HERCULES-2 Project

Fuel Flexible, Near Zero Emissions, Adaptive Performance Marine Engine

Deliverable: **D11.4**

Report on dissemination activities at end of the project

Revision Final

Nature of the Deliverable:	Report
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	MAN Energy Solutions (MAN ES)
	Wärtsilä Finland Oy (WFI)
	Winterthur Gas & Diesel Ltd. (WinGD)
Work Package Leader Responsible:	Nikolaos P. Kyrtatos (NTUA)

Start date of Project: 01/05/2015 Duration: 42 months

Grant Agreement No: **634135-HERCULES-2**

HORIZON 2020

The EU Framework Programme for Research and Innovation

TABLE OF CONTENTS

1 Summary

Work Package 11 of the HERCULES-2 covers the Dissemination Activities of the Project. The objectives are the communication of the results to the scientific community and the general public. The contents of Deliverable D11.4 include the Dissemination Activities of the HERCULES-2 Project, that were executed in Period 2 and Period 3 of the Project (1/11/2016-30/4/2018 & 1/5/2018-31/10/2018), since the activities done in Period 1 are reported in the Deliverable 11.2 “Report on Dissemination Activities at Mid-Term”.

2 Introduction

The European Commission places a lot of emphasis on the Dissemination Activities of the Projects that receive funding from the European Union HORIZON H2020 Programme. The communication of the results of the Projects to public is of great importance, because:

- it proves what European collaboration can achieve
- it contributes to competitiveness and solving of societal challenges
- it shows how the outcomes are relevant to everyday life
- it is helpful for better exploitation of the foreground.

According to the communication policy of European Commission, the Dissemination Activities can take various forms, such as news updates transmitted through the official website of the programme, publications and press releases, interface with EC publicity services and presentations.

The aim of this report is to illustrate the ways, with which the progress and results of the HERCULES-2 Project were disseminated to the public.

3 HERCULES-2 Website

The HERCULES-2 official website (http://www.hercules-2.com/) has been the main gateway for publication and dissemination of the results and progress of the Project.

General information about the programme can be gained through the Public Area of the website, which consists of the following categories: Structure, Partners, Details, News, Progress updates and Publicity information, such as articles, presentations, publications etc. The Progress updates section is refreshed every 6 months with summaries of developments in every Work Package of the Project.

In addition, access to Public Deliverables is open to the general public through the HERCULES-2 website. A table with the public Deliverables can be found below.

Table of HERCULES-2 Public Deliverables				
Del. #	**Deliverable Title**	**WP #**	**Delivery Date (Month)**	**Status**
D2.1	A method for measuring in-cylinder λ-distribution in medium- speed DF engines	2	8	Uploaded
D2.4	Modelling of multi-fuel ignition	2	30	Uploaded
D2.6	Development and application of optical techniques for multi-fuel studies	2	36	Uploaded
D4.4	TMF Model for new cylinder head	4	34	Uploaded
D6.1	Study the result quality of existing subspace-search methods on uncertain data	6	12	Uploaded
D7.1	Literature review regarding SCR engine integration and particulate abatement	7	13	Uploaded
D7.2	Emission measurement systems for integrated after-treatment technologies	7	34	Uploaded
D7.6	Experimental assessment of SCR reduction agent injection systems with sensors for feedback control	7	34	Uploaded
D8.6	Results from test with engine integrated SCR on two-stroke diesel engine	8	41	Uploaded
D8.8	Study an alternative urea decomposition and mixer/SCR configuration and/or study in extended range of operation	8	39	Uploaded
D10.1	Progress review of all Work Packages	10	12	Uploaded
D10.2	Interim presentation of overall project results	10	18	Uploaded
D10.3	Progress review and results update of all Work Packages	10	24	Uploaded
D10.4	Overall review of Project results	10	42	Uploaded
D11.1	Public section of Project Website complete and operational	11	6	Uploaded
D11.2	Report on Dissemination Activities at Mid-term	11	18	Uploaded
D11.3	Compendium of scientific papers published by the Consortium	11	42	Uploaded

The public Deliverable D11.1, titled “Public section of Project Website complete and operational”, which is already completed and uploaded, offers a more detailed description of the HERCULES-2 website.

4 Publications

As depicted in the table below, 47 scientific publications have been already produced from the research work of HERCULES-2. These papers refer to important achievements of the Project and have been presented in Congresses, Conferences and Meetings worldwide.

Table of HERCULES-2 Scientific Publications					
#	**Title**	**WP**	**Conference/ journal**	**Date Approved**	**Authors**
1	Adaptive power-split control design for marine hybrid diesel powertrain	5	ASME Journal of Dynamic Systems, Measurement and Control	11/5/2016	S. Samokhin, S. Topaloglou, G. Papalambrou, K. Zenger, N. Kyrtatos
2	A Model of a Marine Two-Stroke Diesel Engine with EGR for Low Load Simulation	6	EUROSIM 2016, Oulu, Finland	11/5/2016	X. Llamas, L. Eriksson
3	SCR under pressure - pre-turbocharger NOx abatement for marine 2-stroke diesel engines	7	28th CIMAC, Helsinki, Finland, June 2016	19/5/2016	K. Sandelin, D. Peitz
4	From HERCULES A-B-C to HERCULES-2 : A classic cooperative programme in large engine R&D	10	28th CIMAC, Helsinki, Finland, June 2016	19/5/2016	N. Kyrtatos, G. Stiesch, I. Kallio
5	Investigation of Different Piston Ring Curvatures on Lubricant Transport along Cylinder Liner in Large Two-Stroke Marine Diesel Engines	6	17th Nordic Symposium on Tribology 2016	19/5/2016	H.C. Overgaard, P. Klit, A. Voelund
6	Engine Knock Margin Estimation Using In-Cylinder Pressure Measurements	5	IEEE/ASME Transactions on Mechatronics	14/6/2016	G. Panzani, F. Ostman, C. Onder
7	Parameterizing compact and extensible compressor models using orthogonal distance minimization.	6	ASME Journal Engineering for Gas Turbines and Power	27/6/2016	X. Llamas, L. Eriksson
8	Measuring injection of urea solution into a high pressure hot gas test rig for SCR-applications	8	International Congress of Engine Combustion Processes: Current Problems and Modern Techniques	19/12/2016	M. Höltermann, N. Kawaharada, J. Wichmar, F. Dinkelacker
9	Control-Oriented Compressor Model with Adiabatic Efficiency Extrapolation	6	SAE World Congress and Exhibition 2017	21/12/2016	X. Llamas, L. Eriksson
10	Investigation of Ammonia Synthesis for Large Scale SCR-Applications by Means of a Hot Gas Test Rig	8	8th European Combustion Meeting 2017 in Dubrovnik, Croatia	18/12/2017	M. Höltermann, J. Wichmar, T. Wittenbreder, F. Dinkelacker
11	Analysis of Cylinder Pressure Measurement Accuracy for Internal Combustion Engine Control	5	SAE World Congress 2017, Detroit, Michigan, USA.	27/1/2017	X. Storm, H. Salminen R. Virrankoski, S. Niemi, J. Hyvönen
12	Adaptive and Unconventional Strategies for Engine Knock Control	5	IEEE Transactions on Control System Technology	23/3/2017	D. Selmanaj, S. van Dooren, G. Panzani, J. Rosgren, C. Onder
13	Spray Combustion Chamber: History and Future of a Unique Test Facility	1	28th Conference on Liquid Atomization and Spray Systems ILASS-Europe 2017	3/4/2017	A. Schmid, N. Yamada
14	Design and experiments to investigate spray and impingement characteristics of a common rail type lubrication system	5	28th Conference on Liquid Atomization and Spray Systems ILASS-Europe 2017	20/4/2017	M. Stark, A.de Risi, M. Giangreco, S. Diggelmann
15	Engine knock margin control using in-cylinder pressure data: preliminary results	5	56th IEEE Conference on Decision and Control (CDC2017)	20/4/2017	G. Panzani,D. Selmanaj, O. Gallupi, S. Savaresi, J. Rösgren, C. Onder
16	Model Predictive Control for Hybrid Diesel-Electric Marine Propulsion	5	IFAQ 2017 World Congress	25/4/2017	G. Papalambrou, S. Samokhin, S. Topaloglou, N. Planakis, N. Kyrtatos, K. Zenger
17	Flow in axisymmetric expansion in a catalytic converter	8	12th International Symposium on Particle Image Velocimetry	12/5/2017	E. Gotfredsen, K.E. Meyer
18	Modeling of particulate matter emissions from engine combustion	1	SAE 2017 International Powertrains, Fuels and Lubricants Meeting	18/5/2017	K. Hentelä, O. Kaario, M. Larmi, V. Garaniya, L. Goldsworthy

