Abstract Collections 2019

AUTOMOTIVE INNOVATION

—— An International Academic Journal Exploring Automotive Innovation

Preface

Automotive Innovation, as the first international academic journal in automotive industry of China, provides abundant sources of innovative and scientific achievements for automotive engineers and scientists. Submissions are welcome on principles, methodologies and cutting-edge engineering applications. The main topics include but are not limited to energy-saving, electrification, intelligent and connected, safety and lightweight technologies.

Automotive Innovation was founded by China SAE in 2017. Published via Springer Nature, the journal ensures high-quality papers satisfying international standards. Aiming to achieve a world-class level, the editorial board consists of world-renowned experts covering 15 countries and regions. The journal is published quarterly, attracting readers from 72 countries and regions. The highest download of a single article wins more than 8,000.

Throughout 2019, 4 issues have been published online, with a total of 32 papers on hot topics including autonomous driving, safety, electric vehicles, car body design, engine, transmission, dynamics and NVH. All papers have gone through rigorous review process by the editor-in-chief, associate editors-in-chief and reviewers, resulting in perfect appearances of latest cutting-edge technologies. With purpose of providing more convenient access to these technical papers, the 2019 abstracts have been collected and classified on account of publication date and research areas. Dual language has also been displayed for more comfortable reading experience. We hereby present you *Automotive Innovation Abstract Collections 2019*, and sincerely hope this collection enable you to gain a deeper understanding about *Automotive Innovation* and bring more spark and inspirations to keep you going.

Here, we would like to take the opportunity to express our heartful gratitude to all authors for their cooperation, and to the editorial board members as well as the reviewers for their valuable assistance. Special thanks are to China SAE and Springer Nature. We wish the journal could help break technology barriers and advance technological developments of automotive industry but we are together.

Prof. Jun Li
Editor-in-Chief

Prof. Fuquan (Frank) Zhao
Editor-in-Chief

Prof. Fangwu (Mike) Ma
Executive Editor-in-Chief

前言

　　《Automotive Innovation》作为由国家新闻出版署批准的中国汽车行业第一本英文科技期刊，也是中国汽车工程学会为行业打造的重要国际交流平台和展示窗口，旨在进一步推动汽车科技的国际交流与合作，加速中国汽车创新成果跻身国际舞台的脚步。期刊主要聚焦汽车领域具有创新性的理论研究、方法研究以及前沿科技应用研究的学术论文，涵盖节能与环保、电动汽车、智能网联汽车、安全、轻量化等多个技术领域。期刊全面反映汽车技术的发展方向与最新进展，为汽车科技工作者提供重要参考。

　　自创刊以来，期刊以建设世界一流期刊为目标，诚挚邀请全球 15 个发达国家和地区具有影响力的汽车专家担任编委，并与 Springer Nature 平台合作，以国际高标准确保论文水平和出版质量。期刊每季度出版 1 期，读者已涉及 72 个国家和地区，最高单篇下载次数超过8000 次。期刊已得到众多知名学者的大力支持与认可。

　　2019 年共计出刊 4 期，刊出 32 篇论文，其中包括自动驾驶、电动车、车身设计、发动机、变速器、动力学控制、NVH 等多个热点领域的论文，每篇论文都经过主编、副主编及评审专家认真评议后精心遴选，每篇论文都具有独特的创新价值。为方便科技工作者快速查阅信息，期刊编辑部特将《Automotive Innovation》2019 年度的论文摘要进行整理，分别按照刊出时间顺序与研究领域两种分类方法进行分类整理，并配上中文参考译文，形成了《Automotive Innovation Abstract Collections 2019》。我们真诚希望此摘要集能帮助您更深入地了解《Automotive Innovation》，并给您的研究带来有价值的信息。

　　最后，我们真诚地感谢所有作者提供高质量的稿件，感谢所有的编委和评审专家对期刊的无私奉献，感谢中国汽车工程学会和 Springer Nature 的全力支持。也期待在未来能够继续得到各方的支持和关注，期待《Automotive Innovation》能够在汽车科技发展中发挥更重要的作用。

Prof. Jun Li
Editor-in-Chief

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Prof. Fangwu (Mike) Ma
Executive Editor-in-Chief

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III. Energy-saving and Green Vehicles

IV. Car Body Design & Light Weight

V. Others

Crashworthiness Optimization Design of Thin-Walled Tube Filled with Re-entrant Triangles Honeycombs

Fangwu Ma[1] · Ying Zhao[1] · Guowang Wang[1] · Liang Wu[1] · Yongfeng Pu[1]

Abstract

A novel re-entrant triangles-filled tube (RTT) is proposed through decoupling structural stiffness and energy absorption. Inner re-entrant triangles are employed to satisfy energy absorption, and outer thin wall is used to acquire high stiffness. This paper starts from establishment of theoretical models between geometric parameters of re-entrant triangles and relative density, equivalent elastic modulus and energy absorption characteristics, which are validated by experiments. On this basis, the optimal geometric parameters of unit cell are sought to maximize unit volume energy absorption and minimize relative density by adopting NSGA-II method. Subsequently, the cross-section of tube with optimal stiffness is obtained with targets for maximizing axial stiffness and lateral stiffness by employing static topology optimization method. To verify the proposed optimization method, RTT is analyzed and compared with positive Poisson's ratio foam-filled tube (PFT), non-filled traditionally optimized tube (NTT) and pre-optimized square tube (PST). The results show that the novel RTT can improve stiffness and energy absorption performance simultaneously. Compared with the positive Poisson's ratio material, re-entrant triangles honeycomb shows superior advantages in energy absorption. In comparison with the PFT, energy absorption of the RTT increases by 17.23%, and the peak crash force reduces by 5.04%. Therefore, the proposed decoupling design method demonstrates superiority in satisfying various performance requirements simultaneously.

Keywords Thin-walled tube · Re-entrant triangles honeycomb · Multi-objective optimization · Energy absorption · Structural stiffness

内凹三角形蜂窝结构薄壁管碰撞优化设计

马芳武[1] · 赵颖[1] · 王国旺[1] · 吴量[1] · 蒲永锋[1]

【摘要】 基于结构刚度和能量吸收解耦的思想，本文提出一种新型内凹三角形填充管设计。其中，内凹三角形结构用来满足部件的能量吸收需求，外部薄壁管满足高刚度要求。本文首先建立了内凹三角形几何参数与相对密度、等效弹性模量和能量吸收特性之间的理论模型，并通过实验进行了验证。基于此，以单位体积吸能最大、相对密度最小为目标，采用NSGA-II方法，寻求内凹三角形最优结构参数。继而，采用静态拓扑优化方法，以最大轴向刚度和最大横向刚度为目标，优化获得具备最优刚度的薄壁管截面。为验证所提出的优化方法，将内凹三角形填充管与正泊松比泡沫填充管、非填充传统优化管和传统方形截面管进行了分析与比较。结果表明，新型内凹三角形填充管在增强结构刚度的同时可提高吸能特性。与正泊松比材料相比，内凹三角形蜂窝在能量吸收方面具有明显的优势。与正泊松比泡沫填充管相比，内凹三角形填充管在能量吸收方面提高了17.23%，碰撞力峰值降低了5.04%。因此，本文所提出的解耦设计方法在满足多种性能要求方面具有优越性。

