13th INTERNATIONAL SYMPOSIUM ON FUELS AND LUBRICANTS

MARCH 17-19, 2023

Theme: Fuels & Lubricants as Enablers for Net-Zero Goal

Organized by

IndianOil R&D The Power of Possibilities

Under the aegis of

Indian Society on Fuels and Lubricants

Abstract Book (Technical Sessions)

ISFL 2023: Program at a Glance

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Technical Session – I-A: Automotive Oils-I

Paper ID 257: Supporting India's drive for fuel economy: Comb polymer technology for engine oils

Rhishikesh V. Gokhale

Evonik Oil Additives

The engine oil market in India is evolving towards low viscosity grades as OEMs seek to meet ever-tightening emissions standards and fuel economy targets mandates. As a result, lubricant blenders must overcome the challenges of meeting ambitious fuel economy and performance targets, while simultaneously offering novel solutions at competitive costs. Evonik's VISCOPLEX® Viscosity Index Improvers (VII) allow for these competing demands to be met. This presentation will show how incorporating the right VII can improve fuel economy performance within the same viscosity grade

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Paper ID 277: Balancing durability and catalyst compatibility for future motorcycle engine oil applications

Sandeep Pawar

Lubrizol India Pvt. Ltd., Turbhe, Navi Mumbai, India

India is one of the biggest and fastest-growing markets for two-wheelers. For many households in India, a two-wheeler is the primary mode of personal mobility. The booming e-commerce industry in India has also contributed to the increase due to the use of two-wheelers to make last-mile deliveries. Two-wheelers consume the highest percentage of energy eventually contributing to the highest carbon emissions in the passenger sector.

With the advent of Bharat Stage - VI, motorcycles are now equipped with three-way catalysts to control hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NOx). In the past researchers gathered a variety of engine data supporting the hypothesis that phosphorus volatility can have a significant impact on catalytic converter efficiency. Further, onboard diagnostic (OBD) systems for emission control in BS-VI Stage 2, expected in April 2023, will have catalytic converter monitoring. JASO-2016 has set phosphorus limits ≥0.08% and ≤0.12% in motorcycle oils to ensure durability - primarily for gear units. This study evaluates the anti-wear and oxidation capability of unique additive chemistry in low-viscosity and low-phosphorus oils by ensuring improved catalyst protection and maintains hardware durability.

Paper ID 332: Fuel economy improvement in HDD lubricants

Lalit Madan

Infineum India Additive Pvt. Ltd., Bandra East, Mumbai, India

The future of automotive and lubricants business is facing a time of major disruption. Introduction of strict legislation, global pandemic changing the way we do things for now and potentially in the future.

Emissions from transportation sector are of growing concern to governments across the globe. International Energy Agency (IEA) data shows CO_2 emissions from commercial vehicles have risen steadily and this, combined with air pollution means emissions legislation for this sector getting tightened in many regions of the world.

Fuel economy (FE) will be an essential performance feature of future HDD Internal Combustion Engines. As seen with other segments, introduction of tighter emissions legislations has driven to a significant focus of the industry to Fuel Economy. EU legislation has initiated significant targets for CO_2 emission reduction across industries to meet the Paris agreement.

India introduced National Mission for Energy Efficiency which works on creating regulatory and policy regime for Fuel Economy norms such as CAFÉ/ HDFE/ LMDFE.

FE brings value throughout the customer chain, which the lubricant can contribute through CO_2 savings required to meet legislative requirements. Development of future facing formulations will help to align with sustainability goals and to help reduce total cost of ownership.

Sustainability, Carbon footprint is now a target for the industry; Infineum is looking forward at how we can continue to protect the hardware and enable future technologies and ultimately contribute to reducing CO_2 emissions.

Paper ID 330: Fuel-efficient axle lubricants

Satya Pathak

Afton Chemical Ltd.

Due to current and future emission legislation, Vehicle manufacturers/OEMs are working to improve fuel economy and reduce $C0_2$ emissions across their vehicle fleet. Thus, the improvement of fuel economy will remain the key driver for future.

Particularly in India, there is a lot of potential for lowering the viscosity of the driveline fluid to improve the fuel economy for Transmission & Axle fluid. The paper will focus on the impact of Base oil and Viscosity Modifier on the Fuel Economy potential of driveline fluids and will also touch upon the trends & challenges of the low viscosity driveline fluids.

Paper ID 502: Development of green combo lubricant solution for heavy duty commercial vehicles: A step towards reducing carbon footprints from the existing vehicle fleet

Sandeep Kumar, Ratnadeep Joshi, Snigdhamayee Praharaj, Prashant Kumar, Sarita Seth, Pankaj Bhatnagar, Mukul Maheshwari and SSV Ramakumar

Indian Oil Corp. Ltd., R&D Centre, Sector-13, Faridabad, India

Globally the transport sector is responsible for 25% of total carbon dioxide (CO_2) emissions from fuel combustion. In India, it is the third most CO_2 emitting sector and within the transport sector, road transport contributes more than 90% of total CO_2 emissions. India Heavy Duty vehicle market is anticipated to grow in coming five years on the grounds of rising freight movements and growing production of commercial vehicles. This Heavy Duty vehicle segment accounts for a greater share of transportation fuels than other vehicle segment. So the regulations are aimed at reducing fuel consumption and greenhouse-gas emissions from diesel-powered Heavy Duty trucks and buses. Indian Heavy Duty vehicles greater than 12 tonnes represent about 60% of total fuel use and GHG emissions from the entire Heavy Duty vehicles fleet. In order to meet Indian CAFÉ regulations, energy efficient lubricants are the cheapest option and using these generally not require any change in vehicle design. Not only Engine oil, but also Manual Transmission oil and Axle oil contribute in hydrodynamic friction reduction leading to fuel economy gain. Heavy Duty engine oil alone occupy ~20% share of total lubricant market size. Even a small increment in fuel efficiency will lead to huge benefit for the end user when considered for the entire Heavy Duty segment.

Currently for Heavy-duty segment, Engine Oil SAE 15W-40, Transmission Oil SAE 80W-90 and Axle Oil 85W-140 are preferred grades. In this paper, authors discuss the development of a unique product solution called as “Green combo lubricant” which is a combination of Engine oil, Transmission oil and Axle oil.

The combo solution is specially designed by optimizing the viscosity and using innovative additive chemistry to reduce friction in the engine. This resulted fuel economy improvement w.r.t. the conventional lubricants in the vehicle without compromising the durability aspect. Engine oil of Green Combo lubricant meets API CK4 performance level which is the highest Heavy-duty API diesel engine oil specification with excellent engine durability and long oil drain potential. Transmission oil and axle oil meets API GL4 Plus and API GL5 Plus specification respectively with long oil drain capability. The fuel economy studies on the Combo lubricants were conducted as per IS: 11921 method in Heavy duty commercial vehicle. The green combo lubricant solution developed in the authors’ laboratory resulted 4-5% of fuel economy benefit in certified lab testing. The fuel efficiency credentials are also proved by field trial in various State Transport Units in India. The durability was also established by field trial for 1.2 lakh kms run on BS-IV vehicles.

Technical Session – I-B: Oxygenated Fuels

Paper ID 313: Performance and emissions evaluation of a DI engine using methanol-diesel blends for heavy commercial vehicle engine

Senthil kumar G, Narayana Reddy J, Somasekar D, Ashok Raaj K, Sathyanandan M and Krishnan Sadagopan

Ashok Leyland Technical Center, Vellivoyal Chavadi, Chennai, India

The rising prices of fossil fuel are expected to propel the growth of the alternative fuel vehicles market going forward. The global alternative fuel vehicles market is expected to at a compound annual growth rate (CAGR) of 33.4%. Asia Pacific was the largest region in the alternative fuel vehicle market in 2021. Methanol and diesel are not very miscible, which makes it difficult to mix them together as a diesel engine fuel. They are immiscible liquids and a solubilizer additive required to blend both liquids. Depending on the desired Methanol blend required we need to measure out required quantities of methanol, additive and Diesel in individual containers and create a blend by using an electric stirrer so that the final blend is homogeneous. The mixture is to be transferred to a dry container and checked for any layer separation at the top or bottom. The prepared blend should be stable and no visual separation even after 24 hours.

In this study, Methanol is blended (M15) with diesel fuel by using special additive and observed NO phase separation and works without any problems. Experiments were carried out with diesel fuel and M15 back to back on same engine and same test bed. There is 3.5% performance deterioration with M15 fuel compared to diesel fuel in as it is condition. However, performance can be matched with diesel fuel by recalibrating the injection parameters. Emission values are comparable with diesel fuel. There is a reduction trend in HC, CO and PM with M15 compared to diesel fuel... Peak firing pressure is reduced with M15 fuel compared to diesel fuel. Peak hear release rate is reduced. MBF50% is increased with M15 fuel in terms of crank angle (7degCA with diesel 8.2degCA with M15 @1000rpm.)

Paper ID 352: Ethanol diesel blends – review, experience and way forward for India

Robert Paulmer

MIWrk Pte Ltd., 7500 A Beach Road, 1-303, The Plaza, Singapore 199591

Ethanol is one of the most effective weapons against vehicular air pollution. Because it is biodegradable and reduces emissions from vehicle tailpipes and greenhouse gases without requiring an entirely new transportation system, ethanol is a useful tool for addressing environmental problems. Further, as ethanol contains 35% oxygen, it is an excellent oxygen additive for fuel, resulting in cleaner combustion and fewer pollutants in the exhaust. Ethanol-diesel blends can have the same positive effects as ethanol and gasoline. Using a part of ethanol instead of imported petroleum-derived diesel reduces pollution, load on exhaust after treatment systems, and its cold-flow properties. Ethanol-diesel blends can be characterized as low, medium, or high blends. The bulk of these mixtures will require additives to stabilize the fuel, improve its properties, and ensure its safety. Low blends are attractive due to their ease of implementation, which requires minimum infrastructure modifications. In addition, it has almost no effect on vehicle through put and they are fully fungible.

The properties and specifications of ethanol blended with all types of diesel fuel are discussed in this review. The factors that were critical to the commercial use of these blends in four continents since 2000 are highlighted. Blend properties such as stability, viscosity and lubricity, safety, and material compatibility are among these considerations. The impact of the fuel on engine performance, durability, and emissions is also considered. Some studies based on experience with US Air Force non-tactical equipment and ports are described. The paper also showcases an optimal percentage of ethanol blend with diesel without requiring significant changes in existing infrastructure or vehicles, as well as benefits and precautions, as well as a way forward for possible India adoption of ethanol diesel blends.

Paper ID 231: Effect of diesel-ethanol blends on the performance and emissions of a CI diesel engine suitable for stationary application

Rahul Garg, Nalini Kanta Mukherjee, Chithra V., Vasu Choudhary, Bharat Newalkar, Devendra Nene, Manoj Kusumba

Corporate R&D Centre, Bharat Petroleum Corp. Ltd., Greater Noida, India

Diesel engines are primarily used in the power generation sector owing to their characteristics of high efficiency and power, but account for higher emissions, mainly NOX and PM. Ethanol being a bio-based alternate fuel, holds the potential to be one of the most promising fuels for blending with diesel for emissions reduction, primarily due to its oxygenated nature, which results in a lower carbon content than diesel. In this study, four different ethanol-diesel blends have been developed for investigation (a) 5% (v/v) ethanol/diesel blend (E5D95), (b) 10% (v/v) ethanol/diesel blend (E10D90), (c) 15% (v/v) ethanol/diesel blend (E15D85) and (d) 20% (v/v) ethanol/diesel blend (E20D80). Additives and couplers were developed, as well, to address the problem of corrosion, cetane number reduction and blend stability. A detailed physico-chemical characterization was performed to measure various critical properties (density, cetane number, calorific value, flash point, etc.) of various diesel-ethanol blends. Also, all the blends were subjected to the stability test to understand the solubility and separation of ethanol and diesel at various temperatures. Subsequently, detailed experiments were conducted to understand the combustion and engine-out emission characteristics of ethanol–blended diesel fuels. A four-stroke, naturally aspirated, three-cylinder mechanically operated direct-injection diesel engine was used in this regard. Being a stationary genset engine, D2-5 mode test as per ISO 8178 part IV was conducted at 1500 rpm. Engine brake power, torque, specific fuel consumption, inlet air flow rate, exhaust gas temperature, exhaust emissions, and the in-cylinder combustion, as well as fuel injection pump and injector end high-pressure line data were captured.

Performance of the tested engine with ethanol blending remained at par with the baseline diesel, however a reduction in the PM and gaseous emissions establishes ethanol blend as a favorable fuel solution for the tested CI engine. Experimental results indicate that, adding ethanol in diesel results upto a 6% reduction in the cycle NOx (for 20% blend) as compared to the baseline diesel; however, HC and CO were observed to have an increasing trend. A significant reduction of PM (~42%) was observed with 20% ethanol blending, as compared to the baseline diesel. The thermal efficiency was observed to be improved by 7% maximum with 20% ethanol blend. A meticulous analysis of the combustion data indicated no significant change in the in-cylinder pressure and the start of injection from baseline diesel to ethanol blends, at full load condition. However, at part load operation (below 50% load), peak firing pressure was reduced up to 6%, and the start of injection

and combustion got retarded by ~2 deg, which deteriorated the thermal efficiency slightly. 5% ethanol blend came out as optimum for quick implementation in the existing engine perspective. Higher ethanol blend % is also possible for implementation; nonetheless the additional HC/ CO emissions might have to be dealt with by a catalytic converter.

