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Miniature Internal Combustion Engines **Introduction to Modeling and Control of Internal Combustion Engine Systems** **1D and Multi-D Modeling Techniques for IC Engine Simulation** **1D and Multi-D Modeling Techniques for IC Engine Simulation** Introduction to Modeling and Control of Internal Combustion Engine Systems **Engine Modeling and Control** **MODEL-BASED DESIGN AND HARDWARE-IN-THE-LOOP SIMULATION OF INTERNAL COMBUSTION ENGINE CONTROL SYSTEMS** *Structure of Turbulence in a Model IC Engine* Development of Procedures and Tools for Calibration of I.C Engine Combustion Models **Internal Combustion Engines** *Mixture Formation in Internal Combustion Engines* *Observation of Flow Characteristics in a Model Internal Combustion Engine Cylinder* **Combustion Engine Diagnosis** **Turbulent Structure and Decay in a Model I.C. Engine** *Analysis of Injection Processes in an Innovative 3D-CFD Tool for the Simulation of Internal Combustion Engines* **Flying Hot Wire Measurements in a Model IC Engine and Comparison with Visualization Experiments** **Internal Combustion Engines** *Computational Optimization of Internal Combustion Engines* **Measurements of Spatial Structure of BDC Turbulence in a Model IC Engine Using Flying Hot Wire** **I.C. Engines And Combustion** Generalized Model of Flow Restrictions for IC Engine Control Applications **Simulation and**

Optimization of Internal Combustion Engines Numerical Analysis of Mixture Formation and Combustion in a Hydrogen Direct-Injection Internal Combustion Engine Nonlinear Systems and Circuits in Internal Combustion Engines **Observation of Flow Characteristics in a Model I.C. Engine Cylinder** *Study of Periodical Flow Heat Transfer in an Internal Combustion Engine* **Individual Cylinder Model of IC Engine - Variable Pitch Propeller System for General Aviation Aircraft** The KIVA Code with Conjugate Heat Transfer Model for IC Engine Simulation **Engineering Fundamentals of the Internal Combustion Engine** *Engine Modeling of an Internal Combustion Engine with Twin Independent Cam Phasing* **Advances in IC Engines and Combustion Technology** *Low-order Nonlinear Dynamic Model of IC Engine-variable Pitch Propeller System for General Aviation Aircraft* **Intelligent Autonomous Systems** *Artificial Intelligence and Data Driven Optimization of Internal Combustion Engines* *Modelling Diesel Combustion* *Integration of a stick/slip belt with an I-C engine model as used in a starter/generator drive to examine tensioner strategies* **An Investigation of Fluid Flow During Induction Stroke of a Water Analog Model of an IC Engine Using an Innovative Optical Velocimetry Concept** Simulations and Optical Diagnostics for Internal Combustion Engines Quasi 1D heat transfer model of heat transfer in IC engines **Finite Element Modeling of I.C. Engine Component Temperatures**

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This book focuses on combustion simulations and optical diagnostics techniques, which are currently used in internal combustion engines. The book covers a variety of simulation techniques, including in-cylinder combustion, numerical investigations of fuel spray, and effects of different fuels and engine technologies. The book includes chapters focused on alternative fuels such as DEE, biomass, alcohols, etc. It provides valuable information about alternative fuel utilization in IC engines. Use of combustion simulations and optical techniques in advanced techniques such as microwave-assisted plasma ignition, laser ignition, etc. are few other important aspects of this book. The book will serve as a valuable resource for academic researchers and professional automotive engineers alike. Due to the large number of influencing parameters and interactions, the fuel injection and therewith fuel propagation and distribution are among the most complex processes in an internal combustion engine. For this reason, injection is usually the subject to highly detailed numerical modeling, which leads to unacceptably high computing times in the 3D-CFD simulation of a full engine domain. Marlene Wentsch presents a critical analysis, optimization and extension of injection modeling in an innovative, fast response 3D-CFD tool that is exclusively dedicated to the virtual development of internal combustion engines. About the Author Marlene Wentsch works as research associate in the field of 3D-CFD simulations of injection processes at the Institute of Internal Combustion Engines and Automotive Engineering (IVK), University of Stuttgart, Germany. The increasing demands for internal combustion engines with regard to fuel consumption, emissions and driveability lead to more actuators, sensors and complex control functions. A systematic implementation of the electronic control systems requires mathematical models from basic design through simulation to calibration. The book treats physically-based as well as models based experimentally on test benches for gasoline (spark ignition) and diesel (compression