19	Investigation of the Combined Application of Water-in-Fuel Emulsion and Exhaust Gas Recirculation in a Medium Speed Diesel Engine	7	9th International Conference on Modeling and Diagnostics for Advanced Engine Systems (COMODIA 2017), July 25-28, 2017, Okayama, Japan	6/6/2017	B. von Rotz, P. Kyrtatos, K. Herrmann, K. Boulouchos
20	Feasibility of new liquid fuel blends for medium-speed engines	1	Fuel journal	30/6/2017	K. Sirviö, S. Niemi, S. Heikkilä, M. Hissa, E. Hiltunena
21	Transient Load Share Management of a Diesel Electric Hybrid Powertrain for Ship Propulsion	5	International Journal of Powertrains	28/7/2017	S. Topaloglou, G. Papalambrou, K Bardis, N. Kyrtatos
22	Calibration method for the determination of the FAME and HVO contents in fossil diesel blends using NIR spectroscopy	1	Fuel journal	8/8/2017	L. Sherman, S. Heikkilä, K. Sirviö, S. Niemi, P. Välisuo, A. Niemi
23	An Optical Investigation of Diesel-Pilot and Methane Dual-Fuel Combustion	1	Nordic flame days 2017	4/10/2017	Z. Ahmad , J. Aryal, O. Ranta, O. Kaario, M.Larmi
24	Investigation of the Cylinder Cut-Out for Medium Speed Dual Fuel Engines	6	Heavy-Duty - On- and Off-Highway Engines /MTZ Industrial 1/2018	4/10/2017	J. Konrad, T. Lauer, M. Moser, J. Zhu
25	Influence of the Al content on the aqueous corrosion resistance of binary Fe-Al alloys in H2SO4	3	Proceedings Intermetallics 2017	2/11/2017	J. Peng, F. Moszner, D. Vogel, M. Palm
26	Kinematic viscosity studies for medium-speed CI engine fuel	1	Agronomy Research	16/2/2018	K. Sirviö, R. Help, S. Niemi, S. Heikkilä, E. Hiltunen
27	Properties of local produced animal-fat based biodiesel and its blend with fossil fuel	1	Agronomy Research	16/2/2018	K. Sirviö, S. Heikkilä, R. Help, S. Niemi, E. Hiltunen
28	Crank Shaft Torsional Vibration Analysis on the perspective of Improving the Crank Angle Measurement Accuracy for Closed-loop Combustion Control in ICES	5	SAE World Congress 2018	17/2/2018	X. Storm, H. Salminen, R. Virrankoski, S. Niemi, J. Hyvonen
29	Engine Efficiency Optimization under Consideration of NOX- and Knock-Limits for Medium Speed Dual Fuel Engines in Cylinder Cut-Out Operation	6	SAE World Congress 2018	17/2/2018	J. Konrad, T. Lauer, M. Moser
30	Control-oriented modeling of two-stroke diesel engines with EGR for marine applications	6	SAGE Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment	9/3/2018	X. Llamas, L. Eriksson
31	Predictive Control for a Marine Hybrid Diesel-Electric Plant During Transient Operation	5	5th International Conference on Control, Decision and Information Technologies	13/3/2018	N. Planakis, G. Papalambrou, N. Kyrtatos
32	Combustion Property Analyses with Variable Liquid Marine Fuels in Combustion Research Unit	1	Agronomy Research	17/3/2018	M. Hissa, S. Niemi K. Sirviö
33	Impact of catalyst activity and geometry on diffusion and SCR kinetics under elevated pressures	7	Chemie Ingenieur Technik" WILEY-VCH	30/3/2018	D. Peitz, M. Elsener, O. Kröcher
34	High-pressure pyrolisis and oxidation of ethanol	2	Fuel Journal	15/3/2018	H. Hashemi, J.M. Christensen, P. Glarborg
35	High-pressure oxidation of ethane	2	Combustion & Flame Journal	15/3/2018	H. Hashemi, J. Jacobsen, C. Rasmussen, J. Christensen , P. Glarborg, S. Gersen, M. van Essen, H. Levinsky, S. Klippenstein
36	Towards a temperature dependent and probabilistic lifetime concept for nodular ductile cast iron materials undergoing isothermal and thermo-mechanical fatigue	4	Fatigue 2018	11/4/2018	E.G. Trelles, C. Schweizer, S. Eckmann

37	Influence of the Al content and Pre-oxidation on the Aqueous Corrosion Resistance of Binary Fe-Al Alloys in Sulphuric Acid	3	Corrosion Science	8/6/2018	J. Peng, F. Moszner, J. Rechmann, D.Vogel M.Palm, M. Rohwerder
38	Experimental analysis of fuel alternatives for marine propulsion systems	1	ICLASS 2018	13/6/2018	A. Schmid, R. Bombach, T. Yildirim
39	NH_3 sensor measurements in different engine applications	7	SAE INTERNATIONAL POWERTRAINS, FUELS & LUBRICANTS MEETING conference	2/7/2018	T. Murtonen, H. Vesala, P. Koponen, R. Pettinen, T. Kajolinna, O. Antson
40	Skip Firing in Medium Speed Dual Fuel Engines: Detailed Assessment and Engine Performance Optimization in Compliance with IMO Tier III	6	Rostocker Großmotorentagung	18/7/2018	J. Konrad, T. Lauer, M. Moser, E. Lockner, J. Zhu
41	Isothermal Oxidation Behavior of Tribaloy™ T400 and T800	3	NPJ Materials Degradation Journal	21/7/2018	J. Peng, X. Fanga, V. Marx, U. , M. Palm
42	Development of a shear ultrasonic spectroscopy technique for the evaluation of viscoelastic fluid properties: theory and experimental validation.	5	Elsevier Journal Ultrasonics	26/7/2018	M. Schirru, X.Li, M. Cadeddu, R.S. Dwyer-Joyce
43	Transient Simulation of a Large Two-Stroke Marine Diesel Powerplant Operation with a High Pressure SCR Aftertreatment System	6	27th Aachen Colloquium Automobile and Engine Technology 2018	26/7/2018	M. Foteinos, N. Kyrtatos
44	Robustness analysis of the next generation of EGR controllers in marine two-stroke diesel engines	6	International Ship Control Systems Symposium 2018 (iSCSS 2018)	14/8/2018	X. Llamas, L. Eriksson
45	Eindüsung von Harnstoff-Wasser-Lösung mit Zweistoffdüsen für großskalige SCR-Systeme unter Druck	8	16. FAD-Conference "Herausforderung - Abgasnachbehandlung für Dieselmotoren"	25/9/2018	M. Höltermann, P. Roloff, F. Dinkelacker
46	SCR beschichteter Dieselpartikelfilter für schnelllaufende Vier-takt-Dieselmotoren im Marinebereich	8	16. FAD-Conference "Herausforderung - Abgasnachbehandlung für Dieselmotoren"	26/10/2018	M. Kleinhenz, A. Fiedler, A. Döring
47	SCR coated DPF for Marine Engine Applications	8	11th International Congress on Catalysis and Automotive Pollution Control	26/10/2018	M. Kleinhenz, P. Lauer, A. Fiedler, A. Döring

The first page of each publication presented in the above table is included in Deliverable D11.3 “Compendium of scientific papers published by the Consortium”.

5 HERCULES – 2 in Press and Media

Before the official start and throughout the HERCULES-2 Project, several articles have been published in the international press about the Project, its partners and its aims. A list of these articles is found below.

Table of HERCULES-2 articles in Press and Media		
Source	**Title**	**Date**
HORIZON, The EU Research & Innovation Magazine	Cleaner engines and spinning sails propel emissions reductions in big ships	September 2017
Marine Power& Propulsion supplement to The Naval Architect-RINA	Hercules alliance set to break new ground	October 2016
MTZ Industrial	Editorial: The end of Two Eras	September 2015
MTZ Industrial	Hercules-2. Engine R&D Programme	September 2015
Diesel & Gas Turbine Worldwide	EU-Funded Project Hercules-2 Launched	August 2015
Wärtsilä Corporation, Trade Press Release	Wärtsilä, MAN Diesel & Turbo and Winterthur Gas & Diesel to collaborate on major, EU-funded project	July 2015

MAN Diesel & Turbo, Press Release	Wärtsilä, MAN Diesel & Turbo and Winterthur Gas & Diesel to collaborate on major, EU-funded project	July 2015
Winterthur Gas & Diesel , Press Release	Winterthur Gas & Diesel, Wärtsilä and MAN Diesel & Turbo to collaborate on major, EU-funded project	July 2015
NafsGreen Word Shipping News	Wärtsilä, MAN Diesel & Turbo and Winterthur Gas & Diesel to collaborate on major, EU-funded project	July 2015
The motorship	Engine makers collaborate in milestone project	July 2015
Ship & Bunker	Wärtsilä, MAN Diesel & Turbo and Winterthur Gas & Diesel to Lead Project for Ship Engine Efficiency	July 2015
Ship & Bunker	Wärtsilä, MAN Diesel & Turbo and Winterthur Gas & Diesel to Lead Project for Ship Engine Efficiency	July 2015
Ship Efficiency	All hail HERCULES	July 2015
Ship Technology	Wärtsilä, MAN, and Winterthur to jointly develop marine engine technologies	July 2015
Marine Log	European diesel leaders launch Hercules2 initiative	July 2015
The Marine Professional	Engine builders prepare for Hercules sequel	July 2015
Reuters	Wärtsilä, MAN Diesel & Turbo and Winterthur Gas &Diesel to collaborate on major, EU-funded project	July 2015
Wärtsilä Corporation, Trade Press Release	Wärtsilä and MAN Diesel & Turbo initiate HERCULES-2 research project aimed at minimizing emissions	September 2014
MAN Diesel & Turbo, Press Release	Wärtsilä and MAN Diesel & Turbo initiate HERCULES-2 research project aimed at minimizing emissions	September 2014
Maritime Propulsion	Wärtsilä, MAN Diesel & Turbo Renew Emissions Reduction Research	September 2014
Marine Engines and Fuels	Wartsila and MAN Launches Hercules-2 Research Project	September 2014
Seatrade Maritime News	MAN D&T and Wärtsilä team up to reduce fuel use, emissions for large engines	September 2014

6 Press Releases

At the beginning of the Project, in July 2015, the 3 principal partners of the Project, MAN Diesel & Turbo SE, Wärtsilä and Winterthur Gas and Diesel Ltd., issued a common press release. The topics, which were addressed in it, referred to the continuation of cooperation between the three companies in the fourth Phase of the HERCULES Project and the objectives of it. The Press Release was widely reported in the international Media. The Press Release text is mentioned in the D11.2 “Report on Dissemination Activities at Mid-Term”. Furthermore, a Press Release for the ending of the HERCULES-2 Project will be prepared also by the 3 principal partners of the Project, MAN-ES, Wärtsilä and Winterthur Gas & Diesel Ltd., and will be released after the end of the Project.

7 Presentations of the overall Project Results

There have also been general presentations that offer an overview of the progress of the Project. The first general presentation, which was presented in the 28th World CIMAC Congress in Helsinki, June 2016, is included in the Deliverable D11.2 “Report on Dissemination Activities at Mid-Term”.

An overview of the HERCULES R&D programme was presented in the CIMAC Circle at Norshipping 2017, which took place in Oslo, Norway on May 2017. The CIMAC Circle with the theme “Green Shipping – What is it all about?” was held with specialists from the Engine industry addressing an eagerly awaited audience regarding the future of shipping, focusing on environmentally sustainable technologies and solutions. The R&D program HERCULES was presented by Coordinator as an example to show the progression of how ‘green’ engines are taking a center stage today and will continue to do so in the future, underlining some of the technological strides such as multi-stage turbocharging, fuel flexibilities with fuel-injection optimizations, SCR and EGR technologies etc.

Also, another paper titled “The HERCULES-2 Project of R&D on large engines for ships” was presented at Transport Research Arena Conference, in Vienna, April 2018. This paper referred to the milestones that have been achieved during the whole HERCULES Programme, as well as the latest accomplishments of the HERCULES-2 Project, describing the evolution towards the objectives and work-plan as well as the results of the HERCULES-2 project in all areas.

A descriptive overview of the overall HERCULES Programme, its achievements and results titled “The HERCULES (2004-2018) programme of R&D in large engine technologies” was presented also by Coordinator in the SMM 2018 the leading international maritime trade fair which took place in Hamburg, 4-7 September 2018.

Moreover, in the HERCULES-2 3rd Partners Forum and Final Meeting, in October 2018 the Coordinator presented the HERCULES-2 Overview and Round up for the closure of the Project. Also in the Panel discussions which took place in this Forum (see par. 10 below) the Coordinator introduced the Panel themes with two presentations, i.e. the “HERCULES Achievements” and “The future in marine engines”. The whole meeting including the panel discussion was broadcast over the Internet through the HERCULES-2 website.

