About the Authors

Dr. Willard A. Cutler is currently division vice president and commercial technology director, responsible for the customer-facing technology for Corning’s environmental business, for both light-duty and heavy-duty vehicles. Cutler has worked for Corning for nearly three decades, in various research, product development, commercial, and leadership roles. Cutler holds a Ph.D. in materials from the University of California, Santa Barbara, and a B.S. in materials science and engineering from the University of Utah.

Dr. Thorsten Boger is currently commercial technology director—light-duty vehicles, Corning Environmental Technologies—responsible for the customer-technology interface for Corning’s global gasoline and diesel technologies applied to passenger cars and chassis dynamometer certified light commercial vehicles. He also serves as regional technology director for Europe. Boger joined Corning in 1997, working in different roles focused on new technologies for mobile emission control as well as industrial applications in the chemical and refining industry. Boger graduated with a degree in process engineering (Dipl.-Ing.) and received his doctorate (Dr.-Ing.) from the University of Stuttgart.
About the Authors

Christoph Bisig studied pharmaceutical sciences at the University of Basel, Switzerland, before joining Prof. Rothen-Rutishauser’s research group as a doctoral student in 2014 until the beginning of 2018. He has assessed the toxicity potential of several GDI engines with different fuels and exhaust aftertreatment systems. His work in this area has been published in a number of scientific journals. Currently he is a Postdoc at the HelmholtzZentrum München optimising an in vitro exposure protocol using a portable diesel aerosol generator and epithelial lung cells.

Prof. Alke Petri-Fink received her Ph.D. in chemistry from the University of Ulm, Germany, in 1999. After a postdoctoral stay at the University of Gainesville, Florida, she joined the Institute of Materials Science at the École Polytechnique Fédérale de Lausanne (EPFL), first as a postdoctoral researcher, then as a senior scientist. She became an Associate Swiss National Science Foundation Professor in the Department of Chemistry at the University of Fribourg in 2009, and full professor in 2011 at the Adolphe Merkle Institute, Switzerland. Her research focuses on inorganic nanoparticles, their synthesis, surfaces, and interactions with biological cells.

Prof. Dr. Barbara Rothen-Rutishauser received her Ph.D. in cell biology in 1996 from the Swiss Federal Institute of Technology (ETH) in Zurich. From 1996 to 2000 she held a postdoctoral position in Biopharmacy at the Institute of Pharmaceutical Sciences at the ETH, and in 2000 she joined Prof. Peter Gehr’s research group at the University of Bern, Switzerland. Prof. Rothen-Rutishauser is an expert in the field of cell-nanoparticle interactions in the lung, with a special focus on 3D lung cell models and various microscopy techniques such as laser scanning and transmission electron microscopy. In 2011 she took up the new chair in BioNanomaterials at the Adolphe Merkle Institute, University of Fribourg, Switzerland, a position shared equally with Prof. Alke Fink. The research group’s activities stretch over many fields from material synthesis and characterization to biological responses and risk assessment. Prof. Rothen-Rutishauser has published more than 200 peer-reviewed papers and is an associate editor of the journal *Particle and Fibre Toxicology*. 
Dr. Loretta Müller studied environmental sciences at the Swiss Federal Institute of Technology (ETH) in Zurich and joined the group of Prof. Peter Gehr and Prof. Barbara Rothen-Rutishauser for her master’s thesis and Ph.D. in 2006. For her Ph.D., she developed an exposure system to study the toxicity of exhaust emissions in cell cultures and studied the effects of scooter and diesel exhausts. After graduating in 2010, she worked for 2 years as a postdoctoral research fellow in the group of Prof. Dr. Ilona Jaspers at the University of North Carolina at Chapel Hill, USA. From 2013 to 2017 she worked as head of the wet lab of the pediatric pneumology research group of Prof. Dr. Philipp Latzin at the University Children’s Hospital Basel, Switzerland. In 2018 she moved her lab to the University Children’s Hospital Bern (Inselspital) to continue her work as head of wet lab of the research group of Philipp Latzin. Dr. Müller is an expert in the effects of exhaust emissions in in vitro settings and has extensive experience in working with co-culture models of the human respiratory system.
About the Author

Dr Ameya Joshi is director of Emerging Technologies and Regulations at Corning Incorporated, USA. He holds a PhD in mechanical engineering from the University of Delaware and completed his postdoctoral research in chemical engineering at the Colorado School of Mines. His technical background is in reaction engineering as applied to combustion and emissions aftertreatment. His current role is to follow advances in engine technologies and regulations pertinent to vehicular emissions. Previously he has been a regional technology manager responsible for introducing innovative products to customers in Japan and Korea, prior to which he was research manager of Modeling & Simulation, in the Reaction Engineering group where he was responsible for developing a suite of modeling tools to predict the in-use performance of cellular ceramic products.
About the Authors

Prof. Dr. sc. techn. Thomas Koch has been heading the Institute of Internal Combustion Engines at Karlsruhe Institute of Technology (KIT) since 2013 and has been responsible for combustion engine issues in the areas of research, teaching, and innovation. For 10 years prior to this, Professor Koch, as a graduate mechanical engineer, held various positions in the development of commercial vehicle engines at Daimler AG. Already in his doctoral thesis and as postdoctoral researcher at ETH Zürich, Professor Koch has dealt with thermodynamic issues relating to fuel combustion.

Dipl.-Ing. Jürgen Pfeil joined the Institute of Internal Combustion Engines (IFKM) of Karlsruhe Institute of Technology (KIT) in 2001. Today, he works as group leader in the research group “Optics and Oil Circuit” of the Institute. Jürgen Pfeil and his group are applying and improving optical measurement tools for diagnostic tasks in the application fields combustion, sprays, fluid mechanics, and exhaust aftertreatment systems.

Dr.-Ing. Markus Bertsch studied mechanical engineering at Karlsruhe Institute of Technology. He was research associate at the Institute of Internal Combustion Engines (IfKM) at Karlsruhe Institute of Technology (KIT) and worked on several research projects concerning combustion process analysis, optical diagnostics, and exhaust gas analysis on GDI engines with special focus on particle number emissions.

His dissertation titled “Experimental Investigations on Particle Number Emissions from GDI Engines” was published in December 2016.

Dipl.-Ing. Christian Disch received his diploma and doctorate at the Karlsruhe Institute of Technology (KIT). Much of his experimental work has involved the application of sophisticated optical diagnostics to analyze mixture formation and combustion processes of both single-cylinder and multi-cylinder GDI engines. His publication on the optical investigation of transient engine operation presented at the JSAE/SAE Powertrains, Fuels & Lubricants Meeting 2015 (Kyoto, Japan) was honored with the Best Paper Award.
Alexander Heinz (M.Sc.) studied mechanical engineering at Karlsruhe Institute of Technology (KIT). Since 2015, he has been working as a researcher at the Institute of Internal Combustion Engines. His work includes the investigation of particle emission with a focus on transient and real driving engine behavior of gasoline engines as well as the use of special investigation methods in order to characterize this behavior.

Denis Notheis (M.Sc.) has been working as a researcher at the Institute of Internal Combustion Engines at Karlsruhe Institute of Technology (KIT) since 2015. He investigated particle formation in gasoline engines with direct injection for the research project “Investigations to reduce particle number emissions from GDI-engines III” of the Forschungsvereinigung Verbrennungskraftmaschinen (FVV). In his work, he focused on numerical studies of the spray/flow field interactions and their influences on the particle number emission.
About the Author

Georgios Karavalakis joined the University of California, Riverside, in July 2010 where he holds a research faculty position at the Center for Environmental Research and Technology and an adjunct professor position with the Department of Chemical and Environmental Engineering. He has a BEng (Hons) in engineering and an MSc in environmental engineering both from the University of Portsmouth and a Ph.D. from the National Technical University of Athens in chemical engineering.