ignition) engines and uses them for the design of the different control functions. The main topics are: - Development steps for engine control - Stationary and dynamic experimental modeling - Physical models of intake, combustion, mechanical system, turbocharger, exhaust, cooling, lubrication, drive train - Engine control structures, hardware, software, actuators, sensors, fuel supply, injection system, camshaft - Engine control methods, static and dynamic feedforward and feedback control, calibration and optimization, HiL, RCP, control software development - Control of gasoline engines, control of air/fuel, ignition, knock, idle, coolant, adaptive control functions - Control of diesel engines, combustion models, air flow and exhaust recirculation control, combustion-pressure-based control (HCCI), optimization of feedforward and feedback control, smoke limitation and emission control This book is an introduction to electronic engine management with many practical examples, measurements and research results. It is aimed at advanced students of electrical, mechanical, mechatronic and control engineering and at practicing engineers in the field of combustion engine and automotive engineering. 1D and Multi-D Modeling Techniques for IC Engine Simulation provides a description of the most significant and recent achievements in the field of 1D engine simulation models and coupled 1D-3D modeling techniques, including 0D combustion models, quasi-3D methods and some 3D model applications. For a one-semester, undergraduate-level course in Internal Combustion Engines. This applied thermoscience text explores the basic principles and applications of various types of internal combustion engines, with a major emphasis on reciprocating engines. It covers both spark ignition and compression ignition engines--as well as those operating on four-stroke cycles and on two stroke cycles--ranging in size from small model airplane engines to the larger stationary engines. Phenomenology of Diesel Combustion and Modeling Diesel is the most efficient combustion engine today and it plays an important role in transport of goods and passengers on land and on high seas. The emissions must be controlled as stipulated by the society without sacrificing the legendary fuel economy of the diesel engines. These important drivers caused innovations in diesel engineering like re-entrant combustion chambers in the piston, lower swirl support and high pressure injection, in turn reducing the ignition delay and hence the nitric oxides. The limits on emissions are being continually reduced. The- fore, the required accuracy of the models to predict the emissions and efficiency of the engines is high. The phenomenological combustion models based on physical and chemical description of the processes in the engine are practical to describe diesel engine combustion and to carry out parametric studies. This is because the injection process, which can be relatively well predicted, has the dominant effect on mixture formation and subsequent course of combustion. The need for improving these models by incorporating new developments in engine designs is explained in Chapter 2. With “model based control programs” used in the Electronic Control Units of the engines, phenomenological models are assuming more importance now because the detailed CFD based models are too slow to be handled by the Electronic Control Units. Experimental work is necessary to develop the basic understanding of the pr- esses. Optical measurements on an axisymmetrical quartz component engine research model were made to evaluate the flow field encountered during induction. The measurement technique is LIPA (Laser Induced Photochemical Anemometry), a non-intrusive velocimetry concept that provides an investigator of fluid flow with a tool to attain planar information about three-dimensional velocity and vorticity vectors in a single measurement step. The goal of this investigation is to further develop this measurement technique and apply it to study the induction stroke of a water analog model of a four-stroke internal combustion engine. The research conducted in the water analog model is a fundamental scientific inquiry into the flow fields that develop in the induction stroke of an engine at idling engine speeds. As this is the first investigation of its kind using LIPA technique, our goal has been to quantify, in a preliminary manner, the flow field features that develop during the intake stroke. In the process a more comprehensive understanding of the flow field features was developed, and tied to the quantification. The study evaluated the flow field of the intake stroke by estimating fields of velocity and vorticity. On the basis of these data, information about fluid dynamics during induction at engine speeds of 10, 20, and 30 RPM (corresponding to 170, 340, and 510 RPM respectively, when air is the flowing medium) for three different valve lifts was obtained. The overall development of the flow field, its energy content (kinetic, fluctuation) for the different