Chapter 1
Introduction to Advanced Combustion Techniques and Engine Technologies for Automotive Sector

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Abstract To resolve the transportation sector issues such as rapidly increasing petroleum consumption and stringent emission norms for vehicles, researchers have proposed three solution strategies namely advanced combustion techniques, after-treatment systems and alternative fuels. This book covers all three aspects for automotive sector. A dedicated section of this book is based on methanol, which discusses about the methanol utilization strategies in vehicles, especially in two wheelers. Second section of this book is based on advanced combustion techniques, which includes gasoline compression ignition (GCI), gasoline direct injection (GDI), and spark assisted compression ignition (SACI). Fourth section is based on emissions and after treatments systems. Last section of this book includes two different aspects. First is the vehicle lightweighting and second is the development of UAVs for defence applications. Overall this book emphasizes on different techniques, which can improve engine efficiency and reduce harmful emissions for a sustainable transport system.

Keywords Advanced engine techniques · Alternative fuels · Methanol · Emission control

Currently, energy and environment are the two major issues for transportation sector. Rapidly dwindling petroleum reserves are already alarming, which shows the immediate requirement of alternative fuels. Emissions from vehicles also pushing researchers to develop energy efficient and clean combustion techniques (World Health Organization 2018). This book is based on all these aspects related to internal combustion (IC) engines. First section of this book includes one chapter based on introduction of different sections and presents the important aspects of each section.

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Second section of this book is based on methanol utilization techniques. In India, methanol can be produced from different stray carbon resources such as high ash coal, municipal solid waste (MSW) and low-value agricultural biomass. Indian transport sector, two-wheelers play a dominant role compared to four wheelers (Society of Indian Automobile Manufacturers 2018). Therefore, it is important to develop the technologies for alternative fuel utilization in two wheelers. First chapter of this section discusses about the engine control unit (ECU) calibration process for adaptation of methanol in modern two-wheelers. This chapter covers all the challenges in developing the retrofitment kit for existing electronic fuel injection (EFI) two-wheelers with minimal structural changes for successful M85 adaptation. This chapter primarily deals with the methodology for theoretical and experimental investigations for ECU calibration, which can ensure flawless performance and on-road drivability of M85 fuelled motorcycle. Second chapter of this section discusses the material compatibility of methanol with different engine components because methanol has compatibility issues with soft components of fuel injection systems. In this chapter, various research data were studied and cited to understand material compatibility aspects and engineering challenges for engine parts made of metals, elastomers, and plastics. The corrosion, wear of engine components are studied and suggested the suitable material for the engine parts which are coming in contact with methanol. Last chapter of this section is based on development of M15-fuelled two wheelers. In this chapter, conventional carburetor assisted two-wheelers is described. Carburetor is an essential component of these engines, which delivers the fuel to the combustion chamber however, conventional carburetors are designed to operate with gasoline. Therefore, it become necessary to modify design parameters of carburetor to operate with M15. This chapter deals with these challenges and presents possible solutions for using M15 in carburetor assisted two-wheelers.

Third section of the book is based on advanced combustion techniques. First chapter of this section is based on gasoline compression ignition (GCI) technique, which is a futuristic engine technology that takes advantage of good volatility, high auto-ignition temperature of the gasoline and high compression ratio (CR) of the diesel engine for higher thermal efficiency and lower particulate matter (PM) and NOx emissions (Hao et al. 2016). This chapter discusses about the development aspects and challenges involved in practical implementation of GCI technology in commercial engines. There are several issues such as cold start, high CO and HC emissions, combustion stability at part load, and high combustion noise at medium and full load, which need to be resolved. Detailed discussion about the effect of various control strategies on the GCI engine combustion, performance and emissions, optimum fuel requirement of the GCI engine, and adaption of GCI technique in the modern CI engines are few key aspects of this chapter. Next two chapters of this section describe about the gasoline direct injection (GDI) technique. In last few years, this technology became very popular due to its high power output, thermal efficiency and fuel economy. This chapter introduced different strategies of GDI and reviews the developments in the area of GDI technology. This chapter presents the concluding ways for enhancing the performance, way forward for making it more efficient and reliable by overcoming the limitations of GDI engine technologies.

