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HORIBA's Perspective on Emission Technologies and Future Regulations in India

Mr. Kunal Yadav, Senior Manager, (Product Management), Energy & Environment, HORIBA India Pvt Ltd

【 On-board 】
OBS-ONE IRLAM
NH_3/N_2O

【 Stationary Laboratory 】
FTX-ONE-CL
$NO_2/NO/NH_3/N_2O$

MEXA-ONE-XL-NX【 Standalone 】
$NO_2/NO/NH_3/N_2O$

What is infrared spectroscopy & Why it is advantageous in automotive emission R&D?

Molecules possess the ability to absorb specific wavelengths of infrared light. Infrared spectrometry is a method used to determine the concentration of gases by assessing the amount of light at specific/particular wavelengths that are absorbed. In the context of the global shift towards carbon neutrality, which includes technology-neutral regulations like EURO-7, there's a growing need for techniques that can efficiently measure maximum pollutant levels while minimizing the size and enhancing the equipment's response (measuring analyzer). Infrared Red Spectroscopy provides this adaptability and is a vital technique for automotive testing.

Why was real-time measurement of gases difficult to measure with conventional IR technology?

Conventional pollutants like CO2 and CO can be detected using standard NDIR analyzers. However, the recently introduced regulatory pollutants in the latest guidelines including N2O, NH3, and HCHO, pose a challenge for conventional analyzers due to their low sensitivity and significant

EMISSIONS
ELECTRIFICATION
CAV
DATA

OBS-ONE IRLAM

On-board Emissions Measurement System for NH_3 / N_2O

The world's first* on-board emissions measurement system for analyzing NH_3 / N_2O in RDE

*As of July 2021. Based on our research.

- High accuracy measurement with HORIBA's innovative infrared gas measurement method "IRLAM™"
- High reliability and robustness, can withstand environmental temperature and vibration
- No utilities required, such as purge gas cylinder
- Able to connect with other equipment in the OBS-ONE series and integrate data

*IRLAM is a registered trademark or trademark of HORIBA, Ltd.

Powered by IRLAM by HORIBA

HORIBA
Automotive

interference with other gas constituents. To achieve more precise measurements of these components, a new analyzer is essential.

Give a brief of IRLAM advantages over conventional IR technology – what problems does it solve and why should automotive industry R&D test engineers use this solution?

The IRLAM system offers notable benefits in terms of sensitivity and minimal interference. It excels at measuring components that are typically challenging for conventional analyzers to detect with high sensitivity. Furthermore, due to its compact size and resilience to temperature variations and vibrations, IRLAM is compatible with portable emission measurement systems (PEMS). Whether in a controlled laboratory setting or on a vehicle in operation, employing IRLAM will enable the acquisition of closely correlated data, thus enhancing the research and development efficiency for vehicles, engines, and catalysts.

What makes IRLAM a new core analysis technology for gas measurement?

The calculation algorithm used in IRLAM is an exclusive patented technology developed by HORIBA. Furthermore, we manufacture the essential laser component, QCL, internally at HORIBA. We regard this as our foundational technology because it allows us to have full control over everything, from the component specifications to the computational aspects, making it a technology that sets us apart from other companies in terms of competition.

How does HORIBA's knowledge and skillset align with the development and progression of IRLAM technology?

In the automotive market, while other competitors have long relied on purchasing NDIR and FTIR technologies from external suppliers, HORIBA has been producing these versatile technologies in-house for many decades. In 2011, we made automotive history by selling the world's first QCL analyzers, and in 1994 HORIBA introduced FTIR technology to the market. Their deep technological expertise, especially in FTIR, surpasses that of any other competitors, culminating in the development and release of IRLAM.

What are the relative performance and features of IRLAM compared to the alternatives available in the market?

Within the realm of technology, we have a strong conviction that FTIR will be a formidable contender. Nevertheless, FTIR is susceptible to vibrations and its durability is compromised due to the presence of moving components. These attributes may pose inherent drawbacks for PEMS analyzers. Furthermore, whereas FTIR often requires corrections to eliminate noise and enhance sensitivity, IRLAM enables high-sensitivity measurements without the need for such adjustments. We maintain that having access to unprocessed, raw measurement data confers distinct advantages in data analysis.

What motivated HORIBA to select the ECMA (Emission Control Manufacturers Association of India), India as the platform for unveiling its cutting-edge infrared gas analysis technology, and what specific individuals or organizations is the company aiming to connect with during publishing this interaction?

India's swift transition to alternative fuels like H2-ICE and E20, E85 and M20 fuel positions it as a leading region worldwide, prioritizing clean energy research and development. Alternative fuel exhaust gases have a higher water content compared to conventional gasoline or diesel exhaust gases. While water can disrupt many analyzers, IRLAM is less affected by it. This exhibit aims to highlight advanced technologies such as IRLAM and FTIR for a future day when precise measurements of emissions from alternative fuels become crucial.

HORIBA is celebrating its 70^{th} anniversary in 2023, would you like to share more insights into this?

The HORIBA conglomerate is a brainchild of our founder Late Dr. Masao Horiba, who while a student at Kyoto University, Japan founded HORIBA Radio Laboratory in 1945 which was later transformed into HORIBA, Ltd., in 1953.

Under the visionary leadership of Mr. Atsushi Horiba, who followed the footsteps of the Late Dr. Masao Horiba, HORIBA has today acquired many world-renowned companies like JobinYvon from France, SPEX and Dilor from the US, FuelCon from Germany and MIRA from the UK making the HORIBA canopy is much stronger and larger.

The HORIBA Group with 50 companies spread across 27 countries is today a global leader in analytical and measurement techniques. Our products are oriented towards the growing markets of Energy & Environment, Bio & Healthcare and Materials & Semiconductor.

70th Anniversary
HORIBA

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Strategies Adopted by the Indian Automobile Sector for Leaping to Cleaner Air for Tomorrow: A Way Forward

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Execuive Summary : The Indian sub-coninent , especially India is severely afected by high levels of air polluion , especially the urban area. The WHO Report 2019 revealed that 21 out of 30 most polluted ciies in the world, are in India based on $PM_{2.5}$ emissions. Air polluion is esimated to have cost India's economy about 36.8 billion dollars in 2019. The main sources of air polluion , as per the source apporionment studies carried out in India inter-alia include road dust, construcion aciviies , vehicular polluion, and thermal power plants, including episodic crop residue burning. India among the others adopted policy and regulatory iniiaives, viz. leapfrogged to BS-VI emission norms, CAFÉ norms, strict fuel emission standards, low carbon fuels, circularity of material, and launched the Naional Clean Air Program 2019 (NCAP) reducing and improving key air pollutants PM10 and PM2.5 by 20-30% in 2024, compared to 2017 as the base year. Simultaneously, the automobile sector under the stewardship of SIAM has adopted several imperaives to curb air polluion in their respecive domain of the automobile sector. The paper underlines these measures and discusses the environmentally sustainable management of air polluion to achieve the larger objecive of fostering sustainable mobility and atainment of the goals of decarbonizaion **Panchamrit** including sustainable development goals 2030, in the larger context.

1. Introductory: India has a well-evolved legislative & regulatory framework viz. National Environment Policy, 2006, Air (Prevention and Control of Pollution) Act, 1981, Environment Protection Act 1986, and Centre Motor Vehicle Act, 1988, apart from ambient, industry & source-specific technical standards for the prevention and control of air pollution. The Government has set up a comprehensive institutional network of CPCB- SPCBs, and regional offices with required paraphernalia. The National Clean Air Program (NCAP) 2019 has been extended to 132 from 102 non-attainment cities in 2021 for prevention, control, and abatement of air pollution.

The Indian automobile sector is conscious and responsible for its obligation towards human health, the environment with sustainable automobile growth aligned with national policies and international agreements. Accordingly, the automobile sector has a deeper policy and regulatory interface with the Governments of both the centre and states and proactively transitioning to cleaner and greener mobility. In recent years, the landscape of Indian mobility has picked up pace in adopting various pathways of sustainable mobility under the stewardship of the Society of Indian Automobile Manufacturers (SIAM) in collaboration with OEMs, R&D institutions, and civil society. The automobile sector has successfully adopted electric vehicles (EVs), charging infrastructure, hybrid technologies, stringent emission norms, fuel efficiency, recycling and circular economy, and innovative research and development.

The strategies and pathways towards shared mobility as a service are gaining momentum to combat air pollution by fostering more resilient and sustainable mobility in India. The ongoing transformation is catalytic in improving air quality, environment protection, energy security, and economic development. The present article provides an in-depth exploration of the strategies and their outcome adopted by the Indian automobile sector to achieve cleaner air for a better healthier tomorrow. The SIAM is striving aggressively to forge deeper and broad-based coordination and synergy among agencies involved in vehicle manufacturing, technology providers, air quality monitoring, and city-wise sources apportionment of major pollutants for effective compliance, and enforcement to attain the stated objective.

2. **Present Clean Air Status & Trends:** The rising trends in air pollutants from various sources are evident from the national and international reports that covered Indian cities, especially the megacities of Delhi, Mumbai, Bengaluru, and Kolkata. Over the years, there has been a massive-scale expansion in industries, population density, and anthropogenic activities with a many-fold increase in vehicles leading to increased use of natural resources which has degraded the air quality in India. As per the WHO (2019) report, India was ranked the fifth most polluted country by WHO (2019), with 21 of the top 30 polluted cities in India based on the concentrations of $PM_{2.5}$ (Particulate Matter) emissions. The contribution of air pollution in the ambient air of cities and towns from various sources as per the source apportionment studies is available in the public domain. This paper highlights the studies of CPCB (2010) and IIT Kanpur and their key findings are provided in the Table below:

Study	**CPCB 2010, NCT Delhi**		**IIT-K (PM2.5) 2016, NCT Delhi**	
	Both seasons		Summer	Winter
Source	**PM10**	**PM2.5**	**PM2.5**	**PM2.5**
Road Dust	14-29	27.7	28	4
Vehicle	9-20	25.5	9	25
Industry	6-9	17.6		
Construction	23	-	3	2
Secondary Particulate	-	-	15	30
Domestic	3-9	22.7	12	26
MSW burning			7	8
Coal & flyash			26	2
DG sets	7-12	-		
Power		4.8		
others		1.8		

Table: The table is reflective of the estimation of the contribution of PM2.5 and PM10 released in the ambient air by the different sources, as per the **CPCB and IIT-K** Source Apportionment Studies (SAS) recognized and accepted by the Government. As per the data, the maximum contribution of PM comes from the road dust followed by vehicles, industry, construction, secondary particulate matter, domestic, MSW burning, coal & fly ash, etc. However, **the** SAS of **ARAI-TERI 2018 of NCR -** Data of two seasons used both models, revealed that the maximum contribution of PM comes from road dust, industry followed by vehicles and other sources. It may be noted that the vehicle contribution of PM remained static in the range of 9-25% despite the manifold increase in vehicle numbers.

3. **SIAM Environment Strategies Adopted by the Indian Automobile Sector:** Keeping with the pace of technological advancement, SIAM proactively advocating and promoting the transition towards cleaner and more environmentally friendly technologies to improve air quality and reduce the environmental impact of vehicles throughout their life cycle. In this regard, SIAM has deeper interface with the Government and international organizations for aligning with the imperatives of sustainable mobility. Therefore, SIAM has adopted several strategies, and initiatives viz. Strict Emission Standards, (ii) Biofuels as Transportation Fuel, (iii) Electrification of vehicles, (iv) Low Carbon Gas Mobility, and (v) Material Circularity and Circular Economy have been adopted in the landscape of Indian mobility:

(i) Strict Vehicle Emission Standards: The Government of India, in its efforts to minimize tailpipe emissions from vehicles and to improve the air quality in Indian cities, implemented BS-VI standards in April 2020 by skipping BS-V standards. In the BS VI emission norms, the amount of sulphur released by the tailpipe of BS-IV-compliant vehicles has been reduced five times, from 50 ppm to 10 ppm. Further, it is estimated that BS VI emission standards reduced nitrogen oxides by 88.5% and particulate matter by 50% in diesel-based heavy-duty vehicles. Whereas in diesel-based passenger cars, the reduction is 68% and 82% respectively. In the case of petrol engines, the NOx emission rate is down by approximately 25%.

Apart from the stricter उ जुन मानक (emission norms), there are the following technologically advanced devices that are being fixed in the vehicles by the car manufacturers to reduce emissions: (i) Diesel Particulate Filter (DPF), (ii) Selective Catalytic Reduction (SCR) system, and (iii) Lean NOx trap (LNT). Further, Real Driving Emission (RDE) was introduced in India for the first time to measure a vehicle's emission under real-world conditions. The onboard diagnostics (OBD) has also been made part of all vehicles. The government of India has further shown its commitment to minimizing vehicle emissions by implementing efficiency targets for new cars at the equivalent of 130 gCO_2/km in 2017 and 113 gCO_2/km in 2022. Additionally, the reduced fuel combustion would result in less incomplete fuel combustion-related hydrocarbon emissions.

(ii) Biofuels as Transportation Fuel:

The biofuels known for having low carbon and low emissions have been in focus since 2003 and are bio-origin in nature hence renewable fuels. The biofuels viz. ethanol, biodiesel, and biogas are gaining momentum and are being blended with petrol and diesel and in isolation. SIAM has played an instrumental role in ethanol blending since the beginning of ethanol blending of 5% as envisaged in the Ethanol Blended Petrol (EBP) program was launched in January 2003. With the inception of the policy, ethanol blending faced numerous challenges, and could not attain the targets of blending as scheduled.

SIAM with its motto of 'Building the Nation, Responsibly, played a critical role in ensuring the rollout of 10% ethanol-compatible engines for the smooth rollout of ethanol-blended fuels. In addition, SIAM actively engaged with the stakeholders promoting the development of a biofuel ecosystem through advocacy, knowledge sharing, best practices dissemination, and sustainable feedstock, helping in the development of a resilient and inclusive ethanol economy. With the new National Biofuel Policy 2018, India achieved 10 percent ethanol blending 5 months in advance in June 2022 and advanced availability of E20 blend by five years to 2025.

