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Book of Abstracts

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Dr. Arun Kumar Tripathi

Ministry of new and Renewable Energy, India

Potential Role of Green hydrogen in India

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The world is moving towards carbon neutrality, with more countries pledging to reduce their carbon emissions to meet (and exceed) obligations under the Paris Accord and contain the temperature rise within 1.5°C by the end of this century. The approach adopted towards decarbonization is to electrify almost all human activities, including transportation, to the extent possible and decarbonize the power sector through renewable energy, carbon capture and sequestration, and other emerging technologies. Countries like India with good renewable energy resources could produce green Hydrogen locally at its point of consumption, generating economic opportunities and increasing energy security by reducing exposure to oil price volatility and supply disruptions. Globally, green Hydrogen is considered the sustainable solution to decarbonize the "hard-to-abate-or electrify" sectors mentioned above. Therefore, Hydrogen can play a crucial cross-cutting role in a future low carbon economy, with applications across the industrial, transport, and power sectors.

India is preparing its phase-wise National Hydrogen Policy and related roadmaps across sectors with the recently announced National Hydrogen Mission. Hydrogen's properties as a zero-emissions energy carrier and flexibility in its application across industrial, power, and mobility sectors make it a promising energy transition vector to address India's twin challenges of energy security and emissions reductions targets. These developments will help diversify the hydrogen production portfolio and reduce the cost of production in the coming years. Therefore, it is of utmost importance to explore the opportunities of Green Hydrogen among static and mobile applications. In this direction, the presentation will cover developments in supply and demand across the hydrogen value-chain, and provides details on potential opportunities and challenges.

Hydrogen production through thermochemical water splitting cycles – a comparative analysis

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Thermochemical cycles for water splitting are promising and sustainable technologies for a long-term, large-scale production of clean fuel, hydrogen from a renewable source. In this presentation, various hydrogen production routes through thermochemical and hybrid cycles, including 2-step (Zinc oxide), 3-step (Sulfur-Iodine), 4-step (Iron-Chlorine, Magnesium-Chlorine and Copper-Chlorine) and hybrid types (Hybrid Sulfur) are analyzed and compared. The recent advances, major challenges and future directions of these cycles are presented with respect to the design and scale-up. A comprehensive comparison of selected thermochemical cycles is presented based on energy and exergy efficiencies, hydrogen production cost including global warming potential (GWP). The analysis shows that the vanadium chlorine cycle gives the highest exergy efficiency (77%), while the Sulfur-Iodine and Hybrid Sulfur cycles show promise on the basis of GWP with 0.48 and 0.50 kg CO2 eq/kg H2, respectively. These cycles, esply., the Hybrid Copper-Chlorine cycle show great potential if integrated with nuclear waste heat or industrial process/ waste heat or heat from renewable sources.

NISE and Solar PV from an Indian Perspective

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Current Research Status of PEM Fuel Cell for Sustainable Road Vehicles

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The literature on the use of proton exchange membrane (PEM) fuel cells in automotive applications clearly shows that the technology is ready for commercialization. The popularity of PEM fuel cell technology in automotive applications is due to its simplicity, reliability and efficient energy conversion in a compact structure. Further, PEM fuel cell are least polluting when used in automotive application as compared to conventional internal combustion engine. In fact, NOx emissions are eliminated due to conversion of chemical energy of hydrogen into electrical energy, which then drive the electric motor.

Though the PEM fuel cells have technological readiness and few automotive companies have made some prototype of Fuel cell based cars, the research on various facets to improve the performance of PEM fuel cell is still undergoing. The basic metrics for investigating the performance characteristics of the fuel cell based car are the power, voltage, current, and speed it produces under various load circumstances. Researchers are also focusing on the primary sources of degradation for fuel cell systems i.e. start-stop cycles along with other dynamic situations such as idling, load cycling, or high power in analysing the performance of PEM fuel cell incorporated in automotive applications. The current research on automotive PEM fuel cell system also involve steady-state thermodynamics model to explore the impacts of vehicle speed and operating pressure on the size of system components, heat and water creation, fuel consumption, fuel cell, and system efficiency. A huge number of studies are still being conducted to improve the performance of PEM fuel cells and their application in the automotive industry, and they are worth discussing.

The remaining problems and opportunities for improvement for PEM fuel cells are high current density performance, durability, and cost. These issues are likely to be rectified during the next decade, when hydrogen infrastructure becomes more widely available.

Based on the foregoing, the current topic will cover the recent status of PEM fuel cell technology development and applications in transportation, as well as the need for fundamental research in this field. Besides, it will also outline major challenges in fuel cell technology development and the need for fundamental research in the near future and prior to fuel cell commercialization.

Key lessons from the PV sector: Quality infrastructure and technical requirements in public auctions

Niels Ferdinand, Adela Marian, Florian A. Münch, Asier Ukar

This presentation highlights key lessons learnt from international experiences with technical requirements in solar PV auctions. Such requirements with reference to international quality standards primarily aim to reduce frequent quality defects that are identified in PV power plants worldwide in different climate conditions. In the presentation, these defects are mapped to the international quality standards that could have prevented them.

On this basis, strategies are proposed for the introduction of technical requirements in the design of public auctions in newly adopting countries. The potential benefits are substantial: in addition to reducing quality defects and increasing safety, technical standards may help attract longer-term private investment and guarantee that local producers upgrade to the global technology frontier. For these benefits to materialise, policymakers should set clear national goals, e.g. in the form of a mission, and gradually introduce technical requirements. Moreover, the content of technical requirements should be communicated in a clear and effective way, and compliance with international quality standards should be monitored at all stages of the project.

The third part of the presentation explains how the national Quality Infrastructure (QI) system and its individual components constitute the basis for compliance with international quality standards along the PV value chain. To comply with technical requirements referenced in tender documents, the PV sector stakeholders need access to QI services, such as component testing, plant certification and the calibration of reference modules and cells. Depending on the national objectives and existing capacities, different strategies to develop the QI system can be chosen. The presentation closes with a summary of the learnings on the development of the QI system from the PV sector that are relevant for the emerging green hydrogen sector. While there are differences in the specific services needed, both sectors require an early strategic planning of the QI development.

Renewable energy-based hydrogen production methods for sustainable energy innovation

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In this paper, various hydrogen production methods using renewable sources are reviewed and their performance indicators such as energy efficiency and cost are discussed. This analysis indicates that all renewable energy-based approaches for hydrogen production are more environmentally friendly than fossil-based approaches. However, the economic efficiency of renewable energy-driven hydrogen production needs further improvement. Currently, the PV-PEM electrolyzer can achieve a solar-to-hydrogen energy efficiency of about 13% and it is expected that the efficiency can be further improved with the development of high temperature electrolyzer. Future work can be focused on integration of solar heat storage system with high temperature electrolyzer for sustainable innovation.