settings of the engine parameters, vorticity information, and cyclic variations have been quantified. These have been discussed in terms of mixing performance. Stier, Bernd and Falco, R. E. Unspecified Center NASA-CR-197451, NAS 1.26:197451 NAG1-1106... Computational Optimization of Internal Combustion Engines presents the state of the art of computational models and optimization methods for internal combustion engine development using multi-dimensional computational fluid dynamics (CFD) tools and genetic algorithms. Strategies to reduce computational cost and mesh dependency are discussed, as well as regression analysis methods. Several case studies are presented in a section devoted to applications, including assessments of: spark-ignition engines, dual-fuel engines, heavy duty and light duty diesel engines. Through regression analysis, optimization results are used to explain complex interactions between engine design parameters, such as nozzle design, injection timing, swirl, exhaust gas recirculation, bore size, and piston bowl shape. Computational Optimization of Internal Combustion Engines demonstrates that the current multi-dimensional CFD tools are mature enough for practical development of internal combustion engines. It is written for researchers and designers in mechanical engineering and the automotive industry. This book offers first a short introduction to advanced supervision, fault detection and diagnosis methods. It then describes model-based methods of fault detection and diagnosis for the main components of gasoline and diesel engines, such as the intake system, fuel supply, fuel injection, combustion process, turbocharger, exhaust system and exhaust gas aftertreatment. Additionally, model-based fault diagnosis of electrical motors, electric, pneumatic and hydraulic actuators and fault-tolerant systems is treated. In general series production sensors are used. It includes abundant experimental results showing the detection and diagnosis quality of implemented faults. Written for automotive engineers in practice, it is also of interest to graduate students of mechanical and electrical engineering and computer science. This brief provides an overview on the most relevant nonlinear phenomena in internal combustion engines with a particular emphasis on the use of nonlinear circuits in their modelling and control. The brief contains advanced methodologies —based on neural networks and soft-computing approaches among others— for the compensation of engine nonlinearities by using the combustion pressure signal and proposes several techniques for the reconstruction of this signal on the basis of different engine parameters, including engine-block vibration and crankshaft rotational speed. Another topic of the book is the diagnosis of the nonlinearities of injection systems and their balancing, which is a mandatory task for the new generation of gasoline direct injection engines. The authors come from both industrial and academic backgrounds, so the brief represents an important tool both for researchers and practitioners in the automotive industry. 1D and Multi-D Modeling Techniques for IC Engine Simulation provides a description of the most significant and recent achievements in the field of 1D engine simulation models and coupled 1D-3D modeling techniques, including 0D combustion models, quasi-3D methods and some 3D model applications. Internal combustion engines still have a potential for substantial improvements, particularly with regard to fuel efficiency and environmental compatibility. These goals can be achieved with help of control systems. Modeling and Control of Internal Combustion Engines (ICE) addresses these issues by offering an introduction to cost-effective model-based control system design for ICE. The primary emphasis is put on the ICE and its auxiliary devices. Mathematical models for these processes are developed in the text and selected feedforward and feedback control problems are discussed. The appendix contains a summary of the most important controller analysis and design methods, and a case study that analyzes a simplified idle-speed control problem. The book is written for students interested in the design of classical and novel ICE control systems. The present work investigates the mixture formation and combustion process of a direct-injection (DI) hydrogen internal combustion engine by means of three-dimensional numerical simulation. The study specifies details on the validity of turbulence models, combustion models as well as aspects on the definition of hydrogen-air burning velocities with respect to hydrogen IC engine applications. Results of homogeneous, stratified and multi-injection engine operation covering premixed, partially premixed and non-premixed combustion of hydrogen are presented. Results of the numerical simulations are validated using data of experimental analysis from parallel works, employing a one-cylinder research engine and a research engine with optical access. As a fundamental contribution to combustion modelling of hydrogen