关键词 薄壁管 · 内凹三角形蜂窝 · 多目标优化 · 能量吸收 · 结构刚度

✉ Ying Zhao, zying15@mails.jlu.edu.cn
[1] State Key Laboratory of Automotive Simulation and Control, Jilin University, 5988, Remin Ave., Changchun 130025, China

Novel Mechanical Interface Design for Automotive Starting Systems

Alvaro C. Michelotti[1] · Jonny C. da Silva[2] · Lauro C. Nicolazzi[2]

Abstract

Stop–start vehicles (SSVs) represent a potential alternative for improving internal combustion engine (ICE) efficiency. SSVs provide ICEs with the functionality of turning the engine off during traffic halts and restarting it without intervention by the driver. This strategy reduces fuel consumption, especially in dense urban traffic areas, and contributes to emissions reduction to meet green emissions targets. The most widely adopted SSV system has a mechanical interface to connect the electric starter motor to the ICE, which requires increased robustness compared with standard starting motors. This requirement allows the motor to withstand a higher number of engine start cycles compared with a standard starting motor. Nevertheless, it is a critical problem for wider adoption of SSVs. As SSV systems usually are based on the conventional starting system, its durability and noise remains a critical issue to be addressed by automakers. The typical pinion–ring gear interface uses intermittent gear meshing to form a transient coupling interface. The research reported here presents the development of an innovative mechanical interface for starting systems, called the permanent coupling (PC)-type interface, which reduces noise and increases durability compared with the existing design. The results obtained by a functional prototype of the PC-type mechanical interface confirm the feasibility of the proposed concept. The methodology is based on a product development process integrated with lumped-parameter modeling and virtual simulation aimed at reducing failures during prototype testing. The new mechanical interface was proven to be a good candidate for increasing the use of SSVs in the automotive market.

Keywords Starting systems · Internal combustion engines · Stop–start vehicles · Mechanical interface · Lumped-parameter simulation

新型汽车启动系统机械接口设计

Alvaro C. Michelotti[1] • Jonny C. da Silva[2] • Lauro C. Nicolazzi[2]

【摘要】车辆启停功能（SSV）是提高内燃机（ICE）效率的潜在解决方案。SSV为ICE提供了在车辆暂停期间关闭发动机，并在驾驶员不干预的情况下重新启动发动机的功能。特别在密集的城市交通区，该功能可降低燃料消耗，并实现节能减排。目前广泛应用的SSV系统有一个机械接口，用于连接电动起动电机和ICE，其与标准起动电机相比，需更高的鲁棒性。该接口要求允许电机承受更多的发动机起动循环。该要求限制了SSV的广泛应用。同时，由于SSV系统通常基于传统起动系统设计，其耐久性和噪声仍然是汽车制造商需要解决的关键问题。传统的小齿轮-齿圈界面采用间歇齿轮啮合形成瞬态耦合界面。本文为启动系统开发了一种创新的机械接口，称为永久耦合（PC）型接口，与现有的设计相比，该方案可有效降低噪音并提高耐久性。本文对PC型机械接口的功能原型进行了验证，其结果证实了该设计的可行性。该方法以产品开发过程为基础，结合集总参数建模和虚拟仿真，旨在减少原型测试中的故障。新的机械接口可广泛替代原机械接口，将促进SSV在汽车市场的应用。

关键词 启动系统 · 内燃机 · 车辆启停 · 机械接口 · 集总参数模拟

✉ Alvaro C. Michelotti, alvaro.michelotti@zensa.com.br

1   R & D, Zen S.A. Industria Metalurgica, Brusque, SC 88355-100, Brazil

2   CTC-EMC-UFSC, Universidade Federal de Santa Catarina, P.O. Box 476, Florianópolis, SC 88040-900, Brazil

Vibration Characteristics of Framed SUV Cab Based on Coupled Transfer Path Analysis

Wei Yang[1] · Jiqing Chen[1] · Zongjian Liu[1] · Fengchong Lan[1]

Abstract

The vibration transmission paths in a sport-utility vehicle with a frame structure were used to evaluate the coupled vibration of each vibration transmission link. This method was based on the transmission path of an "engine-powertrain mount system-frame-vehicle body suspension-body-driver seat rail," and the research objective was to improve the vibration characteristics of the cab. This coupled transfer path analysis combined analysis and experiment to establish the vehicle vibration transmission path model and a finite element simulation model. With this method, the vibration level of the driver's seat rail was reduced and engineering practice was effectively used to improve the vibration characteristics of the cab. This method was applied to a framed SUV cabin.

Keywords Framed SUV · SUV cabin · Vibration characteristics · Coupling · Transfer path

基于耦合传递路径分析的非承载SUV驾驶室振动特性研究

杨威[1] • 陈吉清[1] • 刘宗建[1] • 兰凤崇[1]

【摘要】针对非承载式SUV驾驶室的振动特性研究，主要采用传递路径分析方法评估各个传递路径的耦合振动。基于"发动机-动力总成悬置系统-车架-车身悬置-车身-驾驶员座椅导轨"传递路径，提出了一种改善驾驶室振动特性的方法，该方法建立了整车振动传递路径模型和有限元仿真模型，其试验验证和工程实例应用均表明，该方法能降低驾驶员座椅导轨处振动水平，有效改善驾驶室的振动特性。该方法适用于非承载式SUV驾驶室。

关键词 非承载式 SUV · SUV 驾驶室 · 振动特性 · 耦合· 传递路径

✉   Wei Yang, 945753880@qq.com

[1]   School of Mechanical and Automotive Engineering , South China University of Technology and Guangdong Provincial Key Laboratory of Automotive Engineering , Guangzhou 510641 , China

Comparative Study on the Temperature Rise of a Dry Dual Clutch Under Different Starting Conditions

Maotao Zhu[1] · **Peng Yao**[1] · **Yubin Pu**[1] · **Tao Liu**[2]

Abstract

A finite element model of the pressure plate and friction plate of the dry dual clutch is established to find the temperature rise of a dry double clutch in operation. Different starting conditions for the temperature of the dry dual clutch are obtained by calculating the temperature rise, and a comparative analysis of the results is conducted. Results show that the temperature rise for clutch 2 is generally higher than that for clutch 1, and the temperature rise of clutch 2 is higher than that of clutch 1, with an increasing throttle opening. A curve of the speed difference between engine and friction plates is extracted by calculating the source power of the wear of the sliding mill. It is found that the clutch speed difference of clutch 2 is generally higher than that of clutch 1 because clutch 1 follows a constant-rotation-speed control strategy at the start of grinding, leading to the temperature rise of clutch 2 being greater than that of clutch 1. A constant-engine-speed shift strategy is finally put forward.