A Hybrid Membrane Reactor (MR)/Adsorptive (AR) Process for Hydrogen Production with Simultaneous CO2 Capture in the Context of Power Generation

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We study here a hybrid system combining a membrane reactor (MR) and an adsorptive reactor (AR) in sequence. We apply this system to the water gas shift reaction (WGSR) in the Integrated Gas Combined Cycle (IGCC) process for H2 generation and simultaneous CO2 capture. The MR-AR system attains a high WGSR conversion exceeding equilibrium, produces a pure H2 product for power generation, and delivers a high-pressure CO2 stream ready for sequestration. We employ highly permselective carbon molecular sieve membranes (CMSMs), which we have field-tested and performance-validated under real gasification conditions. Experiments were carried-out in the laboratory to determine the membrane characteristics, and the MR performance under the IGCC-relevant conditions. The CMSMs and the commercial sour-shift WGS catalyst (Co/Mo/Al2O3) we use displayed robust and stable performance during a long-term run (~750 hr of syngas exposure).

A TEA study was also carried-out for process design/optimization and economic evaluation of the WGS-MR-AR system for a broad range of operating conditions and design parameters. We concluded, based on the TEA findings, that the CMSM-based MR-AR system is a good candidate technology for incorporation into IGCC power plants for environmentally-benign power generation. A pilot-scale system processing 5 SCFM of syngas was then constructed and installed at the University of Kentucky CAER gasifier facility. The MR-AR is presently being field-tested there with coal gasifier off-gas.

Safety-related hydrogen research at TU Dresden

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Technische Universität Dresden, Chair of Hydrogen and Nuclear Energy

To achieve the worldwide formulated CO2 reduction targets, hydrogen is becoming increasingly important. Along the entire hydrogen value chain, it is necessary to identify and reduce risk potentials in order to ensure public acceptance. To ensure a consumption-based supply of electrical energy in the context of the newly emerging energy structure in Germany, the development of a hydrogen economy with hydrogen as an energy storage medium is crucial. Moreover, higher requirements for the intrinsic safety of hydrogen plants may become necessary due to the forthcoming decentralization of hydrogen technologies.

The Chair of Hydrogen and Nuclear Energy has many years of experience in the evaluation of safety-relevant processes and technical equipment in the field of hydrogen technology, which is the focus on this presentation. For this purpose, the experimental facilities regarding hydrogen safety and the new established Hydrogen Research Center are presented. The applied methods and accumulated results concerning theoretical safety analyses are described using the example of the research project INES where new safety analyses for the risk assessment of hydrogen technologies with the focus on the human factor were performed. The results illustrate the need for more holistic approaches and analyses in the hydrogen value chain. Since a uniform conclusion on the safety of hydrogen-based energy systems is currently not possible, further work regarding hydrogen safety is required and necessary.

Measurement Needs for Decarbonising Energy Gases

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The UK government recently announced the Ten Point Plan for a Green Industrial Revolution, which included the use of low carbon hydrogen, greener buildings (such as using biomethane for heat) and use of carbon capture utilization and storage (CCUS). Switching to these technologies will require new measurement methods, standards and guidance to assess gas quality. For example, hydrogen provided to a fuel cell electric vehicle must be sufficiently pure (even 4 nmol mol-1 of hydrogen sulphide could poison the fuel cell catalyst). In another example, measurement of impurities in carbon dioxide are important for safety of CCUS processes, to avoid presence of acidic compounds that could corrode pipeline or other processing equipment.

This presentation provides an overview of NPL's recent activities in the area of gas metrology that support the increased use of clean energy gases, split across hydrogen transport, decarbonizing heat and CCUS. The presentation will cover the relevant standards (CEN/ISO), guidance and available methods for performing gas quality assurance in these three areas. The presentation will also cover key projects that NPL have supported such as the BEIS Hy4Heat, SGN Hydrogen Odorants, Cadent Gas Hydrogen Grid to Vehicles projects and a range of ongoing European Metrology projects.

Risk analysis for a model hydrogen pilot plant

Ulrich Krause and Dieter Gabel

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A quantitative risk analysis (QRA) has been performed for a pilot plant in which for the first time the complete value chain of hydrogen production, storage and use was put into reality. The pilot plant was built in the nineties of last century and remained in operation until 1999. Electricity was generated with photovoltaic panels driving alkaline electrolysers. Hydrogen was stored in two tanks under a pressure of 30 bars g. The hydrogen was used to feed a small-scale block heat and power plant but also transferred to an on-site fueling station.

For the QRA the storage tanks were selected as the components representing the highest hazard potential on the site. The QRA comprises the development of accident scenarios represented by master-logic diagrams, the identification of release scenarios based on event tree analysis and the assessment of failure probabilities of the safety barriers installed by fault tree analysis.

In addition, the consequence assessment was performed by analysing atmospheric dispersion in case of an accidental release of hydrogen and overpressure and heat radiation in case of gas cloud explosion in dependence on the radius of action with the software ALOHA. Computed overpressures and heat fluxes were compared to hazard thresholds.

Sensors, Analytics and Certified Reference Materials safeguarding the quality infrastructure in the hydrogen economy

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The prerequisites for a successful energy transition and the economic use of hydrogen as a clean green energy carrier and for H2 readiness are a rapid market ramp-up and the establishment of the required value chains. Reliable quality and safety standards for innovative technologies are the prerequisite for ensuring supply security, for environmental compatibility and sustainable climate protection, for building trust in these technologies and thus enable product and process innovations.

With the Competence Centre "H2Safety@BAM", BAM is creating the safety-related prerequisites for the successful implementation of hydrogen technologies at national as well as European level. BAM uses decades of experience in dealing with hydrogen technologies to develop the necessary quality and safety standards.

The presentation will draw a bow from the typical basic tasks of BAM in the field of competence "Sensors, analytics and certified reference materials", such as maintenance and dissemination of the national gas composition standards for calorific value determination as Designated Institute for Metrology in Chemistry within the framework of the Metre Convention, to the further development of measurement and sensor technology for these tasks. For the certification of reference materials, a mostly slow and time-consuming but solid reference analysis is common. With hydrogen and its special properties, completely new requirements are added. In addition, fast and simple online analysis is required for process control, for example to register quality changes, e.g., during load changes or refuelling processes.

IECEx - a tool to harmonize national and international certification

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The presentation provides an overview about the growing relevance of the IECEx system in chemical, petrochemical and pharmaceutical industry. Starting from the quantitative analysis of potentially explosive atmospheres (in applying the IEC 60079-10-1/-2), all other aspects like the physical elimination of ignition risks and the certification of competent persons are covered by specific certification schemes within a full life cycle. To illustrate the fruitful contribution of IECEx and the related IEC standards to the field practice, applications with hydrogen/air mixtures are presented as an example how to make use of the applicable IEC standards and the potential certification options of IECEx.

