Herausforderungen und Ziele an die Verbrennungsforschung aus der Sicht der WinGD AG

S. Hensel, Winterthur Gas & Diesel AG

Verbrennungsforschung in der Schweiz, 9. September 2015, Zürich
Agenda

1. WinGD introduction

2. Driving factors for combustion research & development efforts

3. Diesel engine – research fields

4. DF technology development

5. Future trends & activities
Wintherthur Gas & Diesel
Facts & Figures

- WinGD, located in Winterthur, is the centre of excellence and a leading developer for low-speed 2-stroke marine diesel engines.
- The company’s target is to set industry standards and to continue the long tradition of the Sulzer Diesel business which started in 1898.
- Currently there are more than 350 people from 39 nations working in Winterthur and worldwide located subsidiaries.

Since 2015, WinGD is a Joint Venture Company, owned 30% by Wärtsilä and 70% by CSSC, the world’s largest shipbuilding conglomerate, managed from Switzerland.
Licensees worldwide

- Licensing business
  - No own manufacturing facilities, licensing of drawings & service of engines
  - 3 licensors worldwide: Wärtsilä, MAN Diesel & Turbo, Mitsubishi Heavy Industries
Combustion research at WinGD

Main drivers

Environment

$NO_x$

$SO_x$

Particulate matter

$CO_2$

Controlled areas

Fuel price

The New York Times

Weekly price in Jan. 2011 dollars

$140

$23.23

$97.88

Difference in price between natural gas and oil for equivalent energy value

Infrastructures

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Combustion research at WinGD

Scope and targets

- Reduction of fuel consumption and emissions
- Reduction of green house gases (CO2, CH4)
- Lifetime performance, maintain thermal and stress limits

Harbour Hamburg, source dpa
Combustion research at WinGD

Diesel engines
CO2 reduction
Reduction of fuel consumption

- Fundamental investigations of the spray and combustion for better understanding => SCC
- Classical combustion process development:
  - Optimization of combustion chamber shape
  - Injection system, atomizer and strategies
  - Increasing firing pressure
  - Optimization of scavenging process
CO₂ reduction
Alternative fuels / fuel flexibility

- FlexiFuel Combustion: Investigation of non-conventional fuels / biofuels in the SCC regarding spray formation and combustion behaviour
- Hercules-2: Development of a fuel flexible injection system
Emission reduction
Tier III technologies - EGR

- Tests performed at WinGD and Tier III ability proven
- High pressure solution under development
- Further activities in the field of scrubber, combustion system and piston running

![Graph showing ΔbsNOx against EGR rate with data points for HPEGR, RTX-3 and LPEGR, RTX-4]

![Diagram of exhaust receiver, scavenger air receiver, mixing, scrubber, water mist catcher, cooler (copper), and blower]

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Combustion research at WinGD
DF engines
2-stroke low-pressure dual-fuel concept

The Principle

- Engine operating according to Otto process
- Pre-mixed ‘Lean-burn’ technology => Tier III compliance
- Low-pressure gas admission at ‘mid stroke’ location (<16 bar)
- Ignition by pilot-fuel into pre-chambers
2-stroke low-pressure dual-fuel concept

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Key technology developments

Key technologies to convert Diesel engine into DF engine

- **Micro-pilot common-rail system**
  - low pilot-fuel consumption < 1%
  - low NO\(_X\)!

- **Pre-chamber technology**
  - low NO\(_X\) and THC & methane slip!
  - good combustion stability!

- **Gas admission system**
  - safe and reliable gas admission & simple sealing technology with low-pressure!

- **Engine Control & Automation system**
  - integrated engine control and safety!
DF Technology development steps

2011
Concept development:
- Simulations and CFD
- Basic design
- Rig- and 1-cylinder testing

2013
Engine testing RT-flex 50DF
- Concept and reliability verification
- Full scale (6-cyl) testing
- Performance optimisation

2015
Tech-demonstrator 6X72DF
- Verify technology on large bore
- Engine testing and further development
Advanced tool application

CFD applied during the whole development process

- Location of gas ports
- Gas system pressure
- Nozzle shapes / directions
- Valve designs / opening speed
- Inclinations angles
- Pre-chamber design
Advanced tool application
Optical measurement methods / technologies