Paper ID 339: Effect of microbial growth on fuel characteristics of biodiesel-diesel blend

Manoj Kumar, Maya Chakradhar, Fariha Saleem, RP Gupta

Indian Oil Corp. Ltd., R&D Centre, Sector-13, Faridabad, India

The use of biofuels as such and as a blending component for hydrocarbon fuels is increasing worldwide. It may also cause microbial contamination and biodeterioration in the hydrocarbon fuel matrix under certain storage condition. Microbial biomass produced during the biodeterioration process might potentially contribute to the obstruction and reduction of fuel filters lifetime becoming a threat to operational activities. The main factors that help in microbial development are water, temperature and nutrients. Water, in particular, is the factor that has the most impact on microbial development since it naturally enters the fuel supply chain through tanks and transportation systems. Furthermore, microorganisms can also be inserted to the fuel by soil, by air or by polluted wash water and infected pipelines. The kinds of microorganisms that proliferate within fuel systems include bacteria, yeasts and filamentous fungi which can be either aerobes or anaerobes such as sulphate reducing bacteria.

The aim of this study was to investigate the microbiological stability of biodiesel/diesel blends and consequently the impact of microbial proliferation on their quality. A commercially available biodiesel was blended with commercial BS-6 compliant diesel fuels in the ratios of 7, 10 and 20%, v/v. The resultant blends and controls containing only BS-6 diesel and 100% biodiesel were assessed and compared at lab scale over 40-days under accelerated conditions. The simulated test conditions resembled with service station storage, test fuels were kept both with and without the inoculation of microbial consortia from a water drainage tank. During storage the microbiological growth was evaluated by employing both conventional and DNA based methods. At the same time the critical fuel quality parameters, like oxidation stability and acid number which could be influenced by microbial growth were examined. The overall results revealed that sufficient water accumulation at any point of supply chain may leads to microbial growth. Hence, there is a

need to establish a scheduled inspection with radical housekeeping to impede water accumulation from the bottom of the tanks for efficient control and remedy of microbiological growth issues.

Paper ID 309: Performance of a diesel engine using ED fuel

Senthil kumar G, Narayana Reddy J, Pooraja V, Ashok Raaj K, Sathyanandan M, and Krishnan Sadagopan

Ashok Leyland Technical Center, Vellivoyal Chavadi, Chennai, India

Ethanol-diesel blends (or e-diesel) contain up to 15 volume percent ethanol and an additive known as an emulsifier. The fuel mixture is known as a micro-emulsion and is prepared by splash blending, a process that requires no special equipment or temperature control. Ethanol diesel blends have a number of potential advantages including: • Displacement of imported petroleum with a domestic and renewable resource. • Significant lowering of diesel particulate matter emissions. • Possible improvement in cold flow properties imparted by the ethanol. • Possible improvement in fuel lubricity imparted by the emulsifier additives. The main technical barriers to commercializing e-diesel are: • Low flashpoint of this fuel. E-diesel cannot be safely handled like conventional diesel but must be handled like gasoline. This may necessitate some modifications to storage and handling equipment, as well as vehicle fuel systems. Some stakeholders believe that this fact limits the market for e-diesel to centrally refueled fleets, estimated to represent some 5 billion gallons of diesel fuel annually. If the market is limited to fleets, E-diesel represents a potential market for fuel-grade ethanol of several hundred million gallons. • Obtaining OEM warranty acceptance. Currently engine manufacturers will not warrantee their engines for use with e-diesel because of concerns about safety and liability, as well as materials and component compatibility. A large body of test data acquired in close cooperation with the OEM's will be necessary to address this issue. • EPA fuel registration requirements. As a non-baseline diesel fuel, e-diesel will be required to undergo Tier 1 and Tier 2 emission and health effects testing, a time consuming and expensive process. In addition to these major concerns there are issues related to quantifying the stability, water tolerance, and other fuel properties of e-diesel.

In this paper we will be discussing about the trials conducted with ethanol blends (i.e.) ED5, ED10, ED15 on a 6 cylinder Inline BSIII Engine and assessing the performance. For getting better clarity back to back performance assessed using Diesel and ED Blends of fuel. It was observed that clear torque drop seen when ED Blends compared with diesel, however Torque drop to be validated on vehicle level for drivability. Based on this fuel increase is to be decided. Power drop is

to be validated on vehicle level for drivability. Based on this, fuel increase is to be decided. PM is reduced by 10% to 15% with Ethanol blending. NOx is comparable, no significant increase, due to lower cyl. pressure. HC and CO increased marginally, however with in legal limits. BS-III emission limits are met with all fuels. 1. Engine performance with ED10 fuel shows 12% torque drop @1800rpm. 2. No major variation in BS-III emission results with Ethanol blended fuels. 3. Reduction in cylinder combustion pressure, hence no issues on engine parts 4. Torque drop at lower may not affect drivability, higher speed torque drop is comparatively lower, hence no major impact on vehicle application expected.

Technical Session – I-C: Industrial Lubricants

Paper ID 276: Enabling industrial gear oil towards "net zero goal"

Thierry Douchy

Lubrizol India Pvt. Ltd., Turbhe, Navi Mumbai, India

Today's Gearbox industry demands higher power densities which is putting pressure on gearbox geometry, material, and on lubricant (Industrial Gear Oil). Whether it is a paper mill, Cement plant or Steel mill industrial gearbox, one of the major requirements is to run the industrial gear oil cooler to increase lubricant life and operate more efficiently. All these conditions require improved performance for Industrial Gear lubricants.

Industrial Gear Oil performance is key to long-term gearbox reliability; however, the industry truth remains consistent: 'Nothing affects the bottom line like unplanned downtime'. In this article, Lubrizol experts will detail the company's work in the development of additive chemistry that can deliver reliable, energy-efficient Industrial Gear lubricant performance. The article will walk through a range of testing performed that helps demonstrate how a unique combination of chemistries can:

- Reduce operating temperature enabling longer equipment life and enhancing profitability via reduced fuel and energy costs
- Contribute to lubricants as enablers for net zero goal and associated CO_2 emissions, all without compromising on hardware durability.

Paper ID 259: Energy savings are just an oil change away

Thilo Krapfl

Evonik Oil Additives

As climate change is one of today's biggest challenges, energy savings have become a primary target for equipment manufacturers and end users. Life Cycle Assessments (LCA) of energy efficient lubricants compared to currently established fluids quantify the effects an oil change can have on the carbon emissions along the entire life cycle of any machinery. Besides identifying the hotspots in the life cycle, strategies to reduce the Product Carbon Footprint (PCF) of the lubricant itself will be highlighted. The results demonstrate that switching to a high-performance lubricant significantly improves the sustainability performance of stationary and mobile hydraulic equipment, compressors, and industrial gearboxes. Furthermore, a lubricant upgrade is one of the most cost-effective and easiest measures to implement.

Paper ID 220: Power plant lubrication reliability

Anshuman Agrawal

Minimac Systems Pvt. Ltd., Khed Taluka, Maharashtra, India

An interrupted power supply is all that is needed to meet our lifestyle in the growing competitive world, and the same is the goal of any power plant that is to maximize uptime by reducing the failure of the critical equipment involved in power generation like turbines, generators, boiler feed pumps, mills and many more. In a typical thermal power plant, the most challenging areas of lubrication maintenance are the Coal handling plant, Boiler, Turbine, and the Governing system where maintaining the cleanliness level of Lubricating fluid is of utmost priority. Here, the lubricated components like the reservoirs, gearboxes or hydraulic units, servo valves work in a harsh dusty environment and continuously ingress with contamination like water, dust or dirt, chemicals, etc. Reliability of this equipment can be achieved by proper implementation of contamination exclusion practices, oil reconditioning programs, and following standard procedures which prevent the entry of contaminants into the oil & thus to the system. With this technical paper, we attempted to present the challenges associated with lubrication maintenance in a power plant and some important measures to achieve equipment Reliability. Our focus is to minimize downtime and maximize uninterrupted power generation.

Paper ID 329: Troubleshooting compressor lubrication issue at GNFC WNA-II Plant Bharuch: A case study

Rajiv Srivastava, R R Khandpur, Manoj Kumar Sinha, Nitin N Patel

Indian Oil Corp. Ltd. & Gujarat Narmada Valley Fertilizers Chemicals Ltd

The production of nitric acid by the oxidation of ammonia is an important industrial process in fertilizer plant throughout the world. However nitric acid can give rise to serious lubrication problems. Compressors are an important machinery asset in the production of fertilizer and are integral in their ammonia and nitric acid production lines. The tail gas stream from ammonia oxidation plants containing corrosive nitrogen oxides can play havoc with the RPVOT life of the compressor oil once it finds its way into the oil circuit through expander section. This paper presents a case study of troubleshooting a lubrication failure problem faced with a critical compressor application of one of the major fertilizer unit, arresting the frequent shutdowns and ensuing production losses. It further discusses failure mechanisms for the compressor oil and effect on compressor components with reduction of its RPVOT life.

Paper ID 326: Energy efficient refrigeration compressor oils: Enablers for net zero

Saagar Kondaguli

Indian Oil Corp. Ltd.

Most manufacturing facilities, process plants use compressed gas systems for a variety of applications, and keeping these compressors running is critical to keeping the entire plant operation running. Nearly all compressors require a form of lubricant to cool, seal or lubricate internal components. Proper lubrication will ensure that your equipment will continue operating, and the plant will avoid costly downtime and repairs. Proper lubrication also will help compressors run cooler and consume less electrical energy.

It is simple: reduced friction = reduced heat = reduced energy consumption. Compressors in most manufacturing plants consume a majority of the daily power requirements, so at SERVO we are looking for continuous improved product offerings, improve energy efficiency, extend the oil drain intervals, reduce the oil consumption and ultimately add value to our customers by reducing their total cost of ownership.

A) With this objective in mind, IOC R&D has developed a niche synthetic refrigeration SERVOFRIZ SHC 57 compressor oil with friction modifier. The product was offered to one of the leading pharma companies - Aurobindo Pharma in Hyderabad for trials.

With close co-ordination with Customer's Corporate Engg. Energy Audit department, customer has certified below improvements with usage of SERVOFRIZ SHC 57

1. There is an improvement of 4.5% to 13.5% in the energy efficiency.
2. Based on the cost-benefit analysis done there is an average savings of Rs 2 lacs per anum per compressor to Aurobindo Pharma on account of changeover to SERVOFRIZ SHC 57.
3. Also with the usage of the SERVOFRIZ SHC 57 there is 7% reduction in sound level and also 50% reduction in oil consumption.

The oil SERVOFRIZ SHC 57 has demonstrated energy efficiency along with potential of long drain and is differentiated niche product and can be enabler for net zero.

The detailed outcome of the performance monitoring will be presented in the paper.

Technical Session – II-A: Automotive Oils - II

Paper ID 215: Sustainable source based ester amide additives for lubricants

D. Boudreau

Vanderbilt Chemicals, LLC

The trend towards emerging technologies and fill-for-life lubricant requirements increases performance demands on current lubricant additives. Likewise, a conscious trend to reduced reliance on non-renewable sources, limits current technology choices as we push for a sustainable energy future. This work examines two renewable source based additives that provide friction and wear benefit, and in addition, are sulfur and phosphorus free. How these additives can be used to supplement or replace traditional lubricant additives is explored.

Paper ID 251: The performance of low viscosity engine oils with MoDTC under hybrid electric vehicles

Shinji Iino, Koichi Takano, Kenji Yamamoto

Adeka India Pvt. Ltd., Andheri (E), Mumbai, India

Towards achieving net zero, the electrification of vehicles is a global trend. On the other hand, the complete transition to zero-emission vehicles such as BEV faces difficult challenges and is expected to take time. Therefore, Electrified ICE equipped vehicles such as HEV and PHEV which have good fuel economy are expected to play an important role for coming decades. It goes without saying that it is desirable to apply carbon-neutral fuel to HEV and PHEV. However, carbon-neutral fuels still face many problems such as cost before industrial use. From this kind of circumstance, there are high expectations for improved fuel efficiency with low-viscosity fuel economy oil for HEV and PHEV as an early adoptable method. It has already been reported that MoDTC (Molybdenum dithiocarbamate) formulated low-viscosity engine oil shows excellent fuel efficiency in general ICE equipped vehicles. In this study, we estimated how much energy consumption could be saved in HEV using MoDTC formulated low-viscosity engine oil. Testing included standard rig tests, motored engine test and chassis dynamo tests under WLTC. In these tests, MoDTC formulated low-viscosity engine oil showed significantly improved fuel economy performance compared to the latest GF-6 formulation oil.