Metrology for Energy Transition and Hydrogen Economy

Dr. Fabian Plag

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Green Hydrogen Economy – India's Perspectives

Chinnakonda S. Gopinath

CSIR - National Chemical Laboratory, Pune, India

Green hydrogen production announcement by many nations and major companies in India and the rest of the world clearly underlines the real change is to come very soon. Indeed, green hydrogen is the top option and necessity to tackle the climate challenges. Honorable PM Shri Narendra Modi announced the national green hydrogen mission on the last independence day (15/8/21) and a substantial funding to be promised soon for green hydrogen activities. From CSIR also, green hydrogen mission mode programs to be initiated very soon on all the three verticals (Hydrogen production, storage-distribution and utilization). In the present talk, I will highlight some of the activities are being set up and the R&D and R&T activities are in pipeline.

Application of Hydrogen in Power Generation and Transportation Sectors

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Hydrogen is a carbon-free fuel and energy carrier, and its utilization in power generation and transportation sectors would strengthen sustainable energy and the environment. Green Hydrogen could be produced using electrolyzers with renewable energy sources including solar photovoltaic and wind when the demand of electricity is lower than the supply. Hydrogen could be utilized in spark-ignition engines / vehicles and Proton Exchange Membrane fuel cells, and it could facilitate a continuous power supply, and long-distance travel (range). The thermal efficiency of the combustion engines with hydrogen is higher than that of gasoline or natural gas due to an increase in combustion efficiency, better conversion of heat to work, and enhancement of constant volume combustion. The major technical issues including backfire, power drop, and NOx emissions could be addressed using appropriate technologies such as Exhaust Gas Recirculation, Water Injection, retardation of hydrogen injection timing, after-treatment devices, etc. and optimization of design and operating parameters of engines. The PEM fuel cell provides higher efficiency with zero-emission compared to a combustion engine. The transient performance, power density (W/L), durability, and cost ($/kW) of the fuel cell are some major technical issues that are being addressed. The selection of fuel cell or combustion engines for power generation and automotive applications is primarily based on the type of applications with their annual average capacity factors, Levelized Cost of Energy ($/kWh), and Average Transportation Cost ($/km). Hydrogen would play a vital role in sustainable decentralized power generation, and transportation sectors for achieving a part of net zero-emission targets.

Hydrogen production by water splitting: room temperature and high temperature approaches

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Hydrogen is an emerging renewable energy carrier to reduce the massive utilization of fossil fuels and associated environmental problems. Clean and green hydrogen can be generated by water splitting. Thermochemical, photochemical, photo-electrochemical, and PV electrolysis are some of the approaches actively pursued for generating green hydrogen. Polymeric graphitic carbon nitride (g-C3N4) with band gap of ∼2.7 eV is a stable non-toxic photoactive material to harvest solar photons from UV to visible range. The band gap of g-C3N4 is tuned by doping benzene and pyrimidine rings to extend the π-conjugation which resulted in increased water splitting activity without using sacrificial agents. The direct approach of hydrogen production is experimented by thermochemical solid-steam reactions at high temperatures (∼1000 °C). Oxygen is extracted from H2O by oxygen vacancies created by the pre-reduction of ceria based ceramic materials to produce green H2. Both ambient and high temperature approaches can be exploited for generating green hydrogen using solar energy.

Hydrogen-diesel direct injection dual-fuel engines

Prof. Shawn Kook

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This lecture introduces hydrogen combustion engines as a future transportation and power generation technology. Hydrogen-diesel dual direct injection (H2DDI) engines with up to 90% hydrogen energy fraction have been developed by a group of UNSW researchers to realise affordable and reliable carbon-neutral technologies used for marine propulsion and power generation. The fundamentals of 200-bar hydrogen gas jet are discussed based on optical diagnostic results obtained from a high-pressure constant-volume combustion chamber. The CFD results and proof-of-concept engine testing performed in a dynamometer facility are shared with an emphasis on hydrogen mixture formation variations due to the direct injection timing control, and its influence on engine performance and engine-out emissions.

Effective Sea Water Splitting – Myth or Reality

Deepa Khushalani

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The photocatalytic hydrogen production from water splitting is a promising way to fulfil the current energy demand in an eco-friendly and sustainable manner. Conventionally deionized water (DI) has been used as the solvent for PC water splitting, however seawater is the ideal solvent for practical applicability. The presence of various ions (Na+, K+, Mg2+, Ca2+, Cl−, Br−, SO42−, and CO32−) in seawater restrict its usage, as these ions lead to unwanted side reaction. In some instances, charge carrier activity and photo catalyst durability decrease when the solvent is changed from DI water to seawater, while there are few other reports that in fact showcase an augmentation in PC hydrogen production with seawater.[1] These contradicting reports in the literature clearly suggest that the role of the ions in PC efficiency is non-trivial. The majority of systems thus far evaluated for seawater splitting have a neutral inorganic metal oxide-based catalyst. Presented here is a charged semiconductor has been evaluated as it serves as both a semiconductor with photo-activity and ionic sites that help in ion exchange and modulating the catalysis of an ionic electrolyte. It consists of a modified carbon nitride that has been obtained after an ion thermal treatment of the starting material. Polymeric carbon nitride has been considered a promising photo catalyst for water splitting during the last decade, as it is metal-free, cheap, easy to prepare, and carries proper band alignment for water reduction and oxidation.[2] In this study, the simulated seawater water splitting has been done using this charged semiconductor, and the role of various ions in modulating the photocatalytic activity has been evaluated. The data from this study shows that the presence of bivalent cations enhance photocatalytic activity up to 10 times when the ionized organic semiconductor is utilized. Presented will be a detailed study where a variety of techniques have been exploited to systematically understand the unique nature of the catalyst and how ions affect its PC activity for water splitting.

Investigations into numerical and experimental studies on hydrogen and syngas combustion

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In this work detailed experimental and numerical studies will be presented on the combustion characteristics of hydrogen and other hydrogen enriched syngas fuels with air at various conditions. Special attention will be paid to understand the combustion characteristics of hydrogen and syngas at high pressure and high temperature conditions. The role of mixture equivalence ratio, mixture temperature and pressure will be explored in the form of various non-dimensional forms to understand the combustion characteristics. Flame propagation rate measurement at these conditions will be presented for given conditions. The data obtained using a new externally heated diverging channel method will be presented. These observations have helped understand the variation of the flame propagation rate and laminar burning velocity of diluted hydrogen and syngas air mixtures at high pressure and high temperature conditions. Numerical modeling to understand and predict the combustion behavior at various conditions is presented and the efficacy of various existing kinetic models will be validated using the data at high pressure and high temperature conditions.