Further, SIAM under its sustainable mobility initiative, SIAM launched the जैविक पहल (bio initiative) and entered a technical collaboration with Global Ethanol Frontrunners (UNICA, USGC) & sugar manufacturing companies (ISMA). SIAM provided thrust in the strategy through multiple efforts like organizing the Ethanol Pavilion and demonstration of an FFV. The Sukh Da Saah program for preventing paddy stubble burning and its in-situ management in Punjab has been carried out successfully with a ~90% reduction in paddy straw burning since 2018. SIAM advocates mainstreaming biofuels blending across the country going forward in a bid to reduce air pollution, and GHG emissions.

(iii) Electric Vehicles (EVs) Promotion:

India is making untiring efforts to mitigate air pollution and GHG emissions to realize the – "Panchamrit targets" – announced at the COP26 in Glasgow, aiming to have at least 30% of new vehicle sales be electric by 2030. To achieve this purpose, the Government has rolled out several incentives and subsidies to promote the adoption of electric vehicles like National Electric Mobility Mission Plan (NEMMP) 2013, the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme, the Production-Linked Incentive (PLI) scheme for Advanced Chemistry Cell (ACC) etc. In fact, the momentum of EVs in India is reflective of the various demand and supply side incentives by the Government. Of course, efforts and advocacy are an essential part of the success of e-mobility in India.

Therefore, SIAM as the key stakeholder with the vision of sustainable mobility has launched the विद्युतीकरण (electrification) strategy in 2022. SIAM is extensively engaging with Government & expert committees on policy formulation and policy advocacy in support/incentives for enabling electrification across more vehicle segments EV penetration. SIAM is also for a strong regulatory framework for market conformance to the widely applicable standards nationally and internationally. Aligned with the above strategy for the electrification of vehicles, SIAM organized a series of events with EV players through the GEMS conference & pavilion. These initiatives have charted out the roadmap for the xEV revolution. All progressive States have their respective EV policy at the state level. SIAM consistently focuses on State policy harmonization, pursues priority sector lending for EVs, & supports upskilling manpower.

The ongoing electrification of mobility in India is a game-changing measure for cleaner air, however, the source of the electricity used to charge electric vehicles must flow from renewable and low-emission sources. In addition, the sustainability of battery production and disposal should be ensured to reduce the environmental impact associated with the life cycle of EVs. Nonetheless, switching to electric vehicles is a progressive step in the direction of cleaner air, reduced greenhouse gas emissions, and improved public health.

(iv) Low Carbon Gas Based Mobility:

The gas-based mobility is one of the multiple pathways adopted by the Government of India for sustainable and clean transportation. Gas mobility complements the other modes of mobility to attain low-carbon, cleaner, and sustainable mobility. Being the cleanest option and economical and environmentally friendly which facilitates forex savings, generates green jobs, and replaces fossil fuels. Accordingly, the Government has fixed a target of 8,000 CNG stations in 2024 and 10,000 CNG stations by 2030. Additionally,

Aligned with the Government policies regarding गैस गतिशीलिा (gas mobility), SIAM has been advocating expansion and promotion of a gas-based economy for achieving the goals of clean air, and decarbonization by 2070 through the higher adoption of natural gas vehicles (CNG and LNG) in India. SIAM is also supporting Biogas under the SATAT program & Gobardhan scheme to achieve energy security. SIAM's plan of action this year is to highlight CNG's role in the transition to a gas economy (15% gas in energy mix) & advocate for a reduction in the disparity of prices across states. SIAM also plans to bring gas economy stakeholders on a common platform to drive sustainable mobility with minimal tailpipe emissions.

(v) Material Circularity and Circular Economy:

The circular economy is at the core of sustainable mobility binding and integrating all aspects of sustainability together. Not only does Circularity foster decarbonization, but also helps improve air quality and road safety through the replacement of existing old and polluted vehicles. Recycling of ELVs and implementation of the EPR Regime would help with raw material conservation and provide material security. With the च ीयि initiative, SIAM is promoting vehicle scrappage policy to achieve fleet modernization, use of recycled material in new vehicles, replace old vehicles with more advanced, cleaner, and reduce mining emissions through judicious use of material. Accordingly, during the past couple of years, SIAM through policy advocacy, conferences, and seminars underlined the need for ELV Recycling for sustainable mobility integrating imperatives of– economic, environmental, and social. SIAM also unveiled a context paper on the 'ELV recycling: Status of Circular Economy in India' during the inaugural session of the international conference. SIAM plans to set up a portal to ease the ELV scrappage process, initiate discourse about harmonized policy, debottleneck the supply chain, and align with CPCB for post-recycling processing. The Recycling of ELVs in the formal sector will foster road safety and better air quality.

6. Conclusion & Way Forward: The clean air and a resilient environment are the priorities of the Government and automobile sector along with other stakeholders. The Indian automobile sector is transforming into a cleaner and low-emissions sector of the economy and has adopted imperatives like BS-VI emission norms, stringent fuel efficiency standards, mobility based on electric, biofuels, gas-based, and adoption of eco-design vehicles for material circularity for minimizing pollution, waste and GHG emissions for attaining the **Panchamrit** targets of decarbonization and sustainable development goals 2030 in sync with LiFE- Lifestyle for Environment promoting the Planet friendly practices and a sustainable way of living.

These environmental issues are affecting the health of human beings apart from biodiversity and the economy of the country. The prevention and control of toxic pollutants viz. hydrocarbons (HC), oxides of nitrogen (NO_x), and carbon monoxide (CO) among many others required consistent and sound management without compromising on environmental degradation, climate change, and sustainable development. Therefore, sustainable best practices like Environment, Social, and Governance (ESG) as well as Business Responsibility and Sustainability Reporting (BRSR) are the way forward for achieving the stated objective.

In this regard, SIAM with the support of the Government of India, and concerned stakeholders has adopted strategic measures and imperatives of sustainability enumerated in the present paper for achieving inclusive sustainable mobility.

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Pursuit of Sustainable Electro Fuels (E-Fuels) Powered Internal Combustion Engines for the Indian Transport Sector

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Technological advancements are essential for sustainable transport in India. The world is facing an alarming situation due to galloping atmospheric carbon dioxide concentrations. Hence, the discussion about "Net Zero" emissions has taken centre stage in every economic and anthropogenic activity worldwide. India has also pledged a 'Net Zero' in compliance with global concerns by 2070. The transport sector's role is crucial in fulfilling this national pledge, which would necessitate an environmentally sustainable transport ecosystem in India. Therefore, India has started making efforts to decarbonise transport using cleaner fuels. "E-fuels", also mostly carbon-neutral fuels, support the Net Zero pledge by decarbonising the transport sector and utilising carbon dioxide to produce transport/ indigenous fuel. E-fuels family comprise of methanol, hydrogen, ammonia and DME. This article covers "E-fuels" and their advantages in the transport sector in the Indian context. Efforts of the Engine Research Laboratory, IIT Kanpur, in developing E-fuel-powered vehicles and research efforts to promote E-fuels for powering internal combustion engines in India are touched upon.

Increasing atmospheric carbon dioxide (CO_2) concentration has degraded the earth's atmosphere, leading to global warming. From the early 1960s, scientists and policymakers started observing the evidence of atmospheric degradation globally due to global warming, changes in ice core thickness, vegetation, and the life longevity of human beings and animals. One of the anthropogenic reasons for atmospheric degradation is tailpipe emissions from Internal Combustion Engines (ICEs) used in different human activities. Tremendous efforts have been made in the last four decades to monitor and control the tailpipe emissions from IC engines by implementing emission norms globally, such as Euro 1 to Euro 6 norms in the EU (Euro-7 in the draft stage), EPA norms in the USA and similar norms elsewhere in the world [1]. India, the most populous country, realised the importance of tailpipe emission control in the 1990s. It started controlling them in the 2000s by implementing the Bharat stage (BS-I to BS-VI) emission norms [2]. These steps led to changes in engine and fuel injection technology adopted by the OEMs. The pledge of India's Prime Minister to achieve net zero by 2070 led to the expeditious exploration of the adaptation of cleaner fuels and re-thinking of the primary prime movers for the Indian transport sector, such as Green Hydrogen, Electric Vehicles (EVs) and fuel cells [3]. Although the penetration of EVs in the Indian market has started in the last several years, its survival heavily depends on government subsidies. The technology remains quite immature, leading to frequent fire incidents reported on Indian roads, which has shaken citizens' faith in this technology, leading to hesitance in its rapid adaption. A primary concern of many researchers of the scientific community is that EVs are merely shifting emissions from the vehicle tailpipe to the chimney of thermal power plants, with negligible effect on GHG emissions, since electricity in the grid is largely produced by burning coal in India [4]. The effort worldwide and in India is to reduce the CO_2 emissions from the atmosphere for Net Zero. Several LCA studies indicate that EVs certainly do not address that issue and likely make it even worse. On the other hand, if the CO_2 is extracted from the atmosphere or a CO_2 source for producing E-fuels using renewable electricity and renewable feedstocks, it could address the twin problem of energy security and GHG emission control.

Power-to-X conversion is significant for defining the fuel as "E-fuel" (X refers to the E-fuels), which generally denotes the conversion of CO_2-to-fuels. Hydrogen, methanol, and ammonia fall in the category of "E-Fuels" [5]. Ammonia and hydrogen don't contain carbon in their molecules, but sometimes fossil-powered electricity is used to produce them. These E-Fuels can power the existing ICE vehicles by using them as "drop-in" fuels. Also, dedicated engines can harness 100% energy from E-fuels. These E-fuels offer several advantages such as (i) helping in achieving the Net Zero, (ii) reducing fuel import bills as well as promoting indigenous fuel for the transport sector, (iii) minimising the hardware modifications in existing fuel outlets for fuelling, (iv) safety aspects are similar to gasoline/ diesel powered ICEs vehicles [6]. However, it is essential to understand that E-fuels are carbon-neutral but not Zero-carbon fuels, and this difference needs to be understood clearly. The reason for promoting them as carbon-neutral fuels is that CO_2 (sourced from the atmosphere, thermal power plants or some other source) is used for generating them and emits negligible additional CO_2 into the atmosphere.

Methanol is preferable for spark ignition (SI) engines due to its higher octane number. It can be used in compression ignition (CI) engines if appropriate modifications are done in the engine system and appropriate fuel injection system techniques are used for methanol injection. The comprehensive details of these aspects of technology development can be found in our paper [7]. DME is a suitable fuel for powering compression ignition engines, which offer sootless combustion [8]. Ammonia usage in India is in a nascent stage, and some research activities have started at ERL IIT Kanpur in this direction. Several researchers also consider e-gasoline and e-diesel as E-fuels. However, the demonstration of e-gasoline/e-diesel is underway in India on a large scale.

Figure: Transient and 2W Chassis Dynamometers for Methanol Fueled Motorcycle Development at ERL, IIT Kanpur

ERL, IITK realised the potential of "E-Fuels" powered ICEs over conventional diesel/ gasoline-powered ICEs and electric powertrains early on and started developing the "E-Fuel" powered vehicle prototypes. Several prototypes such as M15 [15% (v/v) methanol, 82% (v/v) gasoline and 3% (v/v) isopropyl alcohol] fueled 100 cc and 125 cc motorcycles, M85 [85% (v/v) methanol and 15% (v/v) gasoline] fueled 500 cc motorcycle, M15-fueled Carburetted and PFI Gensets, and a 100% DME-fueled tractor have already been developed by ERL, IIT Kanpur in last couple of years. Most of these prototypes are developed in collaboration with OEMs. Since the production of "E-fuels" using CO_2 has not started in India, ERL is trying to demonstrate the technology for producing methanol using CO_2. This technology will be developed in collaboration with TU Wien, Austria.

Recommendations

India should invest in producing E-fuels and creating infrastructure for its large-scale adaptation. This will reduce the GHG emission concentration in the atmosphere and give indigenous fuels to power ICE Vehicles. E-fuels are a win-win situation for India. Indian vehicle manufacturers should actively try to demonstrate E-fueled vehicle prototypes for the Indian market and ERL, IIT Kanpur is more than willing to work with OEMs to share this vision and help them develop prototypes. It is natural that Indian vehicle manufacturers should collaborate with Indian ICE researchers to make a "fossil-free" internal combustion engine-powered transportation ecosystem in India.

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Professor Avinash Kumar Agarwal joined IIT Kanpur in 2001. He worked as a Post-Doctoral Fellow at the Engine Research Center, UW@Madison, USA (1999 - 2001). His interests are IC engines, combustion, alternate and conventional fuels, lubricating oil tribology, optical diagnostics, laser ignition, HCCI, emissions and particulate control, 1D and 3D Simulations of engine processes, and large-bore engines. Professor Agarwal was a highly cited researcher (2018) in the top ten HCRs from India among 4,000 HCR researchers globally in 22 fields of inquiry. Also, he has been nominated for Member of the Council of the Indian Institutes of Technology (IITs) by the President of India for three years (2022-2025).

Hardikk Valera is pursuing a PhD from the Engine Research Laboratory (ERL), Department of Mechanical Engineering, Indian Institute of Technology (IIT) Kanpur. His research interests include methanol-fueled SI and CI engines, optical diagnostics, fuel spray characterisation, and engine emission control.

AVL

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AVL M.O.V.E In-Vehicle Solution for the Upcoming Euro 7 Legislation

The upcoming Euro 7 emission regulation will raise the bar for the challenge of Real Driving Emissions (RDE) development and testing. A reduction of existing limits and "new" limits are expected such as NH3 and THC/ NMHC for Light Duty Vehicles and N2O, HCHO and NMOG for Heavy Duty Vehicles. The particle number (PN) limit will be for 10nm particles instead of 23nm. For the Euro 7 challenges AVL has developed three new M.O.V.E systems:

AVL M.O.V.E NH3 PEMS

The AVL M.O.V.E NH3 PEMS uses robust laser diode spectroscopy to measure the NH3 concentration during RDE. The device has been developed to address the upcoming Euro7 requirements and is an extension of the M.O.V.E iS+ system.

AVL M.O.V.E FT

The AVL M.O.V.E FT is based on an FTIR spectrometer that simultaneously measures multiple pre-calibrated exhaust gas components. The device has been developed to address the upcoming Euro7 requirements and may be used stand alone or as an extension to a M.O.V.E iS+ system.

