FUTURE READY

Extending the engine research toolbox to validate clean shipping fuels[i]

WIN GD

Introduction

For decades, the choice of fuels used by ships worldwide was small and static. As a result, engine research relied on a well-refined and long-established set of testing and simulation technologies.

But in the past few years the demand for new fuels has emerged, driven by both environmental regulation and the potential benefit of using cargoes as fuel.

To fully understand the implications of these new fuels – and ultimately to select between them - all aspects related to their handling and use must be well understood. This includes the impact on fuel systems as well as engine processes, which reveal how system and component design and operating parameters would need to be adjusted.

WinGD has responded to the need to understand new fuels. Over the past few years the company has extended its testing infrastructure, identified proper validation processes for new fuels and developed its simulation capabilities accordingly.

These investments have cleared a path towards the approval of any new fuel candidate for application on WinGD engines.

Shifting demands

As regulatory requirements become more stringent and wide-reaching, they are having a growing impact on the marine fuel market. Recent shifts in fuel sulphur content highlight that, despite its notoriously conservative nature, the shipping industry can deal with significant changes to its fuel mix.

This will be critical as even more substantial changes will be needed for shipping to contribute to the containment of global warming, as set out in the UN's Paris Agreement and the IMO's Initial Strategy on the reduction of GHG emissions from ships.

To achieve these ambitions, shipping will need to make use of all options for further improving the efficiency of marine transportation systems. This starts from the optimisation of propulsion engines and all other equipment on board as well as overall vessel and hull design in particular. It includes the advanced integration of the energy systems on board and the utilisation of the potential of hybridisation on individual ships.

Smart shipping concepts such as enhanced routing, fleet and cargo management need to be adopted on a wide scale to optimise the entire logistics chain. The increasing use of LNG will also be an important factor in cutting emissions.

But even combining all these steps, global shipping will fall short of the IMO's 2050 targets without the early and massive adoption of 'X fuels' - the term used for all variants of net carbon-neutral fuels, either sustainably produced biofuels or synthetic fuels produced in a climate-neutral manner using excess renewable energy as well as appropriate feedstock.

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X marks the spot

The 'X' designation highlights an element of the unknown. Today there are many candidates for clean shipping fuels but no clear winners. The global nature of shipping means that any fuel to be used in this sector must fulfil specific conditions. It must be:

- **Available in sufficient quantities** and at economically viable conditions worldwide, as a minimum at the major hubs along the main trade routes;
- **Within accepted quality limits** and in compliance with standards and regulations;
- **Safe to use and handle** for a vessel and its crew. Any risks must be minimized by having appropriate handling standards and procedures in place.

The introduction of such new fuels poses challenges to the whole industry, starting from producers and suppliers of the fuels, on-board equipment developers and manufacturers, up to the operators, not to forget regulatory bodies and classification societies having to update and extend the corresponding regulations as well as the procedures for their implementation.

WinGD started developments for extending the spectrum of fuels usable on its engines more than a decade ago. It introduced the X-DF two-stroke engine range based on lean premixed (Otto type) combustion, with admission of fuel gas at low pressure directly into the combustion chamber. And it has invested in the extension of testing infrastructure to investigate fundamental processes associated with fuel admission and combustion.

The company has already successfully analysed the impact of a large range of different fuel qualities, both from the traditional fuels spectrum and alternative fuels, in both publicly funded projects and in partnership with industry stakeholders.

Assessment criteria

WinGD's key assessment criteria cover all aspects of the application of any proposed fuel on the engine itself, as well as the handling of the fuel before the engine.

These criteria include:

- **Compatibility with existing fuels;**
- **Storage and preparation requirements;**
- **Compatibility with existing fuel admission systems;**
- **Combustion requirements;**
- **Impact on engine performance and auxiliary systems;**
- **Impact on engine reliability.**

For each criterion, suitable testing as well as simulation tools must be applied to enable researchers to identify necessary technology developments, procedures to implement or adjust, and any necessary operational guidance.

Fuel analysis

Good knowledge of any proposed alternative fuel's main features, properties and composition is a prerequisite to assessing opportunities and risks

An initial investigation is carried out, involving the comparison of the fuel properties with existing standards, particularly the marine fuel standard ISO 8217.