He is a member of the Society of Automotive Engineers and a member of the American Association of Aerosol Research. He is currently leading and being involved in major research programs funded by California agencies, industry consortiums, and the federal government relating to alternative fuels, engine emissions, and secondary organic aerosol research from combustion systems. He has over 65 publications in high impact factor journals and over 100 publications in technical conferences.
About the Authors

Dr. Mohammad Fatouraie joined Robert Bosch’s Advanced System Engineering division in January 2016. He is currently a principal engineer in combustion and emissions research. Prior to joining Bosch, Mohammad worked as an assistant research scientist in the Mechanical Engineering department of the University of Michigan. In 2010 he received his M.Eng. in automotive and manufacturing engineering and in 2013 he received his Ph.D. in mechanical engineering, both from the University of Michigan, Ann Arbor.

Dr. Kevin Peterson has worked in the automotive industry for more than 5 years and is a senior engineer at Robert Bosch LLC, focusing on engine testing and optical diagnostics for emissions mitigation. Peterson holds a Ph.D. and M.S. in mechanical engineering from the University of Michigan, as well as an M.S. in electrical engineering. He also has a B.A. in physics from Carleton College.

Bopaiah Ittira Biddappa is a very passionate automotive engineer in the systems engineering group at Robert Bosch LLC, Michigan. He graduated with a master’s degree in automotive engineering from Clemson University, South Carolina, and has been with Bosch for 3 years. He has a bachelor’s degree in mechanical engineering from Visvesvaraya Technological University. Bopaiah’s background is in IC engines, combustion and Emissions. He has worked extensively in particulate emission reduction, conducting tests on the engine and chassis dynamometers. He has previously published papers in the Journal of Applied Polymer Science. When he is not saving the polar bears, he loves to go mountain climbing, play soccer with his dog, and play cricket.

Dr. Jacob Larimore is currently a Customer Chief Engineer in the Powertrain Solutions division at Robert Bosch LLC where he focuses on the advancement of powertrain technology, the reduction of emissions, and the improvement of fuel economy. Larimore holds a Ph.D. and an M.S. in mechanical engineering from the University of Michigan, Ann Arbor, as well as a B.S. from Missouri University of Science and Technology, also in mechanical engineering.
Nikolay Livshiz is a graduate of U of M - Dearborn with a B.S. in mechanical engineering and a B.S. in engineering mathematics. Nikolay has been with Bosch since 2012 working in the systems and advanced engineering team on various topics related to ICEs and vehicle powertrain solutions.

Dr. Michael Mosburger is an engineering manager at Robert Bosch LLC. His group focuses on system and advanced engineering aspects in the field of internal combustion engines and powertrain systems development. Dr. Mosburger received a Ph.D. degree in mechanical engineering from the University of Michigan in 2012, as well as an M.S. in physics in 2011. Prior to coming to the United States, Michael studied industrial engineering at Karlsruhe Institute of Technology in Germany and received an M.S. degree in 2007.
About the Author

Dr. Thorsten Boger currently serves as commercial technology director for light-duty products at Corning Environmental Technologies (CET). He is responsible for leading the interface between customer and technology for global Corning customers of gasoline and diesel technologies as applied to passenger cars and chassis-dynamometer-certified light commercial vehicles. In addition, he serves as the regional technology director for Europe, CET. Boger joined Corning in 1997, working in different roles focused on new technologies for mobile emission control as well as industrial applications in the chemical and refining industry. He graduated with a degree in process engineering (Dipl.-Ing.) and received his doctorate (Dr.-Ing.) from the University of Stuttgart.
About the Authors

Dominik Rose is currently serving Corning GmbH as manager of systems engineering in Europe. His team is in charge of several engineering activities related to testing and evaluation of Corning products in the appropriate system environment. These activities include vehicle testing, engine bench testing, numerical simulations, and development of surrogate test methods. He joined Corning in 2004 and holds a diploma in mechanical engineering from Frankfurt’s University of Applied Sciences.

Dr. Thorsten Boger currently serves as commercial technology director for light-duty products at Corning Environmental Technologies (CET). He is responsible for leading the interface between customer and technology for global Corning customers of gasoline and diesel technologies as applied to passenger cars and chassis-dynamometer-certified light commercial vehicles. In addition, he serves as the regional technology director for Europe, CET. Boger joined Corning in 1997, working in different roles focused on new technologies for mobile emission control as well as industrial applications in the chemical and refining industry. He graduated with a degree in process engineering (Dipl.-Ing.) and received his doctorate (Dr.-Ing.) from the University of Stuttgart.
About the Authors

Dr. Patrick Burk is an R&D director in environmental catalysis at BASF Corporation currently responsible for Light Duty Gasoline Exhaust Abatement Technologies located in Iselin, NJ. Patrick began work on environmental catalysis in 1988 at Engelhard/BASF and has successfully managed the development of catalysts for both gasoline and diesel exhaust abatement applications. He has more than 20 patents in this area. Prior to joining BASF, he worked at Smith Kline and French Laboratories and Exxon Research and Engineering Company developing processes for the selective transformation of organic moieties to higher value-added products.

Patrick earned his Ph.D. in organic chemistry with the Nobel Laureate Robert Grubbs at Michigan State University followed by post-doctorals with Prof K. Barry Sharpless at M.I.T. and Prof. John Osborn at U. Louis Pasteur, Strasbourg, France.

Dr. Thomas Schmitz joined the automotive catalyst business in 2001. He held several positions in R&D, Application Engineering, and Sales. In 2011, he took over a project manager position at Gasoline System Development Europe located in Hannover, Germany. He and his team are developing gasoline exhaust system solutions with special focus on European customer requirements, meeting most stringent emission standards. Special emphasis is given to the Four-Way Conversion Catalyst, which is now being introduced to the market.

He received his PhD in physical chemistry from the University of Wuppertal, Germany. In his postdoc, he worked at the research center in Jülich at the Institute for Tropospheric Ozone Research on the characterization of vehicle emissions under real-world driving conditions. His focus was the speciation of hydrocarbon emissions in order to evaluate the contribution of traffic-related emissions to ozone formation.
Dr. Chris Morgan has worked for Johnson Matthey since 1997, and in his current role as Technology Director, Clean Air Europe is responsible for the development, scale-up, and testing of autocatalyst coatings for both gasoline and diesel applications. Chris previously managed the Gasoline Product Development team, developing new families of three-way catalysts and leading JM’s early work on coatings for gasoline particulate filters, as well as the Catalyst Characterisation and Prototype Samples groups. Before joining Johnson Matthey, he completed a DPhil at Oxford University on the preparation and application of high-temperature ceramic superconductors.

Dr. Jonathan Cooper has worked for Johnson Matthey since 1999. Having worked in gasoline aftertreatment in various roles throughout his career, including being part of the team to begin studies into coated GPFs, he is currently Gasoline Development Manager for Clean Air Europe, responsible for developing new TWC and GPF products. Prior to joining Johnson Matthey he completed a DPhil at Oxford University looking at photo-activated electroanalysis using platinum electrodes in flowing solutions.
About the Author

Christophe Colignon studied mechanical engineering and graduated from IFP-School in 1997, with an engines engineering degree. He worked 16 months in the technical Department of Renault UK After-Sales Services before joining Groupe PSA (PSA Peugeot Citroën at that time) in April 1999. He has worked for reducing emissions of gasoline and Diesel engines in all the positions he occupied in the Company, becoming a specialist for particulate filter systems. He also lectures on emissions control systems at several universities.
CHAPTER 12  System Integration and Application for a TWC-Coated GPF

About the Authors

Mr. Jung-min Seo is the leader in the development of after-treatment system of gasoline, diesel, and hybrid engine in the R&D headquarters of Hyundai Motor Group. He joined Kia Motor Co as project manager in 1991 and was the design engineer of diesel engine from 1995 to 2003. Then he developed the diesel aftertreatment system by 2014. His major was mechanical engineering.