- To better understand the processes during gas mixing, ignition delay and combustion itself
- Identify and in case of hot spots also localize the possible pre-ignition sources

pilot injection triggered combustion
pre-ignition
Laboratory test engines
6RT-flex50DF test engine

Engine converted to full scale in summer 2013:
• Engine performance development
• Control system development
• Component reliability tests
>1000 running hours logged

Engine tests continuing:
• Performance improvement
• Increase operating field
• Functionality enhancements
Laboratory test engines
WX72DF test engine

- Cooperation with IHI/DU regarding design of the test engine
- Engine started in January 2015
- DF operation upto 17.3 bar BMEP demonstrated

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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<tbody>
<tr>
<td>Number of Cylinders</td>
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<tr>
<td>Bore x Stroke</td>
<td>720 x 3086 mm</td>
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<tr>
<td>Speed (R1)</td>
<td>89 rpm</td>
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<tr>
<td>MCR (R1)</td>
<td>19350 kW</td>
</tr>
<tr>
<td>BMEP</td>
<td>17.3 bar</td>
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</table>
Combustion control

Engine control & automation system

- Diesel mode
- Engine Control System
- Proportional exhaust wastegate
- Variable hydraulic exhaust valve
- Micro-pilot common-rail injection
- High pressure common-rail injection
- Gas admission valves
- Indicated pressure sensors
- Pressure and temperature at relevant stages
- Knock sensor

- Gas mode
- Boost pressure / air-fuel ratio
- Effective compression ratio
- Thermal efficiency
- Mixture formation

- Miller time (2-stroke)
- Thermal efficiency / pmax
Combustion control
Switching between fuels

- No engine stop needed to switch between the modes!

- No hardware modification required!

- The transfer from gas mode to diesel mode takes place within one revolution

- Transition from diesel to gas requires a gradual change of the fuels (last between 30 seconds and 1 minute)
RT-flex50DF test results

Rating field

Product specification options

- Limited range of operating parameters for reliable operation without knocking / pre-ignition and misfiring
- Lower maximum rating than corresponding diesel engine model
X72DF test results

Pilot injection

Pilot-fuel consumption clearly below specified limit
(measured below 0.5% of fuel input at full load)
X72DF test results

Emissions

- IMO weighted NO\textsubscript{X} emission in gas operation at about half of IMO Tier III limit
- CO\textsubscript{2} and SO\textsubscript{x} reduced in gas operation due to fuel composition
- PM further reduced by DF technology with Lean-burn
- THC (=‘Methane slip’) is low over the entire load range:
  Especially on part and low load well below ‘industry standard’ for ‘lean-burn’
X72DF test results
Combustion stability, $p_{\text{max}}$

**Diesel Mode**

- Pmax variations higher on gas
- IMEP variations comparable or less in gas mode

**Gas Mode**

- Engine rotational speed
  - deviations similar or lower in gas mode

Running stability is similar or better than on ‘diesel’
DF Technology introduction

A total of 33 DF engines on order
DF Technology introduction

2015
First factory acceptance test completed
Type Approval testing of first RT-flex50DF engines

2016
Sea trials of first RT-flex50DF engines:
  • Small scale LNGC
  • Product carriers

2017
Sea trials of first WX62/72DF engines:
  • LNGC’s

To be continued...
Focus of the future DF technology development

- Control system
  - Mixed Mode (‘Fuel sharing’) with variable gas to liquid fuel ratio to balance between available boil-off and desired ship speed
  - Implement model-based control strategies
- Charging and mixing strategy
- Pre-chamber design
- Increase compression ratio
- Reduce methane slip
Summary & Conclusions

- The further evolution of environmental regulations in combination with changing market requirements is triggering substantial development efforts.
- Various technologies are applied and developed for achieving improved overall engine and propulsion systems performance and lower emissions with the focus on:
  - Conventional combustion process improvement (increase pmax, injection system & strategy, etc.)
  - Fuel flexibility
  - EGR
- WinGD has developed and delivered a new series of 2-stroke low pressure dual-fuel engines that is inherently Tier III compliant and offers full fuel flexibility.
Contact information

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Thank you!