Criteria	Parameters
Requirements for storage / preparation and compatibility with existing fuels	Flash point
	Density at 15 °C, Total sediment potential, Cloud point, Cold filter plugging point winter / summer, Upper pour point winter / summer
Compatibility with fuel admission systems	Kinematic viscosity at 40 or 50 °C
	Lubricity
Properties relevant for combustion	Lower heating value, Cetane index
	CCAI
Engine performance impact	Carbon residue, Ash content
Compliance with statutory requirements	Sulphur content
Properties relevant for engine reliability	Acid number, Contents of hydrogen sulphide, FAME, Water, Sodium, Vanadium, Zinc, Phosphorus, Aluminum plus silicon

An overview of the most important parameters of ISO 8217 and how these are linked with the fuel assessment criteria.

As one example of the challenges posed by new fuel types, it is worth noting that a customary analysis according to ISO 8217 may not be sufficient when looking at biofuels. Additional information on the content of specific components may be needed.

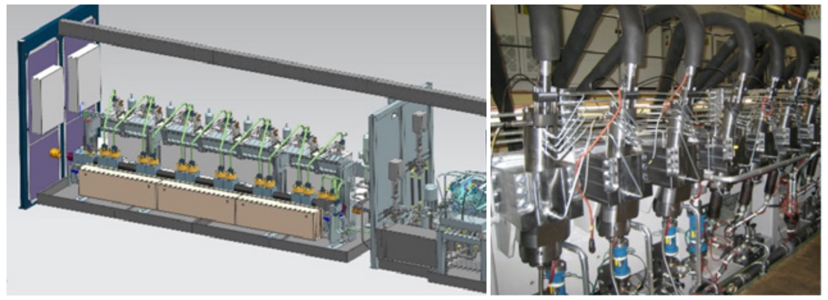
This analysis is highly specialized and qualified, certified laboratories are enlisted when needed.

Fuel systems compatibility

WinGD has developed fuel systems test rigs designed specifically to assess the compatibility of any alternative liquid fuel with existing fuel systems. These test rigs simulate the actual operation of injection systems in service at relevant conditions.

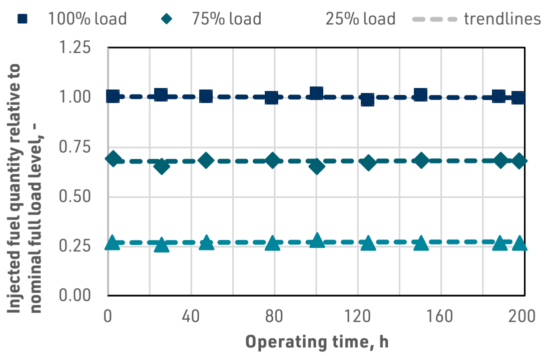
The rigs typically include all key elements of the systems, including a variety of fuel pumps , common rail and injection actuation elements as well as the injection valves.

Dimensions and arrangement of components and connecting pipes are selected such that the configuration can be considered as representative of an actual engine. The modular setup allows either simultaneous testing of different design variants or to facilitate the exchange of key components.



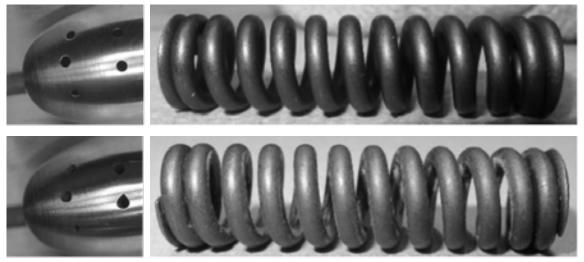
A test rig for examining the compatibility of liquid fuels with existing fuel systems.

The fuel is injected into a chamber and then recirculated to the inlet of the pump. This injection cycle is repeated, at relevant operating conditions, in the range of hundreds of thousands to millions of times.



A biofuel was tested for roughly two million injection cycles each (about 200 hours) at three different loads. The injected quantity remained constant at all loads, indicating that application of the fuel is not associated with any injection system performance degradation that would require taking appropriate countermeasures.

The injection system performance is monitored to identify any degradation that might occur due to fuel property changes during operation or unfavourable interactions with component materials.

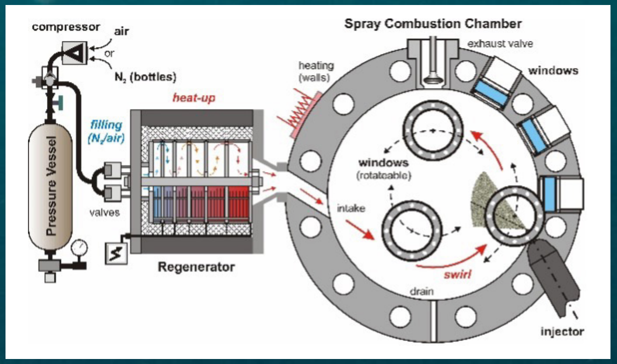


An injector tip and the spring in the injection control unit (ICU) block before and after the tests (above and below respectively). The orifice on the right of the picture of the injector tip shows clear signs of erosion, with some material broken off at the top.