Dr. Chi-bum In earned both his master’s degree in Material Engineering, in 1991, and PhD in Electronic Material Engineering, in 1994, from Korea Advanced Institute of Science and Technology, Korea. His background is in ceramic material and thin film engineering. He joined Hyundai Motor Group in 1991 and is currently working in the area of aftertreatment system development. His current responsibilities include developing the advanced GPF system for the upcoming global emission legislation.
About the Author

Les Hill has worked on automotive emissions measurement for more than 40 years. Originally trained as an analytical chemist at Lanchester Polytechnic, his introduction to exhaust emissions measurement was at Triumph Motor Company in Coventry, England. In 1982 he joined HORIBA Instruments Limited in the United Kingdom and was fortunate to work in many emissions testing facilities on a wide variety of projects that allowed him to increase his knowledge and experience in all aspects of exhaust emission measurement. In recent years, he has been responsible for emissions measurement product planning activities within HORIBA.

In addition to organizing Emissions Measurement and Testing sessions for the SAE Congress, he has contributed to several industry, legislative, and technical working groups on exhaust emissions measurement. This includes the PMP working group responsible for the development and introduction of the particle number measurement method. He also actively works for global coordination for emissions measurement technology and procedures. He is very grateful to HORIBA Limited who actively encourage their employees to support and contribute to the technical organizations of the automotive industry.

He was presented with the Forest R. McFarland Award from SAE in 2007 in recognition of his contribution to SAE activities.
About the Authors

Jim Daley, Advanced OBD Systems Manager, FCA US LLC received his Masters of Science in Mechanical Engineering from West Virginia University (WVU). While at WVU, Jim was a co-captain of the SAE Formula team and vice president of the WVU chapter of SAE. Jim’s research work was on heavy-duty diesel engine emissions and development of a chassis dynamometer-based heavy-duty class 8 emissions test. After graduating college, Jim started working for DaimlerChrysler Corporation and was lead emissions calibrator for the 3.7L V6 and 4.0L I6 engine families. Jim then transferred to OBD calibration where he was responsible for all aftertreatment system calibrations and later became the Center of Excellence leader for Aftertreatment Systems Diagnostics. After Fiat and Chrysler Group LLC merged, Jim was a feature team leader on the Fiat 500 Federalization project that launched the Fiat 500 in the USA.

Jim moved on to become the leader of the Advanced OBD Systems team where he has built a team comprised of outstanding engineers from around the globe. His team is dedicated and focused on designing compliant OBD control systems for all of FCA US future product portfolio.

Joseph Dekar, Advanced OBD Systems Engineer, FCA US LLC received his bachelor’s degree in Mechanical Engineering from Binghamton University. He later joined FCA US as an Advanced OBD Systems Engineer working to develop diagnostics for future engine and aftertreatment technologies. He began his career working on aftertreatment sensor diagnostics specifically related to oxygen sensors and their associated in-use aging and failure modes. Most recently, Joseph supported the global implementation of gasoline particulate filters within FCA US, focusing on development of sensor and filter diagnostics. During his time at FCA US, he has been awarded one patent and is listed on three more pending patents.

Jordan Easter, Advanced Emissions Systems Engineer, FCA US LLC completed her Bachelors of Science in Mechanical Engineering at the University of Alabama–Tuscaloosa and her Masters of Science and Doctorate of Philosophy degree in Mechanical Engineering at the University of Michigan–Ann Arbor. Her research has resulted in several publications and has focused on aftertreatment for advanced combustion modes, advanced particulate sensors, and gasoline soot oxidation characteristics. She has worked for FCA US for the past four years in advanced powertrain emissions and diagnostic organizations. During this time, she has focused on advanced monitor development and future compliance regarding particulate emissions of gasoline direct injection engines.
Nithin Baradwaj, Advanced OBD Systems Engineer, FCA US LLC holds a bachelor’s degree in Mechanical Engineering from Birla Institute of Technology and Science. After graduation, he went on to work for John Deere India Pvt Ltd as a test and analysis engineer in the product verification and validation group. He also holds a master’s degree in Mechanical Engineering from The Ohio State University. During his graduate studies, his research focused on determining the uncertainties involved in soot measurements using on-board resistive PM sensors. After earning his master’s degree, he worked at Cummins Inc. as an aftertreatment OBD calibration engineer. In his current role at FCA US, his focus is on developing OBD-compliant technologies that improve fuel economy and/or reduce evaporative and tailpipe emissions.

Brian Terwedo, Advanced OBD Systems Engineer, FCA US LLC holds degrees in Electrical Engineering from Michigan Technological University and Computer Science from Western Michigan University. He started his career at General Electric Aviation (formerly Smiths Industries Aerospace), where he developed aircraft operational flight software for data recorders, loads monitors, and Integrated Vehicle Health Monitoring (IVHM) systems. Later, he joined the General Motors/Delphi Forward Engine Management Systems Group and developed gasoline engine control software and systems including idle and electronic throttle control. Currently, he is a member of the FCA US Advanced OBD Systems group and is responsible for development of advanced engine, OBD, and aftertreatment systems and software. He has over 20 years embedded systems design experience and is an IEEE member.
About the Authors

Michail Mitsouridis followed a double degree program, receiving his Mechanical Engineering Diploma from Aristotle University of Thessaloniki and his Diplôme d’Ingénieur from École Centrale Paris. He is currently a PhD candidate at Aristotle University of Thessaloniki, under the supervision of Prof. Koltsakis. In his PhD thesis he studies the performance of catalyzed gasoline particulate filters with the support of mathematical models. He is also employed as project manager at Exothermia SA.

Dimitrios Karamitros is a mechanical engineer. He holds an MSc in powertrain engineering from IFP School in France and a PhD in exhaust aftertreatment modeling from Aristotle University of Thessaloniki in Greece. He is currently employed as project engineer at Exothermia SA.

Dr. Grigorios C. Koltsakis received his diploma and PhD from the Department of Mechanical Engineering of Aristotle University of Thessaloniki. He is currently a Professor at the Laboratory of Applied Thermodynamics of Aristotle University, specializing in internal combustion engines and exhaust aftertreatment technology. He has authored more than 100 papers in scientific Journals and international conferences and holds 2 patents. Dr. Koltsakis has received the Arch T. Colwell Merit Award, two Oral presentation awards from SAE International as well as the first Innovation prize from the Research Committee of Aristotle University. Dr. Koltsakis leads a research group active in the simulation and evaluation of after-treatment technologies in close collaboration with the automotive industry. He is a co-founder and scientific director of Exothermia SA, a university spin-off company developing exhaust system simulation software.

Julie Le Louvetel-Poilly did a PhD on fluid mechanics and turbulent flow from 2005 to 2008. From 2008 to 2014, she did fundamental research in Keio University (Japan) and Beihang University (China) on fluid mechanism modeling. She joined Toyota Motor Europe in 2015 as engineer in Powertrain Model Based Development group, where she is in charge to develop the exhaust aftertreatment model for gasoline engines.
Kotaro Maeda studied mechanical engineering at Tokushima University in Japan. He joined Toyota Motor Corporation diesel engine system development and mass production calibration department from 2007 to 2014. He joined Toyota Motor Europe in 2015 as manager in Powertrain Model Based Development group, where he is in charge of the development of engine and exhaust modeling.