Electrochemical and Photoelectrochemical Synthesis of Ammonia (NH_3) through Nitrogen reduction reaction

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Ammonia is a vital component for sustaining life on earth as a powerful fertilizer, hydrogen carrier, and clean fuel. Nitrogen reduction reaction (NRR) is a promising alternative to the industrial Haber-Bosch process due to its eco-friendly and cost-effective ammonia (NH3) production approach. It is challenging to design a photocatalyst with enhanced light adsorption ability, N2 activation behavior, and mass/electron transport kinetics to achieve a high NH3 synthesis yield. A new strategy for the rational design of hierarchical gold-tungsten sulfide anchored reduced graphene oxide for high-performance photocatalytic N2 reduction through hydrothermal and subsequent Au modulation approach is discussed. The hybrid catalyst synthesis involves a cost-effective and straightforward hydrothermal subsequent Au modulation approach. The photocatalyst of WS2 enhances Au's electron enrichment at visible light conditions, resulting in easier N2 adsorption and dissociation on electron-rich Au, resulting in excellent NRR activity and faradic efficiency toward NH3 production. Such enhanced NRR selectivity and efficiency are due to its hierarchical nanostructure with enlarged specific surface area, exclusive porous networks, and high synergistic effects. Most impressively, this catalyst realizes the highest NRR performances even in atmospheric air and outperforms the state-of-the-art NRR catalysts, reflecting industrial aspects. This consequence provides a novel strategy to design a highly efficient NRR photocatalyst for the manufacturing of fertilizers

Ammonia as an Energy Vector

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A hydrogen economy has been the focus of researchers and developers over decades. However, the complexity of moving and storing hydrogen has always been a major obstacle to deploy the concept. Therefore, other materials can be employed to improve handling whilst reducing cost over long distances and long storage periods. Ammonia, a highly hydrogenated molecule, can be used to store and distribute hydrogen easily, as the molecule has been employed for more than 150 years for fertilizer purposes. Being a carbon-free chemical, ammonia (NH3) has the potential to support a hydrogen transition thus decarbonising transport, power and industries. However, the complexity of using ammonia for power generation lays on the appropriate use of the chemical to reach high power outputs combined with currently low efficiencies that bring up overall costs. This complex scenario is also linked to the production of combustion profiles that tend to be highly polluting (with high NOx emissions and slipped unburned ammonia). There is no technology capable of using ammonia whilst producing both low emissions and high efficiencies in large power generation devices, thus efficiently enabling the recovery of hydrogen and reconversion of stranded, green energy that can be fed back to the grid. Tackling these problems can resolve one of the most important barriers in the use of such a molecule and storage of renewable energies. Therefore, this presentation is intended to present state-of-the-art global research that has taken place to understand the combustion features of ammonia blends whilst addressing their application at medium and large power scales. The complexity of nitrogen bounding and its reactivity are discussed with emphasis to tackle NOx emissions. Finally, risks, health and safety, and public perception implications are also presented to provide guidelines for the implementation of facilities to evaluate ammonia for combustion purposes.

Combination of Intake Throttling and Exhaust Gas Recirculation to Improve Low Load Combustion Efficiency of a Dual Fuel Engine

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Reactivity controlled compression ignition (RCCI) strategies in compression ignition engines have shown great potential to utilize low reactive fuels along with the diesel pilot fuel to reduce oxides of nitrogen (NOx) and soot emissions simultaneously. However, poor low load combustion efficiency remains a challenge with this strategy. In this work, a production light duty diesel engine was operated in the RCCI mode with methane as the low reactive fuel. The engine was operated at a speed of 1500 rev/min and a load of 3 bar gross indicated mean effective pressure. The effects of cold exhaust gas recirculation (EGR) and intake air throttling strategies on engine performance and emissions were investigated and compared. The results suggested that achieving combustion phasing close to top dead centre plays a key role in the improvement of the combustion efficiency with both these strategies. However, the improvement in the combustion efficiency with the intake air throttling strategy was significantly higher compared to the cold EGR strategy owing to an increase in the fuel-air equivalence ratio. Very low NOx (<0.4 g/kWhindiacated) and soot (<0.01 g/kWhindicated) emissions were achieved with ~40 % cold EGR; however, NOx emissions increased with intake throttling owing to an increase in the peak combustion temperature. A combination of reduced premix ratio (50 %) and high cold EGR levels (~50 %) resulted in ~90 % combustion efficiency while maintaining very low NOx and soot emissions. This work highlights the importance of understanding the effects of the individual control strategies such as start of injection timing, EGR, premix ratio and intake throttling which then can be combined to improve the performance of the RCCI strategy at low load.

The future of the internal combustion engine

Rolf D. Reitz

University of Wisconsin-Madison, USA

Internal combustion (IC) engines operating on fossil fuels provide about 25% of the world's power (about 3000 out of 13,000 million tons oil equivalent per year), and in doing so, they produce about 10-15% of the world's greenhouse gas (GHG) emissions. Reducing fuel consumption and emissions has been the goal of engine researchers and manufacturers for years. Indeed, major advances have been made, making today's IC engine a technological marvel. However, the reputation of IC engines has been dealt a severe blow by recent emission scandals, as well as by concerns for the environment that require renewed research efforts toward the reduction of transportation sector emissions. Currently there is a trend to replace fossil-fuel powered IC engines with electric-drives or engines powered with alternative low carbon fuels with the goals of further reducing fuel consumption and emissions, and to decrease vehicle GHG emissions. As responsible engineers and stewards of the environment for future generations, it is up to our community to provide an assessment of progress made in the development of IC engines over the past century to meet the world's mobility and power generation needs, and to assess the potential for future benefits offered by competitor technologies to make responsible recommendations for future directions. This presentation will discuss future prospects for the IC engine.

Detailed and Hierarchical Models for the Simulation of Ignition and Combustion of Renewable and Hydrogen-Containing Fuels

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Ignition and combustion of hydrogen containing fuels has attracted much interest during the last years. Detailed numerical simulations of combustion processes using the complete set of time-dependent governing equations and complex chemistry have become an important research tool. Turning such simulations from very generic cases with relatively simple geometries to more complex technical systems can lead to a paradigm shift from empirical knowledge based on combustion data towards the prediction of ignition and combustion processes.

In the talk we will discuss the principle of these modelling strategies and their application to generic ignition and combustion scenarios like auto ignition, ignition by sparks or by hot particles or combustion close to the flammability limits. Although these ”generic” scenarios already allow a good insight into the governing processes, it is important for practical applications to characterize the overall combustion process. Therefore, we shall discuss in the second part of this work how the detailed information can be used to devise models for the overall process. The problem in modelling these (typically turbulent) processes is that the description of chemically reacting systems leads to scaling problems in space and time. In particular, an oversimplification of the coupling processes between chemical reaction and turbulent flow should be avoided by all means to allow a predictive character.

High Efficiency Zero Emissions Argon Power Cycle Hydrogen Engine for Future Vehicle Powertrain

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This topic presents an introduction on the novel combustion concept for future Zero Carbon emissions and Zero Pollutant emissions with high efficiency combustion engine-Argon Power Cycle Hydrogen Engine and the fundamental studies on characteristics of combustion and thermal efficiency in theory and experimental verification of Argon Power Cycle Combustion Engine with fuel of Methane and Hydrogen. The key parameters, such as compression ratio and the concentration of Argon Gases and other parameters related efficiency are considered in the efficiency analysis and test. The results show that the thermal efficiency of the Argon Power Cycle Engines has a potential over 50% under current engine platform and with a higher potential efficiency over 60% by in-cylinder hydrogen injection with control of knock issue.