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Thermal shock risk of On-road application in India use

Author, co-authors (Naoki KAWAMURA ,Hokuto OZEKI, Thalagavara ABISHEK)

Abstract

Exhaust gas regulations are being tightened around the world, and diesel cars are equipped with DPFs to collect soot emitted. Numbers of vehicles with DPF are running now in the Indian market than in 2019 as to meet BS6 regulations. Although DPF system, a mature system, has been used for a long time in Europe and the United States, there are many information of DPF damage related to thermal shock occurs in the field .The authors assumes HC in the ATS derives from heavy traffic causes DPF regeneration out of control. Although traffic conditions in India has been improving, traffic jams still occur frequently in cities. Under the condition, the engine is in an idle state for most of the time, and since the exhaust gas temperature is low in this state, ATS becomes inactive. Specifically, DOC oxidation performance will be reduced and lead to HC adsorption state, and soot accumulated in the DPF cannot passively regenerated. DPFs require regeneration process to remove soot, but if passive regeneration is difficult, DPF need high temperature to force regeneration actively. HC adsorbed on DOC during traffic jams will be supplied to the DPF as temperature rises during driving. It is predicted that this will accelerate soot combustion and lead to abnormal combustion. In this paper, authors conducted DTI* tests in high temperature at 620degC and low temperature at 350degC to investigate the effects of HC. (*Drop-to-idle: Abnormal regeneration caused by supplying high-concentration oxygen to the DPF when the vehicle is in an idle state with the accelerator off during forced regeneration while driving.)

First, authors intentionally idled the vehicle for 4 hours to simulate heavy traffic, and then increased temperature gradually to examine the desorption status of HC. Figure 1 shows desorption of HC from DOC. Under normal driving condition, maximum desorption is approximately 1980ppm, but higher than 10520ppm (approximately 5 times more) was confirmed from the test. .

Figure 1 Maximum HC desorption amount from DOC

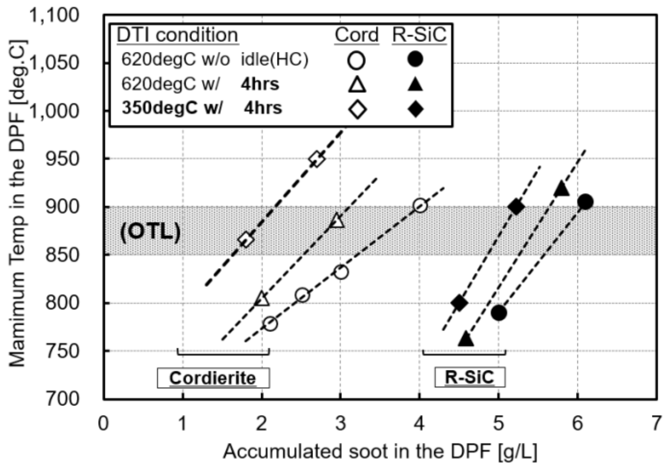

Figure 2 Maximum temperature in the DPF when DTI occured

As next step, DTI was performed with Cordierite filters (9mil/300CPSI) from the market and thin wall products of R-SiC(IBIDEN). Figure 2 shows the relationship between maximum temperature and amount of soot accumulated inside DPFs before DTI. The results showed that maximum temperature reaches higher when HC is supplied from DOC. Arthurs assume that part of HC desorbed from DOC was supplied to DPF as energy source and thus soot combustion was accelerated. On the other hand, DTI at 350degC under HC supply reached higher maximum temperature than that of 620degC even though 350degC is normally not soot combustion temperature. Authors assume HC amount remained higher under lower DPF temperature which accelerated soot combustion.

From the test results, when driving in India where heavy traffic normally occur, there are always high risks of DPF damage. To be on a safe side, authors strongly recommended to use a highly robust DPF, R-SiC DPF, which exhibits high thermal conductivity as well. Both robustness and high thermal conductivity offer high SML and can offer lower pressure loss when thin-wall cell structures are selected. This would also improve power of vehicle and fuel consumption which leads to eco-friendly. Arthurs believe R-SiC would be the best DPF solution when used in India and other regions in the world where heavy traffic are seen.

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Innovative Closed- Couple Metal Substrate for DOC: An Optimized Solution for TREM V Indian Tractor Applications

Paresh Laddha - Emitec Technologies India Pvt. Ltd.

1. Introduction

With Indian Context, the emission limits for TREM V will be derived from European Stage V, so the wide range of experience in EU stage V can be used to implement TREM V in India accordance with the Indian farm tractor usage & application. In this paper we will elaborate and relate the ideas, strategies and technologies used for one of the stage V farm tractor application with innovative closed couple DOC design with the CS substrate structure.

2. Engine Specification & After Treatment System Layout

An engine with 2.9 l displacement (3 cylinders) and 3.8 l displacement (4 cylinders) have 2-valve cylinder heads, a common rail high-pressure injection system up to an injection pressure of 2,000 bar and a cooled exhaust gas recirculation (EGR). To meet the needs of different markets, the engine is offered in a Stage IV/Tier 4 certified configuration with a simple, compact EATS (SCR without DOC), but also as a Stage IIIB/Tier 4 interim version (DOC only) and as a non-emission reduced version. The general impact of these features is reflected in a maximum rated power of 75 kW for the 3-cylinder engine and 100 kW for the 4-cylinder engine.

The Stage V engine is equipped with a DPF to filter out particle mass (PM) from the diesel exhaust by physical filtration. Most of the material trapped in the filter is carbon particles with isolated hydrocarbons (HC). The particle mass can be removed with oxygen (O_2) or with nitrogen dioxide (NO_2). Systems based on NO_2 have clear advantages because the reaction takes place at temperatures that are usually present in diesel exhaust gases.

The DPF uses the so-called Continuously Regenerating Trap, in which an oxidation catalyst is used in front of the filter to generate the NO_2 required for cleaning. Up to a certain PM threshold, the NO2-based oxidation reaction keeps the soot approximately at the equilibrium point and oxidizes the entire particle mass generated by the engine.

3. Innovative canning layout for Stage V

The DPF of a engine works as a passive system that can regenerate using the exhaust gas flow and without additional energy sources. The dissipation of the exhaust heat along the EAT components (DOC, pipes, manifolds, etc.) leads to exhaust gas temperature losses, which adversely affect the chemical reactions that are to take place in the catalysts (HC, CO and NO oxidation in the DOC, the PM oxidation taking place in the DPF).

In the operational regeneration of the particulate filter, the exhaust gas temperature loss within the DOC is minimized by compact DOC system. This avoids the heat exchange between the high exhaust gas temperatures with the environment via the large exchange surfaces of the DOC canning.

In the original geometry, the gases coming from engine enter the catalyst (section 2) directly through the inlet opening of the DOC (section 1). There, the exothermic reaction causes the gas temperature to rise to a level that ensures complete regeneration of the DPF. The hot gases flow out of the catalyst (section 3) and to the outlet opening of the DOC (section 4), washing out all the inner surfaces of the canning, exchanging a large amount of heat with the environment and deteriorating the high energy level of the gases.

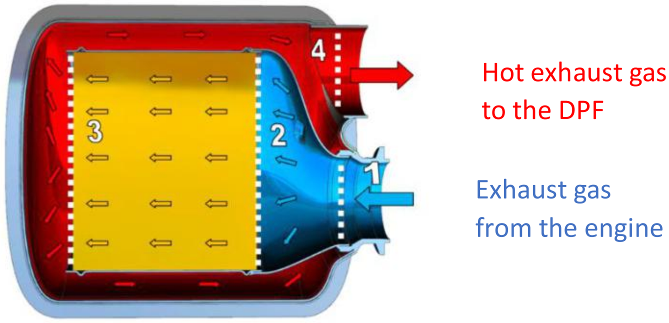

***Figure 1** – Gas flow sequence in the DOC with "direct" flow*

The innovative idea implemented in the DOC of the Stage V engine is a modified gas flow path within the DOC channels to shift the exothermic reaction backwards along the gas path and thus avoid energy loss via DOC canning. Through the inlet opening of the DOC (section 1), the exhaust gas flows around the substrate and then enters the catalytic converter (section 2), where – in certain operating modes of the engine and/or the EATS – HC is oxidized, so that the exhaust gas temperature increases significantly (e.g. mode "Assisted soot oxidation" or "Particulate filter operating regeneration"). The hot exhaust gas (section 3/4) is then directed to the DPF, where the particle mass is oxidized.

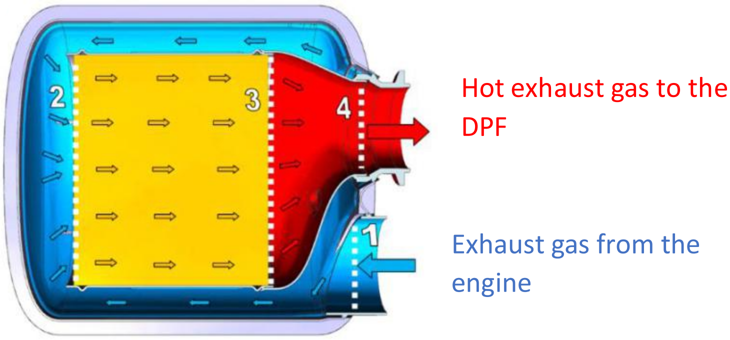

***Figure 2** – Gas flow sequence in the DOC with "reverse" flow*

Thanks to this innovative layout or gas flow sequence (patent pending), the DOC of the engine reduces heat dissipation during the exothermic catalytic oxidation reaction. This reduces the overall exhaust gas temperature loss via the EATS and ensures that there is a sufficient gas temperature before the DPF to support complete PM regeneration over the lifetime of the particulate filter. The exhaust gas temperature gain achieved by the innovative DOC layout was initially predicted using CFD simulations and then confirmed by experimental tests.

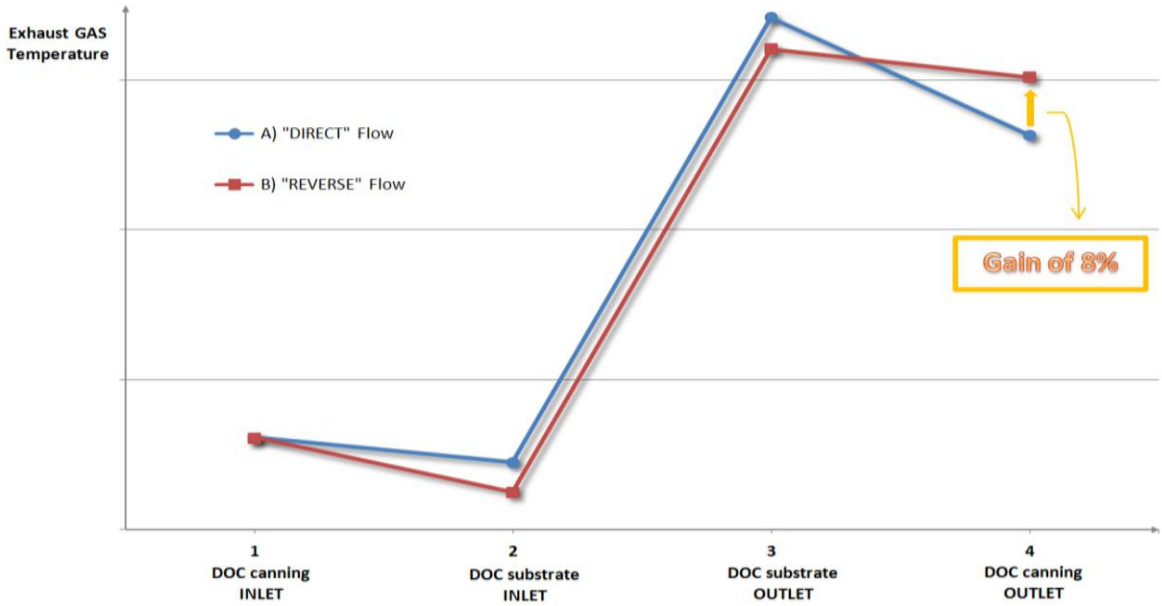

***Figure 3** – Comparison of exhaust gas temperature losses between "direct" and "reverse" gas flow sequence in the DOC of the engine*

4. Optimized Canning Solution for Indian TREM V Applications

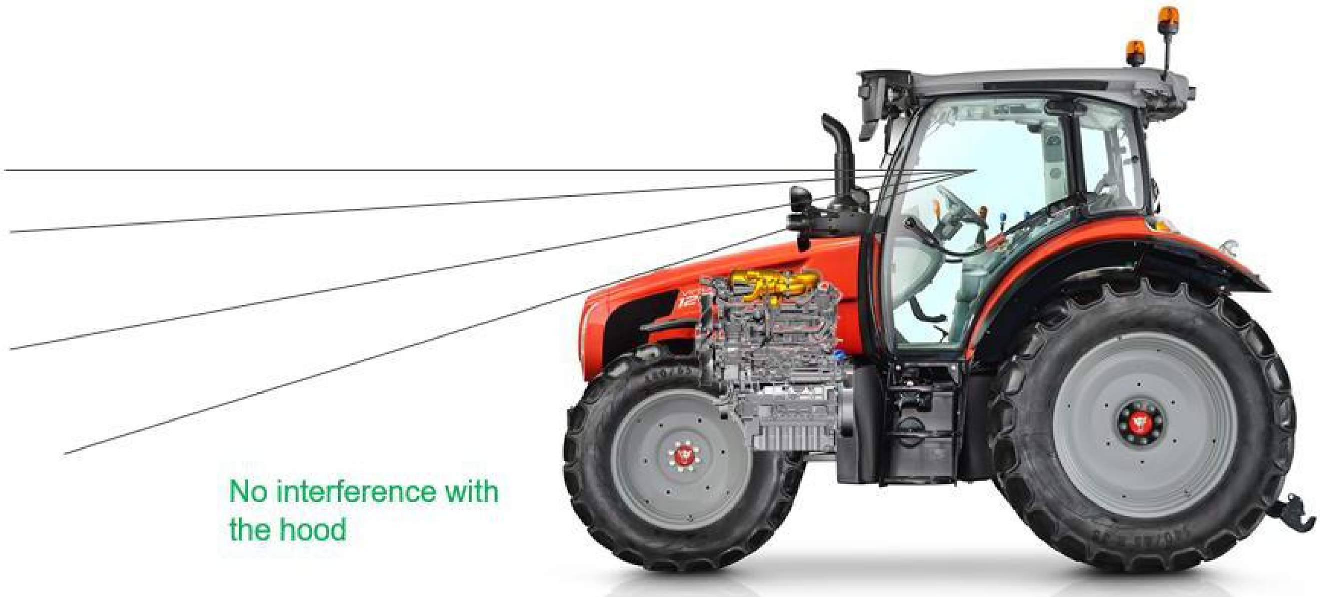

***Figure 4** – Under hood tractor application*

The packaging achieved is an optimal solution as it allows farmers an extended field of vision while complying with safety requirements and emission limits. Based on study and experience in the Stage V, an innovative canning of under-hood application along with closed couple of DOC + DPF will be a good solution for Indian tractors to meet the TREM V regulations. This canning technology reduces heat dissipation during the exothermic catalytic oxidation reaction and helps with the DPF regeneration with enough temperature by having it in the Hybrid canning system.

