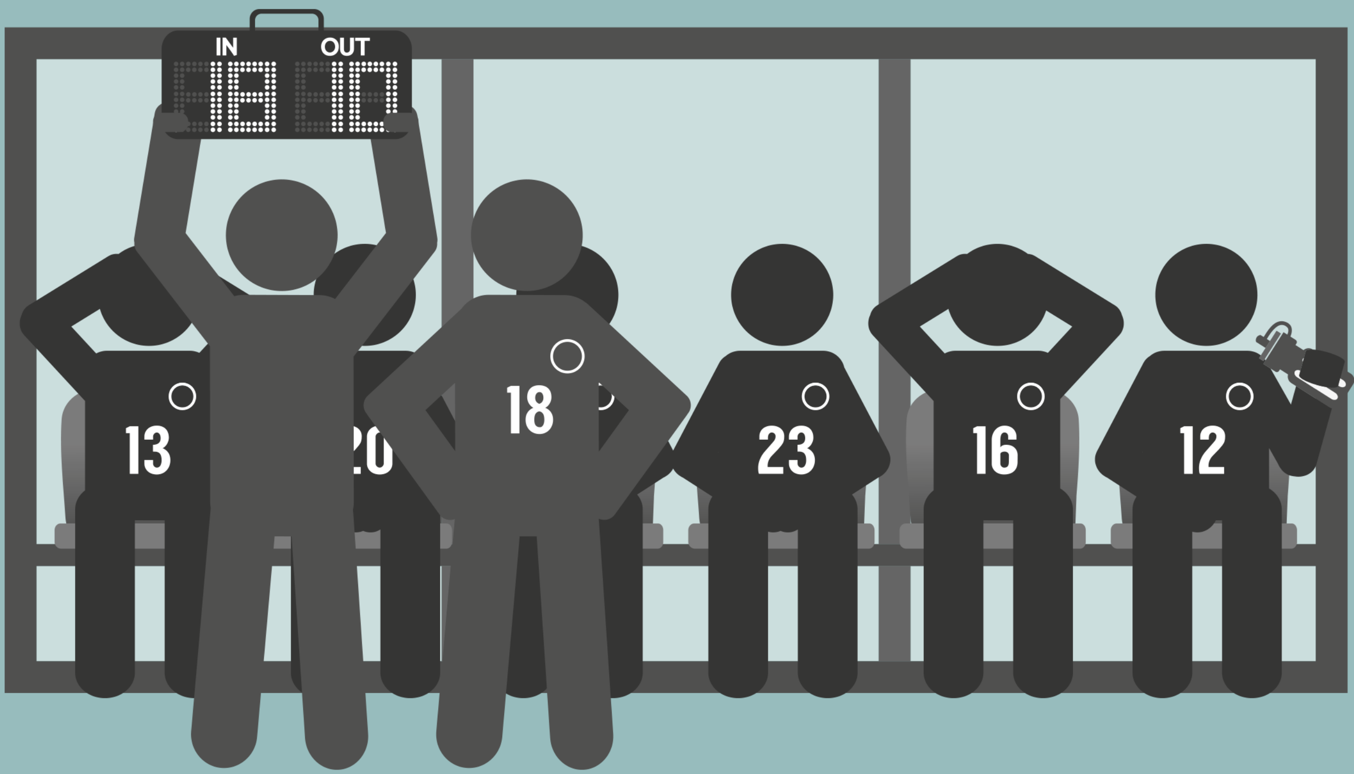

A SUITABLE SUBSTITUTE

Mark Whittle, Quadrise Fuels International plc, UK, discusses blending technology for the production of oil-in-water emulsion synthetic fuel oil, which can be used as a substitute for conventional HFO.

Many refineries produce heavy fuel oil (HFO) from their residue streams, requiring the downgrading of higher value distillate cutter stocks to the fuel oil pool to control viscosity, and potentially sulfur, in response to the International Maritime Organization's (IMO) decision to implement the 0.5% sulfur cap in 2020.

MSAR® (Multiphase Superfine Atomised Residue) blending technology emulsifies high viscosity residues without the use of any distillate cutters. The resultant stable, low viscosity, oil-in-water emulsion is a synthetic HFO that can be used as a direct substitute for conventional HFO, whilst providing economic, environmental and operational benefits.

Oil-in-water emulsion blending technology

Oil-in-water emulsions are characterised by being water continuous, comprising of a suspension of 70% oil phase droplets within a 30% bulk water phase, as opposed to the inverse in water-in-oil emulsions. The advantage of an oil-in-water emulsion, from a rheological perspective, is that droplet packing and water phase properties determine the final viscosity, rather than the underlying hydrocarbon viscosity.