IC engines, a new correlation for laminar burning velocities of hydrogen-air mixtures at engine-relevant conditions is derived from measurements of premixed outwards propagating flames conducted in a single-cylinder compression machine. Numerical results of the direct-injection mixture formation give a detailed understanding of the interrelation between injection timing and the degree of mixture homogenisation. A favourable agreement between the computed fuel concentration and results of Planar Laser Induced Fluorescence (PLIF) measurements is reported for various injection timings. Different two-equation turbulence models, a Shear Stress Transport (SST) model and a k-? model based on Renormalisation Group (RNG) theory as well as a Reynolds Stress Model (RSM) are discussed. The impact of the models on the level of turbulent kinetic energy proves to be of major importance. State-of-the-art turbulent combustion models on the basis of turbulent flame speed closure (TFC) and on the basis of a flame surface density approach, the Extended Coherent Flame Model (ECFM), are examined. The models are adapted to hydrogen internal combustion engines and are interfaced to the established three-dimensional flow field solver ANSYS CFX within the framework of the international research project HyICE. Two different approaches are investigated as input for the laminar burning velocities of hydrogen. Firstly, flame speed data are computed with a kinetic mechanism. Secondly, an existing experimentally derived laminar flame speed correlation is extended to rich air/fuel equivalence ratios (? 1) and is compared to measurements conducted within the present work. In general, the TFC-models show a satisfying agreement for DI operating points compared to experimental data, when mixing computations are conducted with the SST turbulence model. Also, port fuel injection (PFI) operating points demonstrate a good performance with these models, however, the constant model prefactor (multiplier for the closure of turbulent flame speed) has to be defined individually for PFI and DI computations. This effect might be caused by the dissimilar sources of turbulence for the two engine types (PFI and DI) which cannot be adequately predicted by the turbulence models. Combustion computations on the basis of mixture results obtained by the RNG-model generally underrate the level of turbulence intensity for stratified operation points, effecting too weak rates of heat release. The ECFM combustion model shows a satisfying predictability for the PFI case using a constant model prefactor. Computations of DI operating points with this model, however, require a readjustment of the prefactor for each operating point in order to match experimental results. Regarding turbulent combustion, the hydrogen laminar flame speed is recognised to be the crucial quantity for the employed modelling approaches. Since direct-injection hydrogen engines in the stratified case engender a wide range of equivalence ratios, fundamental data for the laminar flame speed has to be provided as a model input within the entire boundaries of ignition limits. A lack of experimental data of laminar flame speed at engine-relevant conditions (high pressure, high temperature) is noticed. In order to perform a detailed study on hydrogen burning velocities, a single-cylinder compression machine is selected to conduct flame speed measurements of hydrogen-air mixtures at ignition temperatures and pressures up to $T = 700$ K and $p = 45$ bar, considering air/fuel equivalence ratios between ? = 0.4 and 2.8. Flame front velocities are acquired by means of optical methods using OH-chemiluminescence and thermodynamic, multi-zone evaluation of pressure traces. In comparison to data of laminar flame speed derived from reaction mechanisms and flame speed correlations found in literature, the experimental results show increased burning velocities due to flame front wrinkling caused by hydrodynamic and thermo-diffusive instabilities. a href="http://ec.europa.eu/research/transport/news/article_5199_en.html" EU Transport Research Since the publication of the Second Edition in 2001, there have been considerable advances and developments in the field of internal combustion engines. These include the increased importance of biofuels, new internal combustion processes, more stringent emissions requirements and characterization, and more detailed engine performance modeling, instrumentation, and control. There have also been changes in the instructional methodologies used in the applied thermal sciences that require inclusion in a new edition. These methodologies suggest that an increased focus on applications, examples, problem-based learning, and computation will have a positive effect on learning of the material, both at the novice student, and practicing engineer level. This Third Edition mirrors its predecessor with additional tables, illustrations, photographs, examples, and problems/solutions. All of the software is ‘open source’, so that readers can see how the computations are