Keywords Dry double clutch · Friction power · Temperature field · Comparative analysis · Speed difference

不同起动工况下干式双离合器温升对比研究

朱茂桃[1] · 姚鹏[1] · 浦宇斌[1] · 刘涛[2]

【摘要】为探究干式双离合器在工作过程中的温升，本文中建立了干式双离合器压盘和摩擦片的有限元模型。通过对干式双离合器温升的计算，得到了不同的起动工况的结果，并进行了对比分析。结果表明，离合器2的温升普遍高于离合器1，随着节气门开度的增大，离合器2的温升较离合器1明显地增加。基于滑摩功计算公式，提取发动机和摩擦片角速度差曲线。结果表明，由于起动过程中离合器1的恒转速控制策略，离合器2转速差一般高于离合器1，导致离合器2的温升高于离合器1。最后，提出了发动机恒速换挡策略。

关键词 干式双离合器 · 摩擦功 · 温度场 · 对比分析 · 速度差

✉ Peng Yao, 915940042@qq.com

1　School of Automobile and Traffic Engineering, Jiangsu University, Zhenjiang 212013, China

2　Shanghai Automobile Gear Works, Shanghai 201800, China

Estimation of Residual Exhaust Gas of Homogeneous Charge Compression Ignition Gasoline Engine Operating Under Negative Valve Overlap Strategy

Huanchun Gong[1]

Abstract

To meet the requirements of the homogeneous charge compression ignition gasoline engine's rapid cylinder exhaust gas rate and accurate control of combustion phasing, a residual exhaust gas rate model was proposed. A heat dissipation model for gas flow in the exhaust passage and exhaust pipe was established, and the exhaust gas was established. Flow through the exhaust valve was considered as an adiabatic expansion process, the exhaust temperature was used to estimate the temperature in the cylinder at the time that the valve was closed, and the cylinder exhaust gas rate was calculated. To meet the requirements of transient operating conditions, a first-order inertial link was used to correct the thermocouple temperature measurement. Addressing this delay problem and modification of the exhaust wall temperature according to different conditions effectively improved the accuracy of the model. The relative error between the calculated results of this model and the simulation results determined using GT-POWER software was within 3.5 %.

Keywords Residual exhaust gas · Negative valve overlap angle · Homogeneous charge compression ignition · Gasoline engine · Numerical estimation

负气门重叠角策略条件下的均质充量压缩点火汽油机残余废气数值估算

宫唤春[1]

【摘要】 为满足均质充压压燃式汽油机快速气缸排气率和燃烧定相精确控制的要求，提出了残余排气率模型。 建立了排气通道和排气管内气流的散热模型，通过排气阀的流动被认为是绝热膨胀过程，排气温度用于估计阀门关闭时气缸中的温度，并计算气缸排气速率。为了满足瞬态工作条件的要求，使用一阶惯性连接来校正热电偶温度测量值。针对延迟问题，根据不同条件修改排气壁温度，有效提高了模型的精度。 该模型的计算结果与使用GT-POWER软件确定的模拟结果之间的相对误差在3.5%以内。

关键词 残余废气 · 负气门重叠角 · 均质充量压缩点火 · 汽油机 · 数值估算

✉ Huanchun Gong, gonghuanchun@126.com

[1] College of Engineering, Yanjing Institute of Technology, Langfang 065201, China

MPC-Based Downshift Control of Automated Manual Transmissions

Xin Li[1] · Jidong Lyu[1] · Jinlong Hong[1] · Jinghua Zhao[2] · Bingzhao Gao[1] · Hong Chen[1,3]

Abstract

Automated manual transmissions, which usually adopt synchronizers to complete the gear shift process, have many advantageous features. However, the torque interruption and the challenging control objectives during the gear shift process limit its industrial application, especially for the power-on gear downshift. This paper proposes a model predictive control (MPC) method to control the clutch engagement process and effectively shorten the torque interruption, consequently enhancing the gear downshift quality. During the control law deduction, the proposed MPC also accounts for time-domain constraints explicitly. After the control law was deduced, it was validated through simulations under two typical power-on gear downshift working scenarios. Both of the simulation results demonstrate that the controller proposed in this paper can shorten the torque interruption time during power-on gear downshifts while minimizing vehicle jerk for overall satisfactory drivability.

Keywords Automated manual transmission · Gear downshift · Heavy-duty trucks · Clutch · Model predictive control

基于模型预测控制的AMT降挡控制

李鑫[1] • 吕吉冬[1] • 洪金龙[1] • 赵靖华[2] • 高炳钊[1] • 陈虹[1,3]

【摘要】机械式自动变速器（AMT）通常采用同步器来完成换挡过程。然而，换挡过程中的动力中断和较大的控制难度限制了其实际应用，尤其是在动力降挡过程中这两个问题更为明显。本文中采用模型预测控制（MPC）方法来控制离合器在动力降挡过程中的离合器接合过程，以有效缩短动力中断时间，提高降挡品质。控制律推导过程中显式考虑了时域约束。最后通过两种典型的重型卡车动力降挡工况的仿真实验验证控制算法的有效性，两种工况下的仿真结果均表明，本文中提出的控制律能够缩短AMT进行动力降挡时的动力中断时间，减小换挡冲击度，从而提高车辆整体驾驶品质。

关键词 机械式自动变速器 · 动力降挡 · 重型卡车 · 离合器 · 模型预测控制

✉ Hong Chen, chenh@jlu.edu.cn

1 State Key Laboratory of Automotive Simulation and Control, Jilin University, Changchun, China

2 Computer College , Jilin Normal University, Siping, China

3 Department of Control Science and Engineering, Jilin University, Changchun, China

Technology Development Analysis on Low Carbon for Power of Heavy-Duty Commercial Vehicle

Jiangwei Liu[1] · Jun Li[2] · Yongjun Wang[1] · Dalu Dong[1] · Yansheng Yin[1] · Huayu Jin[1] · Shijie Sun[1] · Huili Dou[1] · Yanbo Shi[1] · Lei Fu[1] · Fei Ge[1]

Abstract

Commercial vehicle industry worldwide is facing challenges from environmental pressures, stringent limits of CO_2 emission, governmental regulations as well as ever-increased customer demands. This paper analyzes the above-mentioned challenges, especially in China, including the potential improvement to increase the brake thermal efficiency (BTE), with five levels of BTE proposed, ranging from current 45% to 60% in future, corresponding to China fuel consumption regulation (CFCR) in different phases. The authors also proposed the technology roadmaps to meet the upcoming CFCR3 and CFCR4; finally, the authors draw the conclusions to conform with ever-stringent regulation in China.