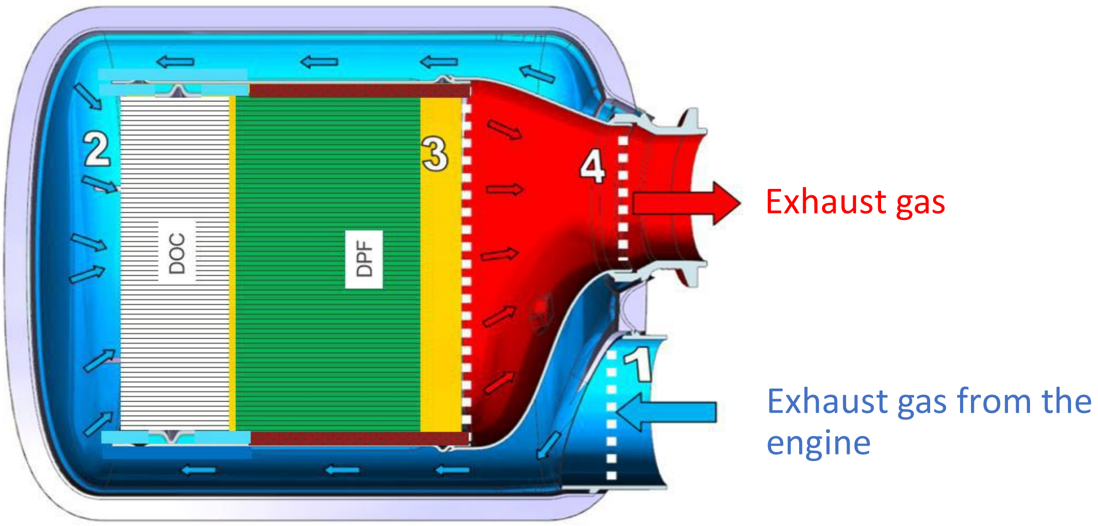

***Figure 5** – Compact design with DOC + DPF*

For Indian tractor application for TREM V, we need more compact solution considering the wide range of operating conditions, so keeping the fact that the most of the Indian tractors are low power tractors we can incorporate both DOC and DPF thus avoid energy losses as well as compact in nature. Through the inlet opening (section 1), the exhaust gas flows around the substrate and then enters the DOC (section 2), where – in certain operating modes of the engine and/or the EATS – HC is oxidized, so that the exhaust gas temperature increases significantly. The hot exhaust gas is then directed to the DPF, where the particle mass is oxidized. And then the exhaust gas leaves the system through section 3& 4.

Summary and outlook

For TREM V Tractor applications, the new compact DOC + DPF layout minimizes space requirement, ensuring robust and complete PM regeneration.

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A Brief Review on the Operability Challenge of Bio diesel due to Cold Flow Properties of Biodiesel and its Blends

C. B. Remesan, India

Introduction

Prime Minister Shri Narendra Modi along with the leaders of Singapore, Bangladesh, Italy, USA, Brazil, Argentina, Mauritius and UAE, launched the Global Biofuel Alliance on 9 September 2023, on the side lines of the G20 Summit in New Delhi.

On the one hand, reduction in GHG emissions, energy security and rural development are the most important drivers for biofuels globally. On the other hand, there are concerns related to increasing the production of biofuels, such as upward pressure on food prices, the risk of increase in GHG emissions through direct and indirect land-use change (LUC) from production of biofuel feed stocks, as well as the risks of degradation of land, forests, water resources and ecosystems.

India's Biofuel Policy 2018 On May 18, 2022, the Union Cabinet, chaired by Prime Minister Modi, approved the Amendments to the 2018 National Biofuels Policy that incorporated various advancements in biofuels production and accelerated the E20 mandate to April 1, 2025.

The revisions aimed for India to reach energy independence by 2047.

Key amendments to the biofuels policy include:

(i) Allowing the scope for more feed stocks toward biofuel production.

(ii) Advancing the target of E20 to ESY 2025/2026 from 2030 (originally announced on January 29, 2021).

(iii) Promoting domestic production of biofuels through Special Economic Zones and Export Oriented Units under the "Make in India" strategy. Developing indigenous technologies and generating more employment in the biofuels sector.

(iv) Expanding the member base of the National Biofuel Coordination Committee (NBCC)

(v) Allowing biofuel exports in specific cases.

(vi) Allows adjustments to biofuel targets stated in the NBP based on decisions taken during NBCC meetings. The 2018 National Biofuels Policy prioritizes ethanol production from sugarcane, sugar juice derived from products including sugar beet, sweet sorghum, starch-containing crops (maize, cassava), and damaged food grains (broken rice).

{Data Sources: Government of India Ministry of Petroleum and Natural Gas and Indian government Press Information Bureau (PIB) announcement|

The policy also makes provision for the use of surplus food grains for ethanol production under the EBP mandate with the approval of the NBCC.

Additionally, India's biofuels policy intends to achieve the following:

(A)Reduced oil import bill and increasing self-reliance: According to the MoPNG's view, a successful E20 program can result in potential savings of $4 billion3 per year. Since 2021, India has imported close to 86 percent of its petroleum requirements, with approximately 98 percent of its fuel requirement in the transportation sector being met by fossil fuels.

(B) Protecting economic interests of farmers: India's OMCs have paid sugar mills approximately $5.4 billion for ethanol through the EBP. Additionally, the inclusion of damaged and surplus food grains as a feedstock means supplemental income for producers.

(C) Reduced emissions: According to MoPNG, from 2014-2021, the EBP would result in 19.2 million metric tons (MMT) less greenhouse gas (GHG) emissions.

(D)Improved ease of doing business through technology: Through the implementation of the Industries Development and Regulation Act, Indian state governments conduct business facilitating activities such as e-approvals and permits, and electronic and GPS tracking of the ethanol logistics fleet.

India has retained its target of achieving five percent blending of biodiesel with conventional diesel by 2030. The Indian government envisions that the targets will be met through the growth in domestic biofuel production (1-G, 2-G, and 3-G 4), use of multiple feedstock, and encouraging biofuel blending to supplement gasoline and diesel use in vehicles and machinery, as well as in stationary and portable power applications.

India retains an aspirational biodiesel blend goal (on-road use) of B5 by 2030. In 2022, the national average blend rate is estimated at 0.07 percent only. The Indian biodiesel industry is limited by low access to feedstock at viable prices. Due to limited feedstock alternatives, Indian domestic investments in production and technology are limited. On the demand side, rampant and widespread use of spurious, cheaper oil alternates are sold as biodiesel, posing regulatory and oversight challenges.

Biodiesel is manufactured from imported palm stearin, palm acid oil, and small volumes of non-edible oils, UCO, and domestically sourced animal fats. For years, field trials used jatropha, some tree-borne oilseeds, and other non-edible oilseeds grown on non-arable, rain-fed lands. Attempts failed to advance due to low yields. Jatropha is a genus of flowering plants in the spurge family, Euphorbiaceae. Treeborne oilseeds include Karanja, Mahua, Neem, Jojoba, Wild Apricot, Cheura, Kokum, Simarouba, etc.

Table 1 India Biodiesel Production from Multiple Feedstocks (Million Liters)

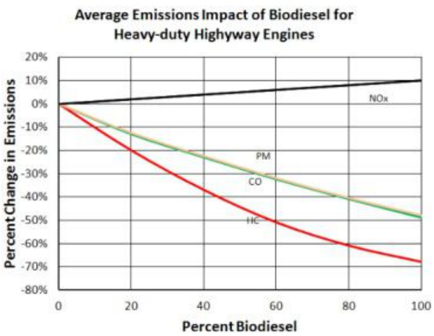
Calendar Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022f
Beginning Stocks	14	15	11	13	13	18	25	23	16	26
Production	132	138	152	158	170	185	230	200	180	185
Imports	0.3	1.7	0.8	2.7	7.1	25.2	7.0	1	1	1
Exports	3.9	41.5	33.1	41.7	7.6	23.1	54.0	68	6	10
Consumption	128	102	118	119	165	180	185	140	165	180
Ending Stocks	15	11	13	13	18	25	23	16	26	22
Production Capacity (Million Liters)										
Number of Biorefineries*	6	6	6	6	6	6	6	6	6	7
Nameplate Capacity	465	480	500	550	600	650	670	580	520	577
Capacity Use (%)	28.4	28.8	30.4	28.7	28.3	28.5	34.3	34.5	34.6	32.1
Feedstock Use for Fuel (1,000 MT)										
Non-edible Industrial	70	75	85	90	100	110	140	145	90	110
Used Cooking Oil	49	50	55	55	55	60	65	50	55	70
Animal Fats & Tallow's	7	6	5	6	6	8	10	9	9	6
Total	126	131	145	151	161	178	215	204	154	186
Market Penetration (Million Liters)										
Biodiesel, on-road use	49	32	41	48	72	83	100	50	10	40
Diesel, on-road use	49,354	49,605	52,239	55,179	56,715	59,220	60,145	44,400	52,927	57,002
Blend Rate (%)	0.10	0.06	0.08	0.09	0.13	0.14	0.17	0.11	0.02	0.07
Diesel, total use	82,256	82,674	87,064	91,965	94,524	98,700	100,241	74,000	76,270	79,283

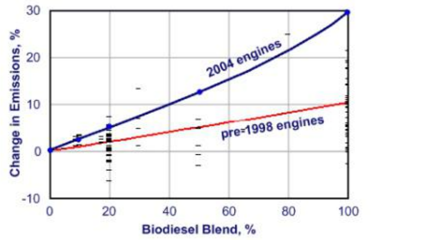
Data source: FAS New Delhi Research and historical data series, TDM and Industry Sources.
f =Year 2022 is projected.
*Indicates theoretical estimate.

The Centre is strongly advocating among transporters and corporate consumers of diesel Gen-sets such as telecom operators for the use of biodiesel. However, its shortage across India, worry about damage to the engine & FI systems when used at different terrains, and lack of clarity on the use of environment-friendly fuel have put a brake on its increased usage.

Biodiesel Quality Challenges

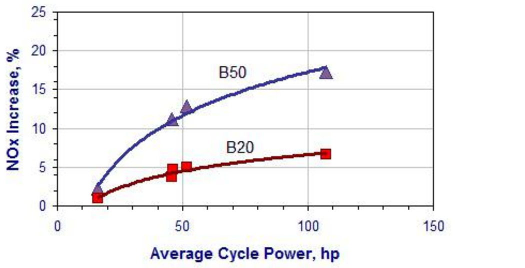
The major drawback of biodiesel is its high density and viscosity. To overcome this limitation, the biodiesel is mixed with conventional oil or diesel to escalate the fuel intake and cold start. Moreover, the lower the energy density, the higher the fuel consumption. Conversely, biodiesel offers impressive performance in traditional IC engines. Using biodiesel in conventional machines reduces the emission of pollutants by approximately 78%. This reduction depends upon the two fuels' blending ratio and quality of feedstock.





NOx emissions with biodiesel blends: Engine dynamometer tests

Scattered data points refer to pre-1998 curve

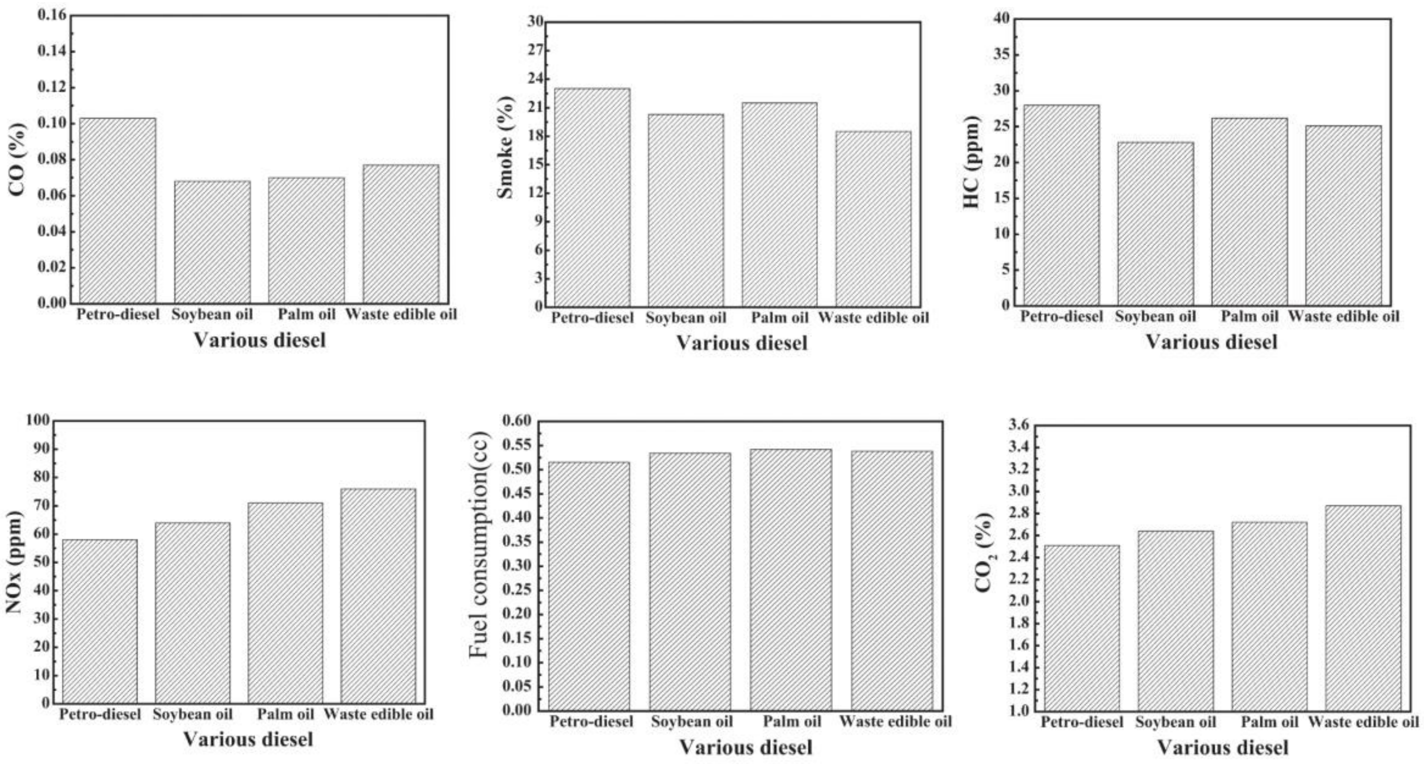


:. Effect of driving cycle average power on relative NOx emissions

Source : U.S. Dept. of Energy– Energy Efficiency & Renewable Energy &DieselNet

Exhaust emission characteristics of various types of biodiesel fuels

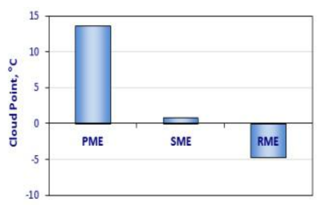
Reduced greenhouse gas emissions are a major advantage of using biodiesel on diesel engines. But the three biodiesels (soybean oil, palm oil, and waste edible oil) in the same engine gives varied performance & emission results as given below.