Francois-Alexandre Lafossas graduated from MATMECA engineering school in 2000. He started his activity in 2000 in IFP Energies Nouvelles as combustion research engineer to support the development of gasoline and diesel combustion models in 3D and 0D applications. He joined Toyota Motor Europe in 2009 as senior engineer in the Powertrain Pre-development group where he was in charge to develop the integration of a modeling tool in the pre-development process. He became manager in Model Based Development group in 2011 with a focus on expanding the modeling area from combustion engines to drivetrain and hybrid systems. In 2015, he became senior manager of the Model Based Development group. He also contributed to more than 30 international publications in the field of powertrain and engine systems modeling.
A

Absolute pressure sensor, 117, 259
Abstraction of hydrogen and acetylene addition (HACA) mechanism, 84
Active regeneration strategy, 213–214
Advanced diffusion charger design, PEMS-PN, 245–246
Air pollution adverse effects, 10, 11
air quality, 11
anthropogenic emissions, 10
automobile exhaust emissions, 11
Clean Air Act, 10
climate change and global warming, 10
inhaled air pollutants adverse health effects, 16–18
airway wall structure of lungs, 12–14
clearance mechanisms, 15–16
fractional deposition efficiencies, 12, 13
lung parenchyma, 13
structure of gasoline particles, 11, 12
in Meuse valley, 10
National Ambient Air Quality Standards, 10
Ash accumulation accumulation rates, 155, 156
ash density, 155
ash layer, 133
ash plugs, 157
average ash layer thickness, 157
back of filter, 213
Ca-based additives, 155
channel volume per mass, 155
characterization, 133
component pressure drop, 154
contributions, 154–155
CT scan of filter, 132, 133
Fe-containing species, 155
filter scale modeling ash layer formation, 302
ash loading impact on pressure drop, 301
ash loading impact with samples, 301, 302
cake formation, 303
catalytic washcoat, 300
clean backpressure and mass filtration efficiencies, 301, 302
CO conversion curves, 306–307
contribution, 302
experimental effect, 302
potential sources, 154
pressure drop effect on, 132
vs. soot load behavior, 133, 134
SEM images, 133, 134
soot-to-ash ratios, 133
tomography scans, 157
tuning impact, 211
Ash fraction, 65–66
material corrosion, 300
plug ash and soot effect on pressure drop, 303–304
pressure drop vs. ash loading, 302, 303
pressure drop vs. combined ash and soot load, 302, 303
wall accumulation, 302
washcoat loading, 304
finding rates, 155, 156
lubricant oils, 155, 157
migration of, 132
oil consumption, 155
pressure drop effect on, 132
vs. soot load behavior, 133, 134
SEM images, 133, 134
soot-to-ash ratios, 133
tomography scans, 157
total mass, 132
tuning impact, 211
Ash fraction, 65–66

B

Biomass-derived ethanol, 83
Brownian motion, GPF, 120–122

C

Cake filtration, 277–279, 281
California Air Resource Board (CARB), 5, 38
Canadian Cancer Registries Epidemiology Research Group, 19
Carbonaceous fraction, 65
Carbon dioxide emission standards, 270
Catalyst heating operation, 75–77
Catalytic three-way catalyst (TWC), 6
Ceria–zirconia oxides (CZO), 185–186
Channel-scale modeling, 270, 271
energy balance, 286–287
inlet and outlet channels, 281, 282
mass-momentum balance, 282
pressure drop
axial flow nonuniformities, 284
breakdown, 283
exhaust mass flow rate and temperature, 283, 284
experimental and simulation results, 283
filter-induced backpressure, 282
filter properties, 284
flow-through-wall distribution, 284
mass-momentum balance equations, 284
term contribution, 283–284
zone-coated filters, 284–286
soot reactions
active regeneration strategy, 295
ash fraction effect, 297
ash particles, 296
direct soot catalysis, 296
full-length GPF cores, 298
gasoline vs. diesel engines, 295
GDI soot sampling conditions, 297
GPF thermal regeneration, 296
“high” ash/soot ratio, 298
indirect soot catalysis, 296
instantaneous soot mass, 298
“low” ash/soot ratio, 298
lube oil-derived metallic ash additives, 297
non-carbonaceous elements, measured impact, 298
passive regeneration, 295
rate expressions, 296
soot accumulation location, 295
soot oxidation rate, 295
steady-state soot loadings, 298
stoichiometric engine, 295
thermogravimetric analysis, 297
species balance
CO concentration profiles, 288, 291
effective diffusivity, 287
governing advection-reaction-diffusion equation, 287
Knudsen diffusivity, 288
light-off behavior, 288–290
mass transfer coefficients, 288
species transfer equation, 287
TWC intrinsic reactivity, 288
washcoat loading, 288
TWC reactions cerium (oxidized state), 292
cerium (reduced state), 292
conventional monolith vs. coated filter, 292–294
experiment vs. model prediction, 292–294
light-off performance, 292–294
NO reduction, 291–292
oxidation reactions, 291
steam reforming, 292
thermal capacity, outlet channel plugs, 295
TWC/GPF, 291
wall-flow filter vs. flow-through monolith, 295
water-gas shift, 292
Charge homogeneity, 106
Chassis dynamometer testing, 146
Chassis roller, filtration performance, 214, 215
China’s Ministry of Environmental Protection, 42–44
Clean Air Act, 10
Close-coupled (CC) position, 116–117
Coated GPF, 204
Cold ambient temperatures, 214
Combustion engine, 10
Condensation particle counter (CPC) actual flow rate, 239
calibration and particle detection efficiencies, 241
detection efficiency, 241
flow rate, 241
outline, 239
PEMS-PN system, 243–244
PN concentration measurement, 239
PN counting with, 238
in single particle counting mode, 240, 241
Conformity factors (CF), 204, 246
Constant Volume Sampling (CVS), 238
Corning DuraTrap® GC 200/8 filters, 220
Corporate Average Fuel Economy (CAFE) standard, 83
CPC, see Condensation particle counter

D
Darcy’s law, 125, 280
Depth-filtration processes, 270, 271
Diesel engine, 10
Diesel particulate filters (DPF), 116, 255
Differential pressure sensors (DPS), 117, 213, 255, 256, 260
Diffusion flames fuel films, 104
surface, 108
Diffusion Size Classifier (DiSC) sensor, 245
Direct-injection (DI) engines liquid fuel, 104
spray characteristics, 104
DPS, see Differential pressure sensors

Durability test
ash effect on SML, 231–232
PN FE, 230–231

E
EMROAD software, 41
Energy balance, channel-scale modeling, 286–287
Energy Independence and Security Act of 2007 (EISA), 84
Engine calibration
fuel pressure, 110–111
injection timing, 109–110
number of injection events, 111
parameters, 109
Engine control unit (ECU), 74, 256
Engine loads, 107
transients, 108–109
Engine speed, 106–107
and load transients, 108–109
Environmental Protection Agency (EPA), 83, 238
EPA Act/V2/E-89 (EPAAct) program, 86
Escaping current PM sensor, 255, 257–258
EU 2017-1154 Directive, 246
EU Directorate-General for Enterprise and Industry (DG-ENTR), 242
EU Joint Research Centre (JRC), 242
Euro 5b regulation, 3
Euro 6d full RDE legislation, 200
European gasoline direct injection (GDI) vehicles, 115
Euro 4 regulations, 3
Exhaust gas recirculation (EGR), 46–47
Exothermic heat release, 287