Keywords Heavy-duty diesel engine (HDDE) · Low carbon · Fuel consumption

中国重型商用车动力低碳技术发展分析

刘江唯[1] · 李骏[2] · 王永军[1] · 董大陆[1] · 尹燕升[1] · 金华玉[1] · 孙士杰[1] · 窦慧莉[1] · 史彦博[1] · 付磊[1] · 戈非[1]

【摘要】全球商用车行业正面临来自环境压力、日益严格的二氧化碳排放限值、政府法规以及不断增加的顾客需求的挑战。本文详细分析了中国重型商用车未来发展面临的挑战，阐述了提高发动机制动热效率（BTE）的潜力，提出了分5阶段提升BTE的建议，包括目前的BTE 45%到未来的BTE 60%，以应对中国重型商用车燃料消耗法规（CFCR）的不同阶段。作者还提出了实现上述目标的技术路线图，以满足即将到来的CFCR3和CFCR4。最后，作者对达成严格的油耗法规进行了总结。

关键词 重型柴油机 · 低碳 · 油耗

✉ Yongjun Wang, wangyj_qy@faw.com.cn

1 China FAW Group Corporation Limited, Changchun 130000, China

2 Tsinghua University, Beijing 100084, China

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Experimental and Performance Analyses on Elastomer-Strengthened Polyethylene Terephthalate/Glass Fiber Blends

Qili Shen[1] · Xu Li[1] · Ying Zhao[2] · Xiaoyu Gu[1] · Weijian Zou[1] · Xiangdong Huang[1,3] · Wenfeng Mao[1,3]

Abstract

Ethylene–methacrylate–glycidyl (EMG) copolymer is employed to strengthen polyethylene terephthalate (PET)/glass fiber (GF) blends. This paper starts from investigating the effects of various EMG contents on mechanical properties, thermal properties and fractured surface morphology of PET/GF blends. All of the above-mentioned properties own extreme limits of EMG concentration. The crystallization ability of the blends increases with an increment in EMG content, whereas the crystallinity keeps stable at a relatively high level of 0–20 wt.% EMG loading. The tension, bending and impact properties of PET blends are enhanced with the addition of a self-made three-dimensional hierarchical porous carbon sponge (3DC) based on an optimal additive amount. Results indicate that EMG possesses the capabilities of increasing the toughness of PET/GF blends remarkably and transforming the blends from brittle fracture to tough fracture. According to the results, the blends exhibit the best overall properties as the content of EMG reaches 10–15 wt.%.

Keywords Polyethylene terephthalate · Glass fiber · Thermoplastic elastomer · Experimental preparation · Performance analysis

弹性体增强聚对苯二甲酸乙二醇酯/玻璃纤维复合材料的实验与性能分析研究

沈启立[1] • 李旭[1] • 赵颖[2] • 顾晓瑜[1] • 邹伟健[1] • 黄向东[1,3] • 毛文峰[1,3]

【摘要】本文中采用乙烯-马来酸酐-甲基丙烯酸缩水甘油酯三元共聚物(EMG)对聚对苯二甲酸乙二醇酯/玻璃纤维(PET/GF)共混材料进行增韧改性。并从不同EMG含量对PET/GF材料机械性能，热性能及断口形貌的影响为切入点进行研究，得出了以上不同特性均具有EMG含量的极限值。随着EMG含量的增加，共混物结晶能力增强，而共混物结晶度在相对较高的0-20 wt.%EMG负载水平下保持稳定。在最佳添加量的基础上，添加自制的三维分层多孔碳材料（3DC）后，可增强PET共混物的拉伸、弯曲和冲击性能。研究结果表明EMG能显著提高材料的韧性，并使材料的断裂形式从脆性断裂变成韧性断裂；当EMG在10-15 wt.%时，复合材料表现出了良好的综合性能。

关键词 聚对苯二甲酸乙二醇酯 · 玻璃纤维 · 热塑性弹性体 · 实验制备 · 性能分析

✉ Wenfeng Ma, wenfengmao123@gmail.com

1 Guangzhou Automobile Group Co., Ltd, Guangzhou 511434, China

2 State Key Laboratory of Automotive Simulation and Control, Jilin University, Changchun 130021, China

3 School of Materials Science and Engineering, South China University of Technology, Guangzhou 510641, China

A Review of Engine Fuel Injection Studies Using Synchrotron Radiation X-ray Imaging

Zhijun Wu[1] · Wenbo Zhao[1] · Zhilong Li[1] · Jun Deng[1] · Zongjie Hu[1] · Liguang Li[1]

Abstract

Fuel spray characteristics directly determine the formation pattern and quality of the fuel/air mixture in an engine, and thus affect the combustion process. For this reason, the improvement and optimization of fuel injection systems is crucial to the development of engine technologies. The fuel jet breakup and atomization process is a complex liquid-gas two-phase turbulent flow system that has not yet been fully elucidated. Owing to the limitations of standard optical measurement techniques, the spray breakup mechanism and its interaction with the nozzle internal flow are still unclear. However, in recent years synchrotron radiation (SR) X-ray imaging technologies have been widely applied in engine fuel injection studies because of the higher energy and brilliance of third-generation SR light sources. This review provides a brief introduction to the development of SR technology and compares the critical parameters of the primary third-generation SR light sources available worldwide. The basic principles and applications of various X-ray imaging technologies with regard to nozzle internal structure measurements, visualization of in-nozzle flow characteristics and quantitative analyses of near-field spray transient dynamics are examined in detail.

Keywords X-ray imaging technology · Fuel injection · Nozzle internal structure · In-nozzle flow visualization · Near-field spray dynamics

同步辐射X射线成像技术在发动机燃油喷射领域的应用综述

吴志军[1] • 赵文伯[1] • 李治龙[1] • 邓俊[1] • 胡宗杰[1] • 李理光[1]

【摘要】燃料喷雾特性直接决定了发动机内燃料/空气混合物的形成规律和质量，从而影响燃烧过程。因此，喷油系统的改进和优化对发动机技术的发展至关重要。燃料射流的破碎和雾化过程是一个复杂的液气两相湍流系统，该系统至今尚未得到充分的阐明。由于传统光学测量技术的局限性，喷雾破碎机理及其与喷嘴内部流动的相互作用还不清楚。而近年来，由于第三代同步辐射光源具有更高的能量和亮度，同步辐射X射线成像技术在发动机燃油喷射的研究中得到了广泛的应用。本文中简要介绍了同步辐射技术的发展，并对世界范围内可用的主要的第三代同步辐射光源的关键参数进行了比较。详细介绍了各种X射线成像技术的基本原理，及其在喷嘴内部结构测量、喷嘴内部流动特性可视化、以及近场喷雾瞬态动力学定量分析等方面的应用。

关键词 X射线成像技术 • 燃油喷射 • 喷嘴内部结构 • 喷嘴内流可视化 • 近场喷雾动力学

✉ Zhijun Wu, zjwu@tongji.edu.cn

[1] School of Automotive Studies, Tongji University, Shanghai 201804, China

Experimental and Numerical Study of Cervical Muscle Contraction in Frontal Impact

Zhenhai Gao[1] · Zhao Li[1,2] · Hongyu Hu[1] · Fei Gao[1,3]

Abstract

In a crash situation, drivers typically make evasive maneuvers before an upcoming impact, which can affect the kinematics and injury during impact. The purpose of the current study was to investigate the response and effect of drivers' cervical muscles in a frontal impact. A crash scenario was developed using a vehicle driving simulator, and 10 volunteers were employed to drive the simulator at 20 km/h, 50 km/h, 80 km/h and 100 km/h. Electromyography (EMG) was recorded from the sternocleidomastoideus (SCM), splenius cervicis (SPL) and trapezium (TRP) muscles using a data acquisition system, and the level of muscle activation was calculated. A numerical study was conducted using data collected in the experiment. The results revealed that the cervical muscles were activated during drivers' protective action. EMG activity of cervical muscles before impact was greater than that during normal driving. EMG activity increased with driving speed, with the SCM and TRP exhibiting larger increases than the SPL. The kinematics and load of the driver were influenced by muscle activation. Before the collision, the head of an active model stretched backward, while the passive model kept the head upright. In low-speed impact, the torque and shear of the cervical muscle in the active model were much lower than those in the passive model, while the tension of the cervical muscle was higher in the active model compared with the passive model. The results indicated that the incidence of cervical injury in high speed impact is complex.

