Matthew Bridgeman and George Davidson, Quadrise Fuels International, UK, explore emulsion fuels as a response to IMO 2020 regulations.

2020 VISION

Emulsion fuel blending is the process of producing a stable mixture of water and oil. This can either be a water-in-oil (WIO) emulsion, which is commonly used for NO_X reduction (due to reduced combustion temperature), or an oil-in-water (OIW) emulsion, which is used to reduce and control residual stream viscosity without using traditional cutter stock, thereby reducing production costs, whilst also achieving the NO_X reduction.

Residual OIW emulsions are a low-cost alternative to conventional heavy fuel oil (HFO), which is normally sold at a discount to crude, creating a loss for the refinery. OIW emulsion production allows the middle distillate used as cutter stock in HFO to be upgraded from the fuel oil pool and to be sold at a premium, as the cutter stock is replaced with water and a small amount of stabilising chemicals (Figure 1).

Cheaper fuel

Whilst the inclusion of water in the emulsion decreases the fuel's calorific content on a mass basis and thereby increases the amount of fuel that must be consumed to provide the same energy, the reduced production cost results in a reduction of the overall fuel bill on a like-for-like calorific basis.

Additional benefits of OIW emulsion fuels include less black carbon emissions due to the tiny droplets of hydrocarbon (approximately 5 μm; Figure 2) resulting in greater surface area and hence more complete combustion, and lower NO_X emissions due to the presence of water in the fuel reducing the flame temperature.

OIW emulsion fuels are proven in a range of steam boilers (50 – 770 megawatts thermal) with over 60 million t fired worldwide. They are also proven in



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2-stroke and 4-stroke diesel engines. On the power side, this includes approximately 150 000 cumulative commercial running hours in Wärtsilä V32 and V46 4-stroke engines at Planta Arizona, Guatemala between 2004 – 2006. On the marine side, a successful operational trial with Maersk in 2016 – 2017 where over 1500 running hours were completed onboard the main Wärtsilä Flex 2-stroke engine of the Seago Istanbul.

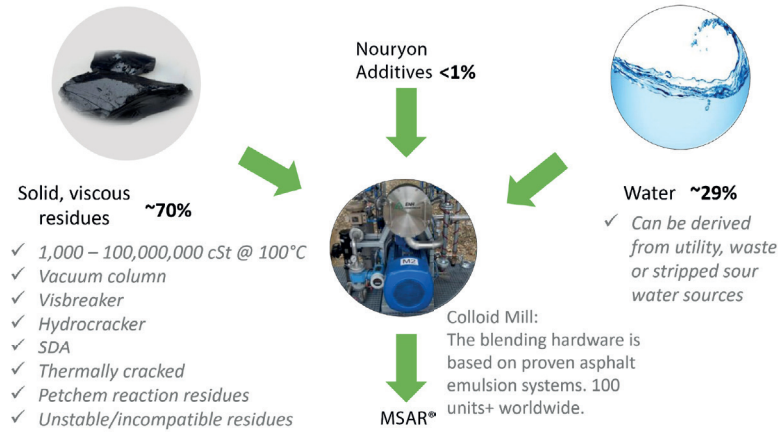


Figure 1. OIW emulsion fuel blending.

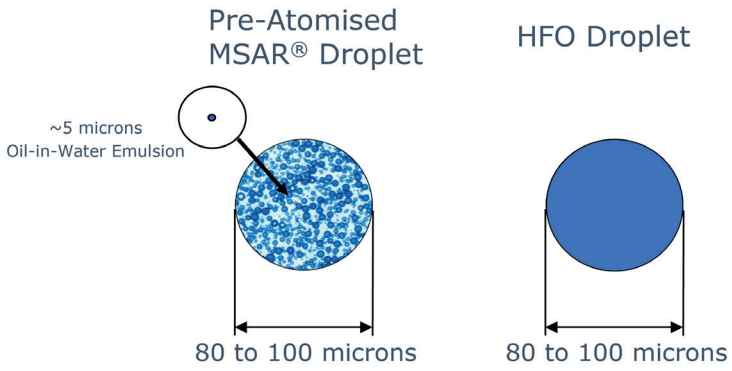


Figure 2. Comparison of emulsified fuel (left) and HFO (right) droplets.