Molecular Design of Processes and Products

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For many products, their function is the main concern during their development. In spite of this, the development of fluid products, like fuels and solvents, is often guided by desired molecular properties, not directly by their function during application or production, which can lead to suboptimal designs. For a spark ignition engine fuel, a high RON number is generally a desirable property, but a fuel designed explicitly for an energy-efficient production and a high thermodynamic efficiency in an engine may be superior, because it may provide better tradeoffs of all desired properties. Such an optimization is possible with in silico by computer-aided molecular design (CAMD) methods. Here we show how the combination of an evolutionary algorithm for the optimization of molecular structures, quantum mechanics, machine learning, and process simulation can identify promising fuel candidates. With an adjusted objective function, the same approach can yield improved solvents and catalysts for the production of fuels and other chemicals. In conclusion, the presented framework successfully designs promising molecular candidates for various applications.

Industrial perspective of Hydrogen Storage, Service, and Safety

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There are many International accords on global warming, and the Paris accord goal is to limit global warming to well below 2°C and achieve Net Zero. To reach Net Zero, emission from home, transport, agriculture, and industry need to be cut. The green Hydrogen could be a critical enabler of the global transition to sustainable energy and net zero emission economies. The time is right to tap into hydrogen's potential to play a key role in managing critical energy challenges. Many countries are venturing into hydrogen fuel usage in transport and heavy engineering industries. Green Hydrogen can supply 25 % of the world energy need by 2050. India has the platform to meet the major share of the above. The Indian Startups and major industries essentially need to focus on Green Hydrogen.

To achieve the above goal, the startups and industries must follow the necessary safety standards on Hydrogen storage and servicing. Hydrogen is so hazardous (Group III), and exposure to cryo Hydrogen vapor can cause asphyxiation, exposure of the skin to liquid cause frostibite. The storage materials are subjected to embrittlement failures. The storage of hydrogen has to be as per STEC/AMCR regulations. The design of cryogenic Hydrogen storage vessel needs special construction in which double wall structure insulated with evacuated Multi Layer Insulation with liquid nitrogen shield. The transfer lines have to be provided with super insulation. The field storage of hydrogen needs special type of lightning protection and earthing schemes. The particle contamination level for fluid servicing circuit is maintained as per "NAS 1638 Class VI" in Aerospace applications. The cryo hydrogen servicing involves media substitution, chilling and filling of tanks and level correction. Hydrogen loading has to be done remotely with safety interlocks through pressure feedback or pump transfer mode. One has to ensure that the gas detection systems are calibrated periodically.

Principle of safety factors has to be adhered for new facilities. The relevant safety standards for industrial processes such as handling of gaseous and cryo Hydrogen are to be followed. The systems and the processes are to be designed for safety. The hazard risks associated with processes, operation with the facility, failure modes of components/systems, leakage of gas, instrument and control devices, control software, and hardware have to follow the safety standards. The layout, fire protection systems, gas detection system, etc need to be used are to be approved by PESO (Petroleum and Explosive Safety Organisation). The safety training for facility personal are essential part of the entire process.

Can Methyl-2-methylbutanoate be a representative biofuel?

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In order to investigate the combustion chemistry of a branched ester namely Methyl-2-methylbutanoate (M2MB), thermal decomposition of M2MB diluted in Argon was carried out behind reflected shock waves in the temperature range 1018 -1615 K using single pulse shock tube (SPST). The post shock mixtures were analyzed quantitatively as well as qualitatively using gas chromatography (GC) and gas chromatography coupled with mass spectrometry (GC-MS). Methane (CH4), Ethane (C2H6), Ethylene (C2H4), Methanol (CH3OH), Propene (C3H6) and Methyl acrylate (C4H6O2) were the major products observed during thermal decomposition. The various oxygenated compounds were found as minor products. The first order rate constant observed for the decomposition of M2MB is $k_{total}^{expt}(T = 1018 - 1615\ K) = (5.17 \pm 1.73) \times 10^{6} \times \exp\left[-\left(\frac{11832 \pm 940}{T}\right)\right] s^{-1}$. The temperature dependent kinetics of the H-migration for the unimolecular decomposition reactions were calculated using RRKM/ME over the temperature range of 1018-1615 K. A reaction scheme involving 40 species and 51 elementary reactions, was proposed to simulate the reactant and product concentration over the studied temperature range. The concentration profiles for reactant and all the products observed from simulations and experimental results were observed to be in very good agreement.

Sustainable and Energy-Efficient Aviation

Doris Pester

TU Braunschweig, Cluster of Excellence "Sustainable and Energy-Efficient Aviation" – SE^2A

The Cluster of Excellence SE^2A – Sustainable and Energy-Efficient Aviation (EXC 2163) – is an interdisciplinary research center with the purpose of investigating technologies for a sustainable and eco-friendly air transport system. Scientists from aerospace, electrical, energy and chemical engineering are working on the reduction of emissions and noise, as well as recycling and life-cycle concepts for airframes and improvements in air traffic management. Technische Universität Braunschweig, the German Aerospace Center (DLR), Leibniz University Hannover (LUH), the Braunschweig University of Art (HBK) and the National Metrology Institute of Germany (PTB) have joined forces in this extraordinary scientific undertaking. Starting in 2019, SE^2A is funded for seven years by the German Research Foundation (DFG), under the "Excellence Strategy" to strengthen outstanding research and further improve its international reach out.

The overview presentation highlights the three core areas of fundamental research activities in SE^2A: Air Transportation System Assessment (A), Flight Physics and Vehicle Systems (B), and Energy Storage and Conversion (C). In order to achieve the SE^2A global goals, these three areas are closely intertwined. They bring together experts along the different requirements and technology readiness levels, from energy-carrier supply (renewable synthetic fuels, hydrogen, battery), to energy conversion, towards related structural requirements, up to the economic and social impacts. Each technological approach has its own challenges when applied to aviation. Thus, the strong interdisciplinarity in SE^2A not only makes this Cluster network unique, but also opens up the design space for innovative solutions.