Keywords Cervical injury · Frontal impact · Active muscle force · Driving simulator

正面碰撞时驾驶员颈部肌肉收缩的实验和仿真研究

高振海[1] • 李钊[1,2] • 胡宏宇[1] • 高菲[1,3]

【摘要】驾驶员意识到即将发生碰撞时，将本能性地收缩肌肉形成自我保护动作，并对驾驶员的运动姿态和损伤结果产生影响。本文主要研究颈部肌肉在正面碰撞中的响应及其对损伤的影响。本文首先在汽车性能模拟器上构造具有高度虚拟现实感的汽车正碰工况，选取10名志愿者分别以20、50、80和100 km/h驾驶模拟器，记录在碰撞发生时驾驶员胸锁乳突肌、头夹肌和斜方肌的肌肉电信号，并计算肌肉激活水平。然后使用实验获取的颈部肌肉激活进行碰撞仿真，研究肌肉活动对颈部损伤的影响。实验结果表明驾驶员在碰撞时产生自我保护动作，此时颈部肌肉的肌肉电信号较正常驾驶时明显升高。肌电信号随着车速增加呈现整体增大态势，胸锁乳突肌和斜方肌的激活程度增幅较大，但头夹肌激活程度增幅不大。肌肉激活对驾驶员的运动姿态和负荷产生影响。碰撞发生前，具有主动肌肉力的主动模型头部向后伸展，而被动模型头部保持直立。在低速碰撞中，主动模型的颈部剪切力和伸张弯矩远远低于被动模型，张力高于被动模型。实验结果也表明颈部损伤情况在高速碰撞中则较为复杂。

关键字 颈部损伤 · 正面碰撞 · 主动肌肉力 · 驾驶模拟器

Integrated Spacing Policy Considering Micro- and Macroscopic Characteristics

Xinjie Zhang[1] · Yiqing Huang[1] · Konghui Guo[1] · Tao Peng[2] · Shengli Sun[3] · Wentao Li[1]

Abstract

An appropriate spacing policy improves traffic flow and traffic efficiency while reducing commuting time and energy consumption. In this paper, the integrated spacing policy that combines the benefits of the constant time headway (CTH) and safety distance (SD) spacing policies is proposed in an attempt to improve traffic flow and efficiency. Firstly, the performance of the CTH and SD spacing policies is analyzed from the perspective of the microscopic characteristics of human-vehicle and the macroscopic characteristics of traffic flow. The switching law between CTH and SD spacing policies and the integrated spacing policy are then proposed to increase traffic efficiency according to the traffic conditions, and the critical speed for the proposed integrated spacing policy is derived. Using the proposed switching law, the integrated spacing policy utilizes the safety redundancy difference between the CTH and SD spacing policies in a flexible manner. Simulation tests demonstrate that the proposed integrated spacing policy increases traffic flow and that the traffic flow maintains string stability in a wider range of traffic flow density.

Keywords Integrated spacing policy · Critical speed · Critical traffic flow density · String stable · Traffic efficiency

融合微观和宏观特性的综合间距策略

章新杰[1] · 黄逸青[1] · 郭孔辉[1] · 彭涛[2] · 孙胜利[3] · 李文韬[1]

【摘要】适当的跟车间距策略能够提高交通流量，提升交通效率，降低交通通行时间和能源消耗。本文融合固定车头时距间距策略和安全距离间距策略的优势，提出综合跟车间距策略，以提高交通流量和通行效率。首先，分析了固定车头时距与安全距离间距策略对人、本车、前车之间形成的人-车微观系统和交通流宏观系统特性的影响规律。然后，阐明了固定车头时距和安全距离间距策略之间的切换律，提出了集成两者优点的综合间距策略，并推导了临界速度解析表达；通过应用上述切换机律，发现所提出的综合间距策略能够灵活利用固定车头时距和安全距离间距策略的安全冗余空间。最后，进行仿真试验，试验结果表明：本文提出的综合间距策略能够有效提高交通流量和通行效率，且交通流量在更广泛的交通流密度范围内保持了线性稳定。

关键词 综合间距策略 · 临界速度 · 临界交通流密度 · 线性稳定 · 交通效率

✉ Xinjie Zhang, xjzhang5885@gmail.com

[1] State Key Laboratory of Automotive Simulation and Control, Jilin University, Changchun 130022, China

[2] Test and Validation Department Engineering Ability Planning, SAIC Motor Technical Center, Shanghai, 201804, China

[3] College of Mechanical and Electronic Engineering, Dalian Minzu University, Dalian 116600, China

Concept Study of a Self-localization System for Snow-Covered Roads Using a Four-layer Laser Scanner

Tetsushi Mimuro[1] · Naoya Taniguchi[2] · Hiroyuki Takanashi[3]

Abstract

Many advanced driver assistance systems have entered the market, and automated driving technologies have been developed. Many of them may not work in adverse weather conditions. A forward-looking camera, for example, is the most popular system used for lane detection but does not work for a snow-covered road. The present paper proposes a self-localization system for snowy roads when the roadsides are covered with snow. The system employs a four-layer laser scanner and onboard sensors and uses only pre-existing roadside snow poles provided for drivers in a snowy region without any other road infrastructure. Because the landscape greatly changes in a short time during a snowstorm and snow removal works, it is necessary to restrict the landmarks used for self-localization to tall objects, like snow poles. A system incorporating this technology will support a driver's efforts to keep to a lane even in a heavy snowstorm.