performed. In addition to additional java applets, there is companion Matlab code, which has become a default computational tool in most mechanical engineering programs. Artificial Intelligence and Data Driven Optimization of Internal Combustion Engines summarizes recent developments in Artificial Intelligence (AI)/Machine Learning (ML) and data driven optimization and calibration techniques for internal combustion engines. The book covers AI/ML and data driven methods to optimize fuel formulations and engine combustion systems, predict cycle to cycle variations, and optimize after-treatment systems and experimental engine calibration. It contains all the details of the latest optimization techniques along with their application to ICE, making it ideal for automotive engineers, mechanical engineers, OEMs and R&D centers involved in engine design. Provides AI/ML and data driven optimization techniques in combination with Computational Fluid Dynamics (CFD) to optimize engine combustion systems Features a comprehensive overview of how AI/ML techniques are used in conjunction with simulations and experiments Discusses data driven optimization techniques for fuel formulations and vehicle control calibration A systematic control of mixture formation with modern high-pressure injection systems enables us to achieve considerable improvements of the combustion pr- ess in terms of reduced fuel consumption and engine-out raw emissions. However, because of the growing number of free parameters due to more flexible injection systems, variable valve trains, the application of different combustion concepts within different regions of the engine map, etc., the prediction of spray and m- ture formation becomes increasingly complex. For this reason, the optimization of the in-cylinder processes using 3D computational fluid dynamics (CFD) becomes increasingly important. In these CFD codes, the detailed modeling of spray and mixture formation is a prerequisite for the correct calculation of the subsequent processes like ignition, combustion and formation of emissions. Although such simulation tools can be viewed as standard tools today, the predictive quality of the sub-models is c- stantly enhanced by a more accurate and detailed modeling of the relevant pr- esses, and by the inclusion of new important mechanisms and effects that come along with the development of new injection systems and have not been cons- ered so far. In this book the most widely used mathematical models for the simulation of spray and mixture formation in 3D CFD calculations are described and discussed. In order to give the reader an introduction into the complex processes, the book starts with a description of the fundamental mechanisms and categories of fuel - jection, spray break-up, and mixture formation in internal combustion engines. Limited amount on the non-renewable fuel sources and the increasingly world wide demand on the fuel have driven new technologies and methods for designing more fuel efficient engines. There are rooms for improvement, e.g., a smaller liquid coolant pump that pumps less liquid for an optimized cooling system. Locating hot spots inside the cooling jacket can be used as a tool to design an efficient cooling system. This study focuses on how to predict hot spots of one of the cylinders of a V8 5.4 L FORD engine running at full load. The KIVA code with conjugate heat transfer capability to simulate the transient heat transfer process between the gas and the solid phases has been developed at the Michigan Technological University and will be used in this study. Liquid coolant flow was simulated using FLUENT and will be used as the boundary condition to account for the heat loss inside the cooling jacket. In the first step of calculation, the coupling between the gas and the solid phases will be solved using the KIVA code. A 3D transient heat flux history at the gas-solid interface is then compiled and used along with the heat loss information from FLUENT to obtain the temperature distribution for the engine metal components, such as cylinder wall, cylinder head, etc. The intermittent turbulence could have a great impact on engine heat transfer because of the transitional turbulence effect. Engine 3D CFD model further proves the existence of transitional turbulence flow. A new multi zone heat transfer model is proposed for IC engines only. The model includes pressure work effects and improved heat transfer prediction compared to the standard Law of the wall model. Abstract: In the modern world, one of the largest concerns is the ever depleting supply of oil. The automotive industry is especially impacted. In recent years the price of gasoline has fluctuated substantially and the price of crude oil has reached record highs. The high price of gasoline coupled with the uncertainty of its availability and future price have put a high priority on fuel economy of an engine. In addition the emissions released from internal combustion (IC) engines are polluting the atmosphere. Many studies have linked the greenhouse