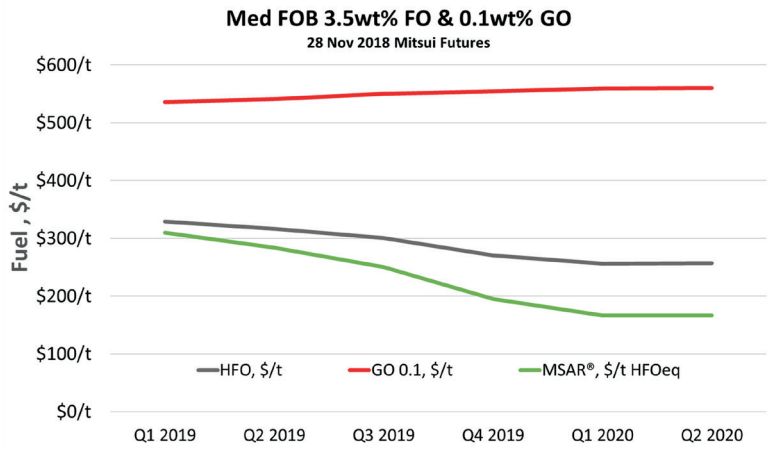


Figure 3. HFO and middle distillates spread

IMO 2020 overview

The International Maritime Organisation (IMO) will be implementing a global sulfur cap of 0.5% for the marine industry as of 1 January 2020, down from the current 3.5% cap.

IMO 2020 is arguably the biggest change to the shipping industry and fuel oil markets in decades. Emission regulations implemented in the last 10 years include a global sulfur cap decrease from 4.5% to 3.5% sulfur in 2012 and a decrease in emission control areas (ECAs) from 1% to 0.1% sulfur in 2015. These ECA restrictions have in comparison only marginally affected the wider shipping industry due to the limited time spent in ECAs, with most vessels currently burning HFO in the open ocean and 0.1% sulfur MGO in ECAs.

As a result of the new regulations, the spread between the price of high sulfur fuel oil (HSFO) and middle distillates is expected to increase significantly (Figure 3), with some experts predicting up to US$400/t at the time of writing.

Marine responses to IMO 2020

In response to IMO 2020, shippers have the option to either continue burning HSFO, in conjunction with exhaust gas cleaning systems or 'scrubbers', or switch to more expensive compliant fuel.

The quantity of middle distillates required to blend to the reduced sulfur specification of ultra-low sulfur fuel oil (ULSFO) can be extremely high. In many cases, refineries will have to redirect low sulfur streams, such as vacuum gas oil (VGO) from other processes, in order to produce ULSFO, which may result in lost margin. These factors combine to increase the price of ULSFO and raise concerns surrounding availability and compatibility of these fuels post 2020.

Whilst MGO may be a simple solution to IMO 2020, it is one that will increase fuel costs substantially given the MGO/HSFO spreads. LNG is another potential option; however, many analysts predict that it will remain a very small contributor in 2020. This is in part due to complex and lengthy retrofits, issues around transport, storage and regasification, as well as methane slip, which can offset much of the potential CO_2 savings.

Many vessel owners believe that burning HSFO with a scrubber will be the most cost-effective method of compliance in 2020, given the wide futures spreads expected, which allow the initial scrubber investment (in the order of US$2 million – US$6 million) to be paid-back quickly, especially on larger

vessels, such as tankers, bulkers and containerships. As a result, through 2018 there was significant momentum building for scrubber orders with estimates of installed scrubbers as high as 2200 by the start of 2020 (or 500 000 bpd of demand) according to *Platts Analytics*.[1]

Refinery response to IMO 2020

With the dramatic increase in spreads expected from 2020, there is a strong driver for refiners to increase their distillate yields. Quadrise's emulsion fuel blending technology (MSAR® - Multiphase, Superfine, Atomised, Residue) offers a quickly implemented, low CAPEX, short-cycle method of achieving this.