Third chapter discusses about the utilization of alternative fuels in GDI engine and the effect of these alternative fuels on particulate emissions. It is well known fact the addition of oxygenated additives to gasoline reduces the particulate formation tendency compared to gasoline. This chapter discusses the optimization strategies of combustion by varying the parameters such as spark timing, fuel injection quantity, etc. Discussion on several disadvantages of oxygenated additives has been also included in the chapter. Last chapter of this section discusses about the mixed-mode combustion in which engine is operated in both combustion modes namely spark-assisted compression ignition (SACI), pure advanced compression ignition (ACI) and spark-ignited (SI) combustion. This chapter presents challenges involved with such combined mode operation. This chapter presents the addition of ozone (O_3) to avoid excessive knocking at the boundaries of load-speed map. O_3 addition stabilized combustion by enhancing the reactivity of gasoline, which thereby enabled stable auto-ignition with less initial charge heating.

Fourth section of this book is based on emissions and aftertreatment techniques. First chapter is based on the $PM_{2.5}$ bound trace metals and associated health effects. In this chapter, passenger cars of different age group as Bharat Stage (BS) II, III, and IV and different fuel type such as diesel, gasoline and compressed natural gas (CNG) have been used for PM sampling. These samples were analysed using Induced Coupled Plasma-Mass Spectrometry (ICP-MS) and total 17 trace metals (Al, Ag, As, Ba, Co, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Se, Sr, Ti, V, and Zn) were found in PM. Out of these metals, the non-carcinogenic and carcinogenic risks for adults and children were calculated for 5 metals namely Cr, Mn, Ni, Zn, and Pb. This chapter concluded that the human health risks associated with the exposure to $PM_{2.5}$ emitted from gasoline and CNG vehicles were higher as compared to diesel vehicle. Last chapter of this section is based on application of diesel particulate filter (DPF) for reducing PM emissions to achieve Bharat Stage-VI. Bharat Stage-VI requires ~90% reduction of PM compared to Bharat Stage IV, which can be achieved by using DPF. This chapter deals with the challenges involved with application of DPF in which appropriate size, accurate position in the tailpipe and minimum pressure drop are important. This chapter discusses the comprehensive details of material and regeneration processes used in DPF, including action plan for developing it BS-VI compatible.

Last section of this book includes two chapters. First chapter is based on design and development aspects of unmanned aerial vehicles (UAVs), which can be used in numerous applications such as surveillance, communication, terrain mapping, reconnaissance, and attack, etc. This chapter discusses the application of reciprocating engine as a propulsion system for UAVs. Main objective of this chapter is to discuss the challenges involved in development of IC engine based UAV, which can provide more durability, reliability, and enhance the flight duration. Discussion about different aspects such as structural and thermal analysis of engine components is an important feature of this chapter. Second chapter of this section if based on vehicle lightweighting strategy for improving the engine efficiency and for emission reduction. This technique is based on replacing parts made with heavier materials with lighter materials in order to reduce the overall weight of the vehicle.

This monograph presents the different technologies, which can be used for increasing energy efficiency and lowering the exhaust emissions. Specific topics covered in the monograph include:

- Introduction to Advanced Combustion Techniques and Engine Technologies for Automotive Sector
- Development of Methanol Fuelled Two-Wheeler for Sustainable Mobility
- Material Compatibility Aspects and Development of Methanol-Fuelled Engines
- Prospects of Methanol Fuelled Carburetted Two Wheelers in Developing Countries
- Prospects of Gasoline Compression Ignition (GCI) Engine-Fuel System
- Overview, Advancements and Challenges in Gasoline Direct Injection Engine Technology
- Study on Alternate Fuels and their effect on Particulate Emissions from GDI Engines
- Ozone Added Spark Assisted Compression Ignition
- Emissions of $PM_{2.5}$-bound Trace Metals from On-road Vehicles: An Assessment of Potential Health Risk
- Role of Diesel Particulate Filter to Meet Bharat Stage-VI Emission Norms in India
- Design and Development of Small Engines for UAV
- Automotive Lightweighting: A Brief Outline

The topics are organized in five different sections: (i) General, (ii) Methanol utilization, (iii) Advanced engine technologies, (iv) Emissions and aftertreatment systems, (v) Miscellaneous.

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