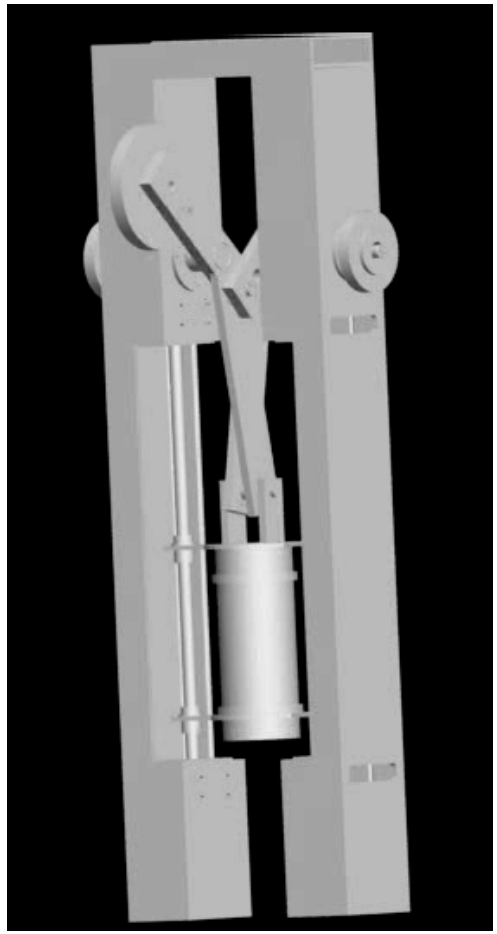
Objectives: Development of engine components with reduced friction losses – on-line control of cylinder condition by optimum lubrication

Progress Highlights:

- Feasibility studies performed - simulation code developed, first results derived
- Design specification of friction tester apparatus – manufacturing of components in progress
- Test specimens for ring groove coatings
- Design of on-line friction monitoring system – new sensors developed and installed in test rig