Keywords Advanced driver assistance systems · Adverse weather · Laser scanner · Self-Localization system

基于四层激光扫描的积雪覆盖道路自定位系统研究

Tetsushi Mimuro[1] · Naoya Taniguchi[2] · Hiroyuki Takanashi[3]

【摘要】先进辅助驾驶系统（ADAS）得到了越来越广泛的应用，同时自动驾驶技术也得到了持续的发展。然而，ADAS技术在恶劣天气下鲁棒性较差。例如，当积雪覆盖道路时，无法采用最常用的前视摄像头进行车道检测。基于上述情况，本文利用一台四层扫描的激光雷达及车载传感器，提出了一种面向积雪覆盖道路的自定位系统。该系统仅利用积雪道路旁边的雪柱进行定位，而不需要对道路基础设施进行检测。同时，考虑到暴风雪和扫雪等因素的影响，自定位系统的参照物通常设置为距离地面较高的目标。该系统可帮助驾驶员在暴风雪等恶劣天气下实现正常行驶。

关键词 先进的辅助驾驶系统 · 恶劣天气 · 激光测距仪 · 自定位系统

✉ Tetsushi Mimuro, mimuro@akita-pu.ac.jp

1 Faculty of Systems Science and Technology, Akita Prefectural University, 84-4 Ebinokuchi, Yurihonjo, Akita 015-0055, Japan

2 Graduate School of Systems Science and Technology, Akita Prefectural University, 84-4 Ebinokuchi, Yurihonjo, Akita 015-0055, Japan

3 College of Engineering, Nihon University, 1 Nakagawara, Tokusada, Tamuramachi, Koriyama, Fukushima 963-8642, Japan

Scale Consistency Quantification for Subjective Evaluation of Vehicle Dynamics

Wan'an Yang[1]

Abstract

The subjective evaluation of vehicle dynamics performance is widely applied in different stages of vehicle development. However, the rating result has frequently been challenged because it is easily affected by various subjective and objective factors. Currently, there is no suitable index for determining evaluator's consistency when performing a subjective evaluation of vehicle dynamics. This evaluation is quite unique, with limited samples, multiple indices, and poor repeatability, in addition to being stratified and two dimensional. The cross-grouped factor analysis (CFA) method is proposed to identify the scale for a subjective evaluation and to quantify its consistency. An application case study revealed that the proposed method is effective.

Keywords Subjective evaluation · Consistency · Quantification · Cross-grouped factor analysis

车辆动力学主观评价尺度一致性的量化分析

杨万安[1]

【摘要】车辆动力学主观评价被广泛应用于整车开发的各个阶段，然而由于评价过程容易受到各种主观或客观因素的影响，主观评分结果经常会受到质疑。对于车辆动力学主观评价这样的小样本、多指标、分层次、两维度且重复性差的情况，迄今为止并无合适的指标用来衡量评价者的一致性。本文提出了一种交叉分组因子分析法，可确定评价过程中的尺度指标，以及衡量该尺度一致性的量化方法。文中案例证明了该方法的有效性。

关键词 主观评价 · 一致性 · 量化 · 交叉分组因子分析

✉ Wan'an Yang, calorie_young@patac.com.cn

1 Pan Asia Automotive Technical Center Co. Ltd., No. 2199, Jufeng Road, Pudong, Shanghai, China

End-to-End Self-Driving Using Deep Neural Networks with Multi-Auxiliary Tasks

Dan Wang[1] · Junjie Wen[1] · Yulong Wang[1] · Xiaodong Huang[1] · Feng Pei[1]

Abstract

End-to-end self-driving is a method that directly maps raw visual images to vehicle control signals using deep convolutional neural network (CNN). Although prediction of steering angle has achieved good result in single task, the current approach does not effectively simultaneously predict the steering angle and the speed. In this paper, various end-to-end multi-task deep learning networks using deep convolutional neural network combined with long short-term memory recurrent neural network (CNN-LSTM) are designed and compared, which could obtain not only the visual spatial information but also the dynamic temporal information in the driving scenarios, and improve steering angle and speed predictions. Furthermore, two auxiliary tasks based on semantic segmentation and object detection are proposed to improve the understanding of driving scenarios. Experiments are conducted on the public Udacity dataset and a newly collected Guangzhou Automotive Cooperate dataset. The results show that the proposed network architecture could predict steering angles and vehicle speed accurately. In addition, the impact of multi-auxiliary tasks on the network performance is analyzed by visualization method, which shows the salient map of network. Finally, the proposed network architecture has been well verified on the autonomous driving simulation platform Grand Theft Auto V (GTAV) and experimental road with an average takeover rate of two times per 10 km.

Keywords Self-driving · Multi-auxiliary tasks · CNN-LSTM · Deep learning

基于多辅助任务深度神经网络的端到端自动驾驶

王丹[1] · 温俊杰[1] · 王玉龙[1] · 黄向东[1] · 裴锋[1]

【摘要】端到端自动驾驶是一种使用深度卷积神经网络（CNN）将原始视觉图像直接映射到车辆控制信号的方法。虽然目前的方法在预测车辆方向盘转角的单一任务上取得了较好的效果，但还不能有效地同时预测方向盘转角和车速。本文设计并比较了各种基于深度卷积神经网络和长短时记忆递归神经网络（CNN-LSTM）的端到端多任务深度学习网络，不仅可以获得驾驶场景中的视觉空间信息，还可以获得驾驶场景中的动态时序信息，提高了方向盘转角和车速预测的准确度。此外，本文中还提出了基于语义分割和目标检测的两种辅助任务，能有效地提高对自动驾驶场景的理解。在公开的Udacity数据集和在自建的GAC数据集上进行了对比实验。结果表明，基于多辅助任务深度网络模型能够更加准确地预测方向盘转角和车速。此外，采用可视化方法分析了多辅助任务对网络性能的影响，并将网络的显著性关注区域进行可视化显示。最后，通过自动驾驶虚拟仿真平台Grand Theft Auto V（GTAV）和实际路试（每10公里驾驶员平均接管2次）对所提出的网络模型结构进行了验证。

关键词 自动驾驶 · 多辅助任务 · CNN-LSTM · 深度学习

✉ Dan Wang, wangdan1@gacrnd.com

[1] GAC R&D Center, 381 Wushan Road, Tianhe, Guangzhou, China

Impact Resistance of Spark Plug's Ceramic Insulator during Ultra-High - Pressure Combustion Under Deto-Knock Conditions

Yunliang Qi[1,2] · Boyuan Wang[1] · Zhi Wang[1]

Abstract

The ceramic insulators of spark plugs in gasoline engines are especially prone to damage when deto-knock occurs. To understand the damage process and mechanism, the present work investigated the impact resistance of ceramic insulators using detonation waves as impact sources. A test device that generates detonation waves was developed, representing a novel means of evaluating the knock resistance of ceramic insulators. Various impact types and detonation intensities were employed, and detonation initiation and propagation at peak pressures greater than 100 MPa were assessed using synchronous high-speed direct photography and pressure measurements. The test results demonstrate that ceramic insulators tend to break at the base of the breathing chamber when damaged by a single high peak pressure detonation wave impact. In contrast, multiple low pressure impacts eventually break the insulator into multiple fragments. The data also show that the positioning of a ground electrode upstream of the ceramic insulator greatly increases the resistance of the ceramic to the detonation impact. A two-dimensional computational fluid dynamics simulation coupled with a chemical kinetics analysis demonstrated that this improved resistance can be ascribed to a reduced peak pressure that appears after the detonation wave diffracts from the electrode prior to contacting the ceramic insulator.