The above mentioned presentations are summarizedin the table below.

Table of HERCULES-2 general presentations			
Date	**Venue**	**Author**	**Title**
10 October 2018	HERCULES-2 Final Meeting & 3rd Partners Forum, MAN Museum, Augsburg	Nikolaos Kyrtatos	Hercules-2 Overview, Roundup
10 October 2018	HERCULES-2 Final Meeting & 3rd Partners Forum, MAN Museum, Augsburg	Nikolaos Kyrtatos, Ulf Waldenmaier, Stefan Mayer, Sebastiaan Bleuanus, Wolfang Östreicher, Dino Imhof	Panel I: HERCULES Achievements
10 October 2018	HERCULES-2 Final Meeting & 3rd Partners Forum, MAN Museum, Augsburg	Nikolaos Kyrtatos, Gunnar Stiesch, Niels Kjemtrup, Mikael Wideskog, Konrad Räss	Panel II: The future in marine engines

6 September 2018	SMM 2018, Hamburg, Germany	Nikolaos Kyrtatos	The HERCULES (2004-2018) programme of R&D in large engine technologies
17 April 2018	TRA Conference, Vienna, Austria,	Nikolaos Kyrtatos	The HERCULES-2 Project of R&D on large engines for ships
31 May 2017	CIMAC Circle at Norshipping 2017, Oslo, Norway	Nikolaos Kyrtatos	The HERCULES (2004-2018) R&D program on 'green' engines for ships
7 June 2016	28th CIMAC Congress, Helsinki, Finland	Nikolaos Kyrtatos	From HERCULES A-B-C to HERCULES-2 : A classic cooperative programme in large engine R&D

8 Interface with EC publicity services

Upon request from the EC Officer, a presentation with the general description of the Project and photos that illustrate parts of the progress made, were prepared and sent on July 2015 for publicity and communication reasons of INEA. A Project Fiche of HERCULES-2 was also prepared to be included in the Project Fiches for the Horizon 2020 Transport Projects which INEA is managing, providing details for the Project. These 2 actions are described in the D11.2 “Report on Dissemination Activities at Mid-term”.

A 4-page HERCULES Programme Leaflet and 1-page HERCULES-2 Project Poster (see below) was produced for communication purposes on October 2017.The leaflets have been circulated by in Project meetings, Technical Conferences and seminars and in Trade Fairs like SMM. The HERCULES Project leaflet presents the achievements and results of the R&D HERCULES Programme from 2004 till today. The HERCULES-2 Project Poster shows the objectives and the Work Package Areas of the HERCULES-2 Project.

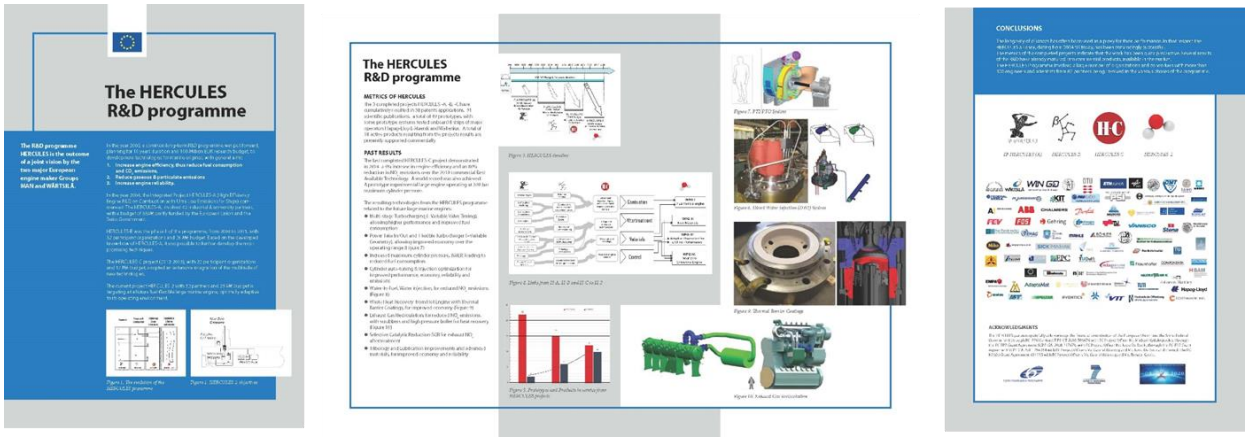


Figure 8.1 HERCULES R&D Programme Leaflet

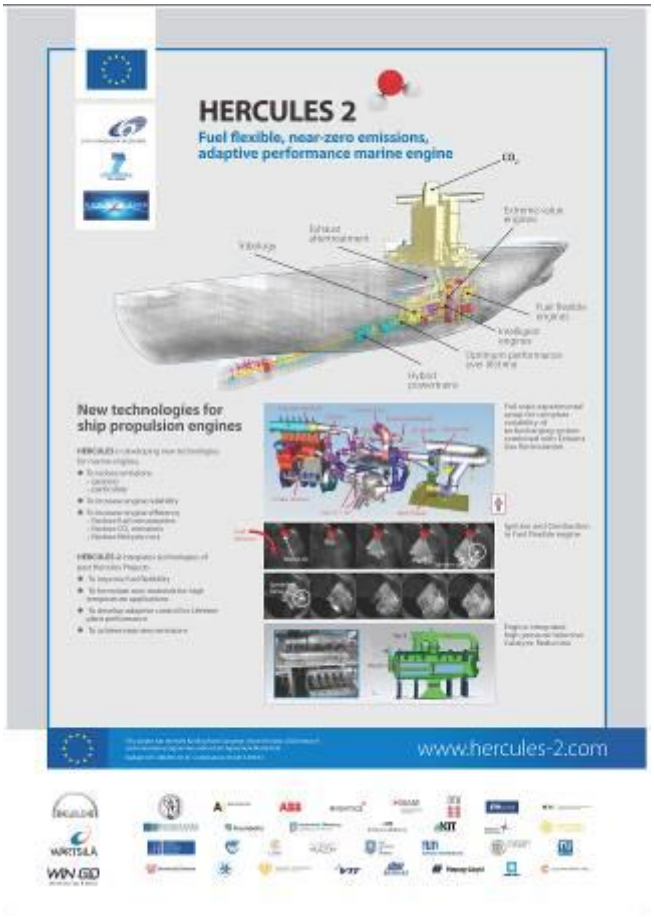


Figure 8.2 HERCULES-2 Project Poster (A0 size)

Also, a video describing the HERCULES Program has been compiled on April 2018. This video has been uploaded on YouTube, has been forwarded to EC Project Officer for INEA's dissemination activities and has been sent to EC RTD so as to be added to the EU-funded R&I projects YouTube Playlist and promoted via social media channels. The video has been added also in the HERCULES-2 website. The video is available in 2 versions on short 1.50 minutes and one full 2.40 minutes.

Further, the HORIZON Research & Innovation Magazine has published an article, titled "Cleaner engines and spinning sails propel emissions reductions in big ships", on 12th September 2017, with Coordinator's interview.

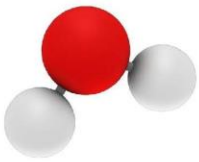
9 Posters

The Partners' Forum is a congregation of representatives of all partners. It convenes annually, organized by the Coordinator (person designated Technical Coordinator & Administrative Manager), to exchange views, present results and assist in bottom-up coordination and assessment of the Project objectives. The Forum program includes a review of the overall progress of the Project, presentations and poster expositions of individual Work Packages results.

During the Project, 3 Partners' Forums were organised, all of which included a Poster Session. In the first two Forums, Posters were exhibited to illustrate the progress of each Work Package. Each

poster contained Objectives, Expected Outcomes, Progress and Plans for each Work Package. The posters of these Forums can be found in the Deliverable D11.2 “Report on Dissemination Activities at Mid-Term”.

In the Final Partners’ Forum, which convened in October 2018, in Augsburg, Germany, the poster session included Posters, which show in an explicit way the final results and achievements of each Work Package at the end of the Project. The eight posters of the respective Work Packages are presented below.

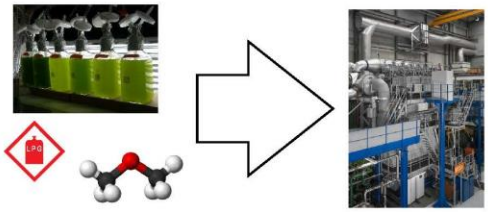


WP 1 Fuel Flexible Engine

WP OBJECTIVES

To develop **engines able to switch between fuels**, whilst operating in the most cost effective way and complying with the regulations in all sailing regions.

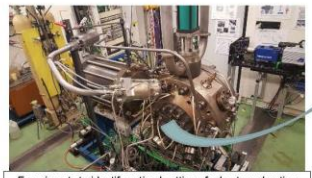
- Study ignition capability of selected fuel candidates
- Develop a fuel injection system for multi fuel purposes
- Demonstrate fuel flexible engine operation
- Perform feasibility study on Rapid Compression Expansion Machine (RCEM)



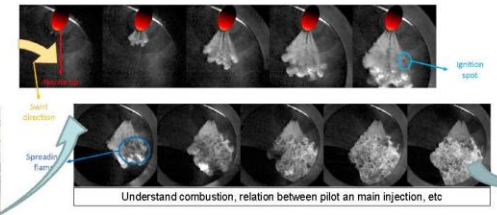
Define and develop fuel injection system and demonstrate fuel flexibility on the engine

ACHIEVEMENTS & FINAL RESULTS

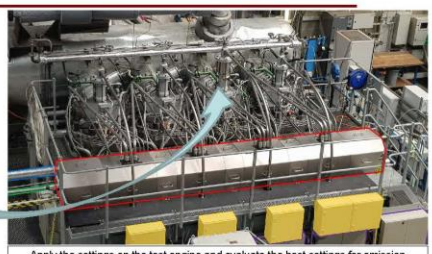
2-stroke



Experiments to identify optimal settings for best combustion

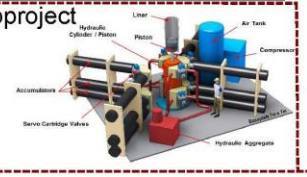


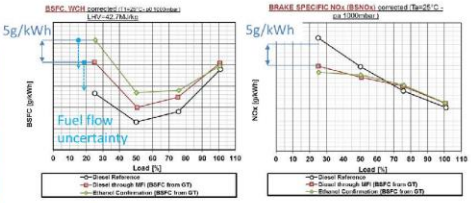
Understand combustion, relation between pilot an main injection, etc

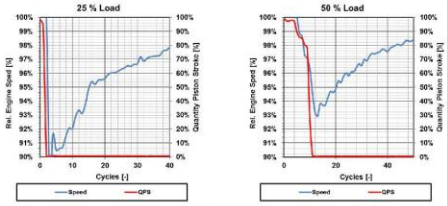


Apply the settings on the test engine and evaluate the best settings for emission reduction and fuel economy

Subproject 1.2



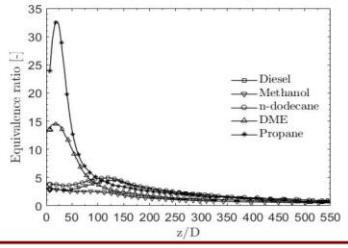


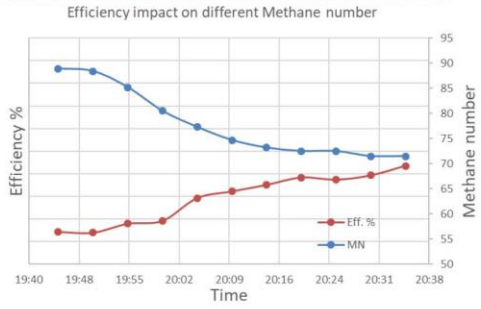


4-stroke

For the first time ever, we measured the droplet sizes (SMD) of methanol sprays.