Source : Sage Journal Article published online on July 15th July 2015 by De-Xing Peng

Cold Flow Properties

Similarly the Cold Flow Properties of Biodiesel and its Blends varies depending on the base feed stock as given below



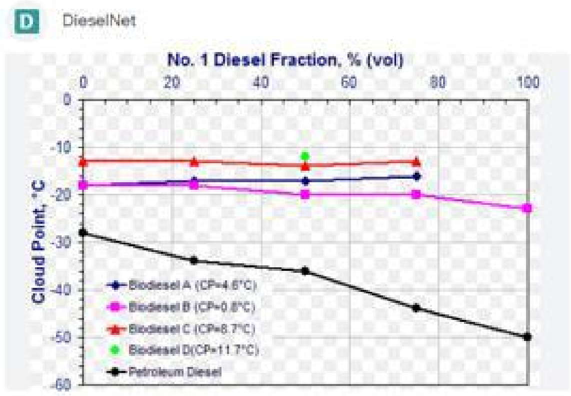
Average Cloud Point for Palm Oil (PME), Soybeans (SME) and Rapeseed (RME) Biodiesel

Biodiesel made from different feedstocks may have different cloud and pour points:

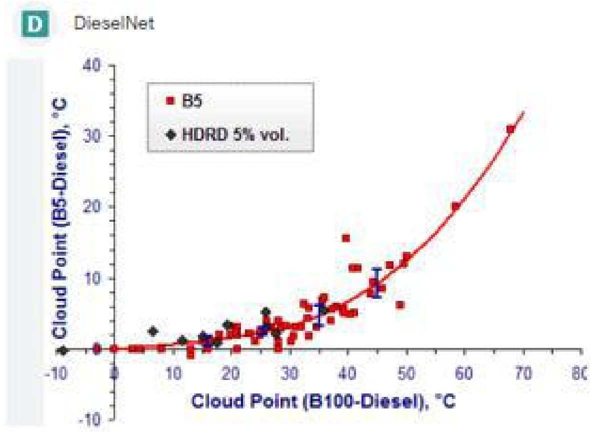
Biodiesel Feedstock	Cloud Point (degrees Celsius)	Pour Point (degrees Celsius)
Soybean oil	1	0
Canola oil	0	-9
Palm oil	17	15
Jatropha oil	8	6
Tallow	12-17	6

Sources: Moser (2008), Vyas et al. (2009), Mittelbach and Remschmidt (2005).

The range of compounds that compose biodiesel, however, are very limited and varying fuel composition provides a much narrower range of adjustment. To add to the challenge, most biodiesel contains a significant proportion of saturated long chain fatty acid s that are very similar to the long chain paraffins whose concentration is undesirable in diesel fuels when low temperature operability range is to be extended. Thus, achieving acceptable low temperature operability limits with biodiesel blends can be a significant challenge.



Low Temperature Operability of Biodiesel



Low Temperature Operability of Biodiesel

Generally, both diesel and biodiesel fuels experience such issues during the winter season and in colder regions of the world; however, the condition is worse with biodiesel. Cloud point (CP) and pour point (PP) are the two primary properties for fuel to determine their cold flow specification (Boros et al., 2009). If blends of diesel and biodiesel fuels are exposed to cold temperatures for a significant period (e.g., parking outside for a few hours at night), the higher CP of the biodiesel could lead to gelation of the biofuel earlier than that of the regular diesel.

There are insufficient field-based investigations and detailed reporting about this cold weather effect on biodiesel, based on an assortment of feed stocks from various regions (Dunn, 2009; Monirul et al., 2015; Tinprabath et al., 2016).

While biodiesel possesses numerous benefits, the cold flow properties (CFP) of biodiesel in comparison with petro-diesel are significantly less satisfactory. This is due to the presence of saturated and unsaturated fatty acid esters. The poor CFP of biodiesel subsequently affects performance in cold weather and damages the engine fuel system, as well as chokes the fuel filter, fuel inlet lines, and injector nozzle. Previously, attempts were made to minimize the damaging impact of bad cold flow through the reduction of pour point (PP), cloud point (CP), and the cold filter plugging point (CFPP) of biodiesel. As per IS 15607 for Biodiesel (B100)- Faty Acid Methyl Esters (Fame) – specification, CFPP specification for Summer & Winter is 18 and 6 deg C respectively.

The CFP of biodiesel fuel can be improved by utilizing different techniques. Winterisation of some biodiesel has been shown to improve CFP significantly. Additives such as polymethyl acrylate improved CFP by 3-9 ° C. However, it is recommended that improvement methods in terms of fuel properties and efficiency should be carefully studied and tested before being implemented in industrial applications as this might impact biodiesel yield, cetane number, etc.

Though generally overlooked by biodiesel producers, the CP is an equilibrium attribute of the fuel which can be expressed as linear functions of both the cold filter plugging point (CFPP) and the low-temperature filterability (LTFT) (Dunn and Bagby, 1995; Boros et al., 2009). If the CP of biodiesel is neglected in an environment having a temperature lower than the CP, the number of crystals produced in the fuel will increase with the reduction of temperature. Thus, this will affect fuel viscosity, pouring ability, filtration capacity, and volatility, etc. As a result, fuel starvation could be engendered in the combustion chambers. The engine's ability for start-up, as well as the drivability, could also be affected due to fuel starvation (Kim et al., 2012; Dwivedi and Sharma, 2014).

Approaches to Improve the Cold Flow Properties of Biodiesel

The cold flow of properties of biodiesel can be improved in a variety of ways. **Winterization** (Dunn et al., 1996), **mixing additives** (pour point depressant) (Chiu et al., 2004; Kumar and Singh, 2020), **blending with diesel fuels** (Magalhães et al., 2019), using branched-chain esters (Lee et al., 1995), **blending with vegetable oils of lower crystallization temperature** (Foglia et al., 1997), etc. are the more commonly used processes to improve the lower temperature flow properties of the fuel.

Winterization of biofuel involves selective long-chain saturated components crystallization using controlled cooling conditions and removal of the crystallized fractions (Kumar and Singh, 2020). This increases the unsaturated FAME contents of biodiesel and reduces both CP and PP (Dunn et al., 1996; Fuel, 2003; Kerschbaum et al., 2008; Dwivedi and Sharma, 2014b). However, the removal of saturated FAME contents by this process decreases the CN of the fuel, as well as the loss of the total yield of biodiesel, by a significant quantity (Edith et al., 2012). Furthermore, this process may also make fuel susceptible to oxidative damage (Kumar and Singh, 2020). The loss may be minimized when the winterization process is executed after adding cold-flow property improving agents (e.g. hexane, isopropanol, etc.) (Knothe, 2005).

Vijayan et al. (Vijayan et al., 2018) carried out winterization of biodiesel at low temperatures (0°C–20°C) and found that sunflower biodiesel exhibited no crystal formation. Kumar and Sharma (Kumar and Sharma, 2018) used a 3-step winterization process and reported a reduction of CP by 5.5°C and a reduction of PP by 8.2°C. However, the authors also reported a reduction of 5.4%–15% biodiesel yield due to winterization.

Nainwal et al. (Nainwal et al., 2015) conducted winterization tests of Jatropha methyl ester and Waste Cooking Oil Methyl Ester at a temperature 2°C lower than the respective CP. They observed a reduction of 4.1 wt% and 2.3 wt% of saturated FAMEs, respectively. The CP and PP were reduced by 11.8% and 8.3% for JME, 20.6%, and 22.6% for WCOME, respectively.

Using Additives

Mixing suitable additives to improve the low-temperature characteristics of biodiesel is one of the more effective and efficient methodologies. Such additives are known as cold flow improvers (CFI). This process is convenient with significantly less investment (Chiu et al., 2004; Wang et al., 2014). CFI additives modify the agglomerative nature of the crystals in low temperatures, as well as transform their shapes from typical plate to needle-like. These smaller crystals do not face viscous resistance while flowing through the fuel filter and injector (Echim et al., 2012). The crystals are also incapable of forming gelation characteristics that disturb the pouring behavior of the fuel. Generally, the pour point depressant (PPD) type CFI additives are most effective for biodiesel (Chastek, 2011).

To observe the cold flow characteristics of WCOME, Wang et al. (Wang et al., 2014) considered four categories of frequently used PPD type CFI additives, namely: polymethyl acrylate (PMA), ethylene-vinyl acetate copolymer (EVAC), poly-α-olefin (PAO), and polymaleic anhydride (HPMA). Analyses showed that the addition of these CFIs of 0.04 wt% of the WCOME can effectively improve cold flow

characteristics by reducing the CP, CFPP, and PP of the fuel. They reported that the effectiveness order of the additives is PMA>EVAC>PAO>HPMA, with the best contribution from PMA. The addition of CFI additives also influences the amelioration of both OSI and kinematic viscosity in favor of biodiesel operability. Leggieri et al. (Leggieri et al., 2018) used dimethyl azelate and triacetin as additives to improve FAME cold flow properties. However, they were only able to improve the CP slightly by 2–3°C. Dimethyl azelate alters the crystal formation to reduce the CP. Monirul et al. (Monirul et al., 2017) used poly(methyl acrylate) (PMA) to improve the cold flow properties of biodiesel-diesel blends.

Ozonized vegetable oils (0.5–1.5 wt%) could be considered as partially effective CFI additives for biodiesel fuels such as SFME, SBOME, RME, and POME (Soriano et al., 2006). The authors stated that ozonized vegetable oil (oz-VO) derived from the same source can be more effective in reducing the PP of biodiesel fuels–e.g., SFME, SBOME, and RME among others, with less effect on CP reduction. The higher amount of saturated FAME content in POME makes the oz-VO of palm oil ineffective to reduce the PP of POME, but the reduction of CP was observed from 18°C to 12°C. The authors explained through microscopic analysis that, the addition of oz-VO on the respective biodiesel forestalls the accumulation of crystals during temperature reduction by forming smaller regular-shaped crystals. As a result, the flow property is improved for biodiesel fuels.

Blending With Conventional Diesel Fuel

When biodiesel is blended with conventional diesel fuel, the overall quantity of FAME is reduced. Various types of biodiesels were blended effectively with diesel fuel such as palm oil, Jatropha curcas, Ceiba pentandra, Reutealis trisperma, Calophyllum inophyllum, etc (Ong et al., 2014; Dharma et al., 2016; Silitonga et al., 2019; Silitonga et al., 2020). As a result, the total effect of the biodiesel fuel property is changed from that of B100. Kim et al. (Kim et al., 2012) investigated the cold temperature (−16°C and −20°C) effect of various blends (B5, B10, and B20) of biodiesel fuels derived from soybean oil, waste cooking oil, rapeseed oil, cottonseed oil, palm oil, and Jatropha oil in both passenger car and light-duty truck engines. Based on the 'start ability test' and 'drivability test' for these samples, the researchers found that the B5 blends could pass the test for all of the test conditions. The other blends experienced some problems in these temperature ranges. Bencheikh et al. (Bencheikh et al., 2019) studied the effect of blending diesel with waste cooking biodiesel on cold flow properties. The authors reported that blending 80% diesel with 20% waste cooking biodiesel reduces CP, PP, and CFPP by 17, 21, and 21°C, respectively.

Nainwal et al. (Nainwal et al., 2015) reported that blending high CP and PP based jatropha methyl ester (CP 20.2°C, PP 18°C) as well as waste cooking oil methyl ester (CP 14.5°C, PP 13.7°C) with conventional diesel (DF2, CP 6°C, PP 5°C) at various ratios results in a reduction of CP and PP of the blends. The CP and PP of B20 blends were found to be 14.9°C and 14°C for JME as well as 12°C and 11.5°C for WCOME, respectively. The researchers explained the effect as a cause of the reduction of total saturated FAME in the blend. The addition of JME and WCOME with kerosene (DF1, CP −10°C, PP −11°C) also reduced the CP and PP of the biodiesel blends significantly. The CP and PP of B20 blends were found as −1°C and −2.2°C for JME as well as −10.5°C and 12°C for WCOME, respectively (Nainwal et al., 2015).

Bhale et al. (Bhale et al., 2009) investigated the effect of ethanol and kerosene blends on improving cold flow properties of mahua methyl ester (MME, CP 18°C, PP 7°C) in place of additives. This involved a blend of MME with 20% ethanol, and 20% kerosene for which the CP and PP reduced to 8°C, 5°C, and −4°C, −8°C, respectively. The researchers reported pour point depression from 7°C to −5°C for the mix of 10% ethanol and 10% kerosene blend but did not publish the CP. The PP reduction (from 7°C to −5°C) of MME fuel was comparable to that of adding 2% Lubrizol.

