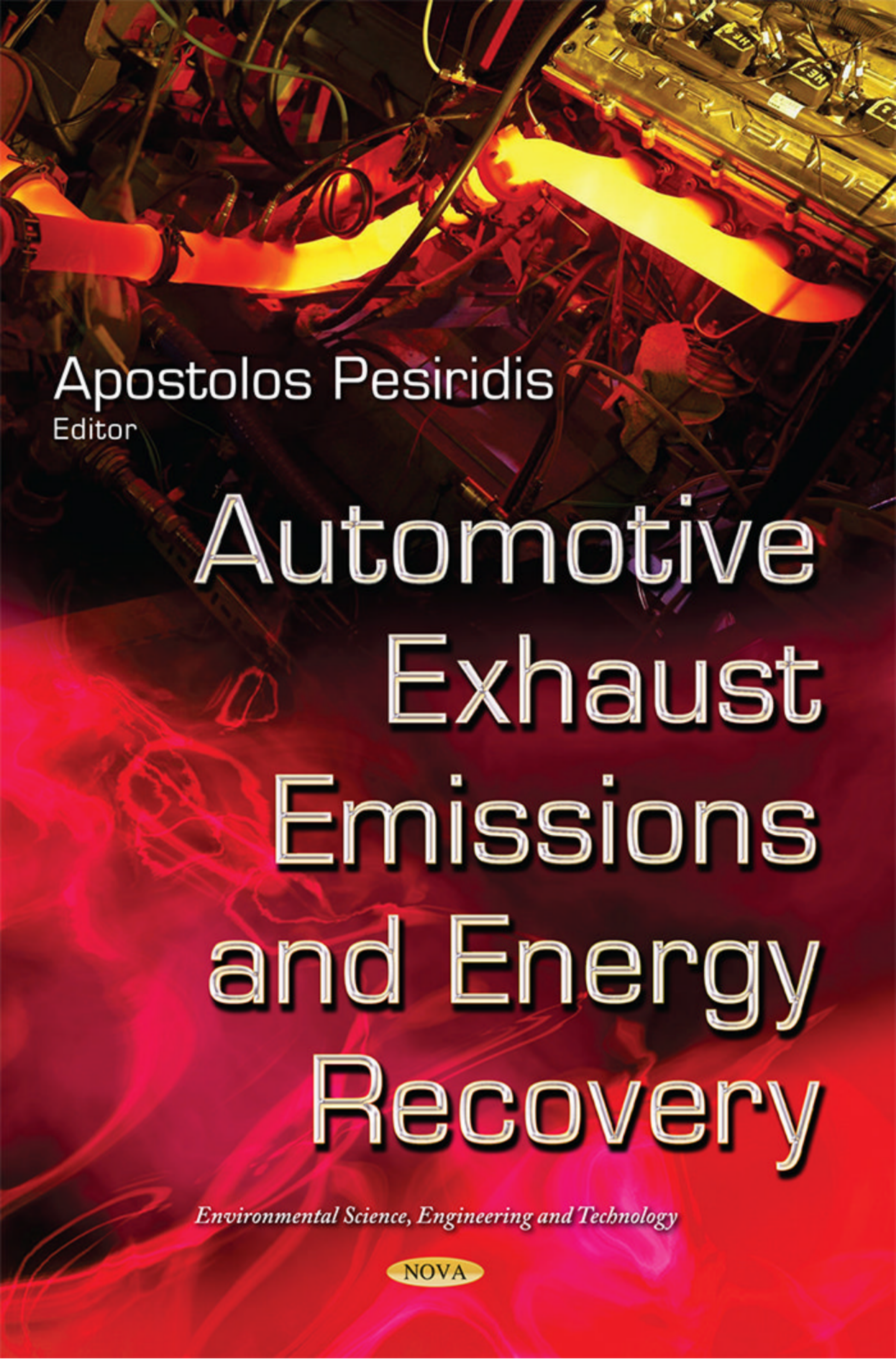

Apostolos Pesiridis
Editor

Automotive Exhaust Emissions and Energy Recovery

Environmental Science, Engineering and Technology

NOVA

ENVIRONMENTAL SCIENCE, ENGINEERING AND TECHNOLOGY

AUTOMOTIVE EXHAUST EMISSIONS AND ENERGY RECOVERY

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PREFACE

Since the invention of the first commercially successful internal combustion (IC) engine by Nikolaus Otto and Eugen Langen in 1866, the ICE has remained the most significant and widely used form of energy conversion technology in the transportation sector. Throughout the years, IC engines have been principally diversified by type of fuel, type of fuel injection and combustion mixing process as well as through the type of air handling and exhaust energy recovery technology used and improvements have made it more efficient and reliable. However, years of air pollution as a result of emissions from IC engines have made the development and integration of exhaust emissions mitigation technologies and systems increasingly significant in the continued effort to provide engines to the market which conform to increasingly stringent emissions regulations.