LES simulations of various fuels indicated significant differences in the local equivalence ratio fields within the fuel sprays. This could have fundamental effects on e.g. emission during combustion.





A variation in gas quality is having a clear impact on the engine performance. This should and can be controlled with online gas measurement and control

WP PARTICIPANTS

WP1 - 4 stroke

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WP1 - 2 stroke

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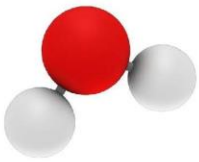
OMT Torino
Winterthur Gas & Diesel Ltd.

WP Contact Information: Andreas Schmid, Winterthur Gas & Diesel Ltd. (Andreas.Schmid@wingd.com)



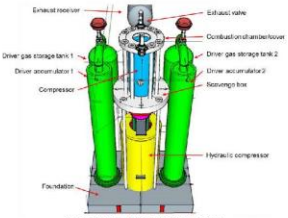
WP 2 Multi-fuel combustion

WP OBJECTIVES

The overall objective is to improve fuel flexibility of marine engines. In order to efficiently exploit a larger variety of fuels an increased understanding of injection, combustion and emissions formation is required. For this purpose we developed experimental facilities with optical access for tests under conditions relevant for marine engines. For furthering understanding of ignition and emission formation numerical tools were also developed and applied. Finally, novel engine control strategies were developed to fully exploit potential benefits of such fuels.

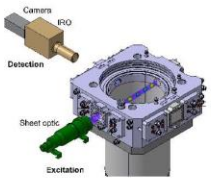
ACHIEVEMENTS & FINAL RESULTS

A test combustion chamber for controlled experiments under realistic conditions designed, but not completed.

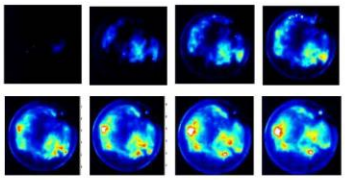


Test combustion chamber concept

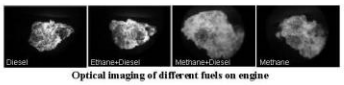
Optical cylinder head and measurement of 3D in-cylinder mixture formation on dual-fuel engine.



Optical cylinder head for medium speed dual-fuel engine

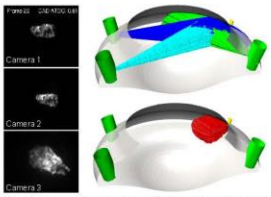


Measurement of flame luminescence with vertical access

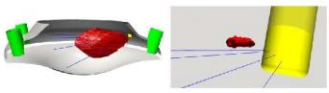


Optical imaging of different fuels on engine

Optical tests on several fuels performed on the 4T50ME-X engine. Those include multi-camera 3D imaging.

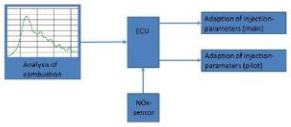


Tri-camera flame imaging for spatial mapping of flames using space carving

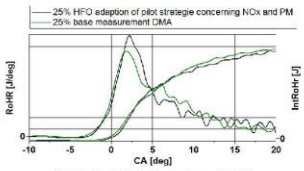


Developed flame (left) and initial ignition kernel (right)

Fuel-specific engine-control strategy developed on single cylinder engine and validated on full scale dual-fuel engine.

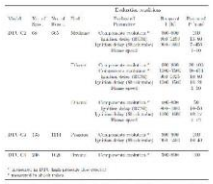


Concept for fuel-flexible engine

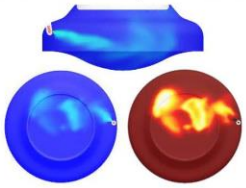


Optimised pilot-injection strategy with HFO

Detailed chemical kinetic models for new alternative fuels developed and CFD of single and multi-fuel performed.

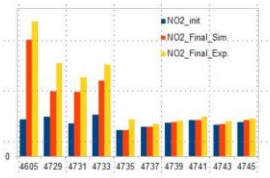


Overview of detailed chemical kinetic models

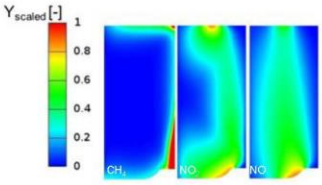


Mixture fraction and temperature calculated using CFD for dual-fuel combustion on low-speed engine

Numerical model to predict NO_2 formation in a dual-fuel medium speed engine



Comparison between NO_2: simulation vs. experiment (exhaust duct model)



Simulated concentration in combustion chamber at BDC

WP PARTICIPANTS

- MAN Energy Solutions: Copenhagen (2-stroke), Augsburg (4-stroke)
- Danish Technical University: Department of Chemical Engineering (Prof. Glarborg)
- Lund University: Division of Combustion Physics (Prof. Mattias Richter, Prof. Xue-Song Bai)
- Technical University of Munich: IC Engines (Prof. Wachtmeister), Thermodynamik (Prof. Sattelmayer)
- Politecnico di Milano: Department of Energy (Prof. Onorati)

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WP Leader: Johan Hult (johan.hult@man-es.com) Deputy WP Leader: Christian Kunkel (christian.kunkel@man-es.com)

WP 3 Intermetallics and adv. materials for marine engines

WP OBJECTIVES

Subproject 3.1: Novel materials for engine applications

Examine possibilities of using novel materials in engines to facilitate the development of components that enable higher engine loads, hereby increasing efficiency and lower emissions. Ensure proper lifetime performance and durability.

Subproject 3.2: Novel materials for turbine casing

Material of turbine casing is reviewed in respect of material and design in order to meet requirements needed for higher exhaust gas temperatures.

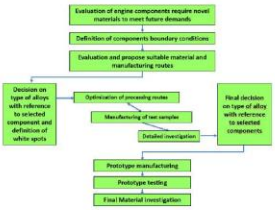
EXPECTED OUTCOME

Subproject 3.1: Suitable new materials can be identified for at least two components for higher load operations and longer life time.

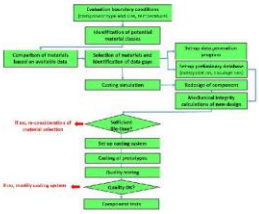
Subproject 3.2: Performance is improved through material / design optimization.

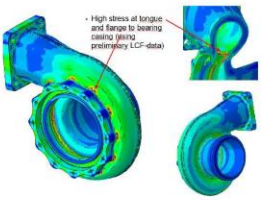
PROGRESS AND PLANS

Subproject 3.1



Subproject 3.2





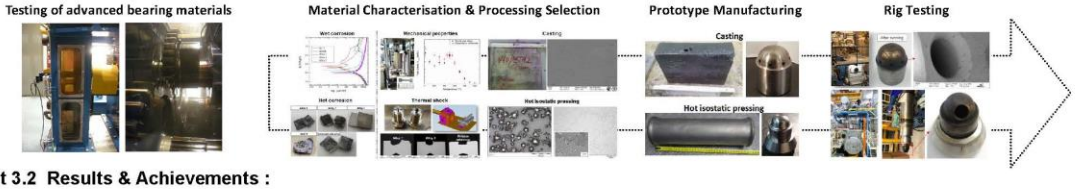
Subproject 3.1 Results & Achievements :

DONE

- Definition of boundary condition and selecting of materials/processing routs
- Detailed material characterisation of samples produced via different routs
- Manufacturing of prototypes and rig testing

CONCLUSIONS

- Investment casting can produce near net shape components
- Alloy 2 exhibits sufficient hot corrosion resistance and for 2-stroke application mechanical properties seems sufficient
- opportunities for enabling higher bearing loads identified



Subproject 3.2 Results & Achievements :

DONE

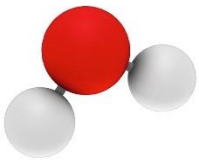
- Decided casting type & manufacturing method
- Preliminary material database setup
- Casting simulation & parametrisation of CAD-model
- Defintion of load profile
- Elimination of stress hot-spots

CONCLUSIONS

- Turbine casing made of heat resistant cast steel is possible
- Lifetime analysis shows which improvements are needed for serial production
- Material data generated highly beneficial for ABB Turbo Systems
- Prototype made, next step would be field testing

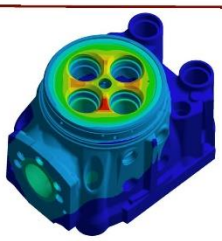
WP PARTICIPANTS

WP lead: WinGD WP deputy: Wärtsilä.



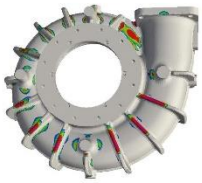
WP4 - New Materials for Higher Engine Efficiency

WP OBJECTIVES

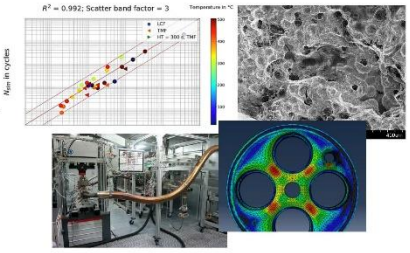


The majority of concepts for emission reduction in internal combustion engines go along with higher component temperatures and mechanical loads. Thus, the thermo-mechanic fatigue (TMF) of engine components comes more into focus. The objective of this Work Package is to develop the use of appropriate material for optimized combustion engines focusing on the cylinder head and the turbocharger turbine casting.