Keywords Spark plug · Ceramic insulator · Detonation wave · Constant volume combustion chamber

超级爆震条件下的火花塞陶瓷绝缘体抗冲击性能

齐运亮[1,2] · 王博远[1] · 王志[1]

【摘要】当汽油机发生超级爆震时，火花塞的陶瓷绝缘体容易受到破坏。为研究超级爆震条件下陶瓷绝缘体的破坏过程和机理，本文设计开发了一种测试火花塞抗爆震性能的新方法及其实验装置，在该装置上使用爆轰波作为冲击源对火花塞陶瓷绝缘体的抗冲击性能进行了测试。测试过程首先使用可视化方法结合压力曲线对爆轰波的起爆和传播过程进行了分析，然后使用不同的冲击方式和爆轰波强度对火花塞陶瓷绝缘体进行了冲击，爆轰波最高峰值压力超过100 MPa。冲击结果显示，在单次高强度爆轰波冲击条件下，当陶瓷绝缘体被破坏时，破坏形式通常为整体断裂，断裂位置处于呼吸腔的根部。而当陶瓷绝缘体在多次冲击条件下才被破坏时，破坏形式则为多片性碎裂。实验结果还显示，当火花塞侧电极位于陶瓷绝缘体的上游位置时，陶瓷绝缘体的抗冲击性能有显著增强。二维数值模拟表明，其原因在于爆轰波在绕过侧电极时会发生衍射，致使侧电极后方的衍射爆轰波压力大幅下降，并使衍射爆轰波碰撞陶瓷绝缘体后的反射压力大幅下降。

关键词 火花塞 · 陶瓷绝缘体· 爆轰波 · 定容燃烧室

✉ Zhi Wang, wangzhi@tsinghua.edu.cn

1   State Key Laboratory of Automotive Safety and Energy, Tsinghua University, Beijing 100084, China
2   Graduate Aerospace Laboratories, California Institute of Technology, Pasadena 91125, USA

Driving-Cycle-Aware Energy Management of Hybrid Electric Vehicles Using a Three-Dimensional Markov Chain Model

Bolin Zhao[1] · Chen Lv[2] · Theo Hofman[1]

Abstract

This study developed a new online driving cycle prediction method for hybrid electric vehicles based on a three-dimensional stochastic Markov chain model and applied the method to a driving-cycle-aware energy management strategy. The impacts of different prediction time lengths on driving cycle generation were explored. The results indicate that the original driving cycle is compressed by 50%, which significantly reduces the computational burden while having only a slight effect on the prediction performance. The developed driving cycle prediction method was implemented in a real-time energy management algorithm with a hybrid electric vehicle powertrain model, and the model was verified by simulation using two different testing scenarios. The testing results demonstrate that the developed driving cycle prediction method is able to efficiently predict future driving tasks, and it can be successfully used for the energy management of hybrid electric vehicles.

Keywords Driving cycle prediction · Markov chain model · Hybrid electric vehicles · Energy management

基于三维马尔科夫模型驾驶循环工况预测的混合动力车辆能量管理算法

赵博林[1]· 吕辰[2]·Theo Hofman[1]

【摘要】本文研究了基于三维随机马尔可夫模型的混合动力车辆驾驶循环在线预测方法及其在能量管理策略中的应用。论文探讨了不同预测时间尺度对驾驶循环生成结果的影响,测试结果表明,当驾驶循环预测时间尺度被压缩为原始尺度的50%,计算负荷显著降低,但对驾驶循环工况预测的额性能仅有轻微影响。所开发的驾驶循环在线预测方法在混合动力车辆实时能量管理算法中进行了应用,并在两种不同的测试场景中对车辆的能量经济性进行了进一步的验证。测试结果表明,所开发的驾驶循环预测方法能够有效地预测未来的驾驶任务,可成功地应用于混合动力车辆实时能量管理算法中,可进一步提升整车的能量经济性。

关键词 驾驶循环预测 · 马尔科夫模型 · 混合动力电动汽车 · 能量管理

✉ Chen Lv, lyuchen@ntu.edu.sg

✉ Theo Hofman, T.Hofman@tue.nl

[1] Department of Mechanical Engineering, Eindhoven University of Technology, Eindhoven, The Netherlands

[2] School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore

Cooperative Lane-Change Maneuver for Multiple Automated Vehicles on a Highway

Yugong Luo[1] · Gang Yang[1,2] · Mingchang Xu[1] · Zhaobo Qin[1] · Keqiang Li[1]

Abstract

With the development of vehicle-to-vehicle (V2V) communication, it is possible to share information among multiple vehicles. However, the existing research on automated lane changes concentrates only on the single-vehicle lane change with self-detective information. Cooperative lane changes are still a new area with more complicated scenarios and can improve safety and lane-change efficiency. Therefore, a multi-vehicle cooperative automated lane-change maneuver based on V2V communication for scenarios of eight vehicles on three lanes was proposed. In these scenarios, same-direction and intersectant-direction cooperative lane changes were defined. The vehicle that made the cooperative decision obtained the information of surrounding vehicles that were used to cooperatively plan the trajectories, which was called cooperative trajectory planning. The cooperative safety spacing model was proposed to guarantee and improve the safety of all vehicles, and it essentially developed constraints for the trajectory-planning task. Trajectory planning was treated as an optimization problem with the objective of maximizing safety, comfort, and lane-change efficiency under the constraints of vehicle dynamics and the aforementioned safety spacing model. Trajectory tracking based on a model predictive control method was designed to minimize tracking errors and control increments. Finally, to verify the validity of the proposed maneuver, an integrated simulation platform combining MATLAB/Simulink with CarSim was established. Moreover, a hardware-in-the-loop test bench was performed for further verification. The results indicated that the proposed multi-vehicle cooperative automated lane-change maneuver can achieve lane changes of multiple vehicles and increase lane-change efficiency while guaranteeing safety and comfort.

Keywords Cooperative automated lane change · Safety spacing model · Cooperative trajectory planning · Trajectory tracking

高速公路多车协同自动换道控制策略

罗禹贡[1] • 杨刚[1,2] • 徐明畅[1] • 秦兆博[1] • 李克强[1]

【摘要】随着车车通信（V2V）的发展，车辆之间可通过共享信息实现协同控制，能有效提高行驶安全性和通行效率。然而，现有关于自动换道的研究多集中于依靠自车环境感知的单车换道场景，多车的协同换道还鲜有研究。因此，本文在3车道8车的场景下，提出一种基于V2V通信的多车协同自动换道控制策略。首先定义共线协同换道和并行协同换道两种模式。接着提出两种模式下的车辆间安全距离模型，作为轨迹规划的约束条件，以确保换道过程的安全性。在此基础上将轨迹规划转化为优化问题，在车辆动力学特性约束和安全距离模型约束下，通过优化求解出协同换道轨迹，最大程度保证换道过程的安全性、舒适性和换道效率。同时还设计了基于模型预测控制的轨迹跟踪方法，以减小跟踪误差和控制增量。最后，为验证其有效性，建立了MATLAB/Simulink与CarSim联合仿真平台对策略进行仿真验证，进一步在驾驶模拟器上开展了硬件在环试验验证。结果表明，本文所提多车协同自动换道控制策略可在保证安全性和舒适性的同时，实现多车协同换道，提高换道效率。

