The changing Face of Marine Fuels and the Effects on Ship Operations

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Each year more than 200 million tonnes of bunker fuels are sold into the marine market globally. In the majority of cases the fuel is supplied in accordance with the ISO 8217 Standard. Regrettably, this standard has a number of key deficiencies. These can result in the supply of fuels that, while apparently meeting the requirements of the standard, are nevertheless totally unfit for purpose. Two key deficiencies are:

1) no control of ignition performance
2) poor definition and control of residual fuel stability

The main part of this paper reports on the feasibility of using the Fuel Ignition Analyzer (FIA) for improved determination of ignition quality of fuel oils.
In relation to stability, while testing is not particularly complex, the existing methods are time consuming, can require expensive laboratory instruments and/or require high calibre laboratory technicians to carry out the tests reliably. This paper briefly reviews the situation regarding stability control and some recent developments in this area.

Changing Environment

Following the oil crises of the 1970s a dramatic change in the oil refining and shipping industries occurred. Reduced availability and increased price of crude oil forced refiners to produce as much distillate product as possible from a given quantity of crude, and resulted in a rapid increase in the number of thermal and catalytic conversion units used in refineries globally.
As the amount of fuels containing thermally cracked residues increased, so did the number of operational problems related to fuels. Residual fuel stability was a major issue, as the thermal cracker operators pushed their units to the limits. On occasions they would push too far, resulting in an unstable fuel. ISO 8217 only contains the Sediment by Hot Filtration–Potential as a specification parameter for stability. However, this test does not adequately control fuel oil stability.
Also during this period, the marine industry experienced its first serious ignition performance problems. These primarily affected vessels that changed over from distillate fuels to one of the low viscosity, high density residual fuel grades. Many of these vessels suffered serious operating problems and in some cases serious engine damage.
The 1980s saw a series of step changes in thermal cracker design and operation resulting in higher than ever net distillate yields. The side effect of this was lower quantities of residues (which were more aromatic and had much lower stability reserves). While stability is well understood and can be managed with existing tools if the issues are fully understood, the big change was the impact of increased aromaticity on ignition performance.

Managing Fuel Compatibility Onboard

Shell has developed the Stability Spot Test to determine the compatibility of residual marine fuels. In cooperation with Zematra, this self contained test kit enables ships' staff to perform this critical check onboard a ship. Mixing residual fuels onboard a ship has always been an operation which carries the risk of producing an unstable blend.

This problem is enhanced when mixing high sulphur fuels with low sulphur fuels. The main area of risk is in the settling and daily service tanks where if totally segregated high and low sulphur fuel systems are not installed, mixing is unavoidable. Experience has shown that mixtures of low and high sulphur residual fuels do not always follow the “normal” compatibility rules. The purpose of this test kit is to enable ships’ staff to determine the compatibility of the fuels onboard and therefore make informed decisions when changing over from low to high sulphur fuels and vice versa.

Classical compatibility thinking suggests that the highest risk of incompatibility occurred around the 50/50 ratio. Work carried out by Shell Research has shown that when blending high and low sulphur fuels containing thermally cracked components, incompatibility can occur at mixing ratios of 10/90 high/low sulphur fuels.

Knowledge of the compatibility of the two fuels that need to be mixed enables the operators toascertain if they are compatible, and decide if mixing can take place without fear of producing sludges or, if they are incompatible, determine the incompatibility range and manage the tank levels and mixing procedures to minimise the risk of producing an unstable mix.

Marine Fuel Quality – Ignition

Due to the robustness of marine diesel engines and the limited variation in fuel quality, for a long time it was not considered necessary to specify the ignition quality of heavy fuel oil. But in view of the increasing ignition problems being experienced with some low viscosity high-density fuels, Shell commissioned a project to devise a simple method of predicting the ignition performance of residual fuels.

The Calculated Carbon Aromaticity Index (CCAI), which arose from this work, is calculated from the density and viscosity of the fuel. Studies on test engines demonstrated the correlation of the CCAI with ignition delay in the engine, and the CCAI proved to be a very useful tool to rank fuels by ignition quality. However, because of the large differences between engine types it was not promoted for specifications, although it was the basis of the reduced density limits for the low viscosity fuel grades contained in the ISO 8217 Standard.

In 2002 the Shell Research laboratory in Amsterdam purchased the Fuel Ignition Analyzer FIA100/X from Fueltech. Having accumulated a considerable amount of data from the FIA, it was recognised that there was a need to compare values obtained from the instrument with actual performance in engines. A series of fuels was prepared for testing. These fuels were tested in two test engines located in Shell’s Marine and Power Innovation Centre in Hamburg, an AVL-Caterpillar 1Y540 and a Bolnes 1DNL190 engine, and in the FIA.