The inclusion of small quantities of highly stabilising chemicals results in a highly stable fuel, with superior combustion and emission performance and similar handling properties to conventional HFO, which

Figure 1. The MSAR manufacturing unit (in a 40 ft container; bottom left), and associated modules at Cespa's Gibraltar San Roque Refinery.

can be sold as an alternative to major fuel oil consumers.

The blending hardware is based around proven asphalt systems that are readily retrofitted to refineries. Hot residue is blended with water and chemicals in a colloid mill, after which the fuel is cooled, such that it can be stored and transported via conventional HFO infrastructure. The residues can originate from a variety of refinery process units and crudes, with viscosities typically ranging from 1000 to 100 000 000 cSt at 100°C, using chemical formulations designed to be robust to refinery process variations and end-user requirements. The process equipment is sufficiently flexible for future upgrade options; for example, a system blending vacuum residue today can be utilised for solvent de-asphalt or hydrocracker residue in the future.

Existing fuel oil infrastructure can be utilised, allowing current fuel oil operations to continue in tandem with emulsion fuel production if desired, increasing refinery options and minimising CAPEX.

Advantages

Oil-in-water emulsion fuels have improved combustion and compatibility characteristics, providing operational and environmental benefits.

The oil phase in the emulsion is pre-atomised, with droplets of 5 – 10 µm size compared to atomised HFO droplets of 100 µm. This higher surface area to volume ratio results in complete combustion. The reduction of 'black soot' particulates in the exhaust gases minimises boiler fouling and reduces the ash and particulate emissions to the level of inorganic material in the fuel, even if the residue contains high levels of asphaltenes.

The water content of the emulsion reduces the combustion temperatures and associated thermal NO_X generation, resulting in significant NO_X reductions of typically 20 – 50%.

Oil-in-water emulsion fuels are liquids at room temperature and can be handled easily at ambient temperatures (circa 30°C), reducing energy consumption during handling and storage compared to HFO, which typically needs to be heated to 60 – 120°C.

The middle distillate yield shift achieved by releasing cutter stocks from the fuel oil pool can be further enhanced through incremental yield benefits that are associated with changes in crude slate and/or increased unit severity without being penalised for the more viscous streams that are produced.

Finally, from a compatibility perspective, because the hydrocarbon droplets are encapsulated within the continuous water phase, operational problems, such as asphaltene precipitation during storage or blending, will not occur because no chemical reactions take place between the oil droplets. This phenomenon is beneficial as it enables unstable asphaltenic hydrocarbons to be blended together without the requirement for settling tanks or fuel pre-treatment and filtering, offering a solution to compatibility issues that are expected to increase as refiners react to the IMO decision.

Installation case study

The MSAR fuel technology was developed by Quadrise and surface chemistry specialist AkzoNobel. A joint development programme with Maersk tested all aspects of the use of MSAR as a bunker fuel, i.e. combustion, quality, transport, storage and bunkering. Meanwhile, a modular 6000 bpd system was installed in 2016 at Cespa's 240 000 bpd refinery, Gibraltar San Roque (RGSR).

The complete system was installed and commissioned within nine months of signing commercial agreements and was designed to produce the emulsified fuel from visbreaker residue derived from a variety of low and high sulfur crudes.

The main process equipment was delivered to site housed in standard ISO shipping containers that were tailored to the refinery's requirements. The modular construction simplified and expedited the integration into the refinery for this project. Existing HFO infrastructure was utilised for fuel storage and transfer to the jetty and end-user.

The MSAR manufacturing unit (MMU) is housed in a 40 ft container, with its own control system, which is integrated into the refinery's distributed control system (DCS). The ancillary equipment includes additive storage (ISO tanks) and blending, water treatment, laboratory, office, workshop, etc., which are all incorporated within a plot of 45 m x 15 m (Figure 1).