Sensor for online monitoring installed in rig



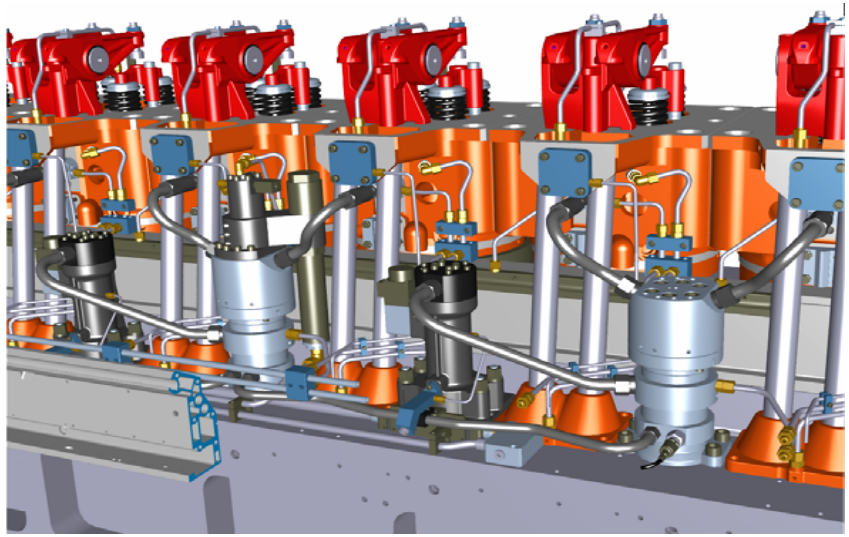
Piston ring friction tester

Partners: MAN, JOWA, iST, Miba, TAMPERE UNIVERSITY OF TECHNOLOGY

TASK 11.1: Adaptive control

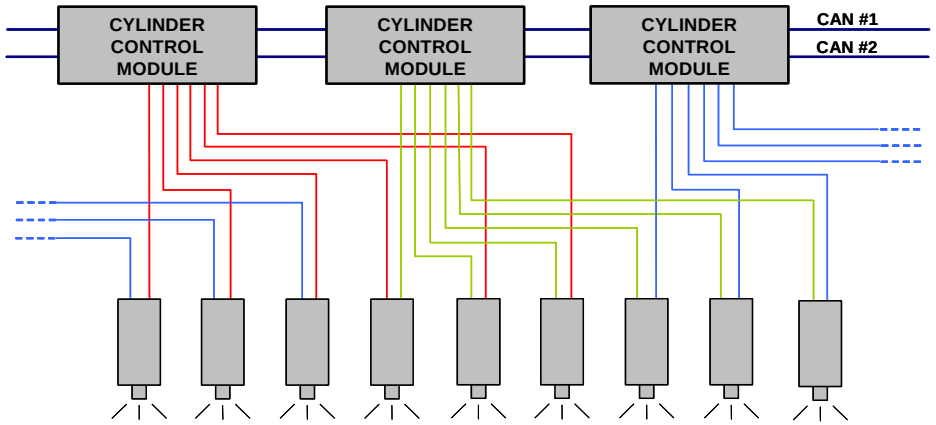
Objectives:

- Feasibility studies in adaptive control of Power Take-In (PTI) turbocompound system and vibration control
- Prototype tests of advanced controls and diagnostics



Progress Highlights:

- Turbocharger PTI modelling and preliminary controller design
- Turbocharger vibration control solutions and actuators - measurements setup
- Definition of adaptive control system structure and preliminary prototype testing
- Prototype system design in progress – Tests planned for 2006



Partners: ÅBO AKADEMI VTT WÄRTSILÄ

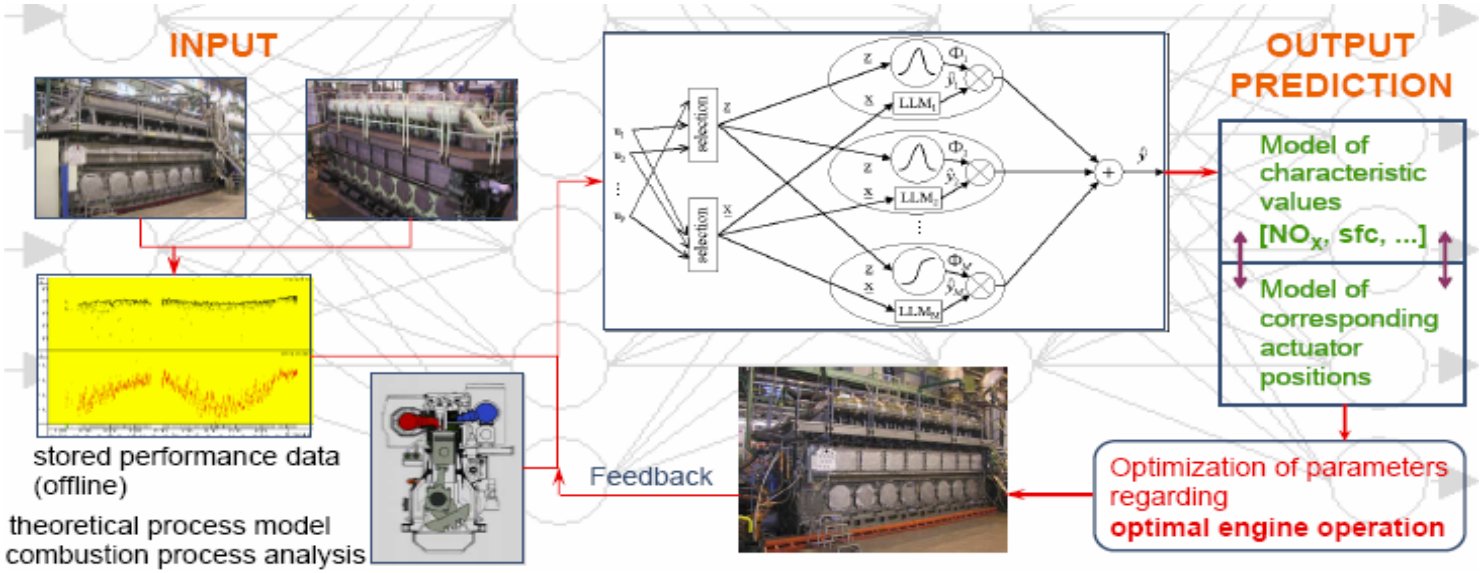
TASK 11.2: Intelligent engine

Objectives:

- Definition of control routines and objective functions, evaluation of controlled variables and actuators
- Evaluation and implementation of control algorithms
- Selection and verification of hardware components and special measurement equipment