Paper ID 236: Fuel efficient additive package technology for new generation motorcycle engine oils

Udayashankar Bhat

Infineum India Additive Pvt. Ltd., Bandra East, Mumbai, India

The need for organisations to set and meet sustainability targets is accelerating, and, in the motorcycle world, OEMs worldwide are increasingly looking for lubricants that boost fuel economy without compromising hardware protection or engine performance. In addition, with the rising penetration of electric bikes due to their lower overall cost of ownership, it became critical to reduce that for conventional motorcycles. Fuel remains one of the major contributors to the cost, and by lowering consumption; the cost of ownership can be reduced.

Formulating engine oil for a wet-clutch motorcycle is challenging with distinctive requirements from all components, and on top of that, formulating for fuel economy is grueling. Conventional friction modifiers are of diminutive use as they may have an adverse impact on clutch operation. Ultra-thin engine oils, as used for today's passenger car engine oils, may adversely impact mechanically stressed engine components as well as the integrated gear system in the motorcycle engine. With extremely high operating temperatures as prevalent in motorcycles, this can be appalling. Formulating fuel efficient motorcycle oil requires the careful selection of new generation additive components that protect from excessive wear, maintain utmost cleanliness, and optimised friction without impacting clutch grip and slip. The paper specifies strategies applied while formulating additive package technology and finished lubricant, discusses fuel economy test results, and demonstrates proof of robust durability performance as tested on engine and vehicle levels, even with E27 gasoline in the field test.

Paper ID 205: Evaluation of long term energy efficiency in automotive gear oils using friction modifiers and viscosity modifiers

Sanjay Kumar, Chidambaram CT, David Hall, Botta Sudhakar,
Jencen Mathai Arivannoor, Dr K Navinkiran, Dr Karthika C, V Vidhya

Gulf Oil Lubricants India Ltd., Ennore, Chennai, India

Reducing greenhouse gas emissions for achieving net zero is undoubtedly the prime driver in the design and development of new vehicles. In a vehicle, this is enabled not just by improving combustion efficiency in an engine and using low friction components, but also by using the appropriate lubricants across all components in the vehicle, such as the engine, transmission, and axles. An energy efficient automotive gear oil for axles can be developed by the addition of friction modifiers to reduce boundary friction between the components and by reducing viscosity to improve hydrodynamic friction to reduce viscous drag. However, it is necessary that the capability to reduce friction is retained during the entire life of the lubricant.

This study evaluates the retention of friction reduction capability of the automotive gear oils over a period of time in the field during usage. Various formulations of different viscosity grades, with and without friction modifiers and viscosity modifiers, were aged in a modified oxidation bench test. The formulations, fresh and aged, were then evaluated in two tribological tests in SRV linear reciprocating tester.

The first test evaluated the oil's ability to reduce friction in a low-load reciprocating test. The second test evaluated the oil's load carrying capacity, using a method designed to simulate the FZG-L42 failure load stage. In our earlier study conducted with engine oils, it has been observed that formulations containing soluble molybdenum friction modifiers, after ageing, have experienced deterioration in performance, while the performance of aged oils containing organic friction modifiers showed slight improvement. The results correlated well with field aged oils.

The present study deals with similar study performed with multi-grade automotive gear oils containing viscosity modifiers and friction modifiers. The study concludes the need for careful selection of additives to ensure that the energy efficient automotive gear oil formulations provide long-term fuel efficiency benefits.

Paper ID 221: Effect of compatibiliser chemistry on performance of synthetic industrial and automotive gear oils

Amitabh Kumar Jain, Abhijit Ajitkumar Sarkar, Ashish Khanna,
Shakti Prasad Mishra, Tarun Sharma

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Oil is the life blood of an equipment and just like the blood in our bodies, it is required to fulfill a number of functions. Oil does not only lubricate, it also carries away heat, dissolves contaminants, carries away debris and provides a working medium. All oils, whether mineral or synthetic, have additives mixed into composition and the chemical and/ or package fortifies the base oil to do its job. The majority of finished lubricants thus all consist of a base oil (or a mixture of different base oils) and an additive package. When referred to the oil being either mineral or synthetic, it is its base oil component. Current trend of highly refined base oils such as severely hydro-treated base oils like Group III, GTL base stocks and PAO, are often regarded as “dry” base oils because they only contain fully saturated non-polar hydrocarbon molecules. The greater the degree of hydro-treatment or dryness, the lower is the solubility of additives and chemicals. Low solubility not only makes it difficult to dissolve some essential additives, but it also compromises some essential quality parameters, such as dispersancy, lubricity, and seal compatibility etc. To derive the benefits of performance enhancing additives and chemicals, use of various compatibilisers is made with dry base oils. Polyol esters, Poly alkylene glycols and alkylated naphthalenes are preferred compatibilisers. The performance of lubricants is greatly affected by the chemistry of compatibilisers.

Improvement in solvency with blend of alkyl aromatics comes at a price of a loss in viscosity index, Blend with synthetic esters downgrade hydrolytic stability. Saturated branched-chain fatty esters themselves often lack lubricity. Even more dangerous is that some linear-chain esters passivate the surface against reaction with extreme pressure (EP) additives, undermining anti-wear protection at high loads. Blend with ionised vegetable oils and oil soluble Poly alkylene glycols offer unique properties, inheriting their positive features such as high lubricity, anti-wear efficiency, and at the same time adding oxidation stability, rust protection and anti-sludge capability.

The laboratory tests on oxidation stability, EP and anti wear properties, sludging tendency, dispersancy, lubricity led us to believe that compatibilisers improvers help formulators address certain challenges brought by a changeover to “dry” base stocks, but their use requires some experience and understanding of chemical differences. For instance, the antioxidant response of ester-based compatibiliser is different from that of hydrocarbon bases, and therefore, the

antioxidant package may need to be redesigned accordingly. Phosphites and some conjugated dual antioxidant systems, such as disulfide based rather than aminic and phenolic antioxidants, popular for hydrocarbon bases. Similarly conventional anti-wear and extreme pressure additives, such as phosphorus and sulfur based which act when a direct asperity-asperity contact occurs in the boundary lubrication regime in conventional lubricants, compaibilisers helped postponing the beginning of the boundary lubrication regime leading to reduced friction in certain cases.

The paper provides details of studies carried out on impact on various performance parameters using compatibilisers in various gear oils used for industrial and automotive applications. This study helped in choosing right chemistries of additives and compatibilisers for given application.

Technical Session – II-B: Fuel Testing & Additives

Paper ID 256: Dorf Ketal performance fuel additives – Novel fuel additives technology for sustainability

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Sustainability is becoming a key driver for innovation in the 21st century. Climate change is happening now and continues to be directly attributed to increased emissions and greenhouse gases. Extensive attention is given to excessive carbon dioxide (CO2) emissions due to fossil fuels combustion. Following the 2015 Paris agreement, 195 countries agreed to limit global temperature rise to 2°C by the end of the century and continue efforts to reduce it further to 1.5°C. To support this global effort, Dorf Ketal has developed novel additive technology that improves the combustion of liquid fuels used in internal combustion engines. This results in improved vehicle acceleration, power output and reduced engine out emissions for a given volume of fuel consumed. The reduction in fuel consumption directly contributes to global efforts to reduce carbonization including CO_2. This paper provides an overview of the data developed to date and the potential impact should the technology be deployed in a timely and appropriate manner.

Paper ID 305: Fuel oil emulsion - transition fuel - low investment high performance

Dean Mihalic / Hemant Sondhi

Fowe Eco Solutions Ltd.

The Cavitech heads are capable of producing FOWE fuel emulsions at almost any water concentration, but generally the favoured range for useful fuels is 10-30% water content. The emulsion produced is extremely well mixed and does not require additives to keep it stabilized. It can be fired in standard fuel oil burners without alterations and produces a cleaner burn with lower emissions of NOx and other pollutants. The micrographs below show processed fuel oil with 10 and 20% water content.

Paper ID 217: Going green thanks to hydrogen fuel. Generation of trace level calibration gases that are essential for the calibration and certification of the H2 purity analysers

Laurent COURTHAUDON

AlyTech, France.

The clean energy market is currently growing very rapidly to meet the global warming gas emission reduction. Hydrogen Fuel and Biogas are probably the key players to meet this challenge. Depending on their production and purification processes, these gases may contain different types of impurities, at varying levels. For hydrogen fuel, for instance, impurities will limit the efficiency of the fuel cells, reduce their lifetime, and will eventually turn into polluting agents. For biogases, it is important to accurately measure the energy properties of the product before it is injected on the distribution network. That directly influences the price of the product. Impurities are also monitored in biogases, at very low levels sometimes. For both products, the challenge is to decide on analytical methods. They are often GC (Gas Chromatography) methods associated with preconcentration processes (Thermo Desorption) and dedicated detectors: Mass Spectrometry, SCD, PFPD, PHID, plasma detectors, laser spectrometers, etc. One parameter is common to all these technologies: They allow detection of low concentrations, even traces, but they require calibration. Multi-level, especially trace concentrations of gases are not commercially available. And, if they are, their stability and precision may be very poor. Generating on site, multi-level, multi analyte, low level calibration gases is a challenge. But making these gases available is extremely valuable for the lab analyst. The presentation will describe the preparation of different types of gases, dynamically and automatically, with certified concentrations and guaranteed uncertainties. The starting materials will be pure gases, concentrated gases with multi analytes and organic and aqueous solutions. The typical examples to be described are: VOC and Btex in air, Siloxane compounds in biogas, organic impurities in hydrogen, with and without presence of water (humidity) as water may create a bias on a TCD response, etc. Hardware and software will be described, including the quality and traceability features

Paper ID 261: Nitrogen interference in sulphur analysis of fuel and solution for true sulphur analysis in fuel

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Nitrogen respond partially to the excitation of UV and gets detected along with Sulphurin the UV Fluorescence technique (ASTM D5453). Normally Nitrogen in fuels are not in the levels where they can interference (less than fifty ppm). Adding boosters (Cetane/ Octane) to the fuel increases the Nitrogen levels and they interfere with Sulphur Analysis. This will create situations where different Sulphur analysers will give different sulphur results. Due to this false positive sulphur result, many batches of fuel may fail in sulphur levels complying with Bharat VI specifications, while actually the sulphur levels are less than ten ppm only. This study establishes such interference in various levels of Nitrogen in fuel and provides solution on how sulphur analysis can be made without any Nitrogen interference without any modification in the instrument, any bias compensation and in full compliance with the latest ASTM D5453.

Paper ID 210: State-of-the-art methodology for determination of trace level of elemental sulfur in aviation fuel by polarograph

Y S Jhala, Mamta Kumari, Jayant Dutta, Pushpak Shah, M Elamaran, Utpal Deka, Hitesh Shah

Indian Oil Corp. Ltd., Panipat Refinery, Panipat.

Aviation is powered by petroleum fuels. This is based on petroleum's recognized advantages. Liquid fuels have higher energy contents per unit volume than gases, and are easier to handle and distribute than solids. Among liquids, liquid hydrocarbons offer the best combination of energy content, availability, and price. Since the primary function of aviation turbine fuel (jet fuel) is to power an aircraft, energy content and combustion quality are key fuel performance properties. Other significant performance properties are stability, lubricity, fluidity, volatility, non-corrosivity, and cleanliness. Besides providing a source of energy, fuel is also used as a hydraulic fluid in engine control systems and as a coolant for certain fuel system components. The corrosion in the fuel system of aeroengines has been invariably attributed to some undesirable sulfur compounds present in aviation turbine fuels (ATF's). The corrosiveness of the fuel is measured by a combination of copper strip and silver strip corrosion tests. Hydrogen sulphide and elemental sulphur were found to be corrosive to copper.

Paper ID 267: Development of differentiated fuels: Role of analytical techniques for quick and simultaneous measurement of multiple qualitative and quantitative parameters

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Differentiated fuels, such as XP-95, XP-100, E20 gasoline, Xtragreen diesel, sustainable aviation fuel (SAF) are considered more premium and desirable fuels as they have better resistance to knocking, better combustibility and are of greener in nature. Many techniques are being routinely used to determine various parameters during development of these differentiated fuels and also to provide solution to troubleshooting. For example, estimation of various parameters, like % of oxygenates, octane booster, hydrogen content as well as hydrocarbon types, such and aromatics, olefins are imperative for the formulate on XP-100 gasoline. Among differentiated fuels E20 gasoline, i.e., 20% (v/v) of ethanol has been the target set by GoI to achieve sustainability in automotive fuel segment. Addition of 20% ethanol in gasoline has two major drawbacks affecting engine performance. One being the decrease in fuel efficiency as ethanol has less calorific value compared to gasoline and other being the fuel becomes more hygroscopic leading to corrosion problems. To address the first one, loss of fuel efficiency, technologists are trying to enhance the combustion \ efficacy by cavitations in E20 gasoline. Cavitation is the formation, growth, and collapse of bubbles filled with gas, vapor, or their mixture under certain operating condition. Study the formation of cavitations, a multicomponent process, by conventional analytical techniques is challenging as the changes are mostly physical and meta-stable in nature. Advance translational diffusion behavior of molecules can be studied by PFGSE diffusion NMR. The use of DOSY NMR can reveal the nature of hydrodynamic cavitation. In the present investigation E20 samples before and after cavitation have been studied by 1H NMR and 1H-DOSY NMR along with other analytical techniques, such as IR, CHNS etc. Results of this study will be presented.