F
Fail decision, 261, 263
Filter scale modeling, 270, 272
ash accumulation
ash layer formation, 302
ash loading impact on pressure drop, 301
ash loading impact with samples, 301, 302
cake formation, 303
catalytic washcoat, 300
clean backpressure and mass filtration efficiencies, 301, 302
CO conversion curves, 306–307
contribution, 302
experimental effect, CO and NOx conversion efficiency, 304, 305
on filter’s filtration efficiency, 301, 304
green-, 3k1-, and FM50h-coated GPFs, 301, 302
layer and plug ash loading, predicted effect, 306
loading cycle, 302
lube-oil consumption, 300
material corrosion, 300
plug ash and soot effect on pressure drop, 303–304
pressure drop vs. ash loading, 302, 303
pressure drop vs. combined ash and soot load, 302, 303
wall accumulation, 302
washcoat loading, 304
fuel cut-off events, filter regeneration in
CO oxidation exotherm, 299
peak temperature response, 300
soot oxidation exotherm and oxygen consumption, 299
soot oxidation rate, 299
temperature, CO, and CO2 evolution comparison, 300, 301
TWC-coated filters, 300
Filtration efficiency
application conditions, effect of boundary conditions, WLTC, 150
CC vs. UF locations, 151
cumulative engine-out PN transients, 150
cumulative particle emissions, 151
filter sizing, 148, 150
filter technology and component size, 148, 149
impact of filter location, 151
particle number emission test data, 1.2L TGDI vehicle, 148
particulate concentration, 148
RTS-95 vs. WLTC, 148, 149
soot accumulation, 150–151
test cycle, 148
vehicle velocity, 151
cake/surface filtration, 277–278
correlation, 122–123
on different test vehicles, 131
evolution, 123
over extended mileage, 152–153
over initial mileage, 151–152
filtration characteristic parameter, 122
as function of particle size, 121
as function of soot load, 123
PN FE durability test, 230–231
evaporation, 225
fuel specification, 225
optimization, 225–226
PM index, 225
target PN values, 224
variability and wash coat properties, 225
pore size, 121, 122, 124
porosity, 121, 122, 124
saturation in, 124
temperature, 121, 122
tests, 214–215
unit collector, 121
“V” shape behavior, 121
wall-flow ceramic filter, 278
wall flow velocity, 121, 122
web thickness, 121, 122
Filtration, GPF ash, 123
Brownian motion, 120–122
catalyst coating, 124
collection efficiency of particles, 121
deposition, 120
design and operating parameters, 121–122
efficiency (see Filtration efficiency, GPF)
interception, 120, 121
mechanisms, 120
on-wall coating, 124
over different emission cycles, 130–132
Peclet number, 121
PN emissions, 131, 132
unit collectors, 120–121
Fleet average values, 270
Flow restriction, 259
Flow-through TWC substrates, 119
Four-way-conversion (FWC) catalyst aging stability, 180
backpressure, 180–182
catalyst location effect, 181–183
catalyst slurry properties, 181
catalytic activity, 180
CC application, 184–185
cold flow backpressure measurements, 186, 187
CZO, 185–186
design architectures, 183, 184
emission requirements, 183–184
Euro 6a vehicle testing, 186
Euro 6d gasoline system configurations, 183, 184
filtration efficiency, 181–183
hydrocarbon and NOx emissions, 187, 188
low catalyst loading, 187, 188
OBD, 179, 185–186
on-wall coating vs. in-wall coating, 181, 182
OSC measurement, 185, 186
particle number emissions, 183
Rh-only, 187
engine calibration
fuel pressure, 110–111
injection timing, 109–110
number of injection events, 111
parameters, 109
engine-out exhaust gas temperature, 271
fuel consumption, 270
lower CO₂ emissions, 270
operating conditions
control response, engine calibration process, 106
engine loads, 107
engine physics, 105
engine speed and load transients, 106–109
oil and coolant temperature, 108
physical parameters, 106
speed/load profile, 105
particle mass emissions, 273
particulate emissions, 271
particulate filter technology, 271
particulate formation mechanisms
engine-out particulate emission, 103
gas phase, 104, 105
high-temperature thermochemical decomposition, 104
liquid films, 104–105
low-temperature chemistry pathways of radicals, 104
regions, 104
sources for, 104
particulates raw emissions, 204
RDE cycle, 271
Gasoline direct injection (GDI) vehicle exhausts aftertreatment system, 49–51
air quality guidelines, 35
China’s Ministry of Environmental Protection, 42–44
epidemiological findings, 18–19
Euro 6d regulations, 39, 40
ex vivo studies, 20–22
fuel-air mixture preparation, 34
fuel considerations, 48–49
fuel economy, 34
global warming, 36–37
health risks, 34–36
in-cylinder methods
EGR, 46–47
electrification, 47–48
fuel efficiency improvements, 46
injection systems, 45–46
lean and low-temperature combustion, 47
split injection strategy, 46
spray-guided system, 45
VCR, 46
wall-guided systems, 45
India regulatory framework, 44–45
in vitro studies, 20–22
in vivo studies, 19–20
PAH emissions, 36
RDE legislation, 39, 41, 42
SOA, 37
United States and California regulations, 37–39
vehicular tailpipe CO₂ targets, 33, 34

RTS 95 test cycle, 186–188
trade-offs, 180, 181
UF position, 186, 187
Fuel impacts on particle formation
air/fuel ratio, 91
aromatics and distillation temperatures, 86
biomass-derived ethanol, 83, 84
distillation end point, 86
double bond equivalent values, 84, 85
E10 fuels, 88
E20 fuels, 90
EPAct program, 86
ethanol/gasoline blends, 87, 89–91
fuel composition, 84
isobutanol blend, 92
low PMI fuel, 86
mixture
inhomogeneities, 87
oxygen/carbon (O/C) ratio, 88
particle size distributions, 87, 89
PMI, 84, 86
PNI, 85
sec-butanol blends, 91
soot oxidation, 84
spray-guided GDI engine, 85, 91
total particulate number and total particulate mass, 87, 88
US06 driving cycles, 85
Fuel pressure, 110–111
Fuel rail pressure, 111
Fuel temperature, 108
FWC catalyst, see Four-way-conversion catalyst

G

Gasoline direct injection (GDI) engines, 4, 233
vs. diesel engines, 270, 271
Gasoline particulate filters (GPFs), 5, 7
aftertreatment architectures, 116–117, 251
application requirement catalyst activity and utilization, 119
filtration performance, 119
mechanical and thermomechanical robustness, 119
passive soot oxidation and soot mass limit, 119
pressure drop, 119
ash accumulation (see Ash accumulation)
catalyst functionality, 129
design based on pressure drop, 135, 136
cell density unit, 118
hydraulic diameter, 118
median pore size, 118
microporous wall material, 118
open frontal area, 118
porosity, 118
porous ceramic honeycomb structure, 117–118
properties, 118
wall-flow particulate filter design, 117, 118
web thickness, 118
design/integration coated GPF, 204
filter selection, 205
functional requirements, 205–206
pressure drop measurement, 208–209
severe regeneration test, 209–210
system operation, 206–207
uncoated GPF, 204
diagnostics (see On-board diagnostics (OBD))
DP-based fault criteria, 260–261
DP trace, 260
early prototypes, 116
exhaust system pressure drop, 158
failure modes cracking and channel damage, 254
missing GPF substrate, 254
filtration ash, 123
Brownian motion, 120–122
catalyst coating, 124
characteristic parameter, 122
collection efficiency of particles, 121
correlation, 122–123
deposition, 120
design and operating parameters, 121–122
efficiency and missing
P-diagram, 261, 262
evolution, 123
function of soot load, 123
interception, 120, 121
mechanisms, 120
on-wall coating, 124
over different emission cycles, 130–132
Peclet number, 121
unit collectors, 120–121
first high-volume applications, 115
first low-volume platform, 115
health monitor, 263, 264
mass production vehicles, implementation in, 233
material selection, 119
mechanical robustness and packaging, 129–130
missing monitor separation, 265
modern powertrain architectures, 115
operating window, 228
particulate emission measurement procedures, 146–147
peak temperature vs. SML, 228
with/without fuel cut, 227
performance characteristics change, 145
pressure drop ash effect, 128
correlations, 124
Darcy’s law, 125
frictional losses, 124
as function of soot load, 127
index, 124, 125
inlet and outlet contributions, 124
in-wall coatings, 125
local flow rate, 125
on-wall coatings, 125
primary contributions, 124
Index