The ICU spring does not show such severe damage but its colour has changed noticeably, which could be attributed to the formation of deposits on its surface.

Combustion characteristics

Investigating combustion requires experimental facilities that can represent the combustion system being studied while allowing for the measurement of optical and laser-optical data.



The spray combustion chamber developed under the HERCULES project.

TheSpray Combustion Chamber (SCC) was developed as part of the Europe-funded HERCULES project. This unique test rig has been used extensively to obtain a better understanding of combustion in large two-stroke diesel engines when applying conventional marine fuels. This knowledge now serves as a basis for assessing the impact of alternative fuels on combustion characteristics.

By developing the SCC further – for example with the use of high speed, high energy laser technology and special optics instead of line-of-sight methods – the combustion phenomena can be observed in configurations even more representative of actual engine combustion systems. This setup has been used for assessing the impact of clearly distinct alternative fuels on combustion. In the HERCULES-2 project the applicability of methanol and ethanol was investigated, including the evaluation of spray and combustion phenomena.

Differences between diesel and the two alcohol fuels observed in the SCC were in line with the fuels' known properties. The low boiling point of the alcohols can be expected to result in substantially faster and more complete evaporation.

Hence the fuel spray was observed to last for less time in the chamber than diesel. Similarly the autoignition point of ethanol and methanol is far higher than for diesel, which translated into increased ignition delays and more variable combustion that were indeed observed in the SCC.

The SCC observations made it clear that using alcohols in engines will not be possible without major adjustments to combustion system layout. To this end, WinGD developed a system capable of dealing with those fuels. The fuel-flexible injector (FFI) with variable flow area was first tested on the SCC.

Another enhancement to the SCC's experimental setup was the integration of a media separator into the injection system. This allows the fuel amount required for tests to be reduced by eliminating the necessity to fill the complete system with the fuel to be evaluated. Such an installation is a prerequisite for assessing the applicability of fuels still in their early phase of development, when only very moderate quantities can be produced.

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Performance impact

Traditionally the impact of new technologies and systems on the performance of an engine is first assessed in lab engine tests. The same applies for alternative fuels.

For many years WinGD has relied on two workhorses for this purpose: The RTX-5 for dual-fuel and the RTX-6 for Diesel technology development. Recently, in view of the multitude of technology and product development needs ahead, WinGD has started to add more lab engines.

Among the new investments is a single-cylinder engine. Unlike the multi-cylinder engine (MCE) based testing approach applied so far, this allows for optimisation of both dual-fuel Otto and Diesel engine concepts with fewer constraints and in more depth, while also being more flexible and cost-effective.

WinGD is also increasing the number of MCE testbeds. Recent additions include RTX-7, a new DF test engine, and the new Diesel lab engine RTX-8. Both will be used extensively in the development for future fuels.

New lab engines – RTX-7 (DF engine, above), and RTX-8 being erected on the commissioning testbed (Diesel engine, below).

In-service confirmation

The confirmation of reliable operation under real-life conditions is the final and most important step in the assessment of any new fuel. Such may include a wide range of ambient conditions and operational parameters, non-ideal engine condition, limited maintenance, potential issues related to bunkering, storage and handling of the fuel and possible interventions (or absence thereof) by the crew.

A thorough preparation and diligent follow-up of such tests is therefore imperative. These tests can only be successful if performed in close collaboration between the chief engineer and his staff and WinGD's field testing experts. Any findings from the preceding validation steps need to be implemented properly and detailed guidance must be given on any items requiring particular attention and any procedures deviating from the standard way of working on board.

An in-service test typically encompasses a few thousand hours of operation. This is because the investigation into whether wear occurs on key components is one of the most important goals of such a test. By nature, measurable wear is normally not detected after the limited periods of exposure during lab tests.

In exceptional cases, shorter field testing periods may nonetheless be admissible. This is specifically true if any new fuel proposed is within specification limits of or largely similar to well-known existing fuels.