Technical Session – II-C: Circular Economy

Paper ID 297: Condition monitoring of regenerated lubricating oil of critical plant equipment

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An integrated steel plant normally uses around 10 lakh litres of different types of lubricating oil annually in equipment installed across the plant. Expenditure on lubricating oil contributes a huge amount of operating cost of plant. Thus, regeneration of used oils in steel plants plays important role in reducing the consumption of lubricating oil, reduction in plant operation cost and protect the environment from pollutant. Regenerated lubricating oil is also used in the auxiliary units as well as some critical areas of one of the SAIL plant. The earlier regeneration process mainly involves dehydration and elimination of contaminants from the used lubricating oils. However, the physico-chemical properties were not evaluated before reusing the regenerated oil. This adversely affects the performance of equipment leading to reduced performance and sometime also resulting in equipment breakdown. In view of this, process improvement in regeneration process was done after analysing the physico-chemical conditions of regenerated lubricating oil. Physico-chemical properties evaluation include measurement of viscosity, elemental analysis, moisture content, wear debris & measurement of total acid (TAN) content of regenerated lubricating oils. Presence of moisture in the regenerated oils was measured using Oil View analysis. Moisture in used oil varies between 10 to 115 ppm and was within the acceptable limit. TAN results of regenerated oil samples indicated minimal deterioration of lubricants. Viscosity analysis of used oil sample indicated increase in the viscosity due to presence of wear debris and other contaminations. Elemental analysis results of regenerated oil also revealed the presences of sufficient concentration of wear metals and contaminants. This was due to the excessive oil pressure during filtration in the filter press. Duplex Ferrograph analysis indicated the presence of sufficient wear metals (DL<5µm &DS>5 µm) in the oil samples. Corrective measures were taken in filtration system to improve the quality of used lubricating oil. The concentration of wear debris was reduced by adjusting inlet oil pressure, use of proper membrane filters and use of contamination free cloth filters. After the improvement in filtration system and regular evaluation of physico-chemical properties, regenerated oils are used in the suitable auxiliary and some of the critical area also. The improved system and regular analysis have led to improved equipment availability and reduced breakdown. This has also helped in optimizing the use of costly lubricating oil and reduced environmental pollution.

Paper ID 247: A unique approach for quality monitoring of petroleum products at customer's doorstep through quality on wheels - mobile lab

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World class quality product of Fuel and Lubricants always produces high caliber performance of the instrument, vehicle, machinery, and the good lifetime as well. Moreover, application of best quality products in the energy sector establishes a constructive socio-economic development. Consequently, it synchronizes with the customer's trust and delight. This necessitated the importance of monitoring the performance and quality condition of the products at customer site besides at production or storage sites. Quality monitoring of the products supplied to customer is as vital as ensuring perpetually the right quality product is delivered. This instrumental concept had originated out as an innovative & unique initiative in BPCL organization well established as "Pure-For-Sure (PFS)". With the change in customer behaviour and to achieve highest level of customer satisfaction, it has been realized that ensuring the quality of product through testing at customer's doorstep is one of the advanced marketing strategies and synergistic beneficial to the customer as well to the organization.

BPCL is pioneer to adopt this strategy which is First of It's Kind in Indian energy sector. BPCL Marketing Quality Assurance (BPCL-QA) department by virtue of its presence in PAN India through network of mobile labs has been fulfilling the goals and the intended objectives of this drive by employing 19 mobile labs covering the business units at Retail, Lubes, and Industry customers for determining the quality of products through onsite testing using state-of-the-art facility in Quality on Wheels. This initiative in Indian petroleum sector provides not only great opportunities to ensure the quality of products at customer site but also addresses the issues faced by the customer w.r.t. fuels, lubricants & other specialty products.

The quality on wheels vehicles with modern aesthetics are equipped with various sophisticated instruments and enabled to perform onsite testing. Retail outlets (RO) of Fuels are the end points of delivery chain. Ensuring the best quality of fuels at the customer's fuel tank is judgmental to fulfill the objectives of future environmental goal i.e. net zero. On this banks, BPCL-QA employed mobile labs to ascertain the quality at ROs across country with a significant coverage target every month by using artificial intelligence and machine learning through route prioritization. These innovative services are extended to industrial customer of fuels and lubricants. The lab visits lubricant customer sites to assess the performance and quality strength of various lubricants

supplied by BPCL. Based on the quality condition of lube oils, the technical inputs are provided like remaining life, prediction in oil change period, reuse of used oils etc. Post testing quality certificates are generated online using digital platform of LIMS with various trend analysis.

This illustrious initiative has been emerging and creating difference in the market to serve the country with better quality products and re-ascertain it. Consequently, BPCL-QA is forerunner in contributing its part towards the sustainable objectives while addressing the global environmental issues.

Paper ID 278: Additive Company's contribution towards circular economy achieving net zero

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The circular economy is a sustainable development strategy that is being proposed to tackle environmental degradation, by re-using and re-cycling products multiple times thereby reducing greenhouse gas emissions, country import bills, and resource scarcity. The world is increasingly becoming conscious of the transformation around the Industrial ecosystem, sustainable production/ consumption & life cycle analysis of products which have been an integral part of the Circular economy

LZ paper presents current practices that have been introduced and deliberates the assessment of the circular economy for an automotive world that is focused on Re Refined Base Oil. This presentation would touch upon the analysis and classification of RRBO. A view on the global practices, ongoing key developments, and challenges in adapting RRBO as part of the modern formulations is presented.

Paper ID 246: Circular economy in used oil waste – REVIVOIL

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In Today's time of transition, the lube industry, committed to carbon-neutral growth, is exploring different pathways to substitute current lube oil with recycled lube oil.

Globally, the massive consumption of oil after extraction from the earth, processing, manufacturing, transportation and disposal contributes substantially to release of greenhouse gases into the atmosphere thereby increasing pollution.
To mitigate this concern, concept of Circular Economy in used oil has gained momentum in past two decades, wherein we not only use the re-refined oil, obtained from used oil for manufacture of lubricants, but also conserve the precious petroleum reserves for safer and healthier tomorrow. This is where Revivoil™, which is the patented technology for re-refining used oil can play a key role.

Very briefly, the technology could be represented with 2 steps:

- Pre-Flash and TDA section dedicated to remove major contaminants. This step maximizes the reliability and the robustness of the technology.
- HDF Section dedicated to:
    - The removal of metals, sulfur, nitrogen, CCR,
    - The restoration of UV, color and thermal stability,
    - The reduction of polynuclear aromatics.

Paper ID 317: Circular economy in lubricating oils

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Lubricants or Lube oils are mainly used to reduce friction between moving parts and reduce wear in automobile engines and various types of machinery. These are composed of one or more base oils and additives. During use, most of the lubricating oils are not consumed but the additives are degraded and need to be replaced. This process generates used lube oils. The best way to dispose-off used lube oils is to recover the parent base oil from it by a suitable environmentally friendly process and reuse it for formulating a new Lubricant.

Use of waste oil is beneficial for environment as it can be cost effective, helps in saving energy and natural resource conservation. Based on consumption patterns and the estimated recyclability of used oil for different applications, it has been estimated that India generates about 1.4 MMT of used oils per annum.

As a part of sustainability initiative in Indian Oil, lube oil formulations blended with 25% re-refined base oils for heavy duty diesel vehicles, petrol driven passenger cars/ SUVs, four stroke two wheelers and tractors have been developed and launched in the market. These grades were introduced in the market with potential to reduce up to 12% of carbon dioxide emissions in the ecosystem.

This paper explains the used oil scenario in India, issues at hand and ways by which recycling of used oils can be done for achieving circular economy in the country. It also elucidates the way forward for all stakeholders, be it re-refiners, Auto OEMs, Industries, Lubricant manufacturers, Municipalities/ local bodies and pollution control board in improving re-refining technology, promoting use of re-refined base oil in formulations, proper disposal and collection of used oil etc. Lowering of taxation on used oil and re-refined base oil will also help the cause of achieving a circular economy.

Technical Session – III-A: NGEOs & Fluids

Paper ID 238: Lubricant development for natural gas (NG) engines

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In a world looking out to move to a net zero society, alternate and low carbon fuels play a pivotal role in the transition. Many alternate fuels are commercially available and new ones are getting introduced to the market at a rapid pace. Crude derived natural gas (NG) fuels achieved a good footing throughout the world for internal combustion engines. The different properties, burning characteristics, and emission profile of these fuels puts different demands on the engine and hence on the engine oil. The lubricants development needs to keep pace with the evolving requirements of these alternate fuels and are also expected to match the performance of the lubricants used for conventional fuels such as Diesel and Gasoline.

There are no industry-wide specifications that provide design standards or guiding principles for natural gas engine oils in mobile applications. The adoption in the area tends to be based on ongoing development of engines technology deploying available lubricant technologies. Established developments in some parts of the world are not necessarily plug and play solutions due to different operating conditions and engine designs. This means the products must go through extra validation at equipment level requiring additional investment and time.

This paper discusses the use of natural gas in mobile heavy-duty application. It discusses a framework for design and testing of such lubricants. It also provides an insight on the impact of NG on lubricant performance in service with focus on issues such as TBN/TAN, oxidation/nitration, and wear performance commonly faced by NG lubricants. The paper also discusses as to how the lubricant performance can be improved for longer service life.

Challenges, such as infrastructure, engine technology evolution, costs etc., faced in the adoption and proliferation of NG as a fuel for the mass market are also the challenges that newer fuels face. Lubricant development for NG and low carbon fuels needs a ground up approach.

Paper ID 281: Dedicated mobile gas engine oil chemistries enabling long drain for CNG commercial vehicles

Sreehari Kumar

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"India market is a cost-sensitive market, BS VI implication and increasing fuel costs continue to be a worry for end users. To alleviate these concerns, there is increased emphasis by OEM/Oil Marketeers to lower Total Cost of Ownership (TCO) by using different levers across products, services & others.

Natural Gas for commercial vehicles becomes an attractive choice for end users from a TCO perspective but also makes up for being a cleaner fuel contributing towards lower emissions & green environment. From a hardware perspective, BS VI platforms have increased thermal load & stress on the engine which demands higher performance from its aggregates which includes engine oil.

Paper ID 506: Liquefied Natural Gas: Solution towards decarbonising long haul fleets in India

Sauhard Singh

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Global energy supply chain is facing the twin challenge of Energy Security and Energy Sustainability. Gaseous fuel i.e. Natural Gas, HCNG and Hydrogen are considered immediate to ultimate solution to this twin problem. India is also considering gaseous fuel as solution and moving towards the gas based economy and having ambitious target to increase the gas energy share from existing 3% to 15% by 2030. Natural gas having methane as main constituent is cleanest hydrocarbon gaseous fuel and considered short term to midterm solution and hydrogen is considered to be the ultimate solution of energy requirement. In India, usage of natural gas in compressed form i.e. Compressed Natural Gas (CNG) is limited to metropolitan cities like Delhi, Mumbai, Bangalore etc. due to limitation of CNG storage and dispensing infrastructure along with low energy density storage. With wide geographical extension approx 3,000 KM east to West and North to South, CNG is not viable. High energy density liquid form of natural gas storage i.e. Liquefied Natural Gas (LNG) can overcome these difficulties and promising in near future. In this line, present work highlight the need for development of efficient fuel storage system, fuel supply

system, engine optimization & calibration, engine lubricant etc. suitable for implementation of LNG for automotive application and describes the framework of LNG engine testing facility, development of dedicated lubricant and performance of the engine and vehicle for LNG application.

LNG engine testing methodology was developed during the LNG internal combustion engine testing at BS-VI complied transient Engine Test Bench. It was planned to transfer LNG from large LNG tanker to trolley mounted LNG tank and then utilize that small tank for engine testing due to safety concern associated to direct connection of large LNG tanker to test bench. Hence, state of the art small & portable cryogenic LNG tank (450 Lit WC) comprised of vacuum and super insulated layered configuration manufactured as per ISO 21029-1 and type tested according to ISO-12991 was designed and utilized. Petroleum and Explosives Safety Organization (PESO) approved LNG dispensing facility was developed. BS VI complied LNG engine testing facility was developed and forced convection heat transfer methodology applied for avoiding icing at RLNG fuel line. BS-VI complied CNG fueled heavy duty engine was optimized for LNG fuel. Optimised LNG fueled engine was subjected to performance and emission testing as per World Harmonized Transient Cycle (WHTC) and it has been observed that LNG shows reduction of CO, THC and CH4 emissions and slight increase in NOx emissions compared to CNG.