- Improvement of thermo-mechanical cycle resistance of factor 2 under increased temperature of 50 K
- Decreased weight of cylinder head of 20%
- Improvement of thermo-mechanical cycle resistance under increased temperature of 70 K under corrosion environment

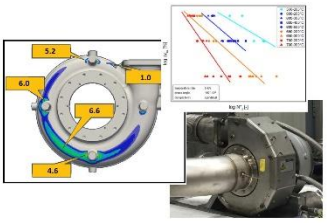


ACHIEVEMENTS & FINAL RESULTS



WP 4.1 New materials and design for cylinder heads

- evaluation the selected material in detail (isothermal complex LCF tests, TMF, metallographic investigations)
- New material model development
- Optimization of Cylinder Head



WP 4.2 New materials for the turbocharger turbine casing

- material model development for fatigue and creep
- validation of developed material model within application on TC inlet casing on hot burner test rig: deviation of max. 23% of predicted life

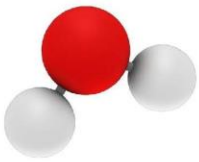
Exploitation:

- Results from WP4 implemented into newest design of cylinder head of 45/60, first engines in field in 2019
- Turbocharger successful tested and design is proofed
- Method for design established for future product development

WP PARTICIPANTS

MAN Energy Solutions SE is a leading supplier of diesel and gas engines for maritime and stationary applications
BAM is the Federal Institute for Materials Research and Testing of the Federal Republic of Germany.
FG Fraunhofer is Europe's largest application-oriented research organization.
HSO The cornerstones of Offenburg University are applied research, innovation and technology transfer sciences.

WP Leader: Dr. Rayk Thumser, rayk.thumser@man.eu, Deputy: Santiago Uhlenbrock, santiago.uhlenbrock@man.eu

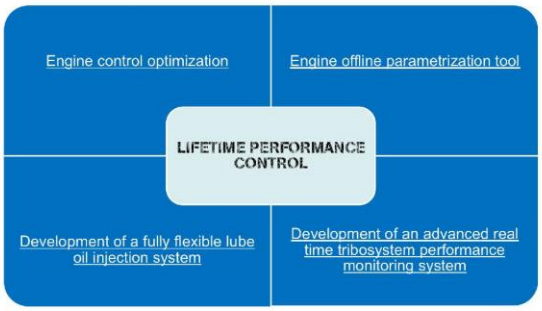


WP 5

Lifetime Performance Control

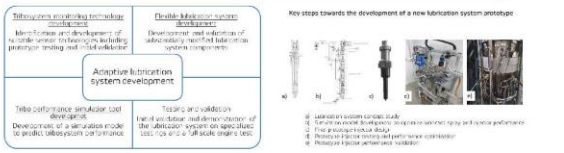
WP OBJECTIVES

Develop methods, systems and processes allowing a continuous optimized performance of the power plant throughout its lifetime

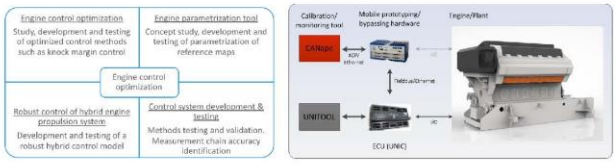


ACHIEVEMENTS & FINAL RESULTS

- Advanced lubrication control system
- Optimized lube oil feed rates
- Optimized control & parametrization algorithms for optimal performance throughout lifetime
- Technology demonstrators at TRL 6
- 15% potential lube oil consumption reduction



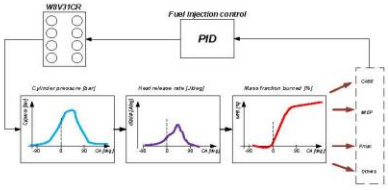
5.3, 5.4: Development steps towards an adaptive lubrication system



5.1, 5.2: Engine control optimization & parametrization

Conclusions: Sub-project 5.1, 5.2:

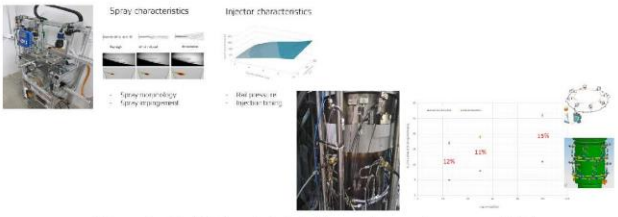
- Successful demonstration of optimized control methods throughout engine lifetime with potential to minimize divergence from "as-new" performance
- Injector trimming, NOx estimation
- Knock margin control
- Predictive control for hybrid-electric propulsion
- Parametrization of controller parameters



Sub-project 5.1: Engine control optimization – hybrid electric controller

Conclusions: Sub-project 5.3, 5.4

- The new common rail type lubrication strategy demonstrates enhanced functionality compared to the standard lubrication system
- Shaping the lubricant jet pattern by adjusting relevant lubrication system parameters inhibits lubricant atomization and therewith supports enhanced lubricant admission
- The new lubrication strategy leads to a more than satisfying lubrication performance and reveals a potential saving of up to 15% of total lube oil consumption related to total injected mass



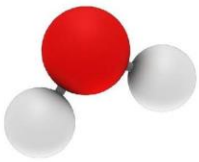
Sub-project 5.4: Full-scale lubrication system performance validation

WP PARTICIPANTS

WP lead: *Wärtsilä*, WP Deputy: *WinGD*

Research partners: WÄRTSILÄ, WIN GD, The University Of Sheffield., ETH, POLITECNICO DI MILANO, Aalto-yliopisto, Vaasan yliopisto, UNIVERSITÀ DEL SALENTO

WP leader: Jonatan Rösgren, jonatan.rosgren@wartsila.com | WP deputy: Matthias Stark, matthias.stark@wingd.com



WP 6 Model-based Control and Operation Optimization

WP OBJECTIVES

- **Reduction of emission in low load operation**
- **Increased part load efficiency**
- **Reducing operating and maintenance costs**
- **Enhance dynamic performance**

WG calculation

$$\dot{m}_W(t) = c_d \cdot A_{geo}(t) \cdot \rho_2(t) \cdot v_2(t)$$
$$= c_d \cdot A_{geo}(t) \cdot \frac{p_2(t)}{\sqrt{R \cdot \vartheta_2(t)}} \cdot \psi(\Pi_2(t))$$

Parameter identification

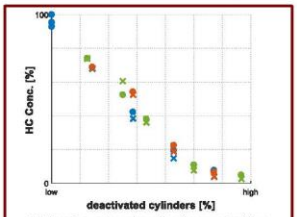
$$\dot{m}_C(t) = g_1(n_{TC}(t), \Pi_1(t), \vartheta_1(t))$$
$$\eta_C(t) = g_2(n_{TC}(t), \Pi_1(t), \vartheta_1(t))$$
$$\dot{m}_T(t) = g_3(n_{TC}(t), \Pi_2(t), \vartheta_2(t))$$
$$\eta_T(t) = g_4(n_{TC}(t), \Pi_2(t), \vartheta_2(t))$$

ACHIEVEMENTS & FINAL RESULTS

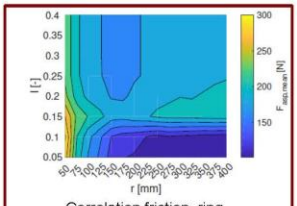
Reduction of emission, increased efficiency at part load and enhanced dynamic performance

Part load emission reduktion and efficiency increase

- Up to 50% reduction of NOx emission
- Up to 97 % reduction of HC emission
- Up to 38% efficiency increase
- Increased combustion stability
- Strong reduction of smoke emissions and very good O_2 control performance
- Prediction of lube oil consumption possible
- An optimum between lubricant consumption and asperity contact friction was found



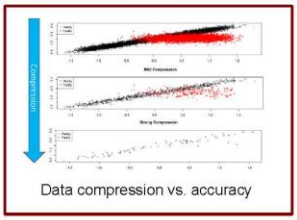
Cylinder cut out emission reduction



Correlation friction, ring curvature lubricant injection position

Dynamic performance

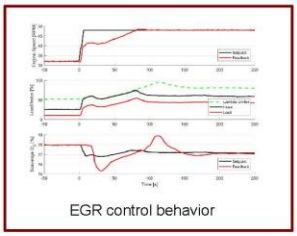
- LQR control performs better then PID, less speed undershot and more precise actuation of devices
- Huge effort to build up the model for the LQR control



Data compression vs. accuracy

Cut operating and maintenance costs

- Electronically controlled actuator for fuel injection tested on Jeppesen Maersk
- Tailored sub space search algorithms investigated
- Influence of data compression on space search investigated (above 60% compression the data quality gets to worse for sub space search)


EGR control behavior

WP PARTICIPANTS

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Karlsruher Institute of Technology: Prof. Böhm
Linköping University: Prof. Eriksson
Aventics GmbH: Mr. Suedekum
Technical University of Denmark: Prof. Glarborg
National Technical University of Athens: Prof. Kyrtatos

WP Leader: Dr. Mathias Moser (mathias.moser@man-es.com), Torbjoern Moeller (Torbjoern.Moeller@man-es.com)

WP 7 On-engine aftertreatment systems.

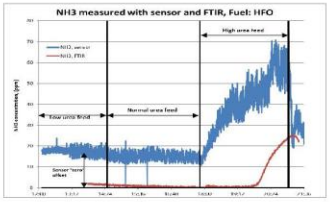
WP OBJECTIVES

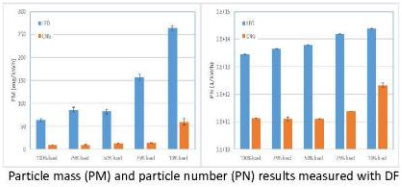
- Integration of SCR (Selective Catalytic Reduction) with the existing strong Miller cycle 4-stroke diesel engine and combining it with particulate emission (PM) abatement technology would enable to achieve more than 80% NOx emission reduction and 25% reduction in PM. Also a combination of integrated SCR and EGR (Exhaust Gas Recirculation) is to be developed. Feasible solutions of combining the above mentioned technologies having as a target the near zero emission engine are also studied.
- Integrating methane and ethane abatement technology into lean burn 4-stroke gas engines will enable compact solutions to reduce methane and ethane slip. The objective is a catalytic system working with the engine and optimization of the engine performance. Also the knowledge on deactivation & regeneration strategies for integrated catalyst solutions and methane formation and location in the engine exhaust system should increase. Target is a greenhouse gas emission decrease up to 15% and fuel savings up to 5%.
- Development of key technology for integration of the currently separated SCR after treatment into existing 2-stroke engine structure, which enables widespread installation of SCR systems on all ship types and additionally increase overall NOx removal efficiency above 80%, reduce overall hydrocarbon emissions (HCs) by 50% or more, reduce PM emissions and lead to potential fuel savings of up to 5%.