Addition of Branched-Chain Fatty Acid Alkyl Esters

Branched-chain fatty acid methyl esters (BC-FAME) can be used as additives (e.g., methyl iso-oleate and methyl iso-stearate) as well as diluents to reduce the CP and PP of biodiesel (Knothe et al., 2000; Knothe, 2005; Dunn et al., 2015). The saturated BC-FAME (Me iso-C18:0) showed a better effect than that of unsaturated BC-FAME (Me iso-C18:1) to improve the cold flow property of the POME, CME, and SME when used as additives (up to 2%). A similar trend of effectiveness was also reported when these BC-FAMEs were used as diluents. Up to 50% mix of Me-iso-C18:0 as a diluent reduced the CP and PP of POME, CME, and SME up to acceptable ranges. Since there is no comparison of combustion and emission performances of these diluent fuel mixtures, further investigation will be required to assess this method's economic impact. Other branched-chain esters, e.g. isopropyl as well as 2-butyl esters of fats and oils, typically have better low-temperature flow properties than their corresponding straight-chain isomers (Knothe et al., 2000).

Etherification of glycerol by-product from the biodiesel production process leads to the production of ethers of glycerol, which is then mixed with the pure biodiesel. As a result, the CP of the fuel reduces to lower than 0°C, approximately −5°C without the addition of any CP reducing reagents. The authors (Noureddini, 2001) also found that the di- and tri-ether glycerol had better performance in reducing the cold flow property of the biodiesel. An overall dose of 12% ethers mixed with 88% methyl soyate can achieve the above-mentioned CP.

Blending of Biodiesels

To solve the problem of poor biodiesel properties, the blending of biodiesels is a simple but effective method. Biodiesels of various FAME profiles are blended to achieve the acceptable CP, CFPP and PP for a particular regional application in the engines. The blending of different types of biodiesels can resolve the shortcoming of some biodiesels to be used in the low-temperature environment (Silitonga et al., 2013; Silitonga et al., 2018; Ong et al., 2019). For instance, palm: rapeseed: soybean blends of 20:60:20, 20:80:0, 40:20:40, 40:40:20, and 40:60:0 showed CFPP of −6°C, −5°C, −2°C, −3°C, and −3°C, respectively (Park et al., 2008). Among these blends, the ternary blend of 20:60:20 (palm: rapeseed: soybean) shows the best cold flow property by making good use of the unfavorable palm (CFPP 11°C) and soybean (CFPP −3°C) oils with rapeseed (CFPP −20°C).

As per the data provided (Park et al., 2008), the total unsaturated FAME content of palm, rapeseed, and soybean biodiesel fuels are 54.26%, 92.88%, and 83.16%, respectively; for which the CFPP value from the above correlations could be found as 9.58°C, −19.172°C, and −4.53°C. The correlations show the variation of −12.9%, −4.14%, and +51% of the reported CFPP values for palm, rapeseed, and soybean biodiesel, respectively. Blending methyl oleate (MO) with POME also reduces the CP and CFPP of the fuel but reduces the OS of the fuel (Altaie et al., 2015; Dunn, 1999). Altaie et al., (2015) observed that the 50:50 (POME: MO) blend can significantly improve the cold flow behavior of POME by reducing its CP from 18°C to 5.33°C and CFPP from 16°C to 1.33°C.

Sbihi et al., (2018) reported that cold flow properties depended upon the saturated and unsaturated FAMEs. Saturated FAMEs have a higher melting point that deteriorates the cold flow properties. In order to reduce the saturated FAMEs, the authors blended Citrillus colocynthis oil biodiesel and Camelus dromedaries fat biodiesel. They reported that the blend reduced the saturated FAMEs and as a result, there was a significant improvement of cold flow properties. Furthermore, the authors also reported an improvement in cetane numbers due to blending.

Ghanei, (2014) blended castor oil methyl ester with conventional diesel fuel, canola methyl ester, and waste frying oil methyl ester to investigate the low-temperature properties CP and PP. The reference value for the blending ratio was determined based on the kinematic viscosity (≤6 mm2/s) at 40°C as per the ASTM D-6751 standard. Based on the investigation, the maximum amount of castor oil methyl ester content in the diesel, canola methyl ester, and frying oil methyl ester are 48%, 35%, and 58%, respectively. The CP of these blends were found as −9.57°C, −6.50°C, and −5.71°C, respectively, and the PP values, are found as −22.20°C, −14.14°C and −13.35°C, respectively, for castor-diesel, castor-canola biodiesel, and castor-frying oil biodiesel blends. This blending technique seems effective, as the process of blending the biodiesel fuels not only improved the low-temperature flow characteristics of the fuel but also kept the viscosity within the standard limit. As a result, the process of improving one property would not have an adverse effect on another fuel property.

Conclusion

The cold flow properties have been observed as a considerable characteristic of fuel only in cold regions. Therefore, thermally susceptible fuels should be treated well by any of the effective methodologies presented here. In addition, the mixing of various methodologies could be significantly acceptable to optimize the result due to the necessity of using the most stable fuel in any environment. Winterisation of biodiesel resulted in the reduction of saturated fatty acid and thus improved cold flow properties. However, sometimes it may also influence biodiesel yield and the cetane numbers negatively. The polymethyl acrylate (PMA) additive improved the CFP by 3 –9°C. Both the blending and mixing of CFI additives present potential candidates for improving the cold flow properties of any fuel or fuel blends. This review includes substantial knowledge that may aid in the selection of proper biodiesel for blending. In order to obtain both stable and improved low-temperature flow in biodiesel fuels, a combined methodology of blending for oxidation stability improvement and then the use of a CFI additive could be the most economical solutions.

India presently imports nearly 60% of its total consumption of edible oils; palm oils (crude as well as refined) constitute nearly 60% of the imports of edible oils & also as the feed stock of biodiesel. To date, most of the biodiesel procured by OMCs has been produced from Palm Stearin Oil, UCO, and negligible quantities from tree borne oils. Palm oil base feed stock has relatively poor cold flow characteristics, though with approprite treatments meet the stipulated specification standards, to be not dependent & to safeguard food security in the country, India should invest in other feedstock varieties like nonedible sources, etc.

It's heartening to read the article released in "Business standard " on August 17, 2023, "The Centre's ethanol blending programme has been a major success for petrol, with E20 petrol (petrol blended with 20 percent ethanol) now selling at more than 1,900 pumps across the country.

It is only logical that ethanol blended diesel be explored as a viable clean fuel. We are closely watching the development," a petroleum and natural ministry official said. Both BPCL and HPCL are in the process of running vehicles on diesel mixed with ethanol, he added." under the title **"Govt eyes ethanol to meet its 5% biodiesel blending target by 2030."**

Acknowledgment& References

The main portion of the text related to the Cold Flow properties are directly taken from the Mini Review published in 18th December 2020 by frontiers in Energy Research

frontiers in Energy Research
MINI REVIEW
published: 18 December 2020

A Mini Review on the Cold Flow Properties of Biodiesel and its Blends

M. A. Hazrat[1], M. G. Rasul[1], M. Mofijur[2,3], M. M. K. Khan[6], F. Djavanroodi[3], A. K. Azad[4], M. M. K. Bhuiya[5] and A.S. Silitonga[6]*

Recommndation for further reading on this specific topic :-

Journal of Oil Palm Research Vol. 34 (1) March 2022 p. 116-128
DOI: https://doi.org/10.21894/jopr.2021.0027

THE COLD FLOW PROPERTIES OF PALM BIODIESEL FOR DIESEL BLENDS MANDATE IN MALAYSIA'S HIGHLANDS

NURSYAIRAH JALIL[1,2]; HARRISON LIK NANG LAU[1*] and RIFQI IRZUAN ABDUL JALAL[2]

svlele.com
http://www.svlele.com › biodiesel_in_india

Biodiesel in India

Government's pricing policy allows State owned Oil companies to decide prices of Diesel. Diesel price is comparable to petrol. Diesel demand in the country is ...

Effect of additives to improve the performance of biodiesel at low temperatures

Evaluation of a novel type of chemistry to improve the Cold Filter Plugging Point of Fatty Acids Methyl Esters

Lopes, P.M. [1]; Muller, D.[1]; Harrison, R.[1]; Bordado, J.C.[2]

1 Arizona Chemical B.V., European Oleochemicals Research & Development Group, Almere, The Netherlands

2 Instituto Superior Técnico, Departamento de Engenharia Química, Lisboa, Portugal

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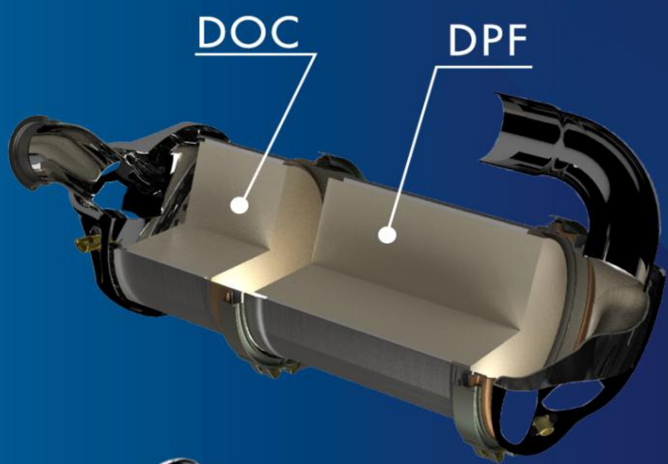

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The Evolution of the Internal Combustion Engine in the transition to Near Zero Emissions

Sudipto Basu, Senior Executive Director & Advisor, ECMA, New Delhi
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Executive Summary: Since almost two hundred years the Internal Combustion Engine has been evolving progressively, at first only to generate power or propel motor vehicles. Later, once the importance of fuel efficiency was felt and later still, the need to control pollution and emission of polluting gases and particulates was recognised, a rapidly changing and continuously developing ICE has surpassed expectations for power, frugality and the increasingly stringent emissions requirements. As sustainability gets centre-stage and depleting fossil-fuel resources as well as the transition to near-zero carbon footprint becomes the norm, ICE too are expected to be further developed to work on bio and gaseous fuels and fuel-blends, synthetic fuels as also Hydrogen , to remain relevant, in a market that will offer multiple choices, to the environment conscious user. Provided of course, that resources to support development continue.

1. Introduction: The drivers for development of the Clean Internal Combustion Engine have been :

i) Market
ii) Regulation.
iii) Technology
iv) Aftertreatment

The Market has been instrumental in determining basic parameters such Power, Torque, choice of Fuel, Fuel efficiency and NVH. Emissions and pollution have largely, not been influenced by the market but rather, by Regulation.

Regulation has been a principal factor in the Emissions performance of engines and vehicles powered by engines. The perception of what should be controlled from engine and automotive exhaust have been the basis of testing pollutants and this has normally been done in a collaborative manner amongst regulators, test agencies, OEM and stakeholders in emissions control.

Thus, available knowledge at that point of time have been the determinant for pollution measurement and control. Products have been designed and developed according to Regulation and this has spawned Technological Development of the engine and Aftertreatment System

2. Regulation: This has evolved to an extent where limits have seen significant reductions:

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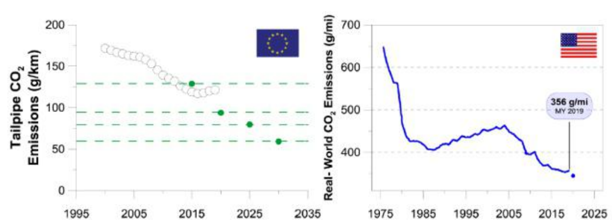


Fig. 3. CO_2 emissions from passenger cars in Europe [9] (left) and light-duty vehicles in the US [11] (right).

Tailpipe CO2 emissions in Europe and North America have dropped and so have average NOx emissions as in Figures 3 and 4.

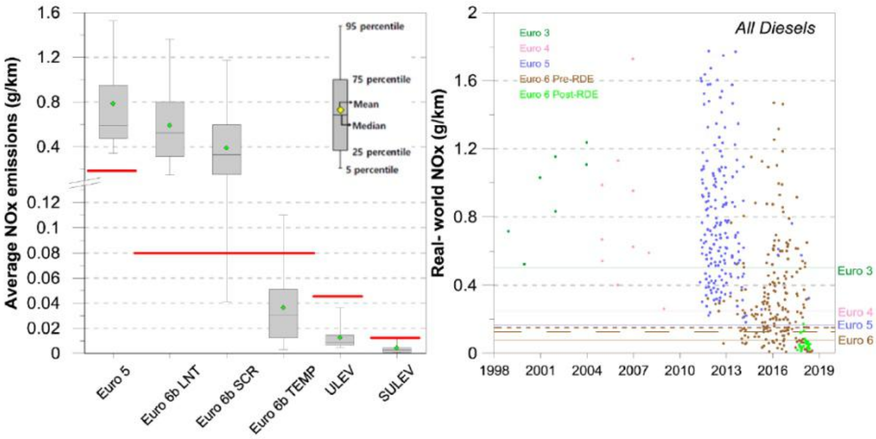
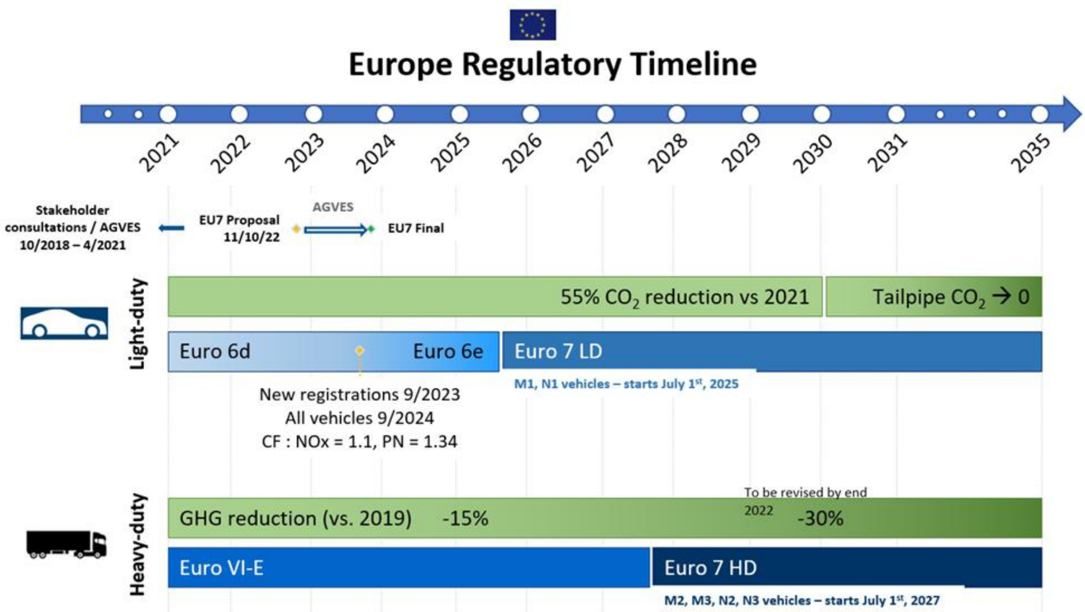


Fig. 4. On-road NOx emissions measured from 74 diesels and 35 gasoline vehicles covering model years 2012–2019 (left) [13], and on-road NOx emission measurements covering Euro 3 – Euro 6 diesel vehicles, (right) [14] Lines on both plots show the respective regulatory NOx limits at each stage. LNT and SCR are commercialized deNOx after-treatment technologies.