vs. soot load, 127
turbulent entrance, 124
for uncoated and
coated GPFs, 126–127
wall permeability, 125, 126
washcoat loading
level, 127
primary function, 146
purely passive
applications, soot
management (see
Vehicle testing, soot
loading)
SEM images, 133, 134
sensing
development phase, 255
DPS, 255, 256
escaping current PM
sensor, 255,
257–258
filter parameters, 255
ion charge sensor,
255, 257
radio frequency
sensor, 255, 258
resistive PM sensors,
255–257
severe soot regeneration
deceleration fuel
cut-off testing, 165
exhaust system
protection, 165
exothermic heat
release, 165
maximum filter
temperature, 166,
167
oxygen
concentration, 166
reaction rate, 166
thermomechanical
exposure, 165
soot load monitoring
closed-loop control,
159
cold start and low
engine
temperatures, 159
engine-out particulate
emissions map, 159
open-loop-based soot
mass models, 159
oxidation rates, 159
simplified
phenomenological
engine models, 158–159
soot emission
information, 158
soot mass balance,
158–160
soot oxidation and
regeneration
carbon, 137
fuel cuts, 137–139
NO\textsubscript{x}, 137
oxidation rates, 138,
139
Printex U, 138
TGA soot oxidation
measurements,
137–139
species transfer
equation, 271
system validation
filtration efficiency
tests, 214–215
vehicle road tests (see
Vehicle road tests)
thermal and chemical
aging, 145
thermal stress (see
Thermal stress)
tuning impact
ash accumulation
amount, 211
engine performance,
211–213
monitoring strategies,
213–214
oil quality, 211
soot storage amount,
211
uncoated filter
backpressure, 211
turbine pressure ratio,
158
underflow GPF, 233
Gasoline-powered vehicle
applications, 145
Gasoline-propelled vehicles, 270
Gas-phase soot
incandescence, 104, 105
GDI engines, see Gasoline
direct injection
engines
Geometrical parameter,
287
Global warming, 36–37
GPFs, see Gasoline
particulate filters

H

Harvard six-city study, 11
High-efficiency particulate
air (HEPA)-filtered air, 240
High-temperature
thermochemical
decomposition, 104
Homogeneous-charge
engine operation, 109
HORIBA OBS-ONE-PN,
243–245
Hyundai Motor Group
(HMG), 233

I

Incandescence, soot
particles, 104
Initial filtration efficiency, 214
Injection timing
engine geometry, 110
fuel consumption and
PN, 109
homogeneous-charge
engine operation, 109
injector spray targeting,
110
load jump at, 109
trade-off timing, 110
In-Service Conformity
(ISC) testing, 246
International Agency for Research on Cancer (IARC), 35
In-wall coatings, 125
Ion charge sensor, 255, 257

K
Knudsen diffusivity, 288
Kuwabara hydrodynamic factor, 274

L
Lambda control, 229
Lambda/oxygen sensor, 117
Liquid films
evaporation of, 106
particulate formation mechanisms, 104–105
Local temperature gradient, 130

M
Material selection, 119
Maximum soot loading (MSL) value, 214
Mean air velocity, 106
Modern powertrain architectures, 115
Mono-size dispersed aerosols, 241
Mucociliary clearance, 15–16
Multi-port injection (MPI) gasoline engines, 204
MVEG-B drive cycle, 197, 200

N
National Ambient Air Quality Standards, 10
National Environmental Respiratory Center (NERC), 20
New European Drive Cycle (NEDC), 4, 39, 197, 204, 253
Nitrate fraction, 65
Non-monotonic emission behavior, higher temperatures, 106
Non-Road Mobile Machinery (NRMM), 242

O
On-board diagnostics (OBD), 6, 179
algorithm validation
GPF health monitor, 263, 264
GPF missing monitor separation, 265
regulatory requirements, 266
standards and methodologies, 263
strategies, 263, 265
emissions thresholds, 252, 254
failure modes
GPF cracking and channel damage, 254
missing GPF substrate, 254
GPF sensing development phase, 255
DPS, 255, 256
escaping current PM sensor, 255, 257–258
filter parameters, 255
ion charge sensor, 255, 257
radio frequency sensor, 255, 258
resistive PM sensors, 255–257
PM/PN reduction, 252
regulations
CARB regulation, 252–254
Chinese regulation, 253–254
European Union regulation, 253
tailpipe emissions standards, 252
sensor-based algorithms absolute pressure sensor, 259
differential pressure signal, 260
DP-based algorithm, 258–259
fault criteria, 260–261
flow restriction, 259
monitor enable conditions, calculations, and thresholds, 263
system identification, 261–263
On-wall coatings filtration, 124
pressure drop, 125
Open frontal area (OFA), 118, 130, 211
Organic fraction, 65
Otto engine, 10
Otto Partikelfilter (OPF), see Gasoline particulate filters (GPF)
Oxygen concentration control, 229
Oxygen storage capacity (OSC), 185, 186, 193