gases produced by an automobile engine to the partial destruction of our atmosphere and to global warming. As a result the US government is passing stricter and stricter emissions regulations. These major issues are putting pressure on automakers to develop new technologies to increase the fuel economy and decrease the emissions while maintaining or improving the engine's performance. Several new technologies have resulted. All of these technologies accomplish these goals by increasing the efficiency of an engine. As a whole these technologies are called variable valve actuation. These technologies achieve a higher efficiency by reducing the constants of the engine. However, the added variability increases the time to calibrate an engine. To address this, more testing is being performed using engine simulations instead of physical testing. This thesis focuses on how to create an engine model and how engine simulation can be used to optimize such an engine. In addition the benefits of a particular variable valve actuation technology, cam phasing, will be explored. This book comprises select peer-reviewed proceedings of the 26th National Conference on IC Engines and Combustion (NCICEC) 2019 which was organised by the Department of Mechanical Engineering, National Institute of Technology Kurukshetra under the aegis of The Combustion Institute-Indian Section (CIIS). The book covers latest research and developments in the areas of combustion and propulsion, exhaust emissions, gas turbines, hybrid vehicles, IC engines, and alternative fuels. The contents include theoretical and numerical tools applied to a wide range of combustion problems, and also discusses their applications. This book can be a good reference for engineers, educators and researchers working in the area of IC engines and combustion. This book presents the papers from the Internal Combustion Engines: Performance, fuel economy and emissions held in London, UK. This popular international conference from the Institution of Mechanical Engineers provides a forum for IC engine experts looking closely at developments for personal transport applications, though many of the drivers of change apply to light and heavy duty, on and off highway, transport and other sectors. These are exciting times to be working in the IC engine field. With the move towards downsizing, advances in FIE and alternative fuels, new engine architectures and the introduction of Euro 6 in 2014, there are plenty of challenges. The aim remains to reduce both CO2 emissions and the dependence on oil-derivate fossil fuels whilst meeting the future, more stringent constraints on gaseous and particulate material emissions as set by EU, North American and Japanese regulations. How will technology developments enhance performance and shape the next generation of designs? The book introduces compression and internal combustion engines’ applications, followed by chapters on the challenges faced by alternative fuels and fuel delivery. The remaining chapters explore current improvements in combustion, pollution prevention strategies and data comparisons. presents the latest requirements and challenges for personal transport applications gives an insight into the technical advances and research going on in the IC Engines field provides the latest developments in compression and spark ignition engines for light and heavy-duty applications, automotive and other markets Abstract : This report studies model-based embedded system design for the control of Internal Combustion (IC) engines. The advantages of model-based design and the development tools are discussed. The application of this method for IC engine control is the focus of the first part of the report. In the second part, the Hardware-In-the-Loop (HIL) simulation is introduced with emphasis on the engine controller and its modification for lean operation control. For the IC engine control, the control functionalities of an engine electronic control unit (ECU) in dSPACE Automotive Simulation Models (ASM) are analyzed. The lean combustion control model is implemented in a hardware engine ECU - MotoTron Engine Control Module (ECM) and validated by a HIL simulator. The HIL simulator used for the simulation study is dSPACE E-

Drive HIL simulator. The HIL simulation result shows that the developed lean combustion control strategy can reduce fuel consumption. The lean operation at a lambda value of 1.2 is seen to have the lowest injection duration while still producing the same amount of torque. It is also found that the implemented method is able to meet the required torque better at the lower load operating conditions. The variation in the output torque is increased at the higher load conditions. Simulation and Optimization of Internal Combustion Engines provides the fundamentals and up-to-date progress in multidimensional simulation and optimization of internal combustion engines. While it is impossible to include all the models in a single book, this book intends to introduce the pioneer and/or the often-used models and