The timeline for stringent Euro 7 Regulations has been set and final discussions for implementation are ongoing among the European Commission, European Council and the European Parliament.

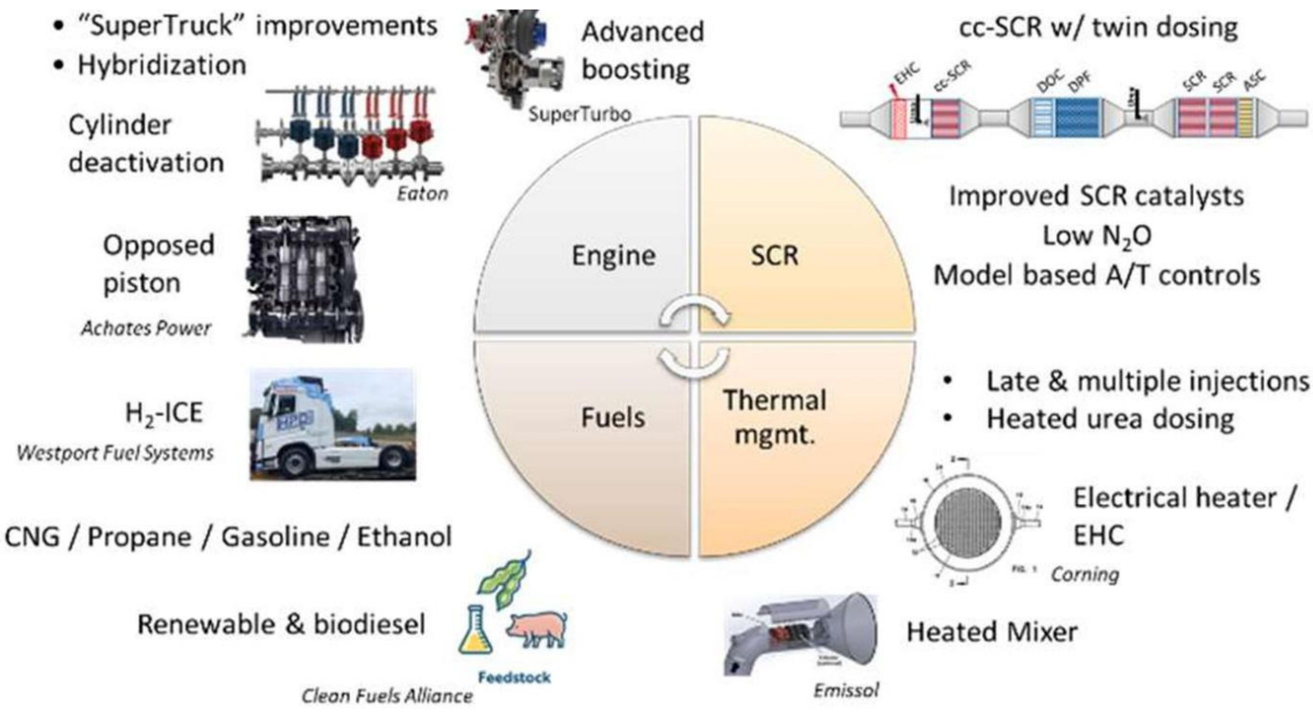
The Euro 7 proposal was published on November 10th, 2022 and represents the culmination of several years of stakeholder consultations and "AGVES" meetings which made recommendations on a few options. Note that there is still a Euro 6e step that starts in 2023, primarily affecting tailpipe criteria emissions through reductions of conformity factors.



3. Technology and Aftertreatment Development: The pace of technological advancement has matched the exigencies of Regulatory controls on tailpipe emissions. Member companies who are manufacturers of emission control devices for control of exhaust emissions, have developed highly efficient solutions through research and development, to meet and surpass all the exigencies for control of tailpipe emissions.

Apart from emission control devices, engine measure as well as types of fuel play apart in achieving the goals set by limits and test procedures for control of emissions.

Below is a schematic for the various innovative measures on engine, with different fuels such as Hydrogen, with thermal management such as Heated Urea dosing and finally, with sophisticated aftertreatment devices that near-zero emissions are being sought to be achieved.



4. The Need for further Research and Development: The evolution of the Internal Combustion Engine over two centuries, from a smoky, noisy, harsh and inefficient power source for mobility and other applications to a clean, powerful, efficient and practical power-house for mobility and other uses, has demonstrated the ability that scientists and engineers have, to transform and continually evolve and improve.

All of this requires resources; resources to support R&D and develop products that meet market requirements. The Market in turn, permitting amortization of costs towards the achievements. Thus, a sustainable, practical transition to goals that are continually revised as humankind discovers, realizes and corrects, to live in a Clean and Pollution-free environment.

The bottom-line is:
The ability to develop, correct and transition to a cleaner future with ICE is established.
What is required, is support and resources to continue the good work done.

Title: Evaluation of High Porosity Substrate Technology for Gasoline Emissions

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Background of evaluation

With the onset of stricter emission legislations – BSVI Stage II and the increasing precious metal prices, NGK has evaluated different porosities of substrates with varying precious metal amounts to cover both requirements on a 1.2L MPI vehicle meeting BSVI stage I. Test cycles used for evaluation include both the current Modified Indian Driving Cycle (MIDC) and Worldwide Harmonized Light Vehicles Test Cycle (WLTC). In the Indian context, WLTC is calculated up to Phase3 and the results and analyses will be presented accordingly. The Close Coupled catalyst layout used on the 1.2 MPI vehicle has a 2-brick system, and only the 1st brick was changed while keeping the rear brick configuration the same throughout all the tests as shown in the table below

Vehicle	1.2L MPI BSIV Stage I
Aftertreatment Layout	CC 2 bricks TWC
Sample size	(1st Brick) 105.7D x 68.0mmL (2nd Brick) 105.7D x 114.3mmL
Coating	BSVI Stage I basis
Aging	Method: Oven Max Temp.: 1050 deg.C Duration: 5hr
Tested cycle (3times each)	1. MIDC 2. WLTC(up to Phase3)

Test Condition

Brick	Cell Structure	Porosity	PGM Loading	Weight	
				Bare	Coating
		%	g/cft	g	g
1st	2/600SQ	27%	100	157	336
	2/750SQ	35%	100	152	295
	2/600SQ	47%	100	130	315
	2/750SQ	47%	100	128	307
			80		270
	3/750HEX	47%	100	142	316
			80		282
2nd	2/600SQ	27%	12	267	461

Sample Matrix

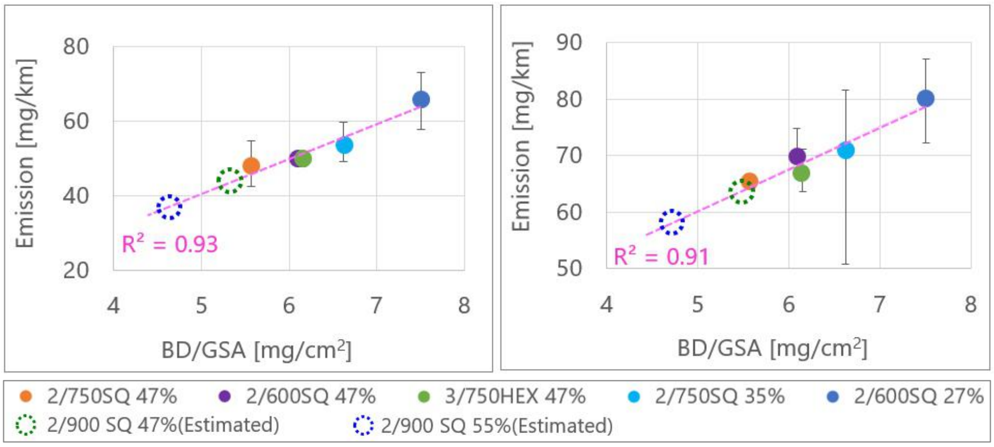
Test results

All mandated species were evaluated – Total Hydrocarbon (THC), Carbon Monoxide (CO) and Nitrogen Oxides (NOx). Of particular interest were the results of the THC as indicated on the chart below. Margin against current regulation could be confirmed under both MIDC and WLTC up to Phase3. Higher porosities (35% and 47%) and cell density (750 cpsi) show improved THC emission results even with lower PGM against the 27%; 2/600 substrate; thus, confirming a strong potential of PGM reduction.

Total Bag Emission for THC (Top: MIDC, Bottom: WLTC)

Analysis and Extrapolation of test results

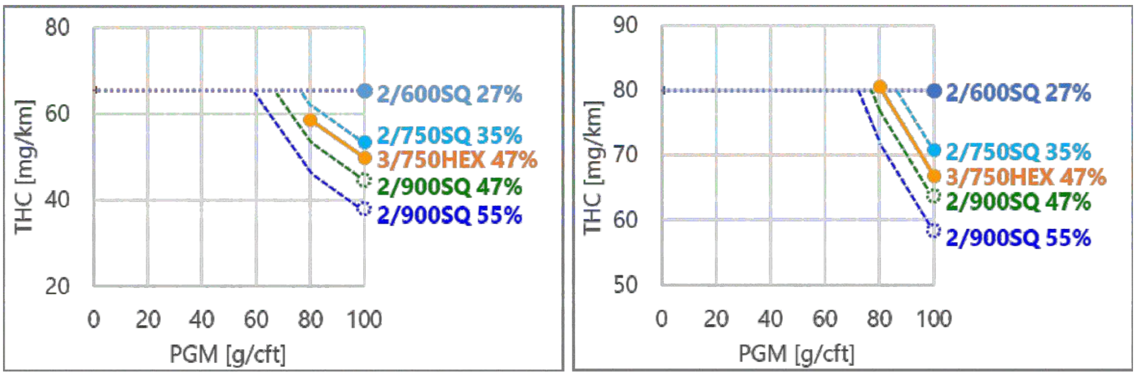
Relationship was analyzed between total bag emissions and parameters such as Bulk Density (BD) and/or Geometrical Surface Area (GSA). THC in MIDC and WLTC has a high correlation with BD/GSA. By extrapolating the emission result, our estimation leads us towards the "NGK 2/900 SQ 55%" for the highest THC reduction.



Estimated THC Total Bag Emission (Left: MIDC, Right: WLTC)

Estimation for potential of PGM reduction

Building on the impact of PGM on THC emissions from test results for different PGM levels, we used a similar slope derived from different PGM of the 47%;3/750HEX and assumption based on experiences for the best proposals from the previous chart to arrive at indications of PGM levels for the varying cell structures and porosities as described in the chart below. Taking 27% THC result as a baseline, NGK 55% porosity substrate has a PGM reduction potential of approx. 40% for MIDC and approx. 30% for WLTC.



Estimation of PGM reduction (Left: MIDC, Right: WLTC)

As part of the future work or direction for this line of study, it would be worthwhile to approximate the saving potential of fuel consumption using the strong correlation of THC conversion to higher porosities and cell structures.

Role of Exhaust After-Treatment Technologies in the Sustenance War of Traditional Power Plants

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In today's world, the environmental impact of vehicular emissions has become a pressing concern. With the rise in the number of vehicles globally, the need for effective strategies to mitigate harmful exhaust emissions has become more critical than ever. Exhaust aftertreatment technology has emerged as a promising solution, playing a crucial role in reducing pollutants and ensuring a sustainable future for transportation.

Exhaust aftertreatment systems serve as a pivotal tool in curbing the detrimental effects of harmful pollutants emitted by internal combustion engines. By significantly reducing the levels of nitrogen oxides (NOx), particulate matter (PM), hydrocarbons (HC), and carbon monoxide (CO) released into the atmosphere, these systems help improve air quality and minimize the environmental impact of vehicular emissions. In the context of global efforts to combat climate change and air pollution, the deployment of effective exhaust aftertreatment technologies has become a key priority for the automotive industry and policymakers alike. In recent decades, there has been continuous further development in the technology of exhaust aftertreatment for spark-ignition and diesel engines. Present fossil fuels – both liquid and gaseous fuels – unfortunately do not combust completely and hence, produced undesired emissions, specially from diesel engines.

Controlling Particulate Matter and Smoke from traditional Internal Combustion Engines

The increasing concerns about the adverse health and environmental impacts of particulate matter (PM) and smoke emissions from internal combustion engines (ICE) have prompted the development of advanced aftertreatment technologies. These innovations aim to effectively mitigate the release of harmful particulates and smoke into the atmosphere, thereby improving air quality and fostering sustainable transportation practices, emphasizing the promotion of cleaner and healthier environments.

Particulate Matter Control Strategies

Advanced aftertreatment technologies have revolutionized the management of particulate matter emissions from ICEs. The incorporation of diesel particulate filters (DPF) equipped with advanced filtration media and efficient regeneration systems has significantly reduced the release of fine particulates into the atmosphere. Furthermore, the integration of wall-flow filters and catalyzed filters has enhanced the efficiency of DPFs, enabling the effective capture and conversion of particulate matter into less harmful substances. Additionally, the application of advanced fuel injection strategies and combustion optimization techniques has played a pivotal role in minimizing the formation of particulates during the combustion process, further complementing the effectiveness of aftertreatment solutions in controlling PM emissions.