Green Hydrogen- challenges and opportunities in India

*R.K. Malhotra

*Hydrogen Association of India, India

Integrated Production of Algal Biofuels and Biocommodities

Dheeban Chakravarthi Kannan

The Energy and Resources Institute (TERI), Navi Mumbai

Microalgae are a promising feedstock for the production of biofuels and biocommodities. A 200 sq. m marine algal growth system with related processing units for harvest and lipid extraction has been set up as part of the DBT-TERI Center of Excellence on Integrated Production of Advanced Biofuels and Biocommodities. Algal growth system is based on a sunlight distribution design. Algae are harvested by a settling pre-concentration method without the addition of any chemicals. The harvested wet algal biomass is processed for lipid extraction at normal temperature and pressure, without the need for a drying step. The extracted lipids are processed for conversion to biodiesel. The deoiled algae is then processed for evaluation of a variety of value-addition biocommodity development streams – aquafeed, cattle feed, biodegradable food packaging plastics, platform chemicals, pyrolytic products. Technoeconomic analysis is carried out for the various integrated production streams of biofuels and the aforementioned value-addition co-products. Aquafeed, in particular, shows promise for commercially viable co-production with biofuels in near/medium term. Challenges remain in terms of sustained long-term productivity of algae in the form of annual yields, scaling up of the algal production and processing systems and development of more streams of value-addition biocommodities to an advanced stage.

Hydrogen Combustion Engine Technologies: An Overview on Present and Future prospects

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Green hydrogen value-chain

Kapil Maheshwari
Reliance Industries Limited, India

A perspective on Hydrogen ICE as a transition technology for the M&HCV segment in the Indian context

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India made commitments in COP26 to reduce 1 bn MT of GHG emission by 2030 and become net zero by 2070. CO_2 emissions form 76% of the overall GHG emissions (2.7 bn MT in 2021) in India. Efforts to improve the fuel efficiency and reduce CO_2 emissions of commercial vehicles by diesel combustion improvement, drivetrain loss reduction, light-weighting and drag reduction with a mix of Battery Electric Vehicle (BEV)/Fuel Cell Electric Vehicle (FCEV) would help in the intermediate term but induction of fully CO_2 neutral energy carriers like Hydrogen (H_2) ICE and BEV/FCEV will have high impact on fleet CO_2 footprint. Currently the M&HCV segment is undergoing tremendous transformation and the path for future lies in a technology that would meet the 2030 levels of CO_2 emissions without compromising the Total Cost of Ownership (TCO) especially in a price sensitive market like India. Global trend of M&HCV moving towards the BEV and FCEV makes good case as it is a zero emission vehicle but needs development efforts directed towards an affordable TCO and reliability like the conventional powertrains. H_2 ICE is a promising transition technology that would provide zero CO_2 capability and also a competitive TCO along with reliability. It is also advantageous because the existing engine can be converted to H_2 ICE and the manufacturing facility can be used with minimal changes. The focus of H_2 ICE technology would be to improve the efficiency to about 45% in the long term and reduce the gap with FCEV's as much as possible. The scenario is also dependent on the cost of green H_2 which is \$5/kg currently and is expected to reduce to \$1/kg by 2030 due to multiple reasons viz; declining cost of renewable electricity, electrolysers getting better and cheaper and increase in production capacity (current hydrogen demand of 90m MT to grow to 130m MT by 2030). In this presentation, we focus on the global trend vs the Indian trends w.r.t the future power- train technologies alongside the TCO. Advantages of H_2 ICE over FCEV/BEV is discussed and methods of enhancing the efficiency of H_2 ICE is detailed. It emerges that H_2 ICE is a viable solution and can act as a transition technology till the BEV's/FCEV's mature in technology.

An Overview of PV Quality Management & Technology in Solar Power Plant

Goutam Samanta

Head PV Technology, Juniper Green Energy

Solar PV system generates clean energy and represents a sustainable solution in Renewable Energy (RE) Sector globally. Nowadays, PV electricity become increasingly competitive, continued market growth depends on assurances of performance and durability. Quality assurance protects and accelerates future PV growth, investments, lowers capital costs, improves performance, extends module lifespans with less degradation, and lowers the resulting cost of electricity (LCOE). The main objective of the abstract is to systematically review "State-of-the-art" research on the PV technology & quality. Innovation in PV manufacturing continues with the industry putting strong emphasis on increasing performance of PV devices. Passivated Emitter & Rear Cell (PERC) technology not only has become a new standard but also achieved its economic efficiency limits. Advance cell technologies with increase in cell efficiencies beyond P-Type PERC: N-Type architectures like TOPCon, Hetero-junction (HJT), IBC & MWT devises are in the pilot production stage at several global tier1 cell manufacturers. With quickly improved in cell efficiencies PV module is not only improved their power output but also in terms of reliability (low degradation on year-on-year basis). Advanced module technologies are commercially available with large wafer (cell) formats (M6, M10 & M12), Half-Cut Cells, Multi-Busbar (9 or 12 BB), Glass-Glass modules, Bifacial (transparent or Glass-Glass) module, Shingling & Paving. The best quality practices highlighted for the potential improvement of efficiencies across life cycle stages of the PV power plant.

Hydrogen Fuel for Automotive Applications

Dr. N. Saravanan

Principal Engineer, Mahindra Research Valley

The world at present is heavily dependent on petroleum fuels and the importance of alternative fuel research for internal combustion engines needs emphasis. Diesel engines are the main prime movers for public transportation vehicles, stationary power generation units and agricultural applications also Gasoline vehicles are primarily used for the personal mobility. Therefore, it is important to find a best alternative fuel, which emits fewer pollutants to the atmosphere. In this regard, hydrogen is receiving considerable attention as an alternative source of fuel to replace the rapidly depleting petroleum resources. Its clean burning characteristics provide a strong incentive to study its utilization as a possible alternate fuel. The major advantage of hydrogen fueled engine is that they emit fewer pollutants (renewable source) than diesel fueled engine. In hydrogen fueled engine the principal exhaust products are water vapor and NOX. In fuel cell there is no emissions. There are a lot of research on fuel cells, which yields very promising results, yet at other side it has several drawbacks such as cost, bulkiness and low efficiency at high loads.

Emphasis on Hydrogen Oxygen reaction mechanism, number of designs, and specially engine operation strategies that utilizes the full potential of hydrogen for high efficiency and low tail pipe emission is Critical. This includes the significant progress required in hardware up gradation, external & In-cylinder mixture formation strategy and safety requirement to make a conventional engine to run on hydrogen. The unique properties of hydrogen also require special attention when designing a safety concept for in vehicle application. By adopting the hydrogen sensors, flame detectors and a proper ventilated design, operational safety of hydrogen fueled can be achieved.

Hydrogen-fueled internal combustion engine can serve as a near-term option for a transportation in a hydrogen economy. The significant advancement and progressive work shows an excellent prospects to achieve very satisfactory IC engine, Fuel cell operation with hydrogen as fuel to achieve future performance and emission requirement.

‘Green’ approach to produce hydrogen ~ A step towards sustainable development

Ms. Charu Sharma
Sembcorp Energy India Limited, India

Background:

While last 2 years shall be remembered for a global health crisis, these have also been unprecedented years for the global energy transition and the growing interest in one of the most sustainable technologies i.e, Green Hydrogen. Many countries have announced strategies to develop hydrogen as a key energy carries for various sectors, India too has recently come up with its Green Hydrogen Policy. This will certainly take the world closer to achieving the net zero targets.