Dedicated Engine oil was developed for LNG fuelled HD Engine. LNG engine endurance test cycle was developed to replicate the actual vehicle road operation characteristics at engine test bench. 1500 hrs endurance test was undertaken to validate the technology and to establish the drain interval period of engine oil. Engine performance was satisfactory and consistent during endurance test and used engine oil sample properties. i.e. kinematic viscosity(KV) @ 40°C, KV@100oC, Total Base Number (TBN), Total Acid Number (TAN), Oxidation, Nitration and wear elements i.e. Iron (Fe), Copper (Cu), Aluminium (Al), Lead (Pb) etc. were well within the permissible limit. As a solution towards long haul fleets in India, field trial was conducted in 2 numbers of LNG fuelled buses for 30,000 km with developed engine oil was undertaken on actual route. Buses performance and used engine oil shows excellent performance on LNG fuel during field trials.

Paper ID 232: Promoting clean cooking fuels in India one step towards net zero

Aniruddha Kulkarni, Satish Dayal Yadav, Renny A. M.

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Food is one of the primary requirements for the survival of human beings and we need the energy to cook food. The energy can be obtained from various sources which are known as fuels. Different fuels used for cooking in India, from traditional to modern, are studied in this paper. There is a tremendous demand for fossil fuels; at the same time, these are depleting at a tremendous rate. To overcome the issues related to depletion of foreign exchange and environment sustainability, we need to find alternate fuels for clean cooking in India To understand India's import dependency for cooking fuels, data is collected for the production and import of various fuels in India With the help of analytical tools, data is analysed and presented. Also, the current use of different fuels and the clean cooking status of India is studied. In this paper, we have calculated the cost of producing food from various fuels – wood, LPG, PNG, hydrogen, electricity, ethanol & methanol, and the data is analysed. The efficiency of the burner plays a vital role in determining the cost. Indoor air pollution is also an important challenge for developing countries as many women and children are exposed to it due to the use of traditional fuels emitting many pollutants. So, to analyse this, data for CO2 emissions to cook food is also presented for the fuels. The results show the requirement to move towards modern fuels such as electricity, hydrogen, ethanol, methanol etc. which will promote clean cooking in India

Technical Session – III-B: Bio-Technology

Paper ID 245: All roads leading to biorefinery – A step further towards sustainable mobility and future

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Many leading analysts have forecasted that due to net zero commitment by 2050, world's energy transition will soon result in a peak in the use of fossil oil-based fuels followed by a decline. The transportation sector is at the forefront of this trend, with total global demand expected to peak in the next coming years and then begin a gradual decline. In contrast, demand for petrochemical feedstock will continue to grow.

It is believed worldwide that a single solution will not be able to substitute the current fossil fuel based energy structure and rather the future demands for energy can be met by overlap of number of technology pathways depending upon availabilities of different feedstock in different geographies. Forward-looking refiners are already looking for opportunities to adjust or modify their production modes to capture growing demand for biofuels and petrochemicals by, for example, by capturing carbon and converting that into fuels or by volarizing Biomass into Ethanol and eventually into SAF or building blocks of other petrochemicals. This means the world's refiners must fundamentally rethink how refineries are designed and operated. Given the present situation, the emerging options available to refineries in terms of technology could be Lipid and biomass conversion pathways or pathways including volarization of ethanol.

Out of these today we will focus on efuels and volarization of ethanol and these pathways are as follows:

1. efuels: eFuels are produced with the help of electricity from water to produce H2 and CO/CO2 is captured from flue gases by Axens DMX process to produce Renewable Diesel/SAF/Naphtha via Axens Fischer Tropsch process "GASEL".
2. Volarization of ethanol: This route is based on the conversion of biomass into 2G Ethanol or already available 1G Ethanol into bioethylene via ATOL process or Bio butterfly viz Biobutterfly process or even production of SAF via ATJ route.

Paper ID 260: Carbon recycling: An innovative path towards aviation decarbonization

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The rising urgency to lower carbon emissions has a new objective: “Net Zero Emissions”. This in turn requires treating Climate Change as a true crisis, in our fossil fuel reliant world, and accelerating the implementation of all new approaches to support the transition away from virgin fossil carbon. When it comes to decarbonizing road transport and power, we see today renewable, carbon-free, solutions taking the lead. However, for hard to decarbonize sectors like aviation that require energy-dense liquid fuels, we will continue to need carbon, but it must be sustainably sourced. To source sustainable carbon at scale, nations must deploy all possible technology solutions. Innovation and Industrial biotechnology hold the key, with a variety of new approaches being commercialized to replace fresh fossil carbon in aviation as well as in all the things we use in our daily lives.

LanzaTech, a carbon capture & transformation company, offers a means to transform waste carbon (from agri-residue, municipal wastes, industrial point sources, and CO2) into sustainable fuel ethanol, which in turn is a platform for manufacturing other fuels, chemicals, and materials, creating a circular carbon economy. LanzaTech’s waste-based ethanol serves as a feedstock for sustainable aviation fuel (SAF) through the LanzaJet™ Alcohol-to-Jet (ATJ) pathway, displacing fossil jet and offering a route to decarbonize aviation.

To accomplish its energy, economic and climate objectives, India must lead in adoption of innovative pathways like these to create a multilevel impact across rural and urban economies, as well as manufacturing and to build an indigenous SAF industry. This presentation will describe LanzaTech’s journey to harnessing waste-based ethanol to make SAF and chemical-building blocks, providing a path for India to align economic growth and national prosperity with environmental justice in a positively reinforcing cycle.

Paper ID 268: Bioconversion of CO_2 to transportation fuels

Prakash C. Sahoo, Manoj Kumar, R.P. Gupta, D. Bhattacharyya, SSV Ramakumar

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Recycling of CO_2 into fuel precursors is an attractive option to address the global warming and the energy crisis without impeding development and urbanization. Conversion of CO_2 is scientifically a challenging task, but it has significant benefits. Various methods such as photoelectrochemical, photocatalysis, electrocatalysis, thermocatalysis, and radiolysis, techniques have previously been utilized for CO_2 conversion and each methods has their own advantages and challenges.

Recently, bio-based production of fuels has been attracting increasing interest due to its low energy and sustainable nature. Hydrocarbon, in particular alkanes would be an ideal substitutes for the currently used fossil fuels, because they can drop in directly in the current infrastructure and engines and have high-energy density and low hygroscopicity. Currently, most of the microbial alkane production studies have focused on alkane production from biomass derived sugars. In contrast, CO_2 could serve as sustainable carbon source for large-scale production of alkanes. Further, microbial CO_2 conversion has several limitations such as low product yields and high residence time.

Herein, we have developed new platform microbial strains and synergistically manipulated the genetic material by a plasmonic nanoparticle. The plasmonic nanoparticles modified strain capable of producing a mixture of C_4–C_{12} short-chain hydrocarbons using CO_2 as carbon source. This was possible by manipulating the metabolic pathways by genetic engineering and sensitizing the redox cofactors by plasmonic nanoparticles. The current research will serve as a stepping stone for establishing bioprocesses for direct conversion of CO_2 to transportation fuels.

Paper ID 501: Integrated biorefineries for sustainable fuels and chemicals

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Climate change issues, inadequate resource utilization, unsustainable consumption of materials and waste generation are prompting a gradual shift from a fossil-based linear economy to a circular economy. The cradle-to-cradle approach offers a sustainable and green platform to utilize waste as a resource to produce bio-based products analogous to the petro-based refinery enabling decarbonizing in the supply chain of each energy carrier. Waste-fed bio-refineries impressively advocate for a sustainable circular bio/economy, which assists in carbon neutrality by reducing process emissions and significantly addressing global concerns.

The scope of implementing ‘circular loops’ that strategically direct the flow of resources, their use, extracting value in the form of nutrients, energy and materials post-consumption within the system is essential. Waste-fed biorefineries can also enable the concepts of chemurgy and semi-synthesis wherein the former focuses on waste as a resource for industrial products while the latter predominantly uses raw material isolated from the natural products as a precursor for any chemical synthesis.

Additionally, with the concept of circular economy, thermochemical/ biochemical/ electrochemical routes can be integrated with each other for more efficient/enhanced product profiles. Thus, waste-fed biorefineries can provide low-carbon and renewable energy/materials addressing the green economy, decarbonization and climate sustainability in a unified approach.

Paper ID 507: Pilot-scale production of biodegradable plastics through fermentation technology

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Polyhydroxyalkanoates (PHAs) are accumulated as a water-insoluble intracellular energy storage granules synthesized by a wide variety of bacteria through fermentation technology. Due to their biocompatibility and biodegradability, PHAs have attracted extensive interest in a wide range of applications in different industrial sectors such as packaging, tissue engineering, drug delivery, energy, and agriculture.

PHAs are divided into two major groups, i.e., the short-chain-length (C3-C5) PHAs (scl-PHA) and the medium-chain-length (C6-C14) PHAs (mcl-PHA). The type of PHAs produced depends on the bacterial strains, carbon sources, and culture conditions.

In the present study, a high cell density fermentation process was developed to produce mcl-PHAs using Pseudomonas bacteria. A bacterium was incubated with glucose and fatty acids as carbon source. The rate of glucose feeding was varied by increasing amounts, followed by constant feeding. Initially experiments were performed in 0.5L Erlenmeyer flasks, and then in 1L bioreactors. After optimizing all the conditions, process scale-up was done in 40L mobile pilot plant. The effect of phosphorous concentration on mcl-PHAs production was evaluated. We also examined the properties of the mcl-PHA polymer accumulated during this bioprocess.

After optimizing all the fermentation conditions, our study produced higher amounts of mcl-PHAs, and it can be commercialized in the near future with minor modifications.

Technical Session – III-C: Metal Working Oils

Paper ID 212: Advantages of using sulfur based EP additives in metalworking Fluids

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Sulfurized natural or synthetic esters or olefins, also called sulfur carriers, are today the most commonly used EP additives in metalworking applications. Due to their broad variety in sulfur content, molecular size, reactivity and polarity they can be versatilely used to reduce friction and to prevent adhesive and abrasive wear in boundary and mixed lubrication.

Compared to other additive classes, sulfur based EP additives offer an often higher EP-performance even at elevated machining speeds and temperatures. Furthermore, the frictional forces in certain metalworking processes are more than 25% lower by using suitable sulfur carriers, which also leads to a reduced energy consumption of the manufacturing equipment. Several sulfur carriers additionally provide high lubricity and film strength due to polar groups in their molecular structure. They are non-bioaccumulating and non-toxic to human health and to the ecosystem. Some of them are even suitable for the formulation of environmentally acceptable lubricants.

The presentation will explain how the molecular structures of EP additives influence their properties and how they prevent adhesive wear by forming protective layers on metal surfaces. It will show how sulfur carriers can reduce the environmental footprint of metalworking fluids while maintaining or even enhancing their performance. It will also indicate how they can support the metalworking industry on their way to a more sustainable future by increasing tool life and reducing energy need in manufacturing processes.

Test results from tribological laboratory tests and also from field tests on machine tools will demonstrate how sulfur carriers outperform other additives like chlorinated paraffins in different metalworking processes and how they can be synergistically combined with other additives to fulfill the requirements of heavy duty machining processes.

Paper ID 206: Experimental studies on stability and tribological performance of renewable resource based water-extendable metalworking fluids

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Water-extendable metalworking fluids (MWFs) based on mineral oils are widely used as lubricants for machining operations to maintain work piece quality, reduce tool wear, and increase process productivity, but they have sustainability issues like environmental and occupational health consequences. Furthermore, as legislative rules tighten and societal awareness grows, industries are under pressure to reduce their use of mineral oil-based MWFs. As an alternative to conventional mineral oil based MWFs, sustainable MWFs can be made utilizing renewable resources like vegetable oils. Therefore, in this study, Turbiscan and Tapping Torque Tester were used to assess the stability and lubricity of products based on vegetable oils and compared with mineral oils based water-extendable MWFs. In our investigation, oil in water emulsions of vegetable and mineral oils with different water hardness levels were prepared at different concentrations and their stabilities were analyzed at different temperatures by measuring the global turbiscan stability index (TSI) values by using Static Multiple Light Scattering (SMLS) technique. Further, the study was extended to evaluate the lubricity of the formulations by using Tapping Torque Tester. The comparative results are discussed in this article.

Paper ID 203: Rapid screening of rust preventive performance of lubricant

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Rust prevention is an essential property for lubricants wherein contact with water is anticipated in the application/field. Performance of lubricant is strongly influenced by the environment of the field, oil chemistry, water chemistry, etc. The governing specifications are firmed up accordingly to simulate field conditions in laboratory and develop lubricant meeting the performance requirements. The evaluation of rust preventive properties of lubricant containing rust inhibitors is usually based on rust preventing characteristics bath, humidity cabinet test, salt spray test and numerous OEM/user defined test methods. These tests are of long duration and consume time and resources, often extending the development cycle of lubricant. These long duration tests evaluate film formation and wettability capability of lubricant formulation which acts as a barrier to

prevent attack of water on metal surface thus preventing rust formation. In the present work an attempt has been made to evaluate and analyse the surface-active properties of commercially available rust preventives by measuring changes in the oil-water interfacial tension and contact angles. The study enabled association of surface-active properties with the outcome of long duration laboratory tests, allowing rapid screening of rust preventive characteristics of a lubricant formulation.