DPF Regeneration at Low-Temperature Engine Operation: Challenges and Strategies

Diesel Particulate Filters (DPFs) have proven to be an effective solution for reducing particulate matter emissions from diesel engines almost producing near-zero PM emission. However, one of the significant challenges associated with DPFs is their limitation to regenerate efficiently during low-temperature engine operation. In colder climates or during short-distance driving, the exhaust gas temperatures may not reach the levels required for effective passive or active regeneration of the DPF.

At low operating temperatures, the accumulation of soot in the DPF can impede the regeneration process, leading to increased backpressure and potential engine performance issues. The insufficient exhaust gas temperature not only hinders the combustion of soot particles during passive regeneration but also poses challenges for initiating active regeneration cycles. As a result, incomplete combustion and frequent regeneration failures can compromise the overall efficiency and longevity of the DPF, leading to increased maintenance costs and potential emissions non-compliance. The unique complexities associated with ensuring effective DPF regeneration at low temperatures necessitate the development of innovative and reliable solutions to mitigate the adverse effects of cold weather conditions on diesel engine performance and emission control.

To overcome the challenges associated with DPF regeneration at low temperatures, several innovative strategies and technologies have been developed. One approach involves the integration of electric heaters or energy management systems within the DPF to elevate the exhaust gas temperature and facilitate the regeneration process. By preheating the DPF or utilizing electrical energy to initiate the regeneration cycle, these systems ensure the optimal conditions for soot combustion, even during low-temperature engine operation. Additionally, the utilization of advanced catalyst formulations and coating technologies has enabled the development of catalyst-assisted DPFs, which exhibit enhanced regeneration efficiency and reduced sensitivity to low exhaust gas temperatures. These advancements have significantly improved the overall reliability and performance of DPFs, particularly in regions characterized by colder climates and frequent low-temperature operating conditions.

Smoke Emission Mitigation Techniques

The mitigation of smoke emissions from internal combustion engines has been a crucial area of focus in the development of advanced aftertreatment technologies. The implementation of advanced turbocharging systems and exhaust gas recirculation (EGR) technologies has facilitated improved combustion efficiency and reduced the formation of smoke during engine operation. Furthermore, the integration of advanced oxidation catalysts and particulate filters has enabled the effective conversion of smoke components into less harmful substances, significantly contributing to the reduction of smoke emissions.

SCR and Ammonia Injection Strategies for Start - Stop Engine Operations

Selective Catalytic Reduction (SCR) systems, coupled with ammonia-based reductants, have emerged as a key technology for reducing nitrogen oxides (NOx) emissions from various combustion engines. However, the implementation of SCR systems in vehicles with start-stop engine functionality presents unique challenges due to the intermittent operation of the engine.

Start-stop engine systems, designed to enhance fuel efficiency and reduce emissions during idle periods, can pose challenges for SCR systems due to the intermittent nature of engine operation. The reduction in exhaust gas temperature during engine shutdown can affect the efficiency of SCR catalysts and the decomposition of stored ammonia, leading to potential catalyst deactivation and increased NOx emissions during subsequent engine restarts. Furthermore, the limited availability of exhaust gas during start-stop cycles can impact the uniform distribution of ammonia within the SCR catalyst, further complicating the NOx reduction process. Addressing these challenges is critical to ensuring the reliable and efficient performance of SCR systems in vehicles equipped with start-stop engine technology.

To optimize SCR performance during start-stop engine operations, innovative strategies have been developed to address the challenges associated with intermittent engine cycling. One approach involves the integration of advanced control algorithms and predictive modelling techniques to regulate the dosing of ammonia-based reductants based on the engine's operating parameters and the SCR catalyst's temperature profile. By precisely controlling the timing and quantity of ammonia injection, these systems ensure the optimal distribution and availability of reductants, thereby enhancing the conversion efficiency of NOx across varying engine operating conditions. Additionally, the implementation of intelligent SCR catalyst designs and coating technologies has enabled the development of robust and durable catalysts capable of withstanding the thermal stresses and dynamic operating conditions associated with start-stop engine systems.

Advancements in after treatment technology has reached to a state that it can support the IC Engines to play war for their existence. For example, DPF technology can probably technically neutralise the emissions from diesel Engines. It is quite possible that quality of vehicle tail-pipe exhaust emission is purer than the quality of intake air drawn by the vehicle engine.

The Exhaust Aftertreatment for Hydrogen IC Engines

The exhaust aftertreatment of hydrogen engines differs from conventional internal combustion engines due to the unique nature of hydrogen combustion. Hydrogen engines produce minimal harmful emissions, with water vapor being the primary exhaust component. Therefore, the exhaust aftertreatment focuses primarily on managing any remaining trace pollutants and optimizing energy efficiency. Several key considerations in exhaust aftertreatment for hydrogen engines include:

1. Water Management: As water vapor is the primary by-product of Hydrogen ICE combustion, efficient water management systems are essential to prevent water accumulation and potential system corrosion. Strategies include water recovery systems, condensation management, and effective drainage to ensure the safe and efficient operation of the engine.

2. Trace Pollutant Control: While hydrogen engines produce minimal pollutants, traces of nitrogen oxides (NOx) and particulate matter may still be present due to combustion conditions. Selective catalytic reduction (SCR) systems and catalyzed particulate filters can be integrated to further minimize these emissions, ensuring compliance with environmental regulations and improving air quality.

3. Heat Recovery: Given the high-temperature nature of hydrogen combustion, capturing and utilizing exhaust heat for additional energy generation or thermal management is crucial. Incorporating heat exchangers and thermoelectric generators can enhance the overall energy efficiency of the hydrogen engine system, reducing waste and improving the overall sustainability of the vehicle or power generation system.

4. Integrated Monitoring and Control Systems: Implementing advanced sensor networks and intelligent control algorithms allows for real-time monitoring of exhaust emissions and the overall performance of the aftertreatment system. These systems can optimize the efficiency of the aftertreatment processes, ensuring the effective removal of any remaining pollutants and maintaining optimal engine performance.

5. Durability and Longevity: Ensuring the durability and longevity of the exhaust aftertreatment system is vital for the reliable and sustainable operation of hydrogen engines.

Advanced materials that can withstand the corrosive nature of water vapour and innovative design approaches that facilitate easy maintenance and component replacement are essential for prolonging the lifespan of the aftertreatment system.

The development of efficient and reliable exhaust aftertreatment technologies for hydrogen engines is critical to realizing the full potential of hydrogen as a clean and sustainable energy carrier. Continuous research and innovation in this field will be instrumental in advancing the adoption of hydrogen as a viable solution, specially for medium and heavy duty applications, for reducing greenhouse gas emissions and addressing the challenges of climate change and air pollution.

Is there any need of aftertreatment for Fuel Cells potentially usable in future mobility?

Fuel cells, which convert chemical energy from a fuel directly into electrical energy through an electrochemical reaction, generally produce only water and heat as by-products, making them inherently clean energy sources. Unlike traditional internal combustion engines, fuel cells do not produce significant amounts of harmful emissions such as nitrogen oxides (NOx), particulate matter, or volatile organic compounds (VOCs). Consequently, they do not require complex exhaust aftertreatment systems like those necessary for conventional engines.

However, it's worth noting that certain types of fuel cells, such as those based on reforming hydrocarbon fuels like natural gas or methanol, may produce trace amounts of pollutants such as carbon monoxide (CO) as by-products. In such cases, low-temperature catalytic converters might be employed to further reduce these emissions to meet stringent environmental regulations.

Additionally, as with any energy system, the heat management and water management systems of fuel cells require careful consideration. Effective thermal management systems are crucial for maintaining optimal operating temperatures, while efficient water management systems are necessary to prevent water accumulation and potential system corrosion.

Overall, the aftertreatment requirements for fuel cells are significantly simpler compared to traditional internal combustion engines, with the focus primarily on managing heat and water, as well as potentially addressing any trace pollutants resulting from the fuel reforming process.

What is ahead then?

In recent years, the global automotive industry has been undergoing a monumental shift, with a notable surge in the production and adoption of electric vehicles. This surge has left many pondering the fate of the once-dominant diesel engine. The future of diesel appears shrouded in uncertainty, as various factors, including environmental concerns, technological advancements, and shifting consumer preferences, are challenging its existence. The diesel engine is known for its efficiency and torque, which makes it a popular choice for heavy-duty vehicles and long-distance transportation. Its fuel efficiency, coupled with robust torque output, made it an attractive option for commercial and industrial purposes. Despite its excellence, the diesel engine has faced criticism due to its higher emissions of nitrogen oxides and particulate matter, contributing to air pollution and health concerns.

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Quest For Sustainable Tomorrow Through Clean Air Solutions

Rapid economic and industrial growth has historically taken toll on the environment globally, be it GHG emissions leading to global warming or right to clean air. India is not exception to this. Central pollution control board lists 131 cities as non-attainment cities with million plus population under National Clean Air Programme (NCAP). A state of global air report 2022 published that Delhi, Kolkata and Mumbai are among the top 20 most polluted cities in the world in terms of PM2.5 levels with their rank being 1,2 and 14 respectively. Air pollution is responsible for 1 in 9 deaths worldwide and accounted for 6.7 million deaths in 2019 alone. Of these, more than 4 million deaths were linked to exposure to outdoor fine particle pollution worldwide.

India has shown greater awareness and actions towards cleaner environment and is evident through various emission norm roll outs – namely, advance roadable vehicle emission norms (BSVI, CEV/TREM BSIV & V) and stringent generator emission norms (G.S.R. 804(E)/CPCB IV Plus), push towards natural gas adoption, mobility electrification, curb on industrial pollutions, monitoring pollution from specific industries and an ambitious plan towards renewable energy portfolio. Most of these actions shape up better and cleaner tomorrow however addressing emissions and pollution from in-use sources remain a global challenge. With vehicle and equipment life cycles being fairly long, these units keep adding to emissions inventory for significant time and hence delaying our path to clean air. Scrappage policies for such vehicles and equipment are controversial and many times not conducive to economics. This is where retrofitment solutions find their way to address the issue effectively by reducing emissions at the source.

Retrofitment solutions although feasible in many cases and driven by latest technologies, may exhibit limitations when it comes to equipment such as vehicles due to packaging constraints, older technology engines as well due to shear variety of the models. Mobility retrofitment efforts across the World has seen limited success due to these aspects and largely diverted focus on alternate fuel adoption, dual fuel conversions and repowering. Whereas stationery engine installations and industrial units such as incinerators, boilers become viable candidates for effective retrofit implementations. Reducing emissions at the source is the best strategy.

While obvious polluting sources such as mobility get more attention, there is need to address emission sources from traditional industry, practices followed over generations and even comparatively newer challenges while dealing with waste and refuse as part of changing

Pi Green Innovations Pvt Ltd

Pi Green Innovations Pvt Ltd is a Pune based Cleantech Company driven by vision of 'A Pollution Free Tomorrow'. The company has invented a unique Filterless design to reduce PM emissions from sources such as diesel Gensets, industrial boilers, incinerators etc. this technology is patented across 30 countries including India, USA, UK, EU, China and Singapore.

- **First company to receive Class 1 Certification for DG Retrofit Emission Control Device (RECD)**
- **Type Approved Solutions ranging from 225 to 910 kVA**
- **1010 to 2500 kVA stack emission compliant RECDs**
- **Partnership and endorsement from major DG engine OEMs for RECD distribution and service**

Industrial solutions offered,

- **1 to 5 TPH Industrial boilers**
- **Crematoriums and industrial incinerators**
- **Jaggery Unit exhaust PM reduction**
- **Net Zero Machine – a novel GHG capture and gaseous pollution reduction technology**

No Manual Cleaning	No Choking	No Replacement	Low Maintenance	No Filter	No Water	No Chemical	No Solvent

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lifestyles. Numerous opportunities can be mentioned such as jaggery making units, kilns, small bakeries, mineral crushing units, crematoriums, incinerators those can be targeted for at-source particulate matter reduction. Impact of these efforts although statistically minor contributor, could be seen over time in positive health impact to the population exposed to it if not gross air pollution. A rational policy effort regarding such initiatives is important aspect to materialize these benefits. Effective and economical technologies and proven solutions are available those can be deployed for such efforts.

Beyond emission control at source, highly polluted local areas and hotspots can be addressed through ambient air cleaning solutions for particulate matter where high volume flow filter-less solutions can make a breakthrough addressing exposure to the local population. Such efforts are seen in the form of clean air towers however seldom seen as a sustainable solution owing to high cost of operation due to filter element replacements which further adds to landfill concerns.

Pi Green Innovations Pvt Ltd, a company driven by vision of 'A Pollution Free Tomorrow' focuses on innovative solutions those target particulate matter reduction from engine and process exhaust at the source as well as clear air solutions for pollution hot spots. We use unique filter-less technology that separates particulate pollutants, that too in agglomerated form that is easy to recycle and seldom provide possibility of re-suspension. Offers very lucrative energy efficiency and can be augmented with air sanitization options where applicable.

Global warming is a real climate threat and many species sustainability is in question if the "business as it is" approach his considered. Carbon neutrality is a big challenge Worldwide where many industries are pledging for carbon neutral operations or zero carbon footprint by year 2050. Governments are already bringing policies and norms to make future sustainable. Any fossil fuel consumption for energy creates GHG footprint and alternatives such as carbon less fuels such as Hydrogen also has it's carbon footprint if not managed well and will defeat purpose. Grey Hydrogen has significant carbon foot print and Blue Hydrogen required produced CO_2 to be sequestered in underground reservoirs while cleanest Green Hydrogen requires electricity produced by renewable sources. The typical term used in mobility analysis - 'overall well to wheel' energy impact is something that will drive rational future solutions.

In this regard, Pi Green Innovations provides novel solutions for Green House Gas (CO_2) reduction along with gaseous criteria pollutant reduction such as NO_x, SO_x. Such technology pioneered produces CO_2 capture and sequestering in a commercially usable and environmentally neutral end product. Pilots on this application are already in progress.

We have a mission to address air pollution aggressively for sustainable tomorrow and being responsible towards next generations. The time to act is now!

- **Team Pi Green Innovations**