P
Particle concentration reduction factor (PCRF) criteria, 241
determination, 241
dilution ratio, 241
Particle Measurement Programme (PMP), 238
Particle number (PN) emission, 204, 271
counting
CPC, 238
for non-exhaust emissions, 247
performance criteria, 241
for RDE, 242–243
system design, 240–241
engine load effect, 107
transients, 108–109
engine speed effect, 106, 107
engine temperature, 108
fuel pressure, 110–111
injection timing, 109–110
limit
EURO 5 compression ignition vehicles, 242
light-duty and HD vehicles, 242
on-road trucks and buses, 242
measurement
concentration, 239
future within EU, 247
number of injection events, 111
PEMS
advanced diffusion charger design, 245–246
automotive exhaust applications, 246
CPC, 243–245
CVS, 243
instruments, 243
RDE package 3, 243
targets, 243
Working Group, 242
steady-state engine warm-up process, 108
on T-GDI (EU6b) test vehicle, 131, 132
Particle number index (PNI), 85
Particulate formation mechanisms
engine-out particulate emission, 103
gas phase, 104, 105
high-temperature thermochemical decomposition, 104
liquid films, 104–105
low-temperature chemistry pathways of radicals, 104
regions, 104
sources for, 104
Particulate matter (PM) emissions
core, 237–238
measurements, 238
removal, 223
Particulate matter index (PMI), 48, 84
Particulate number filtration efficiency (PN FE)
durability test, 230–231
evaporation, 225
fuel specification, 225
optimization, 225–226
PM index, 225
target PN values, 224
variability and wash coat properties, 225
Pass decision, 261, 263
PCRF, see Particle concentration reduction factor
Peclet number, 121, 273
PEMS, see Portable emissions measurement systems
Periodic calibration and validation, 241–242
PN emission, see Particle number emission
PN FE, see Particulate number filtration efficiency
Polycyclic aromatic hydrocarbons (PAH) emissions, 36
Polycyclic aromatic hydrocarbons (PAH) formation process, 66–68
Portable emissions measurement systems (PEMS), 146, 147, 204
advanced diffusion charger design, 245–246
automotive exhaust applications, 246
CPC, 243–245
CVS, 243
instruments, 243
RDE package 3, 243
targets, 243
Working Group, 242
Port-fuel injection (PFI) gasoline engines, 115, 204
Pressure drop
ash effect, 128
vs. ash loading, 301–303
channel-scale modeling
axial flow nonuniformities, 284
breakdown, 283
exhaust mass flow rate and temperature, 283, 284
experimental and simulation results, 283
filter-induced backpressure, 282
filter properties, 284
flow-through-wall distribution, 284
mass-momentum balance equations, 284
term contribution, 283–284
zone-coated filters, 284–286
vs. combined ash and soot load, 302, 303
correlations, 124
Darcy’s law, 125
frictional losses, 124
as function of soot load, 127
index, 124, 125
inlet and outlet contributions, 124
in-wall coatings, 125
local flow rate, 125
on-wall coatings, 125
primary contributions, 124
vs. soot load, 127
turbulent entrance, 124
for uncoated and coated GPFs, 126–127
wall permeability, 125, 126
wall-scale modeling channel width, 279
depth-filtration region, 281
differential pressure drop, 279
filter inlet channel, 279
gas density, 280
gas mean free path, 280
gas velocity, 280
between inlet and outlet channel, 281
particulate layer thickness, 279
soot permeability, 280
steady-state soot loading, 281
through porous filter wall, 280
trinomial function, 280
wall-and cake-soot accumulation, 281
wall permeability, 280
wall-soot mass, 281
washcoat loading level, 127
filtration performance, 214
introduction calendar and limits, 204
legislation, 39, 41, 42
PN counting systems, 242–243
limits, 242
standards, 74
testing, 146, 147
Resistive PM sensors, 255–257
steady-state particle filtration experiment, 278
transition period, 278
impact, 270, 272
Soot formation
combustion-generated particles accumulation mode, 63, 64
ash fraction, 65–66
carbonaceous fraction, 65
chemical composition, 64
course mode, 63
nitrate fraction, 65
nucleation mode, 63
organic fraction, 65
sulfate fraction, 65
influencing factors, 68, 69
at high specific loads, 73
in-cylinder charge motion, 73
inhomogeneity, 68, 70, 71
low particle number emissions, 74
spray-wall interactions, 68
steady-state operation, 68
surface-to-volume ratio, 73
tip sooting, 70, 72
transient operation points, 74–77
PAH formation process, 66–68, 84
primary soot particles, 67
schematic diagram, 66–67
soot oxidation, 67, 68
Soot load monitoring
closed-loop control, 159
cold start and low engine temperatures, 159
Secondary organic aerosols (SOA), 37
Simulated clean filter filtration efficiency flow rates, 275, 276
mean pore diameters, 274, 275
wall porosity, 275, 276
SML, see Soot mass limit
Soot accumulation effect on filtration
cake/surface filtration, 277–279
collector diameter, 276
gine-out PM emissions, 278
filtration efficiency, 276–277
fraction of inlet soot, 277
local porosity, 277
partition coefficient, 277
permeability, 277
semi-empirical correlations, 277
size evolution of unit collector, 277
slabs, 277
soot cake, 279
soot mass emissions, 278
Radio frequency sensor, 255, 258
Real driving emissions (RDE), 271, 4, 177, 179
engine-out particulate emissions map, 159
open-loop-based soot mass models, 159 oxidation rates, 159 simplified phenomenological engine models, 158–159 soot emission information, 158 soot mass balance, 158–160 vehicle testing data acquisition systems, 162 drive cycles, 160 environmental and geographical boundary conditions, 160 EU5 and EU6 vehicles, 160 in extended city mode, 163 filter position impact, 164 initial soot loadings, 164 maximum and average temperature, exhaust gas, 162 oxygen concentration, 163 passive oxidation rate, 164 passive regeneration, 160, 163 reaction rate, 164 soot load trace, 163 soot mass, 162, 164–165 soot oxidation, 162–164 speed variation, 160 “stable” soot load, 165 test sequence, 162 UF position, 164 urban drive pattern, 160–162 vehicle velocity, 163 Soot mass limit (SML) ash effect on, 231–232 GPF operating window, 228 peak temperatures, 228 under theoretical air-fuel ratio, 229 Soot oxidation, 67, 68, 84 Soot reactions, channel-scale modeling active regeneration strategy, 295 ash fraction effect, 297 ash particles, 296 direct soot catalysis, 296 full-length GPF cores, 298 gasoline vs. diesel engines, 295 GDI soot sampling conditions, 297 GPF thermal regeneration, 296 “high” ash/soot ratio, 298 indirect soot catalysis, 296 instantaneous soot mass, 298 “low” ash/soot ratio, 298 lube oil-derived metallic ash additives, 297 non-carbonaceous elements, measured impact, 298 reaction rate, 229–230 rate expressions, 296 soot accumulation location, 295 soot oxidation rate, 295 steady-state soot loadings, 298 stoichiometric engine, 295 thermogravimetric analysis, 297 Soot regeneration deceleration fuel cut-off testing, 165 efficiency, 229 exhaust system protection, 165 exothermic heat release, 165 vs. GPF inlet temperature, 229, 230 vs. initial soot loading, 229, 230 maximum filter temperature, 166, 167 oxygen concentration, 166 rate, 229–230 reaction rate, 166 with respect to oxygen concentration, 226–227 soot mass limit, 228–229 thermomechanical exposure, 165 Soot-to-ash ratios, 133 Source apportionment technique, 19 Spark ignition (SI) engines, 84 Species balance, channel-scale modeling CO concentration profiles, 288, 291 effective diffusivity, 287 governing advection-reaction-diffusion equation, 287 Knudsen diffusivity, 288 light-off behavior, 288–290 mass transfer coefficients, 288 species transfer equation, 287 TWC intrinsic reactivity, 288 washcoat loading, 288 Spray momentum, 110 Spray penetration, 110, 111 Spray turbulence, 110 Start of injection (SOI), 105 Steam engines, 10
Sulfated ash, phosphorus, and sulfur (SAPS), 232
Sulfate fraction, 65
Surface filtration, 277–279
System identification, OBD, 261–263

**T**

Tailpipe particulate emissions, 116, 152
Temperature sensor, 117
TESTO NANOMET-3, 245–246
*The Lancet*, 4
Thermal expansion coefficient, 130
Thermal shock resistance, GPFs, 119
Thermal stress, 130
due to severe soot oxidation
filter robustness, 171–173
filter survivability, 170, 171
non-uniform temperature field, 169
radial and axial temperature gradients, 169
robustness testing, 169
spatial temperature distribution, 169, 170
due to transient changes
catalyst heating mode, 168
cyclic thermal stress test, 168, 169
exhaust gas flow rate and temperature, 167
maximum exhaust gas temperature, 167, 168
maximum transient temperature change, 167, 168
ramp rates, 168
temporary temperature gradient, 167
transient temperature gradients, 167
TWCs, 167
Thermogravimetric analysis (TGA), 137–139
Three-way catalyst (TWC) system, 6, 117
coated GPF, 191–192
filter coating design and gaseous conversion activity and
durability requirements, 193
coated flow-through vs. filter, 196, 197
coating light-off temperature, 196
coating location, 194, 196
degree of freedom, 194
efficiency, 193, 194
filter backpressure, 193
flow-through catalyst, 196
gas flow, 195–196
gas velocity, 195
GPF coating loading, 193, 194
in-wall and surface coating, 196
NOx conversion, Rh content on, 194, 195
particle size distribution, 193
particulate number filtration efficiency, 193
physical properties, 196
washcoat loading, 193
gaseous emissions conversion, coated GPFs
aftertreatment system, 192, 197, 198
equivalent HC performance, 200
Euro 5 and Euro 6b gaseous emissions limits, 197
Euro 6d full RDE legislation, 200
European PN, 197
MVEG-B drive cycle, 197, 200
RDE testing, 197
TWC + GPF system, 200
TWC only vs. TWC + GPF system, 197, 198
TWC + TWC + uncoated GPF system, 199
twin TWC system, 198, 200
underfloor position, PN control, 199
washcoat loadings, 197, 199, 200
WLTC test, 197–198
GPF system architectures, 192–193
integration into particulate filters aging stability, 180
BASF, 179
CC TWC catalyst, 183–184, 186
FWC™, 179
gas-phase emission reduction, 179
gas-phase standards, 179
HC, CO, and NOx conversion efficiencies, 179
NEDC vs. Hannover test cycles, 177, 178
oxygen storage and release function, 179
Index