The technology mechanically mills extra heavy refinery residues into superfine particles (~5 µm). These are dispersed in water forming an OIW emulsion (70% residue, 30% water) with a small amount of specialist surfactants, supplied by the company's technology partner Nouryon (formerly AkzoNobel Surface Chemistry), used to keep the emulsion fuel extremely stable. The synthetic fuel oil produced can be used as a direct substitute to fuel oil in all applications.

A 1000 tpd (6000 bpd) unit can be installed for around US$5 million, with OPEX in the range of US$20 – US$35/t of MSAR, dependant on the fuel application. The modular nature of the unit allows for fast installation and phased expansion of capacity as required.

Many refineries are responding to bottom-of-the-barrel drivers by installing upgrading technology such as solvent de-asphalting (SDA) and hydrocrackers. Whilst these units increase a refinery's conversion there is often a residue stream that is disposed of via the fuel oil pool and this residue may be a suitable candidate for emulsification. Directionally, the more viscous the residue, the more economical the use of OIW emulsion technology is, as more high value cutter stock can be released from the fuel oil pool. The following case studies explore the cost and timeline for installation of a manufacturing plant as well as potential savings, compared to HFO.



Figure 4. The CEPSA MSAR plant.

Refinery implementation

A recent trial was undertaken, which successfully produced marine MSAR as a bunker fuel for Maersk. The production occurred at the 240 000 bpd CEPSA Refineria Gibraltar San Roque (RGSR), emulsifying visbreaker residue.

The MSAR manufacturing unit and ancillary equipment were installed in the refinery for less than US$5 million and was operational within nine months of

Table 1. Generic refinery economics: SDA pitch cut with LCO for 380 cSt HFO vs MSAR

Refinery fuel oil blend assumed	**Market (US$/t)**	**Viscosity (cSt at 50°C)**	**Fuel oil blend (wt%)**	**Mitsui futures (1 November 2018) – Singapore FOB 1Q20**
HFO, 3.5 wt% S	341	380	100	Fuel oil 380cSt
made from cutter stock (LCO)	553	6.5	50.5	LCO value = 85% of 500 ppm gasoil (US$650/t)
made from refinery residue	125	75 million	49.5	Netback calculation
MSAR blend economics	**US$/t**	**MSAR blend (wt%)**	**US$/t of MSAR**	
Refinery residue	125	70	87	
OPEX (water 29%, additives <1% etc.)		30	35	
MSAR cost of production (variable cost basis) = residue + water + additives			122	
MSAR value normalised for lower NCV				
Assumption: HFO NCV	40.8 GJ/t			
Assumption: resid NCV	39.5 GJ/t			
Assumption: MSAR NCV	27.1 GJ/t	MSAR on HFO basis = 40.8/27.1 × 122 = US$184/t HFO equivalent		
MSAR margin vs HFO (normalised for NCV) =		341 – 184	US$157/t HFO equivalent	46% discount vs. HFO. Margin to be shared
US$157/t HFO × 27.1/40.8	US$104/t MSAR	350 000 tpy	US$36 million/yr	MSAR production = 1000 tpd (350 000 tpy)

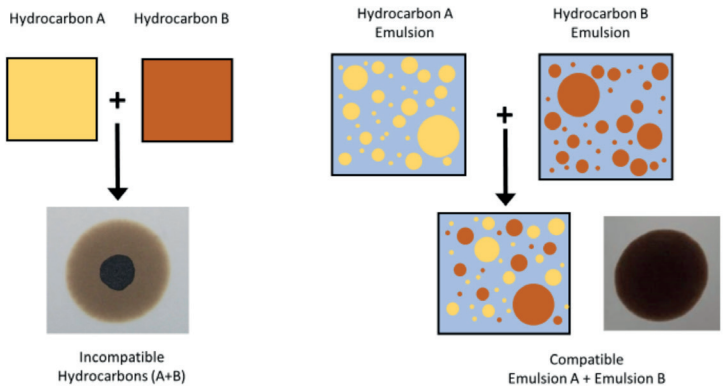


Figure 5. Spot testing of incompatible hydrocarbons and compatible emulsions of the same hydrocarbons.

signing contracts. The unit operated reliably in both continuous operation and batch modes, consistent with the required MSAR loading schedule. The unit produced MSAR from residue derived from various crude slates, including high and low sulfur.