the physics behind them providing readers with ready-to-use knowledge. Key issues, useful modeling methodology and techniques, as well as instructive results, are discussed through examples. Readers will understand the fundamentals of these examples and be inspired to explore new ideas and means for better solutions in their studies and work. Topics include combustion basis of IC engines, mathematical descriptions of reactive flow with sprays, engine in-cylinder turbulence, fuel sprays, combustions and pollutant emissions, optimization of direct-injection gasoline engines, and optimization of diesel and alternative fuel engines. This research book contains a sample of most recent research in the area of intelligent autonomous systems. The contributions include: General aspects of intelligent autonomous systems Design of intelligent autonomous robots Biped robots Robot for stair-case navigation Ensemble learning for multi-source information fusion Intelligent autonomous systems in psychiatry Condition monitoring of internal combustion engine Security management of an enterprise network High dimensional neural nets and applications This book is directed to engineers, scientists, professor and the undergraduate/postgraduate students who wish to explore this field further. Abstract: As the world oil reserves continue to deplete, the need for more fuel efficient vehicles has become a necessity among the society to counteract the increasing fuel prices. In order to meet these demands advanced internal combustion engines are being developed; however the controls for these engines has become more complex, due to added degrees of freedom, which adds time to the calibration process. As a result, engine modeling has become popular for control design to reduce the calibration stages. This research developed a methodology for combustion analysis and modeling processes for advanced internal combustion engines. The methodology was valid over the entire operating range of the engine subject to changes in engine speed, manifold pressure, spark timing, intake cam position, and exhaust cam position. This research was part of a much larger effort to improve the modeling capabilities of advanced engines. The objective is to use "model based" techniques to facilitate these advanced engines entering the market, creating positive impacts on fuel economy and emissions. The overall project will consist of experimental set-up, data collection, analytical analysis and modeling. Model engineers have been making models of internal combustion engines since the invention of the real thing, but it has always been surrounded by a mystique, and a perceived difficulty that has put many people off. A study of fluid mechanical effects on unburned hydrocarbon generation was made in a single compression expansion model automobile engine. Full optical access allowed the color Schlieren observations of various gas motion alongside the engine cylinder. Motion pictures of the gas motion and flame propagation were taken at a rate of seven thousand frames per second for the following cases: (1) intake stroke; (2) exhaust stroke; and (3) compression power stroke with combustion and blow-down with appropriate exhaust valve opening. Unburned fuel concentrations were measured by means of a gas chromatograph. The results show that turbulent motion of the mixture increases the amount of unburned fuel. It is implied that the rolled-up vortices play an important role on wall flame quenching processes in an engine. Internal combustion engines (ICE) still have potential for substantial improvements, particularly with regard to fuel efficiency and environmental compatibility. In order to fully exploit the remaining margins, increasingly sophisticated control systems have to be applied. This book offers an introduction to cost-effective model-based control-system design for ICE. The primary emphasis is put on the ICE and its auxiliary devices. Mathematical models for these processes are developed and solutions for selected feedforward and feedback control-problems are presented. The discussions concerning pollutant emissions and fuel economy of ICE in automotive applications constantly intensified since the first edition of this book was published. Concerns about the air quality, the limited resources of fossil fuels and the detrimental effects of greenhouse gases exceedingly spurred the interest of both the industry and academia in further improvements. The most important changes and additions included in this second edition are: restructured and slightly extended section on superchargers, short subsection on rotational oscillations and their treatment on engine test-benches, complete section on modeling, detection, and control of engine knock, improved physical and chemical model for the three-way catalytic converter, new methodology for the design of an air-to-fuel ratio controller, short introduction to thermodynamic engine-cycle calculation and corresponding control-oriented aspects.

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