Small scale test bench at the roof of engine test cell

ACHIEVEMENTS & FINAL RESULTS

- Literature review regarding SCR engine integration and particulate abatement.
- Emission measurement systems for SO3, NH3 and PM emissions to support integrated after-treatment technologies
- Experimental assessment of integration of methane abatement technology into gas engine structure
- Concept about catalyst aging from in-field monitoring and laboratory experiments
- Experimental assessment of SCR reduction agent injection systems with sensors for feedback control
- Experimental assessment of selected combined on-engine emission reduction system for strong Miller cycle 4-stroke diesel engines with tests on rig/engine
- Experimental assessment of newly developed vibration resistant SCR catalyst in field



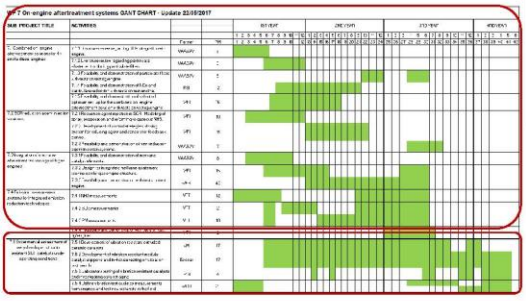


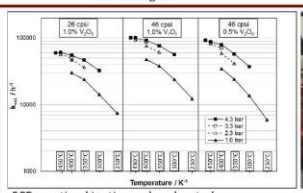
Particle mass (PM) and particle number (PN) results measured with DF marine engine.

PROGRESS

Wärtsilä

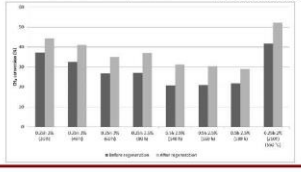
WINGD





SCR reaction kinetics under elevated pressure

Hot shaker test bench

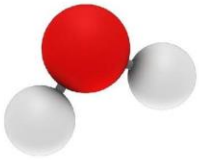


Average CH_4 conversions during the experiment at 500 °C and at 550 °C.

WP PARTICIPANTS

Wärtsilä Finland Oy, Wärtsilä Iberica, Winterthur Gas & Diesel, VTT, Unversity of Vaasa, Dinex Ecocat, Johnson Matthey, Paul Scherrer Institut

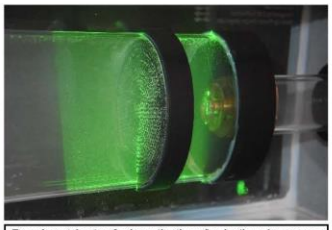
WP Contact Information: WP Leader Mr. Jukka Leinonen, jukka.leinonen@wartsila.com



WP 8: Engine integrated SCR and combined SCR and DPF

WP OBJECTIVES

- Investigation of LP and HP SCR processes like urea injection, mixing, decomposition and flow distribution to design more compact SCR systems
- Installation and test of a new integrated HP SCR design on the 4T50ME-X R&D engine
- Adaption and integration of a compact after-treatment system for the combined PM & NO_X reduction on the 12V175D R&D marine distillate engine



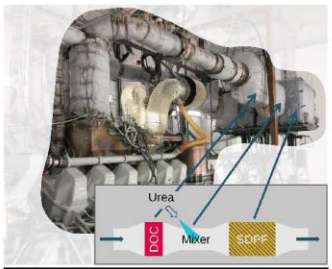
Experimental setup for investigation of pulsation phenomena in Lyngby

ACHIEVEMENTS & FINAL RESULTS

- Characterization of fluid phenomena in a simplified SCR reactor with pulsating flow for optimization of flow conditions and validation of numerical models
- Set-up of a hot gas test rig and investigation of the urea injection, mixing and decomposition processes under the influence of temperature and pressure
- Set-up and investigation of an ammonia generator as a compact device for urea decomposition in the hot gas test rig
- Good agreement of experimental characterization and numerical simulation of spray breakup and flow profile
- HP SCR process investigated in pilot scale testbeds before scale-up
- Engine integrated HP SCR designed, installed and successfully tested on the 4T50ME-X R&D engine in full-scale
- Reduction of the required installation space of the new HP SCR design by more than 90 % compared to traditional HP SCR systems
- Measurement device for traverse NH_3 measurements developed and tested on the 4T50ME-X R&D engine
- Benchmark of SCR coated DPF in laboratory scale based on measurements in a synthetic gas test bed as well as BET and SEM/EDX investigations
- Investigation of a full-scale EAT system comprising SCR coated DPF (SDPF) and a sulphur resistant DOC, which provides the required NO_2 for the passive soot regeneration, on the 12V175D R&D marine distillate engine
- Fulfilment of the 80 % PM and NO_X reduction based on IMO Tier II engine out emissions with the compact SDPF system

Hot exhaust gas flow rig for investigation of urea injection, evaporation and mixing in Hannover

Integrated SCR receiver installed on a 4-cylinder two-stroke R&D test engine in Copenhagen



EAT system comprising DOC, mixer and SDPF installed on a 12-cylinder four-stroke R&D test engine in Frederikshavn

WP PARTICIPANTS

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MAN ES-AUG (Manuel Kleinhenz)

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Leibniz University Hannover (Prof. Dinkelacker)

WP Leader: Lone Schmidt, MAN ES-CPH, Lone.Schmidt@man-es.eu

10 Final Partners' Forum - Plenary

In the 3rd Partners' Forum and Project Final Meeting, the Plenary session, which included presentations by the Coordinator and the Work Package Leaders, was webcasted to the public through HERCULES-2 website in order to disseminate the results and achievements of the Project. In addition, two Round table Panel discussions "HERCULES Achievements" and "The future in Marine engines" were webcasted as well. The first round table discussion "HERCULES Achievements" offered to the public an insight to the overall HERCULES achievements" and the Project contribution to the development of marine engines. The Panel "The future in Marine Engines" presented the prospects in marine engines from the viewpoint major partners of the HERCULES-2 Project.

The Plenary Session and the Round table Panels discussions presentations can be found in the HERCULES-2 website.

11 Final Exploitation Strategy

The exploitation of the project results is of major importance because it demonstrates the added value of the projects and ensures the use of the knowledge generated.

Additionally, it promotes further scientific developments for the future and maximises the impact of the funding granted in the market. It also ensures sustainable growth, more and better jobs, and shows how the outcomes are relevant to everyday life. The exploitation of results is very important because it contributes to the promotion of industry competitiveness, as well as the solving of societal challenges.

HERCULES-2 is an interdisciplinary R&D project of wide thematic spectrum, since engine development requires parallel progress on many technological fronts. The project is consolidating the breakthroughs and the technologies proven successful in the past HERCULES projects, is considering further potential breakthroughs in several technologies as well as integrating identified new technologies. In all cases, the aim is to go beyond the state-of-art and by definition this can only be achieved through innovations.

Such innovations within HERCULES can be widely classified in 3 categories and relate to all Work Package Groups:

1) Basic scientific concepts or primary technology
2) Component or system prototypes
3) Prototype application experimental test installations

The overall Project outputs, suitable for commercial exploitation, are the following:

- Complete next-generation marine engines of higher efficiency and ultra low emissions, encompassing the successful technologies developed during the project.

- Components and subsystems reaching test prototype form during the project, which can be further developed as commercial products for the new-building or retrofit market in ships.
- Design methodologies and software tools to be incorporated into computer-aided engineering products for engines and processes.

The major partners, engine makers and component suppliers, are in the business of manufacturing and selling engines as well as licensing engine and component designs. The commercial exploitation of all successful developments within the HERCULES-2 is therefore assured.

11.1 Work Package 1: Systems for increased fuel flexibility

Fuel Flexible engine operation for 2-stroke engines

Within the Work Package 1 WinGD and partners successfully developed, built and tested a fuel flexible injection system. WinGD installed and commissioned the new injection system on the RTX-6 test engine. Tests have been run with different fuels in order to investigate the engine operation behaviour. This prototype will help to further understand the nature and properties of new fuel alternatives for marine applications. Based on the knowledge gained with the HERCULES-2 Fuel Flexible Injection system, the next step will be the development of a reliable and state of the art injection system for serial application,

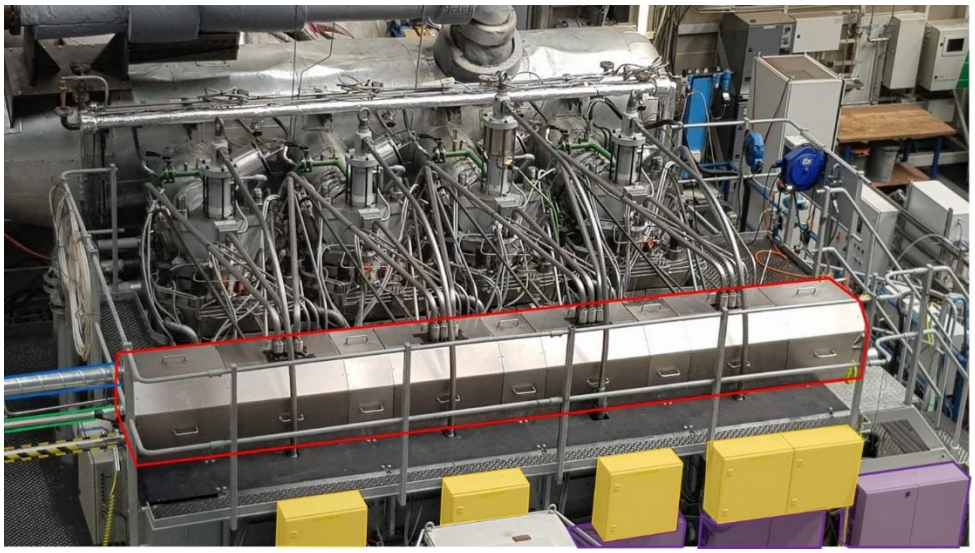

Figure 1: Installation of the Fuel Flexible Injection System on the RTX-6 test engine

The prototype flexible injection systemwill be used for further investigations with alternative fuels. Especially in combination with the further developed Spray Combustion Chamber (SCC), test facility new fuels can now stepwise be tested throughout their development process. The SCC allows, through various imaging techniques, to investigate both spray propagation as well as combustion behaviour of fuels and injector designs in a full-scale setup. WinGD encouraged fuel suppliers and research institutes to have their fuels tested during the different research and development phases.

Already with small quantities of new fuels first investigations regarding spray and combustion of liquid fuels can be made, to understand the fuel and guide development into the right direction and/or approach possible investors for further developments.