particle number and NOx emissions, 177
RDE cycle, 177, 179
trade-offs, 180, 181
legislative requirements, 192
Tip sooting, 70, 72
Trade-off timing, 110
Turbocharged gasoline direct injection (TGDI) engine, 147, 179
Turbo-GDI platforms, 233
Turbulence, 106
spray, 110
TWC-coated GPF design categories, 223–224
durability test
ash effect on SML, 231–232
PN FE, 230–231
gaseous emissions reduction function, 223
parameters, 224
particulate matter (PM) removal, 223
PN FE evaporation, 225
fuel specification, 225
optimization, 225–226
PM index, 225
target PN values, 224
variability and washcoat properties, 225
soot-filtering function, 223
soot regeneration efficiency, 229
vs. GPF inlet temperature, 229, 230
vs. initial soot loading, 229, 230
rate, 229–230
with respect to oxygen concentration, 226–227
soot mass limit, 228–229
TWC reactions, channel-scale modeling
cerium (oxidized state), 292
cerium (reduced state), 292
conventional monolith vs. coated filter, 292–294
experiment vs. model prediction, 292–294
light-off performance, 292–294
NO reduction, 291–292
oxidation reactions, 291
steam reforming, 292
thermal capacity, outlet channel plugs, 295
TWC/GPF, 291
wall-flow filter vs. flow-through monolith, 295
water-gas shift, 292
TWC system, see Three-way catalyst system

ΔP evolution, honeycomb particulate filter, 219
driving profiles, filtration performance, 218
engine bench pressure drop characterization with and without ash, 219
exhaust gas temperature upstream and downstream, 218
filter durability, 215
pressure drop behavior with ash, 215
real-life endurance test data acquisitions, 215, 217
driving profile statistics, 215, 216
short-distance tests, 215
Vehicle testing, soot loading data acquisition systems, 162
drive cycles, 160
environmental and geographical boundary conditions, 160
EU5 and EU6 vehicles, 160
in extended city mode, 163
filter position impact, 164
initial soot loadings, 164
maximum and average temperature, exhaust gas, 162
oxygen concentration, 163
passive oxidation rate, 164
passive regeneration, 160, 163
reaction rate, 164
soot load trace, 163
soot mass, 162, 164–165
soot oxidation, 162–164
speed variation, 160

Uncoated cordierite GPF application, 220
Uncoated GPF, 204
backpressure, 211
Underfloor (UF) position, 116–117
United Nations Economic Commission for Europe (UNECE), 238
US06 Supplemental Federal Test Procedure (US06) driving cycles, 85

U

Variable compression ratio (VCR), 46
Vehicle road tests, GPF cold flow bench pressure drop evolution, 218, 219
“stable” soot load, 165
test sequence, 162
UF position, 164
urban drive pattern, 160–162
vehicle velocity, 163
Volatile particle removal
(VPR) system, 241
Volumetric flow, 259

Wall filtration

- clean grain diameter, 273
- depth filtration, 273, 275
diffusional deposition, 272, 273, 275
- flow rates, 275, 276
- geometrical and microstructural properties, 274, 275
- inertial deposition/interception, 272–275
- Kuwabara hydrodynamic factor, 274
- mean pore diameters, 274, 275
- particle diffusivity, 274
- Peclet number, 273
- simulated clean filter filtration efficiency, 274–276
- single collector filtration efficiency by diffusion, 273
- single collector filtration efficiency by interception, 274
- total bed filtration efficiency, 274
- unit collector, 273
- wall-flow filtration principle, 272, 273
- wall porosity, 275, 276

Wall-scale modeling, 270, 271

- pressure drop channel width, 279
depth-filtration region, 281
differential pressure drop, 279
- filter inlet channel, 279
gas density, 280
gas mean free path, 280
gas velocity, 280
- between inlet and outlet channel, 281
- particulate layer thickness, 279
- soot permeability, 280
- steady-state soot loading, 281
through porous filter wall, 280
- trinomial function, 280
wall-and cake-soot accumulation, 281
wall permeability, 280
wall-soot mass, 281
soot accumulation effect on filtration
cake/surface filtration, 277–279
- collector diameter, 276
- engine-out PM emissions, 278
- filtration efficiency, 276–277
- fraction of inlet soot, 277
- local porosity, 277
- partition coefficient, 277
- permeability, 277
semi-empirical correlations, 277
size evolution of unit collector, 277
- slabs, 277
- soot cake, 279
- soot mass emissions, 278
- steady-state particle filtration experiment, 278
- transition period, 278
wall filtration
- clean grain diameter, 273
depth filtration, 273, 275
diffusional deposition, 272, 273, 275
- flow rates, 275, 276
- geometrical and microstructural properties, 274, 275
- inertial deposition/interception, 272–275
- Kuwabara hydrodynamic factor, 274
- mean pore diameters, 274, 275
- particle diffusivity, 274
- Peclet number, 273
- simulated clean filter filtration efficiency, 274–276
- single collector filtration efficiency by diffusion, 273
- single collector filtration efficiency by interception, 274
- total bed filtration efficiency, 274
- unit collector, 273
- wall-flow filtration principle, 272, 273
- wall porosity, 275, 276
Working Party on Pollution and Energy, 238
World harmonized light vehicle test cycle (WLTC), 4, 146, 147, 204
World harmonized light vehicle test procedure (WLTP), 39, 253

Z

Zone-coated filters, 270, 271 coated GPF configurations, 284, 285 light-off behavior, 288–290

simulated axial soot distribution, 286
wall-flow distribution patterns, 285
“Zoned High:Low” GPF, 284–286, 291
“Zoned Low:High” GPF, 284–286, 291
For years, diesel engines have been the focus of particulate matter emission reductions. Now, however, diesel particulate filters emit less particles than a comparable gasoline engine. This transformation necessitates an introduction of particulate reduction strategies for the gasoline-powered vehicle.

Many strategies can be leveraged from diesel engines, but new engine and emission control technologies will be needed to meet the latest gasoline regulations across the globe. Particulate reduction is a critical health concern in addition to the regulatory requirements. This is a vital issue with real-world implications.

Reducing Particulate Emissions in Gasoline Engines encompasses the current strategies and technologies used to reduce particulates to meet regulatory requirements and curtail health hazards - reviewing principles and applications of these techniques. The goal is to provide a comprehensive assessment of gasoline particulate emission control to meet regulatory and health requirements - appealing to calibration, development and testing engineers alike.

Reducing Particulate Emissions in Gasoline Engines is a must-read for those looking for the latest strategies to reduce emissions in gasoline engines.

RELATED RESOURCES:
Internal Combustion Engine Volume 1 Regulations and Modeling
Author: Ronald Douglas Matthews
Product Code: R-486

more related resources inside...