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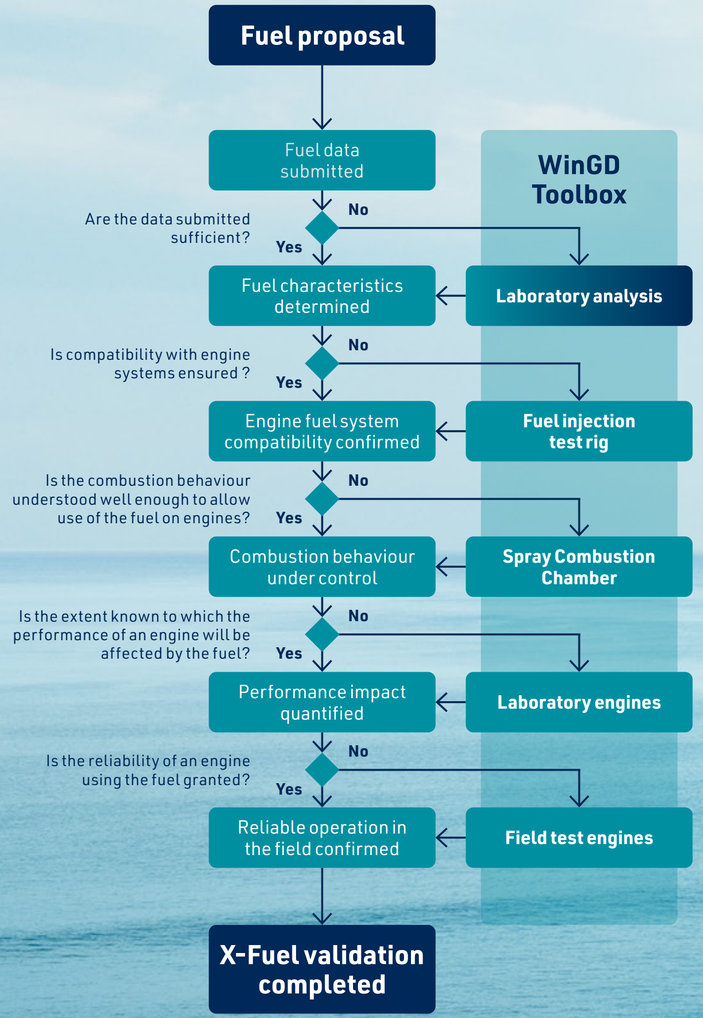
The WinGD fuel validation process

On the basis of experience accumulated over the years, WinGD has introduced a dedicated fuel validation process. A flexible, modular approach allows to properly address the different possible issues and challenges arising from using alternative fuels. Multiple questions must be answered before any new fuel can be approved for the free use on our engines.

The ultimate target of any fuel validation is the approval of the fuel for application on WinGD engines, in the form of a No Objection Letter (NOL) issued to the supplier of the fuel.

Validation would normally include an in-service confirmation as a minimum. However, there are two examples of fuels, for which there is no such need for extensive testing, due to their specific nature: bio- and synthetic methane require no adjustments at all, or even allow further optimisation in view of their higher purity compared to natural gas. Therefore, they must be considered highly viable X-Fuels and may already be used on existing X-DF engines in the field without any modification.



WinGD is well positioned to identify those fuels that not only hold the promise of contributing to the decarbonisation of international shipping but are also fit for being applied on large seagoing vessels.

Conclusions

Based on extensive experience acquired in recent years, WinGD has developed a comprehensive fuel validation process that provides a clear path towards release for application on WinGD engines for any developer or supplier of an alternative fuel.

This modular process addresses the key questions related to the applicability of non-customary fuels and involves suitable tools to provide the answers to all key questions. In parallel, the company has invested heavily in extending testing infrastructure and now has a comprehensive set of tailored test rigs at its disposal.

With this toolbox, WinGD is well positioned to identify those fuels that not only hold the promise of contributing to the decarbonisation of international shipping but are also fit for being applied on large seagoing vessels without impairing the health of the crew, operational safety and environmental impact.

Through this investment WinGD continues to develop its engine technology to accommodate X-fuels well before the fuels become available in adequate quantities – and at sufficiently attractive conditions – for application in marine installations.

[i] Based on Weisser G., Stark M., von Rotz B., Rozmysłowicz B., Mäder R. (2020). Extensions of the Toolbox Applied in Large Engine Research and Development as Called for by the Advent of Alternative Fuels. Paper presented at Rostock Large Engine Symposium (RGMT 2020), Rostock, Germany.