Opportunities, technology, global collaborations, and future landscape:

As per the assessment of Green Hydrogen’s use cases, it is found that there are lot of opportunities available as replacement demand and new demand. Replacement demand includes usage of hydrogen in Process Industry plants such as Ammonia, Steel Production & Refineries. New demand includes usage of hydrogen as fuel for transportation (Aviation and Ships) as well as Energy (Power and Heat Generation). Green Hydrogen is produced from clean energy sources such as Wind/ Solar/ Hybrid wind and solar etc. It is produced by splitting water into hydrogen & oxygen by electrolysis. While installation of electrolysers such as PEM, Alkaline and SOE is still limited, a detailed analysis and testing with pilot installations is under implementation across the world. It is imperative to deliver the hydrogen at an optimum cost to make it a viable option for adoption. The largest potential for near term cost reduction is in the balance of plant (BoP), while R&D is required to reduce stack cost and increase its performance and durability. A fine balance needs to be achieved between stack and BoP cost to continually reduce the levelized cost of hydrogen. Global collaboration can certainly be a catalyst for widespread and coordinated support across the value chain of hydrogen production, storage, and transportation.

Potential of Power-to-X, and Hydrogen fuels for high power applications

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A sustainable reduction in greenhouse gas emissions from high power applications like ships etc. will only be achieved by defossilizing the fuel. Thus, e-fuels, produced with renewable energy by Power-to-X (PtX) technology, are essential. PtX enables the coupling of the electricity and mobility sectors and allows the usage of existing infrastructure for the transportation of renewable fuels globally. While e-fuels are not an economically viable option yet, a market ramp-up is expected after 2030, evoked by ambitious CO2 reduction targets. Therefore, this presentation focusses on answering two main questions:

- What are the potentials of PtX and e-fuels?
- How to decarbonize high-power applications from well-to-wheel?

The potential of e-fuels produced with PtX is covered in the first part of this presentation. The global projected demands of e-fuels as well as the efficiencies of different fuel options (well-to-wheel) are identified and shown for high power off-highway applications. The comparison of decentralized (small scale) and centralized (large scale) PtX e-fuel production highlights the production potentials and its impacts on costs, resulting in expected fuel production costs. Furthermore, the implications of the location and its suitability for renewable energy harvesting is assessed globally and represented by a harvesting factor.

The second part of this presentation showcases the different paths to CO2-neutral propulsion. It presents the challenges and opportunities from using the key fuels of a future decarbonized industry.

This research emphasizes the increasing importance of e-fuels for the decarbonization and defossilization of high-power applications from production, over logistics to the application in high power industries.

Quality in construction of hybrids

Srinivas Popuri

Greenko Group, India

Quality as perceived by many plays a very importance and critical role in any project. This holds good even in Integrated Renewable Energy Projects (IREPs) or also called as Hybrids. An IREP or Hybrid project in the way I put is, combination of more than one renewable source (in this case, I am talking about Wind, Hydro and Solar). An integrated project is the future energy generation source for India. This is important in view of round the clock (RTC) power supply which is a credible and reliable alternative for the fossil fuel-based power generation.

Before we go forward in the quality aspect, I will enlist few critical aspects of quality for each vertical of power source:

I. Wind:

a. Soil investigation
b. Wind turbine foundation
c. Foundation plate leveling and bolts grouting
d. Erection of transmission towers and stringing
e. Construction of power transformers

II. Solar:

a. Soil investigation
b. Construction of table piles
c. Installation of MMS
d. Installation of PV modules
e. Provision of cable trenches and laying of cables
f. Construction of Inverter blocks

III. Hydro:

a. Soil investigation
b. Designing of embankment material
c. Laying of embankment
d. Asphalt mix design and laying
e. Construction of Dam
f. Turbine foundation
g. Water circuit

Now let us see quality role in embankment design and laying. For our project we have opted for an AFRD (Asphalt Faced Rock Filled Dam). It means the dam embankment will have a core of rock filled material and is covered with Asphalt. Embankment filling material is categorized as 3A, 3B and 2B (filter) material. Gradation of these materials is very critical and important. The sizes will determine the quality of laying and compaction. This is done by laying the material and compacting with vibration rollers of 16T capacity for a few passes. After this a Static Plate Load (SPL) Tester is used to determine Strain Moduli Ev2 and Ev1 and ratio Ev2/Ev1 (a figure for the compaction level). The modulus is an indicator for the bearing capacity of the soil or embankment under the loading plate.

Hydrogen Production and Liquefaction Processes

B. Chellathurai

ISRO Propulsion Complex, ISRO, Mahendragiri, TamilNadu, India

Ultrapure liquid hydrogen is required for powering Cryogenic stage of Geo Synchronous Launch Vehicle. Liquid hydrogen and Liquid Oxygen are used as propellants for Cryogenic stage. Hydrogen gas produced from different type of processes is purified, pre-cooled and liquefied. Ortho para converter is inbuilt in the liquefaction plant for the long-term storage of product liquid hydrogen. Suitable adsorbents at cryogenic temperature are used to remove trace level of Nitrogen and Oxygen in the product liquid Hydrogen. Ultrapure liquid hydrogen thus produced is collected in the Super insulated storage cum transportation tanker for road transportation and servicing at launch complex.

Roy Hermanns
Technical University Eindhoven, Netherlands

Sustainable mobility solutions with FCEV

Chandan Swahney

Tata Motors, India

Advance in Hydrogen Energy in Brazil

Sérgio Oliveira, Valnei S. da Cunha

Scientific and Technology Directorate-Dimci. National Institute of Metrology, Quality and Technology-Inmetro. Brazil

Hydrogen energy has been receiving a lot of attention from Brazilian and foreign companies lately. A lot of academic work on hydrogen and fuel cells in many academic groups is a reality in Brazil since the beginning of the 90´s. A not so long international boom arised in 2003 by the creation of forum IPHE that includes Brazilian Government since then. Inmetro has participated since 2004 at IPHE´s RCS (regulations, codes, and standards) working group and in 2007 at (and coordinating since 2016) ABNT´s technical committee CEE-067 on hydrogen technologies, that is a mirror of ISO TC-197 on both hydrogen technologies and hydrogen production, as well as keeps a close connection with IEC TC-105 on fuel cell technologies. Brazil has been sharing the international approach on clean hydrogen which aims the use of low carbon green hydrogen from the mid-term on whereas blue hydrogen is to be used in near-term (transitional phase) only. Internal R&D work at Inmetro encompasses studies on metrological reliability and measurement uncertainty by way of Monte Carlo simulations as well as cooperation with UEZO for the combination of both sulfonated polymers and clays, with appropriate fillers, in PEMFCs electrolytes. Additionally, Inmetro is developing capacity building for gas metrology in the field of hydrogen use, basic in the determination of purity assessment.