Paper ID 318: Sustainable, biobased Metal Working Fluids (MWFs)

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The increased concerns for climate change and environmental protection have resulted in minimizing the use of mineral oil-based lubricants and developing new environment-friendly biobased lubricants. The mineral oil-based lubricants have proved to be polluting the environment and disrupting marine ecosystems and terrestrials. As a result, globally, the trust is to use environmentally benign lubricants. The new challenge provides an opportunity to identify suitable new materials that can replace petroleum-based lubricants.

The present study focuses on the synthesis of ester-based bio lubricant from byproducts. The lubricant is produced from residual vegetable oils/byproducts by suitable chemical modification in the feedstock chain. The reaction was carried out at 110°C using feedstock with a range of fatty acids (C_6-C_{18}) in the presence of an acidic catalyst and solvent (toluene). The synthesized esters were then purified, characterized by analytical techniques (IR, 1H and 13C NMR) and evaluated for their physicochemical characteristics. The synthesized products show promising features such as a higher viscosity index of 200, a low pour point (up to <-27°C), and a wear scar diameter (WSD) of 0.88-0.90 mm. The synthesized esters find potential applications as biobased ecofriendly metalworking fluid (MWF).

Paper ID 328: Field validation of innovative water based synthetic cutting fluid for auto ancillary industries

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Cutting fluids have been used extensively to facilitate the cutting operation. In the beginning cutting fluids consisted of simple oils applied with brushes to lubricate and cool the machine tool. As cutting operations become more severe cutting fluid formulations became more complex. Much progress has been made in recent years in improving cutting fluid. Today's cutting fluids are special blends of chemical additives, lubricants and water formulated to meet the performance demands of the machining industry. Cutting fluids can be broadly categorized as neat cutting oils or water-miscible fluids. Use of water-miscible fluids, including soluble oils, synthetics and semisynthetics is approximately 80 to 90 percent in machining applications.

Recently, IOC has Synthetic Cutting Fluid comprising innovative mix of corrosion inhibitors, lubricity & film forming additives. This product exhibits excellent rust inhibition, biostability and lubricity characteristics w.r.t existing high and low mineral oil content based soluble as well as semisynthetic cutting fluids.

This paper covers activities related to field validation of newly developed water based synthetic cutting fluid in different auto ancillary units. This Innovative water based synthetic cutting fluid used in different cutting applications has provided benefits to customers in terms of improve in productivity, sump life, biostability, clear visibility, surface finish, tramp oil rejection besides providing safer work environment for employees.

Technical Session – IV-A: Base Oil & Additives

Paper ID 204: Active behaviour of synthetic esters as anti-oxidant boosters

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Synthetic esters are well known for their excellent thermo-oxidative stability, amongst other properties. This is particularly true for neopolyol esters, thanks to their specific chemical structure. Whilst esters have long been used as components in non-polar formulations to ensure additive solubility and seal compatibility, this paper explores the ability of esters to boost thermo-oxidative performance in hydrocarbon base fluids. Introducing esters as components in hydrocarbon based, ashless formulations results in improved resistance to oxidation and cleanliness, as showed by oxidation and coking test results on ISO VG 32 and ISO VG 100, group II and PAO based compressor oil formulations. Whilst it is somewhat expected that introducing an oxidatively stable base fluid in a formulation proportionally reduces the effects of oxidation, things may not be that intuitive.

First, the improvement on oxidation results does not always follow the amount of ester introduced in the formulation: there is an optimum treat rate in some cases. Second, thermogravimetric analyses tend to show that the whole formulation behaves differently, just as if the presence of ester delivered a supplemental antioxidant effect.

Further discussions lead us to consider interactions between esters and antioxidants, resulting in improved results. Esters do seem to be able to extend the action of antioxidants.

Another laboratory exercise aiming at optimizing the antioxidant system in a PAO based formulation demonstrated again the ability of esters to boost thermo-oxidative and cleanliness properties. This was confirmed with alternate antioxidants, with an optimized, synergistic system. Esters may therefore be considered as components of a full antioxidant system delivering maximum performance. Introducing performance esters in mineral or PAO based formulations appears like a cost-effective, boosting technology, delivering improved resistance to oxidation and cleanliness, amongst other benefits like reduced volatility and improved frictional properties.

Paper ID 292: Low viscosity low volatility synthetic basestocks “doing more with less targeting high performance european specifications"

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The lubricant market is constantly evolving particularly in the Light Duty category, where OEMs are developing new engines and powertrains to meet the ever more stringent emission requirements. The engine oil can play a significant role in achieving these targets, but it still needs to provide exceptional hardware protection. The European market is where these needs are coming to the forefront, and that is where the Low Viscosity Low Volatility (LVLV) Synthetic Basestocks can help to meet these challenges. In this presentation we will discuss the benefits associated with the use of a LVLV Basestock when formulating a Light Duty Engine Oil. Particularly we will focus on a 0W-20 grade designed to meet the new ACEA 2021 specifications and to demonstrate the potential benefits of the LVLV Product in specific OEMs tests.

The use of this novel LVLV Basestock will provide increased formulation flexibility, lowering the baseoil viscosity while maintaining excellent levels of hardware protection. The performance of the engine oil formulated with the LVLV Basestock will be compared against those of candidates manufactured with conventional synthetic basestocks. Some of the tests that will be included in this study are the CEC L-109 Oxidation Test, the TDi3, the Toyota Turbo Charger Deposit Test and the JASO M366 Fuel Economy Test.

The preliminary results that have been generated so far suggest that the LVLV Basestock can achieve similar, or sometime even better performance as compared to those of a fully formulated lubricant designed with higher amount of conventional synthetic basestocks, confirming that is possible to be Doing MORE with less! Finally, we are going to share some preliminary results to demonstrate the possibility of formulating high performance engine oils combining the LVLV Basestock with readily commercially available Group II Basestock.

Paper ID 510: Coolants for modern engines as well new energy vehicles

Neville Colaco

BASF India Ltd.

With the exception of small air-cooled engines, an engine coolant plays a crucial role in engine durability and reliability. In particular, the corrosion inhibitors play a critical role in protecting various metal components. Over the years, the engine coolant composition has evolved to accommodate changes in engine hardware as well as regulations. This presentation firstly looks at some of the trends influencing an ICE coolant.

In the meantime, New Energy Vehicle (NEV) is taking a significant growth across the world in recent years. It is reported that a total of 10.5 million new BEVs and PHEVs were delivered during 2022 globally, an increase of +55 % compared to 2021. NEV embraces different powertrain systems, vehicle control, safety requirements and so on. This puts a different requirement to thermal management system, i.e. material, working temperature range even coolants. As a leading chemistry company, BASF closely follow up the automotive electrification trend and successfully developed dedicated coolants for Battery Electrical Vehicle (BEV) and Fuel Cell Electrical Vehicle (FCEV). This presentation will demonstrate BASF's solutions for NEVs.

Paper ID 235: Creating a sustainable future through innovative chemistry

Mohnish Shukla

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The imperative of sustainability is on everyone's agenda today. As a result, we're seeing several announcements of initiatives by governments of various countries, oil companies and OEMs. Lubricant companies are starting to set goals or aspirations to decarbonize the complete lubricants value chain and to head towards net zero.

OEMs continue to innovate for improvement in IC engine efficiency focusing on fuel economy, reliability, exhaust emission and drivability. So, ICE innovations will still very much be part of the drive to reduce GHG emissions. Also, alongside BEV, Hybrid vehicles are expected to have a larger penetration than what is currently forecasted and may be used as a bridging solution. As a result of all these dynamics, advanced engine oils and e-Fluids will have an important role to play to enable these changes. Such Advanced lubricants will look for ways to reduce consumption and increases recycle and reuse of resources.

This paper lists the key developments as enablers for achieving net zero targets by OEMs and lubricant companies. These enablers include single component development with favorable surface chemistry and viscosity for fuel economy, delivering sustainability via lower Carbon base oils, Hybrid suitable solutions to meet the growing Hybrid vehicle needs, lower carbon footprint lubricants, etc.

Technical Session – IV-B: Alternative Fuels

Paper ID 516: Alternate fuels development for Marine / Decarbonisation and sustainable fuels

Sachin Kulkarni, Pankaj Misra

Wartsila India

Paper ID 280: Alternative fuels – Preparing for the impact on marine lubricants

Ian Bown

Lubrizol India Pvt. Ltd., Turbhe, Navi Mumbai, India

"Regardless of the alternative fuel solution selected by a ship owner/operator to meet IMO 2030, 2040, and 2050 milestones, it is inevitable that alternative fuel characteristics in conjunction with enhanced engine efficiency design and materials will see differing combustion phenomena being experienced.

To formulate the most effective marine cylinder lubricants for use with alternative fuels it is important to gain the best possible understanding of engine designs, combustion characteristics, and the technological and formulation challenges they may present.

Cylinder lubricant requirements must be considered for the multiple fuel types that the marine industry is already using and is likely to adopt soon including Ammonia, Methanol, and Biofuels so that effective and robust solutions can be created, enabling continued safe, efficient, and reliable engine operation.

This presentation illustrates the actions we have taken to advance our understanding of the range of alternative fuel types, summarizes the findings of our research and development, and how we are evolving our cylinder lubricant technology in response to our results.

Paper ID 244: Kinetic study of thermal decomposition of monopropellant (ammonium perchlorate)

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Propellant is a high energy materials used for ballistic, cruise and hypersonic missiles and vehicle system. Reliability of solid rocket motor performance is strongly depends on stability of combustion behaviour of propellant, a polymeric mixture of fuel, oxidizer and other additives. Hydrocarbon based solid propellant consist of 65-70% of ammonium perchlorate an inorganic oxidizer and 16-20% of aluminium powder as a metallic fuel. Since, Ammonium perchlorate holds major weight percent of propellant, accordingly thermal decomposition of same governs overall performance of rocket fuel system.

In present work, efforts were made to develop a kinetic model of thermal decomposition on presence of different kind of transition metals and reduced graphene based oxide (rGO) based catalyst with varying weight percent of catalysts. Investigation of different kinetic parameters, activation Energy (Ea), Pre-exponential factor (A) and reaction rate constant (K) was carried out with employment methods of Kissinger, Ozawa-Flyn-Wall, Kissinger-Akahira-Sunose and Friedman. Thermal decomposition of ammonium perchlorate was studied with differential thermo-gravimetric analysis (DTA) at different heating rate. The calculated kinetic parameters, activation energy, pre-exponential factor and reaction arte constant are 100 KJ mol-1, 1.18x107 s-1 and 0.006827 s-1 respectively.

Paper ID 286: Managing the transition from fossil fuels to renewable – Challenges, opportunities & implications

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Managing the transition from fossil fuels to green energy or renewables as they are normally referred to – a basket of energy forms that include solar, wind, hydroelectric, geothermal, hydrogen or biomass energy – will be critical to limiting global warming to the 1.5°C target aspired to in the 2015 Paris Agreement. However, barely weeks into the signing of the Paris Agreement, the initial euphoria & celebrations made way for caution as diverse stakeholders realized the enormity of the task. After all it was going to be the largest energy transition in the history of mankind in a relatively short period of time.

Despite growing attention on clean energy, fossil fuels still account for almost 80 percent of global energy consumption and 75 percent of greenhouse gas emissions.

While the fossil fuel-based energy systems that are presently in use come at a massive environmental cost and Fossil fuels drive both ecological and economic vulnerability, the large scale replacement of most forms of fossil fuels will need enormous scale of investments even in countries and communities that may not be able to easily afford it. Besides scaling up production, there will be a need to establish supply chain infrastructure which will require money, time and coordinated effort. This paper explores some of these challenges, opportunities and the implications for the same.

Technical Session – IV-C: Refining Technology

Paper ID 201: HP-TRIJET: A tandem catalyst based technology for production of sustainable aviation fuel/ green diesel from used cooking oil

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According to International Civil aviation organization, CO_2 emissions from aviation sector is likely to grow seven fold by 2050. International Air Transport Association (IATA) has committed to reduce the carbon emissions to half of 2005 levels by 2050. In order to accomplish these targets, continues investment in new technology, sustainable fuels were required. Carbon offsetting reduction scheme for international aviation (CORSIA) focuses on net increment on CO_2 emissions from aviation sector, which was launched in 2016, India is not yet a signatory but must participate by 2026. In this regard, HPCL has developed its own renewable based technology (HP-TRIJET) to produce SAF and Green diesel (GD) from used cooking oil (UCO), which can reduce the anthropogenic CO_2 emissions. Annually around 23 MMT of vegetable-based cooking oil is consumed in India As of today, UCO is either disposed in an environmentally insensitive manner or it mostly consumes at smaller restaurants. According to Food safety and standards authority of India (FSSAI), there is a potential to recover about 3MMT of UCO. This recovered UCO can be valorized to fuels, which in turn can decrease the net CO_2 emissions.