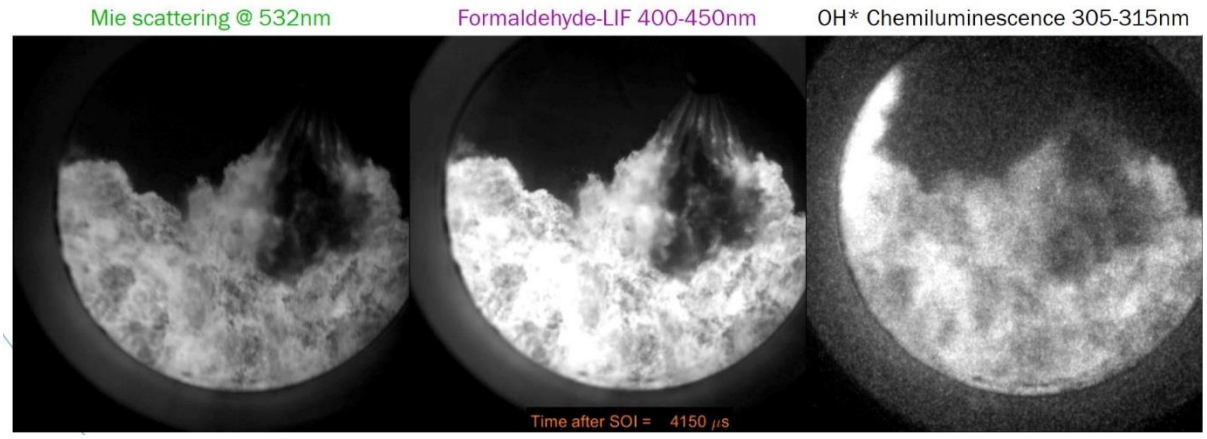

Figure 2: Spray of ethanol into a large scale pilot flame, investigated at three different wavelengths: 532 nm for liquid phase,400-450 nm for Formaldehyde LIF (due to strong soot incandescence the signal to noise ratio is rather weak), 305-315 nm for OH* chemiluminescence (due to strong soot incandescence the signal to noise ratio is rather weak)

A feasibility study for a Rapid Compression Expansion Machine was conducted. The study showed how such a machine could be built. It revealed that with the current – and planned – experimental setups, such a machine is not warranted yet. But based on the findings within this study, an installation could be effectively realized, if the need should arise in the future.

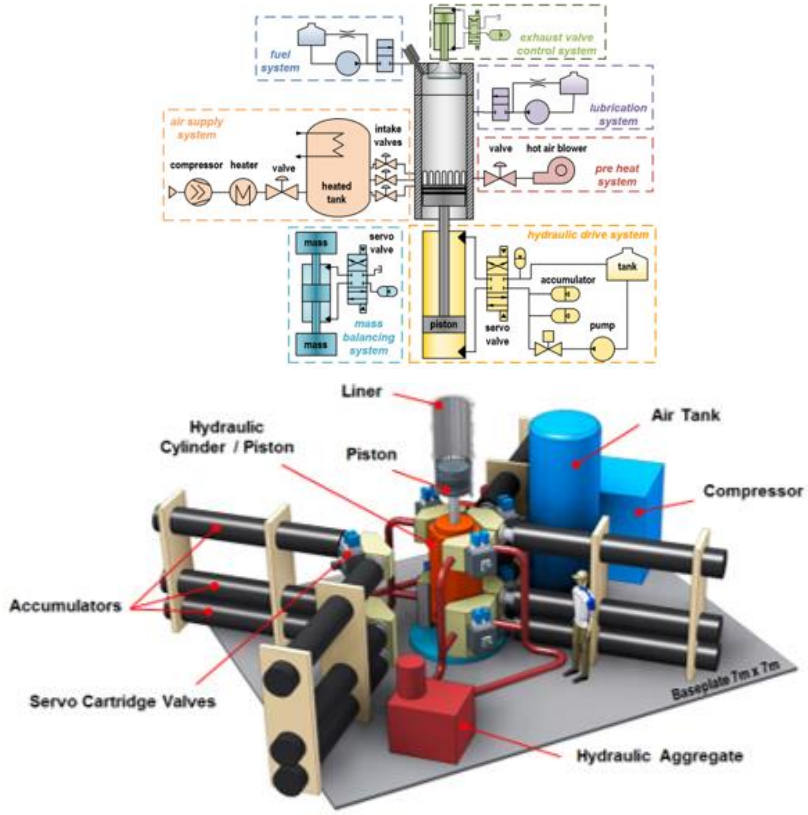

Figure 3: Upper image shows the conceptual setup of a RCEM and the lower image shows a possible setup in a laboratory

11.2 Work Package 2: Multi-Fuel Combustion

Fuel flexible engine:

The engine tests and optical studies of alternative fuels has contributed to increased understanding of multi-fuel combustion (in particular ignition concepts) and thus also to the successful development, construction, installation and operation on fuels as LNG, ethane, methanol and LPG. Two-stroke engines for operation on all of those fuels have been introduced into the market (engine types ME-GI for LNG, ME-GIE ethane, ME-LGI for methanol and ME-LGIP for LPG). The new engine types have been well accepted and led to sales. Numerical techniques have now also been developed for dual-fuel engines, which will allow future refinement and increased flexibility of engine operation on these fuels.

Injection and ignition test facility:

The fuel-flexible test facility was designed but not constructed within the project time frame. It has thus not led to any exploitation yet, but some components from the design will be used in future test platforms.

Optical diagnostics:

The multi-camera imaging technique developed and demonstrated in WP2 allows for spatial mapping of flames and ignition kernels inside the combustion chamber, which is very useful e.g. for studying interactions between pilot and main injections in dual-fuel engines. This approach will be used also for future research studies, potentially with even more than three cameras to allow even better 3d reconstructions.

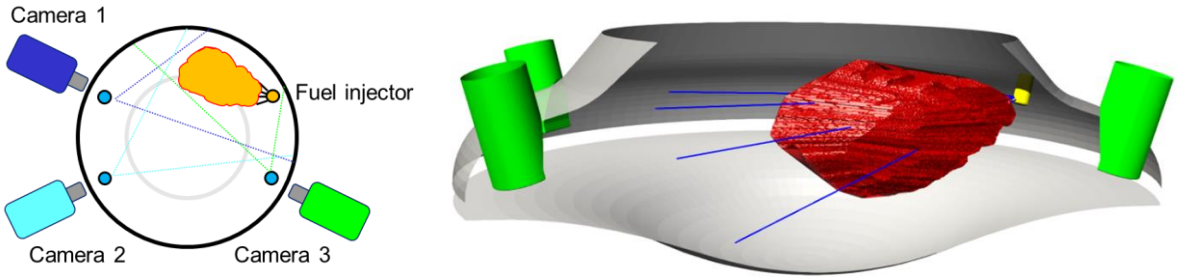

Figure 11.2.1 Left: Arrangement for multi-camera imaging. Right: Reconstructed flame shape.

Optical engine:

The optical investigations helped to get a deeper understanding of the processes inside the combustion chamber and will thus help to improve future engine releases. Some of the new knowledge is already used in the new 35/44DF and 51/60DF releases. Furthermore, the results help to improve the 3D-CFD combustion model which is used as a development-tool.

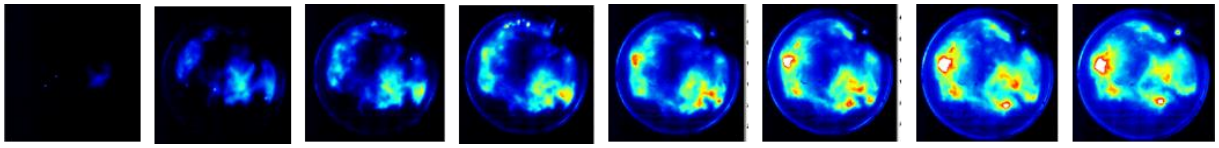

Figure 11.2.2 Measurement of flame luminescence with vertical access

Advanced engine control strategy:

The optimized injection strategy was partly implemented in the new engine 51/60DF-release. In future releases the strategy will be partly or even fully implemented, depending on the engine concept.

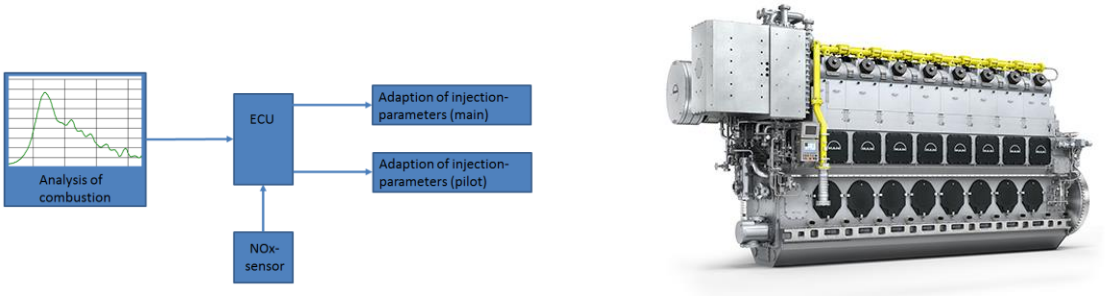

Figure 11.2.3 Illustration of possible concept for a fuel flexible engine (left), MAN-51/60DF(right)

11.3 Work Package 3: Intermetallics and advanced materials for marine engines

Overall, promising materials for use in marine engines could be identified and proven. Valuable material data were generated. For sub-projects 3.1 prototypes of a new (none-commercially available) material with an interesting combination of properties, such as excellent hot corrosion resistance, processability via conventional methods, low cost of alloying elements, were successfully produced and rig tested. For sub-project 3.2 prototypes using a heat resistant cast steel could be fabricated, which enables higher temperatures for turbine casing of turbochargers. Field testing (after the Hercules project) is already scheduled to further elaborate on a commercial use.

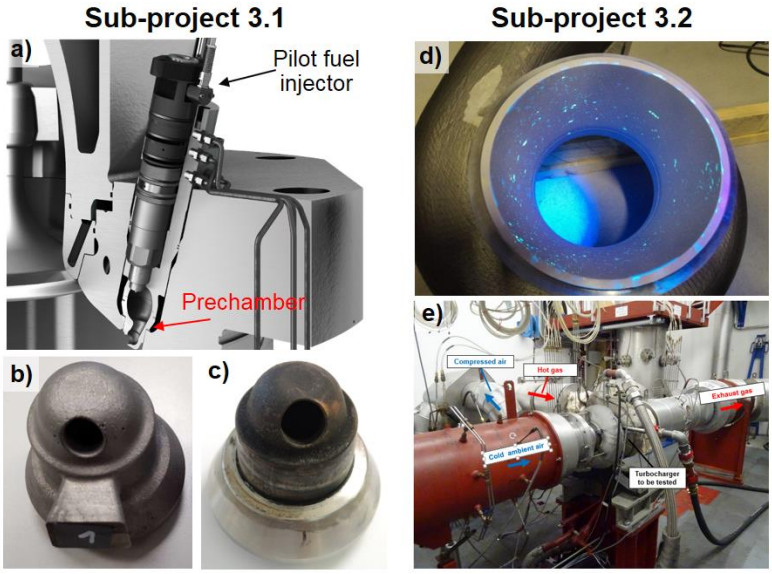

Figure 11.3.1. Picture exemplary showing results from sub-project 3.1 (a-c) and sub-project 3.2 (d-e); a) Visualisation of the combustion chamber showing details of the pilot injector; b) Prototype of the prechamber made of the new material via casting; c) Prechamber prototypes after the engine test; d) Prototype casing of turbochargers made of heat resistant cast steel; e) Test rig with assembled turbocharger

11.4 Work Package 4: New materials for higher engine efficiency

The results of WP4 “New Materials for higher engine efficiency have already been implemented into the newest design of the new 45/60 engine for cylinder head and turbo charger. The first engines will be in the field in early 2019.