H_2Giga eModule – Integration profiles for series produced Electrolyzers

Daniel Erdmann

VDMA Working Group Power-to-X for Applications

H2Giga is one of Germany's Federal Ministry of Education and Research's flagship hydrogen projects launched to implement the National Hydrogen Strategy. The overall aim is to bring electrolysers into series production. The eModule subproject is concerned with the modeling, automation, integration and optimization of electrolysis modules.

Together with its project partners DLR, HSU Hamburg, Semodia and TU Dresden, VDMA Power-to-X for Applications will develop a reference plant in which various operating and utilization scenarios of electrolyzers can be mapped. The goal is to determine as precisely as possible how the individual electrolyzer components as well as the electrolyzer as a whole behave under volatile conditions and what specific requirements they are subject to. In dialog with industry, the project partners want to draw up a catalog of requirements and enable manufacturers of electrolyzers and components to gain experience before the actual series production of electrolyzers begins and to align the plants with future requirements.

Precious Metals – Indispensable Elements for a Hydrogen Economy

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Hydrogen is a pivotal contributor to the path of decarbonization and climate protection. Precious Metals play an important role in various applications being deployed for establishing a hydrogen economy. We will cover the various applications but will focus in the presentation on Precious Metals for PEM Electrolysis.

PEM Electrolysis is a prominent technology to generate Green Hydrogen from water with renewable energy and requires Platinum and Iridium Catalysts. Precious Metals such as Platinum and Iridium are scarce metals of high value and hence the loadings of precious metals need to be carefully considered with respect to long-term availability of the metals and the costs for PEM Electrolyzers. We present on latest development concerning catalysts for PEM Electrolysis, allowing for significant reduction of precious metals loadings and for increasing competitiveness of PEM Electrolyzers. Based on these latest developments and efficient concepts for recycling of such catalysts, Green Hydrogen by means of PEM Electrolysis will be a sustainable tool for decarbonization and climate protection – now and in the future.

Hydrogen Combustion for Commercial Engine Applications

Reza Rezaei

IAV GmbH, Germany

One challenge for the development of commercial vehicles is the reduction of CO2 greenhouse, where hydrogen can reduce the fleet CO2. Another challenge is EURO VII or ultra-low NOx in USA, also for hydrogen combustion. Based on a roadmap for emission regulation and scenarios for future heavy-duty engines, the requirements for the combustion system and after-treatment system are defined. Advantages of hydrogen fuel as well as challenges will be addressed using HD single-cylinder and validated simulation models. The effects of a combustion and thermal management on EAT system to fulfil future regulations are discussed. Additionally, the use of a H2-DeNOx and a possible EAT system for HD H2-ICE are evaluated and using test data of PM, the need of DPF for future emission concepts will be addressed.

Safety considerations for new hydrogen applications

Thorsten Arnhold

R. STAHL AG Waldenburg – Germany

Every year millions of tons of hydrogen are produced, transported and used globally. Many important chemical and petrochemical processes depend strongly on hydrogen as a valuable reactant. Especially because of its high flammability, hydrogen must be handled with care. Respective safety concepts for the appropriate handling in the industrial are tried and tested since many years.

With the global movement towards carbon free value chains hydrogen got a new level of importance for the society and industry. It is considered a major energy carrier, as feedstock for the chemical industry as climate-neutral-replacement for coal in the steel production etc. With this, significantly broader scope of use, hydrogen is no longer exclusively handled in dedicated industrial facilities with restricted public access under the operation of sufficiently qualified persons. New decentralized production technologies for hydrogen like electrolysis will be scaled up to new dimensions. To ensure a sufficient acceptance among the population it is necessary to adopt the safety concepts for hydrogen.

Based on the specific hazards and risks of hydrogen the author gives an overview about the international safety standards and regulations and the underlying technical concepts along the new value chains for green hydrogen. Special consideration is given to explosion protection and the integration of IEC TC 31 standards in the new concepts.

Dr. Lukas Virnich
FEV GmbH, Germany

Alternative renewable fuels and hydrogen – Fluid conditon monitoring

Mr. Klaus Lucka
Tec4Fuels GmbH, Germany

Renewable and eFuels take us closer to the climate goals

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Over the past 200 years, fossil fuels have come to power the vast majority of transport on land, at sea and in the air. Knowing the challenge that climate change is pressing on us today, the era of fossil fuels must end. This urgency to address emissions from transport sector drives a fundamental change in the way we power mobility. Business as usual is simply not an option anymore.

The real key for improved sustainability in the transport sector is replacing all fossil fuels with climate-friendlier alternatives.

Neste was one of the first companies to take steps towards this goal by committing to renewable fuels production already at the beginning of the 2000s. During the following decade and with the help of the legacy of innovation and strong focus on renewable feedstocks based on waste and residues, Neste has developed renewable solutions further and become the world's largest producer of renewable diesel.

We have not stopped there, over the longer term Neste's raw material range will be expanded to include several new sources. These include algae, lignocellulose, municipal solid waste, as well as converting renewable energy and carbon dioxide into liquid fuels (Power-to-Liquid and Power-to-X solutions).

But why focus on fuels, electrification of transportation is just around the corner? Knowing the extent of the task, every possible means of reducing carbon emissions in the Well-to-Wheel perspective should be considered. With this approach, renewable fuels have already a significant impact and together with efuels they have potential for much more.

Fuel Science – Mobility based on Renewable Resources

Bastian Lehrheuer[1,2]

[1]RWTH Aachen University, Thermodynamics of Mobile Energy Conversion Systems (TME)

[2]Cluster of Excellence „The Fuel Science Center“ (FSC)

One of the greatest challenges facing our society today is the increasing demand for energy and the need to replace our current fossil energy supply. The growing availability of non-fossil energy technologies opens up unprecedented opportunities to redesign the interface between energy and material value chains for a sustainable future. The Fuel Science Center (FSC) therefore brings together researchers from different disciplines to replace today‘s static fossil fuel-based scenario with adaptive production and propulsion systems based on renewable energies and carbon resources under dynamic system boundaries. The aim of FSC‘s work is to integrate renewable electricity with the shared use of bio-based carbon raw materials and CO2 to provide high-density liquid fuels (“bio-hybrid fuels”) that enable innovative engine concepts for highly efficient and clean combustion. A key component of the research is the "Fuel Design Process", which represents an integrated approach between fuel synthesis and propulsion technology.

Waste Plastic to Fuel Concept

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The rapid urbanization and increased population have increased the demand for plastics. About 60% of the plastics end up as waste after a single use with significant contributors like polyethylene (PE), polypropylene (PE), polyethylene terephthalate (PET), and polystyrene (PS). Disposed plastic wastes have created a massive load on municipal solid waste management. Existing treatment techniques like incineration and other techniques possess high operational cost/environmental impacts. This talk will discuss the pyrolysis process as a viable option for recovering valuable fuel oil by treating a variety of plastics.