Progress Highlights:

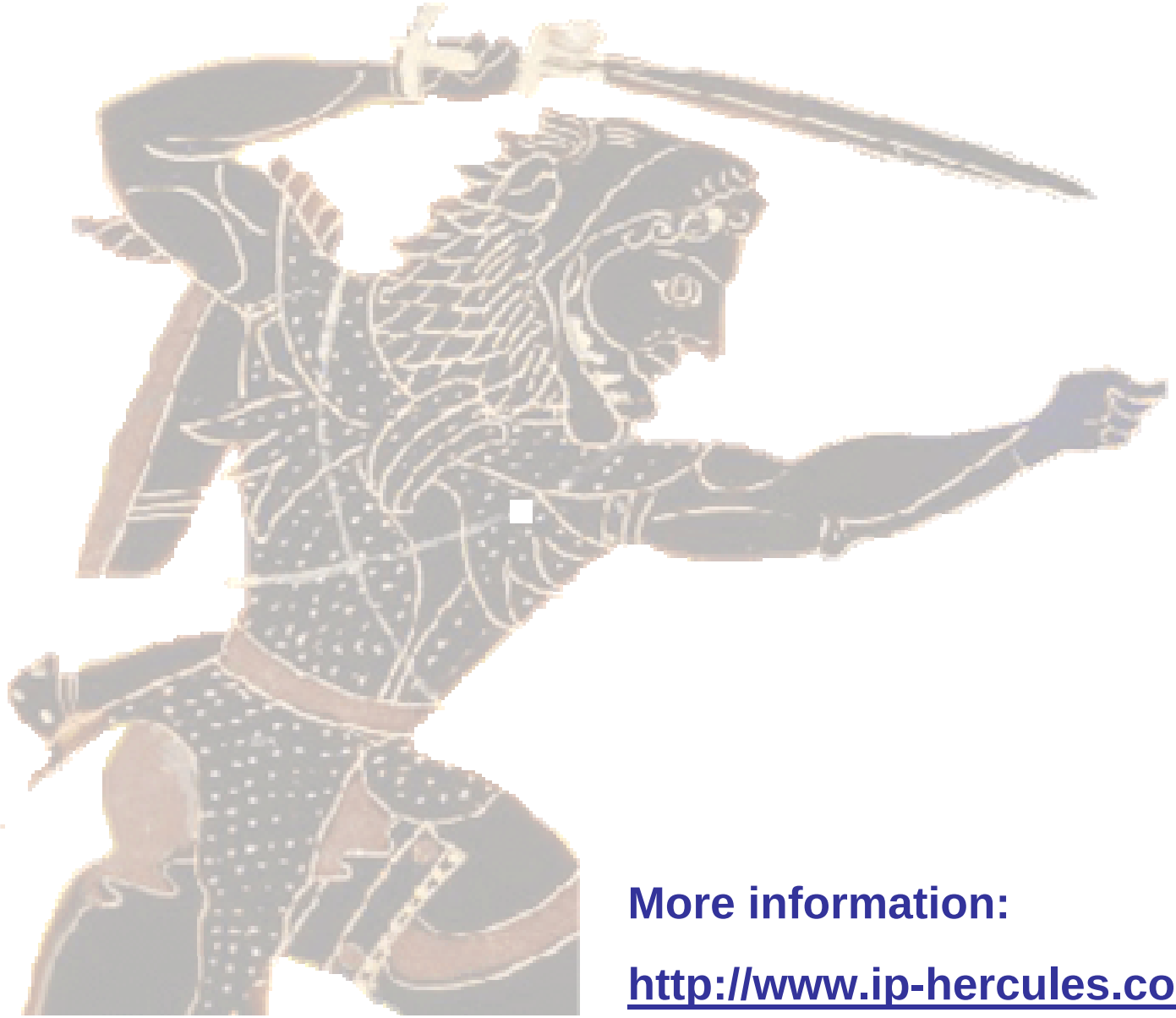
- Evaluation of controlled variables, analysis of physical/mathematical relations, definition of objective functions completed
- Investigation of suitable control algorithms and neural network software
- Actuators and controllers identified for the exhaust gas bypass system to be installed on experimental engine



Partners:

MAN

KRISTEN NAVIGATION INC.



More information:

http://www.ip-hercules.com