The methods and new materials which have been investigated and developed in WP4 have further been established in the design process for future product development

11.5 Work Package 5: Lifetime Performance Control

The new common rail type lubrication strategy of WP5 demonstrates superior functionality compared to the standard lubrication system. Controlling the lubricant jet by adjusting relevant lubrication system parameters over the entire engine load range allows to inhibit lubricant atomization and thus supports enhanced lubricant admission, which has led to a more than satisfying lubrication performance. Fig.11.5.1 shows key steps towards the development of a new lubrication system prototype.

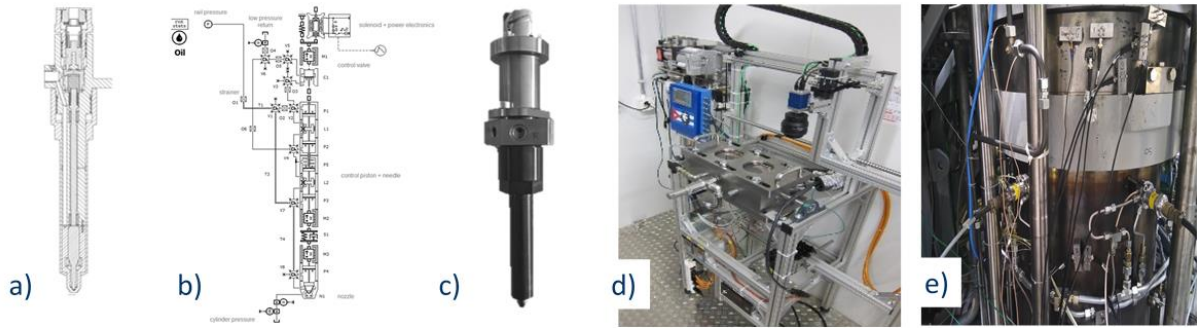

Figure11.5.1: key steps towards the development of a new lubrication system prototype. a) Lubrication system concept study to nominate a suitable lubrication strategy, b) Simulation model development to optimize lubricant spray and injector performance, c) Final prototype injector design, d) Prototype injector testing and performance optimization, e) Full-scale prototype injector performance validation

A current design review demonstrates optimization potential regarding nozzle geometry and a more compact, simplified and retrofittable design of the common rail type lubrication system. The establishment of development tools, which were elaborated within the project, support present efforts in bringing this prototype to a field testing level and elaborated monitoring technologies provide the possibility to operate the system under desired performance parameters.

11.6 Work Package 6: Model-based Control and Operation Optimization

Operation of EGR engines in non-normative conditions

The research work resulted in the implementation of a next generation EGR controller to solve acceleration issues with EGR engines. This controller was put into commercial use in 2018.

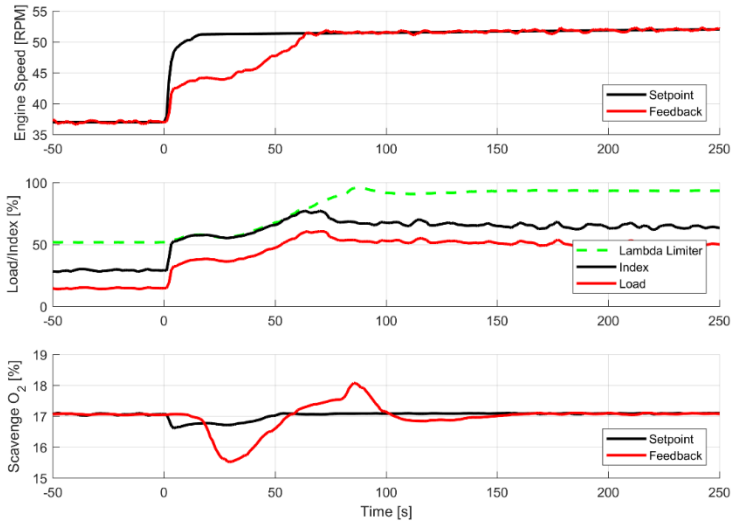

Figure 41.6.1 – Acceleration performance from a successful test on vessel with EGR operating at sea.

11.7 Work Package 7: On-engine aftertreatment systems

Small scale oxidation catalyst test setup was designed and integrated to lean burn gas engine exhaust system. Results showed high conversion rates for unburnt hydrocarbons, indicating potential for future exploitation of ethane and methane reduction.

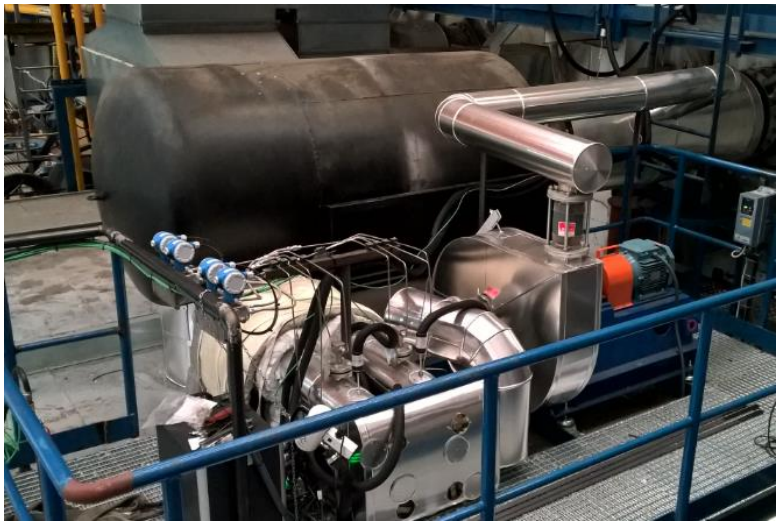

Figure 11.7.1 Small scale catalyst testing unit on the roof of the engine test cell.

Particulate emission reduction system test was in operation for nine months, and utilization degree depending on the engine operation. Measurement results indicate that with EN 590 compliant fuel the Electrostatic precipitator (ESP) provides a good exploitable potential for reducing particulates from exhaust. The same is for HFO applications, but with improvements in system stability still needed.

Figure11.7.2 Container and inlet pipe during installation

For the use of SCR ceramic catalysts in an integrated SCR system, the development of a vibration-resistant catalyst element frame is required. In WP7.5, a functional element frame for ceramic catalysts was designed. The complete catalyst element was tested promisingly in the laboratory and in the field as part of the Hercules-2 project.

Figure 11.7.3 SCR Ceramic Catalyst test setup

WinGD will extend the technology tests to validate the performance for medium-term use in the WinGD engine series application.

11.8 Work Package 8: Integrated SCR and combined SCR and filter

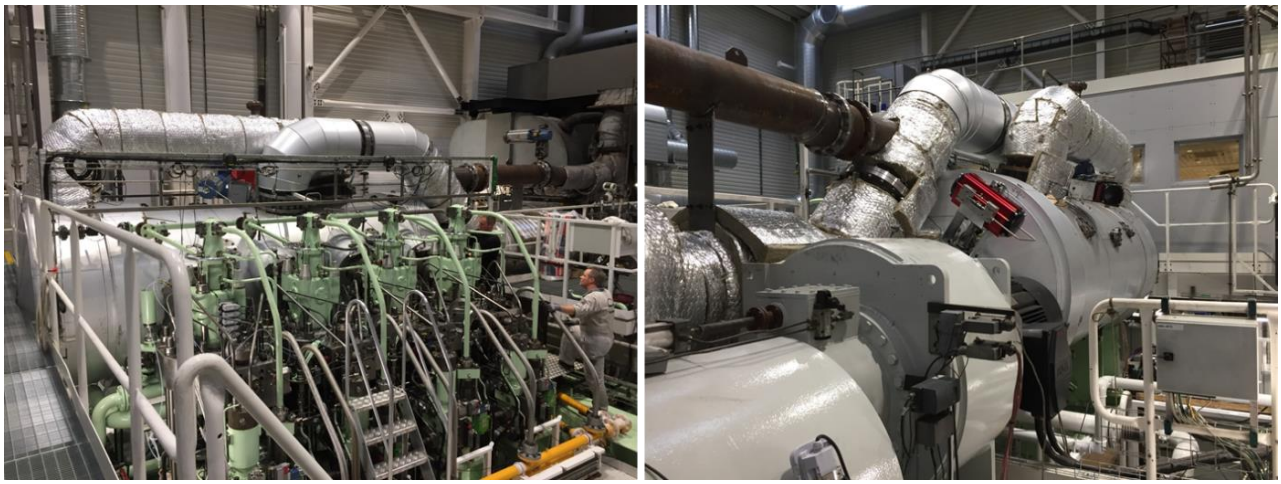

Figure 11.8.1 Integrated SCR receiver installed on 4 cylinder two-stroke R&D test engine, Copenhagen

An engine integrated high pressure SCR system has been developed, installed and tested on MAN Energy Solution's two-stroke R&D engine in Copenhagen, Figure 1.8.1. A second generation is to be planned, in order to solve mechanical challenges and improve access for maintenance.

Figure 11.8.2 SCR coated DPF installed on high speed marine distillate R&D test engine, Frederikshavn

Prototypes of SCR coated Diesel particulate filters (DPF) have been designed and investigated in laboratory scale. Based on the results, a full-scale exhaust aftertreatment system, which comprises Diesel oxidation catalyst (DOC), urea mixing unit and SCR coated DPF, has been installed on a four-stroke R&D engine in Frederikshavn for validation test, Figure 11.8.2.

12 Conclusions

The Dissemination Activities presented in this Report cover the whole duration of the Project. Through the Dissemination Activities, the results and applications of the Projects that receive funding from the European Commission are made known to a wider public.

The HERCULES-2 Project Dissemination Activities have taken various forms such as scientific papers, publications, deliverables, presentations in Conferences, Congresses and meetings, poster exhibitions, press releases, project leaflets and videos in website and social media. The main Dissemination gateway is the Public Section of the HERCULES-2 website (www.hercules-2.com) which is operational since Month 6 of the Project.

Several project outputs have already been included in series products or are planned for production following field testing.