The technology installed is flexible for most future residue upgrading plans (i.e. those producing residue

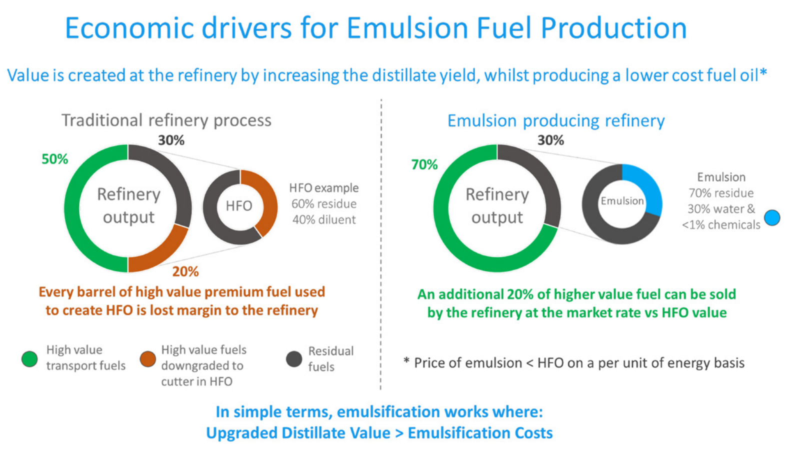

Figure 2. Economic drivers for emulsion fuel production are illustrated in this concept.

streams) and can produce fuel for both marine and power applications.

Land and sea-borne proof of concept tests and operational engine testing by Wärtsilä and MAN Diesel & Turbo have confirmed that emulsion fuel is safe to use, with no detrimental engine impact. Oil-in-water emulsion fuel has also been tested successfully in major utility boilers in excess of 300 MWe.

Economic case study

Downstream bottom of the barrel investment decisions are typically complex, given capital constraints and the risks associated with projects that take several years to implement.

Emulsion blending technology offers an atypical solution for refineries, whether they are semi-complex (where conventional upgrading may not be viable due to scale or financial constraints) or complex refineries producing small quantities of very heavy residues, as these projects are low CAPEX, fast to implement and low risk.

Project CAPEX is typically US$3 – 7 million for a standard 1000 tpd (6000 bpd) system with OPEX in the range of US$20 – 35/t MSAR, depending on the application. CAPEX is largely a function of available infrastructure and tankage, whilst OPEX is largely a function of MSAR grade produced and fuel stability required. Power applications typically have lower CAPEX and OPEX than marine applications, where stability requirements are extremely high. The technology lends itself well to phased investment and future expansion plans.

The economic value of implementing emulsion manufacturing is based on comparing the value created by upgrading the cutter stocks from the fuel oil pool to the distillate pool (i.e. it is a function of the gasoil to fuel oil 'spread' against the production costs, including chemicals and an adjustment for calorific value).

Whilst the exact impact of the IMO decision is unknown, the general consensus is that the gasoil/fuel oil spread will widen further as 2020 approaches, which strengthens the case for emulsion fuel blending.

Applications: utilities, marine, refinery and upstream

Oil-in-water emulsion fuels are proven for major utility and industrial consumers. The IMO 2020 regulations are likely to result in HFO and oil-in-water-emulsion fuel being competitive sources of energy.

Currently, Quadrise and major stakeholders are in the final stages of defining a commercial scale proof of concept combustion project in the Kingdom of Saudi Arabia (KSA). The scope is production for sea-borne supply to a modern 400 MWe boiler with full air pollution control equipment installed. Following the trial success there is the potential for oil-in-water emulsion fuel supply opportunities for both domestic and international refineries. HFO use in KSA today is approximately 500 000 bpd, with approximately 50% sourced domestically and the remainder imported.

Oil-in-water emulsions can also be used as marine bunkers and are compatible with exhaust gas cleaning systems. BP forecasts that high sulfur fuel oil's share of the bunker market will rise in 2020 – 2025, reaching approximately 40% by the end of the period as scrubber uptake increases and HFO remains the most economic fuel option.

There are also selected opportunities for refinery own-use and upstream optimisation applications, where this technology has the potential to produce lower cost fuel and/or mobilise and monetise stranded oil assets.

Conclusion

Oil-in-water emulsion blending technology is a game-changer for refiners as it offers low CAPEX, fast-track opportunities to significantly improve refinery yields and margins by producing lower cost synthetic fuel oils that remove the need to downgrade high value distillates to fuel oil.

The technology enables refiners to realise low risk, alternative disposition strategies that are potentially complementary to future upgrading strategies and projects.

Emulsion fuel can be transported, stored and combusted in the same manner and systems as HFO, and is suitable for applications including power, marine, upstream and refinery own-use.

The primary benefits of improved refinery margin and lower cost fuel are complemented by enhanced combustion features and associated environmental benefits, such as complete carbon burnout and reduced NO_X levels, as well as operational benefits including improved fuel oil stability and the avoidance of asphaltene precipitation after blending, providing operational flexibility.

Successful demonstrations show the technology is proven and supported by world-scale industry participants covering technology, engineering, production and end-use.