Paper ID 250: Steps towards net zero commitment

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Oil and gas will remain part of the energy mix until renewable energy sources adequately replace them. For the world to meet ambitious emissions reduction targets, a premium value needs to be associated with the lowest carbon-intensity oil and gas assets. India is gearing to enter $ 5 trillion economies. Energy consumption is a harbinger of growth of an economy. Distillation systems are responsible for the highest amount of energy consumption in refineries. Use of fossil fuels is responsible for environmental problems such as global warming and air pollution, which affect the quality of life of populations. The most effective way to reduce GHG emissions is to reduce the consumption of fossil fuels. Optimization of process parameters, digital transformation, use of Dividing Wall Columns (DWC) etc. can deliver increased energy efficiency as well as minimize the carbon footprint of the industry. BPCL refineries are embarking the journey to meet the net zero

target by 2040. This paper shares about the reconfiguration of Naphtha Splitters in BPCL Mumbai Refinery, which is a step towards BPCL's net zero commitment.

BPCL Mumbai Refinery (MR) is a pioneer in oil & gas industry, especially in the field of energy conservation and environment protection by means of innovative approaches. Naphtha management is crucial for improving the overall Gross Refining Margin of any refinery. Naphtha can be managed by effective separation and upgradation and optimizing the blending strategies, which in turn minimizes the overall Naphtha production. MR was having three Naphtha Splitters namely Reformer Feed Preparation Unit (RFU) Splitter I, RFU Splitter II and Isomerization Unit (ISOM) Naphtha Splitter, to split Stabilized Naphtha from the Crude Distillation Units into light and heavy components. RFU Splitter I and Splitter II were operating in series configuration. It was found that the separation efficiency was low and energy consumption was high in the existing configuration.

In order to address these issues, different schemes were configured and simulated. Based on economical and operational benefits, one of these configurations was selected for implementation. The selected configuration was to convert RFU Splitter II into a DWC so that RFU Splitter I & II can be operated in parallel and ISOM Naphtha Splitter can be shut down. Thus, RFU had undergone reconfiguration, after which MR is able to operate RFU Splitter I & II in parallel configuration, thereby shutting down ISOM Naphtha Splitter. In addition to product quality improvement post-reconfiguration, yield of Top as well as Bottom cuts have been increased considerably thereby reducing the mid cut which goes to Naphtha pool. Quality of Mid cut has also improved with less overlap of the stream with Top and Bottom cuts. On account of shutdown of ISOM Naphtha Splitter, MR could achieve huge reduction in fuel consumption, which contributes to a reduction in emission of approximately 29043 tons/annum of Green House Gas (GHG), which is a step towards India's net zero commitment to combat global warming. Technologies coupled with improved energy efficiency can support a more sustainable energy system with less carbon emissions.

Paper ID 255: Reducing carbon footprint of transportation fuels by processing waste plastic pyrolysis oil in refinery: sustainable approach to net zero goal

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Reduction of carbon foot print in the transportation fuel is a key imperative to reduce carbon footprint of transportation fuel which is gaining hold as one of the approaches towards CO2 emission reduction. Use of waste derived feedstock in petroleum refineries is one of the pathways to achieve the same. Global production of plastic has reached about 400 million tons in 2022 and is continue to grow at a healthy CAGR of 5%. This continuous rising of plastic demand led to the growing in waste accumulation every year. India's plastic waste generation is expected to increase to 31.4 million tons by 2031 and further to 55 million tons by 2041, thus showcasing an urgent need to address the concerns from the growing plastic waste in our country. In order to overcome this menace, chemical recycling method such as Pyrolysis is considered as a suitable route to manage plastic waste by pyrolyzing the plastic waste to generate waste plastic pyrolysis oil (Pyrolysis Oil).

Traditionally, Pyrolysis Oil has been utilized as a FO blend component; however it is not capable of handling Municipal Solid Waste (MSW) plastics. Hence, proper utilization of pyrolysis Oil generated from different types of waste plastics including multi-layered was not possible. Thus, Co-processing of the pyrolysis oil generated from different types of waste plastics including multi-layered in secondary refinery units such as Delayed Coking Unit is an attractive option for reducing the major environmental concern of waste plastic disposal. This will also enable to reduce the overall crude oil import & overall carbon footprint of the refinery but also bring in circular economy and waste to wealth creation leading to a path for sustainable future. In the present study, detailed study on distribution profile of impurities content in pyrolysis oil especially Si, Cl content. Also, Micro-Coker reactor experimentation with blends of petroleum residue and waste plastic pyrolysis oil were carried out at Delayed Coking process conditions for optimization of blend composition, estimation of product yields and distribution of the impurities content in the product streams. The optimized blend composition of pyrolysis oil in RCO was found to be 1-2 wt% based on the allowable impurity content distribution in product streams suitable for downstream treating units. Moreover, blending of pyrolysis oil in RCO and processing it at delayed coker conditions resulting in the overall increase liquid yield and reduction in coke yield. This reduction in coke yields become crucial step for reducing the carbon footprint of refinery in terms of SCOPE-I, II & even SCOPE III emissions, without compromising the existing hardware.

This paper describes how the processing of waste plastic pyrolysis oil in delayed coker unit along with resid feed in refineries could become crucial step for reducing the carbon footprint of refinery, without compromising the existing hardware instead increasing the refinery margins by increasing overall liquid yield and reducing coke yield.

Paper ID 299: Dual functional surfactant/ waxy containing biodegradable Warm mix additive for asphalt mixtures

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Asphalt mixtures are the most widely used material in the construction of pavements for roads. The regular Hot Mix Asphalt (HMA) require high manufacturing temperature (around 160°C), which is associated with the release of a large volume of greenhouse gases. Thus, in order to limit these problems, bituminous mixtures with lower manufacturing temperature are required without impacting their mechanical behavior. One possible alternative is the use of Warm Mix Asphalt (WMA), which is manufactured at 20-40°C lower than the conventional Hot Mix Asphalt (HMA).

WMA process leads to (i) lower emissions, fumes and odors and (ii) reduction of ageing of the bitumen. There are three types of additives associated with WMA production, namely, chemical, organic additives and foaming additives (water-containing). We have developed two new families of dual functional (wax and surfactant) biodegradable WMA additives from alkyl ester of oxalic acid and diamide of triglyceride oil. Reduction of viscosity at temperature close to compaction/mixing was achieved with 1-2 % w/w dosage of in-house developed warm mix additives with bitumen. During the field trials, 25°C reduction of compaction/mixing temperature was observed at a dosage of 2%.

The Key Novelty of in-house developed warm mix additives are: (i) Biodegradable, (ii) Dual functional additive, (iii) Combination of surfactant/wax mechanism and, (iv) Surfactant and Wax functionalities are linked by ester and amide groups

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Technical Session – V-A: Operating Fluids for EVs

Paper ID 315: Nano fluid coolant for automotive cooling applications

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Continuous technological developments and stringent emission norms in automotive industries has increased the demand for high efficiency drivetrain which results in high heat dissipation requirements. With limitations on size and technology on Radiator unit and fan assembly, there is an urgent need for new and innovative heat transfer fluids to increase heat transfer rate in an automotive cooling circuit. Nano fluids, operating fluid for EV Radiator show considerable promise as a potential substitute of conventional coolants in engine cooling system. In this paper, a detailed literature of various Nano particles and their impact on the heat transfer characteristics is done. Based on performance and suitability to mass production considering cost and availability, a suitable Nano particle is selected. The detailed preparation process for the Nano particle with existing OAT coolant mixture is elaborated. Additionally, the thermal conductivity improvement for various mixing ratios of the Nano particle are studied and compared to the base coolant, and the optimized ratio chosen for an automotive cooling system application.

Paper ID 216: Managing the challenges of cooling electrical vehicles and their systems

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ARTECO Coolants India Pvt. Ltd., Pune, India

While the level of complexity and associated challenges of cooling battery electric vehicles (BEV) and internal combustion engines (ICE) can be very different, some of the challenges in cooling these systems are identical or at least very comparable. In ICE we have experienced a steady increase of compositional and system complexity by a push for reduced emissions of the equipment or vehicle. Although base fluid chemistry, water in combination with ethylene glycol, did not change for decades, the technology push on coolants additive technology has culminated in the maximum one can imagine getting out of applied chemistry. Drawing on the immense knowledge available for ICE coolants but rethinking the composition in considering engineering and architectural differences in BEV systems (e-Motors, batteries, power electronics), different approaches for BEV coolant design are necessary. The presentation will identify those differences, what needs to be understood and learned from them, and how this relates to differences in cooling system architectures. A particular aspect of interest is safety. It is often wondered in part of the

industry why glycol-based coolants are used while they are electrically conductive. This paper / presentation will shed light on an exciting development where electric conductivity can be reduced to provide safe operation, and still retain the best available cooling properties amongst liquid coolants.

Paper ID 279: e-fluid technology for electrified drivetrains

Nilesh Kadu

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"New driveline e-fluids, designed to enable the latest electrified powertrains to perform at their very best, are entering the market. Many earlier electric vehicle powertrains were developed using automatic transmission fluids (ATF). Not optimized for EVs. Increasingly these are being superseded by the latest generation of lubricant fluid technology, termed driveline “e-fluids”. These include the most recent type of e-fluid technology to enter the market, which has no corrosive active sulfur additive present, sometimes termed “sulfur-free”.

The e-fluid is an engineered component and forms part of the overall design of the electrified hardware. The presentation will cover the fundamentals of the latest e-fluid design, fluid properties, and how fluid is best evaluated for performance. Key issues resolved by the e-fluid such as corrosion, oxidation and fouling, thermal management, electrical insulation compatibility and component wear protection will be described.

This presentation will be of interest to engineers seeking an understanding of the fundamental principles behind e-fluid design and the latest fluid testing methods to address some of the hardware challenges.

Paper ID 321: Development of dedicated transmission lubricants for electric vehicles

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Global drive for reducing CO2 emissions and stringent emission regulations are the main driver for emergence of E-mobility. Growth of electric vehicles (EVs) is continued since its introduction in early 19th century and has grown substantially thereafter. Further growth in EVs is expected in future and beyond 2030. Electric vehicles require transmission oils which are different from the conventional oils mainly due to change in hardware technology such as e-motor system and new materials (copper windings, elastomers, plastic and other materials).

Any lubricant when used in an electric vehicle should offer unique performance attributes including optimal electrical properties, thermal management and material compatibility apart from the traditional performance features including extreme pressure/ friction performance, oxidation and wear control specifically in architectures where lubricant comes in contact with the e-motor. Lubricants with optimal electric properties can mitigate electrical damage commonly found in electric vehicles. The copper compatibility and superior heat transfer properties of a lubricant ensures efficiency and durability of its components.

The present work is focused on development of dedicated transmission lubricants for EVs. Various candidate blends were evaluated for physico-chemical characteristics such as electrical, heat transfer, and copper material compatibility properties. Results of the current study emphasize that the tailor-made lubricant composition designed with carefully selected components play a critical role in offering required electrical & heat transfer properties, and material compatibility.

Technical Session – V-B: H2 as future fuel

Paper ID 517: Optimal exhaust after treatment solutions for H2-ICE

Shravan Srisailam

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With the announcement of National Hydrogen Mission by the Government of India in 2023 there has been an increased attention on the hydrogen internal combustion engine (H2-ICE).

H2-ICE offers an opportunity to meet targets of reduced the carbon footprint in India and reducing reliance on fuel imports. It is a very promising engineering approach in the automotive industry in moving towards climate-neutral solution. Heavy Duty Industry around the globe including India is focusing on H2 as it is the best available alternative fuel.

However, this approach has its own challenges as most are targeting diesel-like indicated efficiency through constant lean burn. H2-ICE during its operation emits NOx emissions along with high amount of water content.

NOx can be removed through conventional Selective catalytic reduction (SCR).

Unlike diesel engines, where the water content is low around 10%, H2-ICE may lead to 30% water content in its exhaust which can have pronounced effect on the after-treatment system either in terms of NOx conversion efficiency, NH3 storage, N2O selectivity, and the durability.

In this study, we evaluated state of the art BASF SCR technologies towards NOx control in the presence of varied amounts of water and H2.

Studies were performed to understand the impact of water on SCR reaction selectivity, SCR reaction rate besides catalyst deactivation studies due to the different amounts of H2 in the feed. Results indicate that BASF's SCR systems are capable of meeting NOx reduction targets in H2-ICE systems.

Guidance on system sizing and durability concerns are also shared here.

Paper ID 504: Decoding hydrogen ecosystem for India

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Underpinned by the global commitments towards environmental protection and seismic shift towards decarbonization, hydrogen is emerging as an important lever in the energy ecosystem. With the release of National Green Hydrogen Mission, a comprehensive action plan has been laid for establishing hydrogen ecosystem in the country and catalyzing a systemic response to the opportunities and challenges of this sunrise sector.