The FIA is a constant volume combustion chamber based instrument designed to resemble engine conditions (although there are of course some significant differences). Work to date shows that the FIA fuels with a short ignition delay (ID) also produce a high maximum rate of heat release (maxROHR). Such fuels also have a high combustion rate. However there are some exceptions, in particular at the lower and higher end of the ignition delay.

Attempts to correlate combustion parameters from the FIA (e.g. EC, ABP) with corresponding engine parameters failed, both with the AVL and Bolnes test engines. This may be partly due to differences in test conditions between FIA and the engines, affecting reaction kinetics. However, apart from other differences, fuel injection in the engines is also very different and strongly affects the combustion process. This area is subject to further work.

There is evidence that the composition of a fuel has a major influence on ignition and combustion characteristics: fuels with the same or very similar physical properties can have completely different ignition performance.

To improve our understanding of the relationship between ignition quality of components and those of blends, a series of blends was prepared on the basis of a visbroken (VBR) residue which was diluted with distillate components having different ignition qualities, respectively heavy cycle oil (HCO), light cycle oils (LCO-1 and LCO-2) and vacuum gas oil (VGO).

The blending curves clearly do not follow simple linear rules, which means that FIA ECN of a blend cannot be calculated from the properties of the individual components. When producing fuel oil, the situation is often even more complex, as most contain three or more components, instead of two. So predicting the ignition quality of blends is a complex matter. Without an extensive knowledge of the ignition performance and composition of components it is difficult to predict reliably in the ignition performance of the final blend. Further work is needed to improve our understanding of the relationship between fuel composition and FIA results.

Fuel composition has a significant affect on the ignition performance of finished fuels. It cannot be assumed that generic refinery streams, e.g. cycle oils, will have similar ignition performances. Nor can the ignition performance of blends be predicted, particularly if the streams come from different sources.

Low Sulphur Fuels (LSFO)

The ignition quality of heavy fuel oils in general is believed to deteriorate as result of refineries increasing conversion of residual streams thereby optimising yield of the more valuable distillate products. The same perception is that with the increasing demand for LSFO, refineries will blend increasing amounts of less valuable components which are poorer in quality, in particular the ignition and combustion quality.
Recent Shell LSFO ignition studies (FIA) do not confirm the perception, but indicate that the fuel ignition quality is not directly influenced by sulphur content. The ignition and combustion performance of fuel oils are determined by the source and composition of the blend components.
By maintaining strict control over these process and blending operations, Shell can ensure that all fuel oils including LSFO meet specifications and are fit-for-purpose, (i.e. will burn satisfactorily in marine diesel engines).

Fuel Oil Quality Assurance System (FOQAS)

To ensure that its Fuel Oils meet customer requirements, Shell Marine has developed a Fuel Oil Quality Assurance System – FOQAS. Shell tests its Fuel Oils for more properties than contained in ISO 8217:2005 and where necessary has stricter controls than given in the ISO standard.
FOQAS is a quality system that covers operating procedures for the complete fuel oil supply chain - starting from the manufacture through to storage, transportation, and up to the final delivery of the fuel oil to the vessel.
FOQAS includes strict controls over and procedures for:

- The type of components that can and cannot be blended into Shell Marine fuels
- The source of the different components used in Shell Marine fuels
- The management of pipelines, storage tanks, barges, truck tanks to avoid possible contamination resulting from multi-product handling
- Approval of quality assurance laboratories
- Sampling and testing of fuel oil quality and performance to ensure the fuel oil meets customers' expectations.

Every storage and delivery location is regularly audited to ensure FOQAS compliance.
FOQAS gives a very high degree of performance confidence by ensuring that fuels delivered by Shell are the correct specification andwill burn in marine engines, and will not damage the engines.
The Fuel Oil Quality Assurance System of Shell Marine is designed to ensure that quality fuels are delivered in every part of the world where Shell Marine operates.

Conclusion

Understanding and controlling of Marine Fuel ignition and combustion quality requires access to a large database with:

- Physical and chemical properties
- FIA properties
- Compositional data and origin.

Shell Marine's ongoing investment into quality management of marine fuel oils and research and development are to ensure that Shell Marine fuels are fit-for-purpose and to take the risk out of bunkering.

Keith Forget joined Shell Tankers (UK) Limited in 1969 and served on a wide range of tankers before coming ashore to join the London based superintendents team in 1979 responsible for the design and installation of crude oil washing systems on VLCCs and VLOBOs.In 1981 he transferred to the marine technical department of Shell's International marine fuels and lubricants organisation within the Shell International Trading Company dealing with the development and implementation of technical service offers, technical support to the local operating units. Today Keith Forget holds the position as global technical manager for Shell Products Limited. Additionally, he is manager of the Marine Technical Solutions Centre, London.