Quadrise was responsible for the system installation, commissioning, operations and quality control, working effectively with the refiner, engineering company and end user throughout (Figure 4).

Case study 1

A refinery producing HFO from SDA pitch and light cycle oil (LCO) cutter would create a margin of US$36 milion/yr by installing one unit producing 1000 tpd of MSAR.

The margin created by the technology is shared between the refinery and the end user. Assuming 50% of the margin goes to the refiner and a worst-case basis (lower percentages of cutter stock in the blend, reduced gasoil – fuel oil spreads, higher CAPEX, and additional costs for licensing and marketing), the payback would be generally less than 12 – 18 months for the example explored above, with high project IRRs and economics robust to changing fuel prices (Table 1).

Case study 2

Using a similar methodology to Case study 1, with hydrocracker residue and a 10% fuel saving, potential savings for vessels switching to MSAR are over US$750 000/yr. This is based on a very large crude carrier (VLCC) (30 MW installed engine power, consuming 21 500 tpy) with an open-loop scrubber. The conversion costs of US$0.4 million are paid back in approximately 6 months.

Blending of incompatible low sulfur streams

For shippers not opting for scrubbers in 2020 and refiners producing compliant low sulfur fuels, one of the main concerns is the compatibility of the refinery streams used to create low sulfur fuels and the compatibility of those fuels with each other.

Theoretically, there are enough low sulfur refinery streams to meet low sulfur fuel demand, however the reality is that many of these streams may predominantly be aromatic or paraffinic. As such, they may be incompatible with each other, which poses the issue of availability of compliant, compatible low sulfur fuel.

If hydrocarbon streams are incompatible, they can precipitate out asphaltenes or wax, which can damage ship engines and clog systems, resulting in extensive flushing and repairs, and potentially loss of propulsion. This compatibility issue and concerns around contaminated fuel means that more vessel owners are now looking at term fuel supply agreements direct from refiners to ensure fuel provenance.

Compatibility issues can arise both at producer and consumer ends in the supply chain. Refiners could potentially have streams that could be blended together to produce low sulfur fuel specifications, but these streams may be incompatible, and shippers run the risk of loading fuel at a port that is incompatible with the fuel already on board.

Emulsion fuel blending offers a solution to the incompatibility issue. Quadrise has demonstrated that incompatible hydrocarbon streams, which precipitate significant amounts of asphaltenes when mixed together, can be emulsified as separate streams and then mixed without any incompatibility issues arising. This is due to micron sized droplets of hydrocarbon being suspended in a continuous water phase, which prevents the hydrocarbon droplets from contacting each other and reacting, hence negating asphaltene precipitation.

Results from marine fuel compatibility testing (spot test), as per ASTM D4740, are illustrated in Figure 5. The left-hand side of Figure 5 shows the incompatibility of two hydrocarbons, A and B, as illustrated by the concentric circles, showing severe asphaltene precipitation. Whereas on the right-hand side, when the two incompatible hydrocarbons, A and B, are emulsified separately and the emulsions are blended, the resultant fuel shows no sign of incompatibility as per the homogenous spot test result.

Summary

Emulsion fuels offer an attractive solution to various problems posed by IMO 2020, both economically and operationally. The increase in refinery distillate yields from emulsion fuel blending can result in significant savings for both the refiner and end user, which are amplified by the widening HFO/MGO spreads as 2020 approaches. In addition, the ability to blend incompatible streams via emulsification offers a potential solution to what is likely to be a significant problem post 2020.

Reference

1. JORDAN, J., 'Marine scrubber installations may peak at 6,000: Platts Analytics', Bunkerworld, S&P Global Platts (30 November 2018), http://www.bunkerworld.com/news/Marine-scrubber-installations-may-peak-at-6-000-Platts-Analytics-152661, (accessed 10 January 2019).