IndianOil has been pioneering the RD&D activities in hydrogen since two decades. The presentation would highlight key initiatives by IndianOil R&D in the research domain of hydrogen production, storage, transportation, dispensing and end applications and IndianOil in strategically aligning the business verticals with this emerging area. The talk will highlight the critical challenges pertaining to development of indigenous technologies in the hydrogen ecosystem besides proposing research imperatives in key areas of the hydrogen value chain. A comprehensive life cycle assessment will also be covered in the discussion for producing hydrogen from multiple pathways in India.

Paper ID 351: Hydrogen ICEs for commercial on-road and off-road applications: realization of robust and cost-effective carbon free combustion engines

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Due to the increasing thrust on reducing greenhouse gas emissions, the transportation sector is under pressure to replace fossil fuels. Long-haul trucking and off-road sector, has a high energy consumption, and is therefore, responsible for a significant share of fossil fuel consumption and at the same time is difficult to electrify. Therefore, carbon free fuels can make an important contribution to the de-fossilization of this sector.

Recently the Govt of India has launched an ambitious National Hydrogen Mission (NHM) to realize a faster infrastructure and supply chain built up, regulations and public outreach as broad activities for an accelerated introduction of Hydrogen as a fuel.

The H2 internal combustion engine (ICE) is gaining an increasing interest, especially for heavy duty commercial on road and off-road applications. It offers a unique possibility to use existing robust engine systems as base, in contract to battery electric and fuel cell applications. Current studies have demonstrated that the hydrogen engines can achieve similar performance levels compared to the diesel engine.

One of the key points for high efficiency and high-power density is a good mixture formation. PFI (Port Fuel Injection) can lead to nearly homogeneous mixture and in combination with VGT boosting concept, it offers a robust and cost-effective solution, which could be implemented in short term. On the other hand, DI (Direct Injection) technology offers advantages with regards to power density and efficiency, but it poses more technical challenges regarding the injector design as well as associated cost.

This publication outlines FEV's engineering approach and the associated steps for converting conventional powertrain to hydrogen operation. After a smart selection and utilization of the components originated from the base engine, core sub-systems are updated for hydrogen operation. Extensive design and simulation front loading are made prior to testing phase, on which engine efficiency is further optimized, and combustion anomaly is suppressed. It is also shown how combining the right exhaust after-treatment system layout with an advanced engine control

algorithm can reduce NOx raw emissions and achieve high NOx conversion efficiency to comply with future zero-impact pollutant emission standards.

The overall result from the current project clearly demonstrate that Hydrogen powered ICE show a good potential as enabler for the faster de-carbonization of transport sector.

Paper ID 302: Effect of low temperature and low humidity on Nafion based membrane electrode assembly for PEM fuel cell

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Due to the increasingly serious issues of resource scarcity and climate warming, an energy revolution has been established by optimizing energy consumption structure and introducing effective low-carbon technology. Hydrogen fuel, as an alternative energy with short re-fueling time and broad resource, may potentially revolutionize the energy supply chain and decarbonize fuel consumption by a certain hydrogen energy conversion device. The proton exchange membrane fuel cell (PEMFC) has been widely used in carrier vehicles for its high energy conversion efficiency, short start-up time, low operating temperature, and quick response to load changes. In the PEM fuel cells, hydrogen reacts with oxygen to generate water, heat and electricity. Water management plays an extremely important role in the normal output of a PEM fuel cell. For one thing, hydration of the membrane is required to ensure the proton delivery in the PEM and maintain high levels of the fuel cell performance. For another, excessive water generated during the oxygen reduction reaction at cathodes may result in flooding in a fuel cell, eventually impeding the diffusion and flow of reactant gases and increasing the risk of performance degradation (i.e., gas starvation). Proper water content and balanced distribution are important factors to ensure that the PEM fuel cell performs well.

The relative humidity (RH) of both the cathode and anode has a significant influence on the water content of the membrane and the condensation of water. Therefore, many studies have investigated the effect of the RH at ambient temperature. Reducing RH can result in slower electrode kinetics, including electrode reaction and mass diffusion rates, and higher membrane resistance. In the present study, In-house Nafion based membrane electrode assembly (MEA) was prepared and it consist of Pt/C catalyst layer, gas diffusion layer (GDL), Nafion membrane and Nafion ionomer. Variation in the anode and cathode catalyst loading totally 3 nos. of MEA was

prepared. To fabricate coated membrane (CCM) ultrasonic coating machine was used. CCM was sandwiched with GDL and assembled as MEA in single cell (25 cm2).

The RH for the operation of single cell assembly was optimized 68% at anode and 57% at cathode at optimized inlet gas temperatures of 40°C under atm pressure using optimal flow-design. Then the cell was operated using neat hydrogen (99.999%) with a flow rate of 0.5 NLPM at anode and air with a flow rate of 2.5 NLPM at the cathode. The performance of single cell with higher performance was found in 68% at anode and 57% at cathode at optimized inlet gas temperatures of 40°C. The results of this study show that the current density of 0.67 A/cm^2 was obtained at 0.6 V at the loading of 0.1 mg/cm^2 at anode and 0.3 mg/cm2 at cathode catalyst layer. The in-house slurry composition and coating configuration of CCM layer helps retaining sufficient moisture for a PEMFC to function at low humidity conditions.

Technical Session – V-C: Greases

Paper ID 319: Developing & validating an automotive grease: Beyond field trials

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The Automotive Industry generally uses the field trial route to evaluate the performance of any new grease/ lubricant formulation against the existing baseline data. Field trials are very common and still considered the most reliable of all methods currently available within the industry. The development & validation of a new grease formulation could take several years owing to the extensive field trials involved. This trial process could involve a huge amount of data collection and close monitoring in the field end application for millions of kilometres.

This approach suffers from the following drawbacks.

- Recording, managing and analysing this data could prove to be very challenging.
- Unreliable data may affect the process quality & breakdowns in field can further push the deadlines.
- Human Resource Problem: Extensive skilled manhours are needed to conduct and monitor the field trials.
- This validation process cost incurred may run into crores of Rupees

So to validate a new part, years of planning is required to synchronize the requirement vis-à-vis actual availability. Due to these factors, it becomes difficult to approve new products and induct alternate suppliers. Owing to this, several major automotive companies tend to depend on single source for supplies. This lack of flexibility could lead to higher purchase cost, and consequently higher overall cost of ownership for the vehicle user. Besides, competitors with better products may gain market-share.

Globally, lubricant manufacturers use laboratory methods to validate the performance and life of grease under simulated conditions. However, this has been mostly limited to development for industrial applications where the conditions may not be so variable as experienced in automotive applications. Therefore, this approach has not been popularly adopted for automotive grease validation. Customised laboratory test to simulate automotive applications is an ongoing research topic. The major challenge encountered has been to validate the grease within a limited time without the need for field trials (which could take several years to yield meaningful results) and while doing so, replicating the field conditions inside a laboratory to effectively correlate with the

grease life. Another challenge has been to develop a grease formulation which is cost effective, having better performance coupled with increased life.

This paper discusses the success story of the development, validation and approval of a next-gen synthetic automotive grease for a leading automotive OEM, using a world-class envisioned laboratory test, without conducting any large scale field trials. This led to the creation of a replicable statistical model for the OEM for any future iterations and placing it ahead of the curve. In doing so, this led to the saving cost of crores of rupees and prevention of thousands of tonnes of potential CO_2 emissions if a field trial was run.

The re-greasing interval of Hub (Axle) increased by 1.5 times by developing a unique formulation. Not to mention, this led to a direct cost savings of about Rs 7 Crores (in developmental Cost) and recurring benefits of about Rs 10 Crores per annum (in cost of grease)

Paper ID 290: New approaches to understanding critical grease properties with novel investigative equipment

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With the advent of Electric Vehicles, the lubricant content of E mobility vehicles is more biased towards use of greases of various types for different applications from motors to breaking generators and several other areas in E mobility transportation.

Apart from this high - speed trains, huge windmills and such large machineries are using high performance grease formulations.

With all these applications, the critical properties of grease formulations need to be understood with more clarity and less subjective tests. Two such critical properties of greases are: TACKINESS and EDM breakdown point of greases.

Tackiness is a kind of internal property of grease and EDM breakdown point is a kind of external property of grease caused due to friction and interaction with metal surface, especially rolling surfaces. Till recently and currently also, grease formulators use subjective tests for tackiness and normally do not measure EDM breakdown point. The 90 year old grease worker or the less aged FOUR BALL TESTER or FBT are “make or break” kind of tests and we really do not know what

happens to grease or the metal or at the interface till the specified time of test is over and we are allowed to examine the surfaces and grease residues. But two new approaches to the two above mentioned critical properties of greases are changing and expanding our understanding of these two properties. This paper examines these two approaches, the principle and construction of the equipment involved and results from experimental use of these approaches. Tackiness and Adhesion force measurement using Tackiness & Adhesion Analyser (TAA) is a new approach that takes the subjectiveness out of the measuring of this critical property of greases. The construction of the test unit, protocols of testing and experimental results are discussed in this paper. Application of this approach to understanding Tackiness is explained.

The traditional FBT or Four Ball Tester is modified to examine the interface using impedance measurement and track the ohmic resistance and capacities and also the EDM currents with determination of breakdown point. This is a very impressive development in grease testing and this allows the operator to monitor the degradation of grease and metal interface and not wait till the end of test to find out the damage.

Results from using such a sophisticated attachment and intuitive software for real time calculation and display are discussed.

Paper ID 225: Evaluation of CNTs in lubricating greases

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Development in the field of nanotechnology has led to the growth of carbon nanoparticles as lubricant additives. Owing to their unique physical and chemical properties, carbon nano additives can play several roles in lubricating oil and grease. Nanomaterials such as carbon nanotubes (CNT), carbon nano horns (CNH), graphene and graphene oxide were added into the lubricating grease to improve extreme pressure (EP), anti-wear and friction-reduction properties. Carbon nanotubes (CNT) have been studied as grease additive for application in bearing and other mechanical parts to increase life; lower operating costs and improves power efficiency. Their application as thickener of lubricating greases is also studied. CNT as an additive to lithium and calcium based greases are reported in literature. However, the current generation shifts beyond traditional metal soap based greases, especially considering the global crisis in availability of lithium. High temperature greases like polyurea, clay, calcium sulfonate complex greases have gained rapid popularity owing to their versatile properties. So far not much literature is reported on the CNT addititized high temperature greases.

In this technical paper we have evaluated CNT, especially multi walled carbon nanotubes (MWCNT) in polyurea, lithium-polymer and clay greases. Our in-house lab synthesized CNT was characterized and evaluated as an additive in the greases mentioned above at varying treat rates. The CNT greases were compared with greases having other solid additives like graphite, MoS2, molybdenum dithiocarbamate (MoDTC) etc. All the solid additives (including MWCNT) were characterized by particle size analyzer, SEM, XRD, DSC. The effect of solid additives on grease with respect to consistency, dropping point, color, appearance, oil bleed, and shear stability experiments was studied. Special tests like fretting wear, deleterious particle tests etc were performed in order to evaluate, if, MWCNT additized grease has any advantage. Several tribological tests like SRV, weld load and wear scar diameter were studied simultaneously. Lastly a binary additive system, “comprising of MWCNT and various other AW/EP additives” was evaluated and tribological performance was evaluated. Lubricating performance of MWCNT is thoroughly discussed with respect to their structural properties such as larger surface area, size and affinity towards metal surface.

Paper ID 230: Study on the application of novel rosin ester as potential eco-friendly multifunctional additive in polyol based grease

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Abietic acid is an abundant renewable resource found in nature and derived from the resin of conifer trees. Many traditional additives are in use to improve the performance of greases but most of them are harmful materials that cause environmental pollution due to their implicit toxicity. Therefore, due to environmental concerns, it is essential to develop new and environmentally benign additives. Trimethylolpropane rosin ester (TMPRE) was synthesized by esterification of abietic acid with trimethylolpropane (TMP).

The complete synthesis of novel rosin ester was confirmed by employing elemental analysis, FT-IR, and NMR spectroscopic techniques. The performance of TMPRE as an environmentally benign multifunctional additive in polyol based calcium grease for improving the tribological behavior and oxidation stability.

The tribological results (ASTM D2266) reveal that 1% TMPRE concentration decreases the AWSD (average wear scar diameter) to 0.526 mm from the 0.601 mm AWSD for polyol-based reference grease; however average coefficient of friction reduction was minimal. At the same concentration, the worn surface after the test was observed to be substantially smooth with minor scratches, whereas several pitting with deep grooves were observed in the case of reference polyol based grease. Oxidation stability of the grease was also observed after doping different concentrations of TMPRE by using the modified ASTM D942 and it was revealed that the maximum degree of oxidation reduction after a given period of test time was observed at 0.3 % concentration.

So, TMPRE may be considered an eco-friendly additive and a potential alternative to traditional additives for formulating eco-friendly bio-based greases.