ICE development has to take into account air pollutants such as Nitrogen Oxides (NO_x), Carbon Monoxides (CO) and Hydrocarbons (HC), particulate matter (PM) as well as greenhouse gases (GHG) such as Carbon Dioxide (CO_2) and Nitrous Oxide (N_2O). In Europe, for example, Euro1 introduced in 1992 is the first of many subsequent EU regulations which regulates air pollutants. In 2009, the European Commission brought about mandatory CO_2 emission targets to regulate the new passenger car fleet CO2 emissions at 130 g/km by 2015 and 95 g/km by 2020. Emissions regulations require the mitigation of certain, previously unregulated emissions posing a health risk such as Nitrogen Dioxide (NO_2), ammonia as well as the formation of GHGs. New legislation is now including limits for NH_3 and certain specialist applications have been required to cap NO_2 and N_2O.

Another immediate concern for improved engine efficiency and fuel economy includes customer demand to own and drive more fuel efficient vehicles. This market-driven demand places additional pressure towards the development of more efficient engines in addition to emissions mitigation requirements and has resulted in a proliferation of systems and technologies in the exhaust system of the IC engine to recover the significant levels of exhaust gas energy expended after the combustion/power stroke. These include new forms of turbocharging, turbocompounding and waste heat recovery technologies.

The above driving concerns for fuel economy and reduced emissions make the topic of emissions control and exhaust energy recovery a timely one for both gasoline and diesel engines. Whereas diesel engines have been predominantly turbocharged only a relatively small percentage of gasoline engines is similarly equipped (especially in the US and large Asian markets) which has led towards significant efforts by engine manufacturers in recent years to downsize and downspeed these engines. On the other hand, the relative focus in diesel engine development in terms of emissions and exhaust energy recovery has shifted towards devices other than the turbocharger for enhanced energy recovery and in emissions control technologies to allow the diesel engines of the future to keep up with the twin demand for very low emissions and increasing levels of fuel economy.

The present volume on "Automotive Exhaust Emissions and Energy Recovery" focusses, therefore, on the exhaust system and on the technologies and methods used to reduce emissions and increase fuel economy by capitalising upon the exhaust gas energy availability (either in the form of gas kinetic energy or as waste heat extracted from the exhaust gas). It is projected that in the short to medium term, advances in exhaust emissions and energy recovery technologies will lead the way in IC engine development and pave the way towards increasing levels of engine hybridisation until full electric vehicle technology can claim a level of maturity and corresponding market share to turn the bulk of this focus away from the ICE.

The book is comprised of ten chapters which in most cases provide a review of recent developments as well as future directions for both gasoline and diesel four-stroke engines. As such the present volume is aimed at engine research professionals in the industry and academia in the first place but also towards students of powertrain engineering. The collection of articles in this book aims to review both fundamentals of relevant, recent exhaust system technologies but to also detail recent or on-going projects and to uncover future research directions and potentials where relevant. The content is not divided in sections but individual chapters follow the approximate route of the exhaust gas from in-cylinder formation in the initial chapters to waste heat recovery technologies at the end with discussion on bio-fuels included where relevant.

The initial chapter run of six chapters is principally dedicated to the emissions (mitigation and control) part of the book. Chapter 1 starts off with a description and review of emissions mitigation and control systems for both gasoline and diesel engines. The systems covered are three-way-catalysts, exhaust gas re-circulation (EGR), oxidation catalysts, particulate filters, selective catalytic reduction (SCRs) and leanNO_x trap designs as well as water injection systems. Diesel in-cylinder NO_x and soot formation by means of optical techniques is investigated in Chapter 2 for rapeseed methyl ester (RME) combustion. Further to the topic of NO_x, the influence of different EGR rates to diesel engine emissions is experimentally investigated and presented in Chapter 3. Chapter 4 is a review of literature on the effects of biofuel/diesel blends on particulate matter (PM) emissions from diesel engines operating under transient conditions and a statistical analysis allows comparisons to be drawn for the different types of fuel. Chapter 5 is a review of aftertreatment technologies with the provision of not only the physico-chemical phenomena and the respective mathematical modeling equations describing the transport and reaction processes but moves beyond the discussion of Chapter 1, also, in that it focusses on system design challenges from the control and optimisation points of view. Chapter 6, concludes the initial chapter run on in-cylinder measurements and aftertreatment technologies by focussing exclusively on Diesel Particulate Filters (DPFs); the chapter is a review of DPFs with a focus on filter material choices and the wall flow DPF design considerations.

The final chapter run of four chapters focusses on exhaust (both mechanical and thermal) energy recovery technologies and its impact on fuel economy (as well as emissions). Chapter 7 is a review of turbocharging technology, covering fundamentals as well as engine-turbocharger matching and applications of such systems in modern use. Chapter 8, focusses