关键词 协同自动换道 · 最小安全距离 · 协同轨迹规划 · 轨迹跟踪

✉ Yugong Luo, lyg@mail.tsinghua.edu.cn

1 Department of Automobile Engineering, Tsinghua University, Beijing 100084, China

2 Huawei Technologies Co. Ltd, Shanghai 200135, China

Modeling and Simulating a Battery for an Electric Vehicle Based on Modelica

Dongchen Qin[1] · Jianjie Li[1] · Tingting Wang[1] · Dongming Zhang[1]

Abstract

Battery is the key technology to the development of electric vehicles, and most battery models are based on the electric vehicle simulation. In order to accurately study the performance of LiFePO$_4$ batteries, an improved equivalent circuit model was established by analyzing the dynamic characteristics and contrasting different-order models of the battery. Compared to the traditional model, the impact of hysteresis voltage was considered, and the third-order resistance–capacitance (RC) network was introduced to better simulate internal battery polarization. The electromotive force, resistance, capacitance and other parameters were calibrated through battery charge and discharge experiments. This model was built by using Modelica, a modeling language for object-oriented multi-domain physical systems. MWorks was used to implement the cycle conditions and vehicle simulation. The results show that the third-order RC battery model with hysteretic voltage well reflects the dynamics of a LiFePO$_4$ battery. The difference between the simulated and measured voltages is small, with a maximum error of 1.78%, average error of 0.23%. The validity and feasibility of the model are verified. It can be used in unified modeling and simulation of subsequent multi-domain systems of electric vehicles.

Keywords Electric vehicle · LiFePO$_4$ battery · Hysteresis · Equivalent circuit model · Modelica

基于Modelica语言的电动汽车电池建模与仿真

秦东晨[1] • 李建杰[1] • 王婷婷[1] • 张东明[1]

【摘要】电池是电动汽车发展的关键技术，大多数电池模型都是基于电动汽车仿真的需要。为了准确地研究磷酸铁锂电池的性能，本文通过分析电池的动态特性和对比不同阶次的电池模型，建立了一个改进等效电路模型。与传统模型相比，考虑了滞回电压的影响，并引入三阶RC网络用于更好地模拟电池内部的极化效应。通过充放电实验对电池的电动势、电阻、电容等模型参数进行了辨识。利用面向对象的多领域物理系统建模语言Modelica构建电池模型，并在MWorks仿真平台上实现了循环工况和整车仿真实验。实验结果表明具有滞回电压的三阶RC网络模型能够很好地反映磷酸铁锂电池的动态特性，仿真结果与实测电压差值很小，最大误差为1.78%，平均误差为0.23%。模型的有效性和可行性得到充分验证，可用于电动汽车后续多领域系统的统一建模与仿真。

关键词 电动汽车 · 磷酸铁锂电池· 滞回特性 · 等效电路模型 · Modelica

✉ Jianjie Li, 1178787313@qq.com

[1] School of Mechanical Engineering, Zhengzhou University, High-Tech Zone, 100 Science Avenue, New Campus of Zhengzhou University, Zhengzhou 450001, Henan, China

Numerical Implementation of High-Order Vold–Kalman Filter Using Python Arbitrary-Precision Arithmetic Library

Linhe Ge[1] · Fangwu Ma[1] · Jinzhu Shi[1] · Hongbin Yin[1] · Ying Zhao[1]

Abstract

The Vold–Kalman order tracking filter plays a vital role in the order analysis of noise in various fields. However, owing to the limited accuracy of double-precision floating-point data type, the order of the filter cannot be too high. This problem of accuracy makes it impossible for the filter to use a smaller bandwidth, meaning that the extracted order signal has greater noise. In this paper, the Python mpmath arbitrary-precision floating-point arithmetic library is used to implement a high-order VK filter. Based on this library, a filter with arbitrary bandwidth and arbitrary difference order can be implemented whenever necessary. Using the proposed algorithm, a narrower transition band and a flatter passband can be obtained, a good filtering effect can still be obtained when the sampling rate of the speed signal is far lower than that of the measured signal, and it is possible to extract narrowband signals from signals with large bandwidth. Test cases adopted in this paper show that the proposed algorithm has better filtering effect, better frequency selectivity, and stronger anti-interference ability compared with double-precision data type algorithm.

Keywords Noise order analysis · Vold–Kalman filter · Arbitrary-precision arithmetic library

基于Python任意精度计算库的高阶Vold-Kalman滤波器数值实现

葛林鹤[1] · 马芳武[1] · 史津竹[1] · 尹红彬[1] · 赵颖[1]

【摘要】Vold-Kalman阶次跟踪滤波器在各个领域的噪声阶次分析中都起着至关重要的作用。然而，由于双精度浮点数据类型精度有限，最多只能精确到小数点后十五位，使得滤波器的阶数不能太高。因此，滤波器频率响应的通带不会非常平坦，而且速度测量偏差变大时将在阶次信号提取中产生更大的偏差。这种精度问题使得滤波器不可能使用较小的带宽，这将造成提取的阶次信号具有较大的噪声。本文采用python mpmath任意精度浮点计算库实现了一种高阶Vold-Kalman滤波器算法。基于该库，可以在需要时实现任意带宽和任意阶数的滤波器。该算法可以获得较窄的过渡带和较平坦的通带，即当速度信号的采样率远低于被测信号的采样率时，仍然可以获得良好的滤波效果，并且使得从大带宽信号中提取窄带信号成为可能。实验结果表明，与双精度数据类型算法相比，该算法具有更好的滤波效果、更好的频率选择性和更强的抗干扰能力。

关键词 噪声阶次分析 · Vold-Kalman 滤波器 · 任意精度计算库

✉ Fangwu Ma, mikema_pro@163.com

[1] State Key Laboratory of Automotive Simulation and Control, Jilin University, 5988, Renmin Ave., Changchun 130025, China

Characterization of Automotive Brake Discs with Laser-Machined Surfaces

Shuwen Wang[1] · Wang Guo[1] · Kang Zeng[1] · Xuegang Zhang[1]

Abstract

In the automotive and transport industry, braking noise and vibrations are persisting issues and difficult to control. Automotive engineers and researchers are putting considerable effort into overcoming these problems, and significant breakthroughs have been made in this area. In this study, M-shaped grooves are bionically designed and manufactured on the frictional surfaces of four automotive brake discs using a laser machine. Various tests were conducted to characterize the physical and mechanical performance of the modified discs along with their noise and vibration responses. The experimental results demonstrate that discs with laser-machined grooved surfaces have better surface hardness and residual stress reduction than discs with ungrooved surfaces. Significant improvement in the braking performance was observed in terms of disc thickness variation, friction and wear, noise, and vibration reduction. It is concluded that the reduction in braking noise and vibrations is mainly caused by the reduction in the coefficient of friction and wear, increase in damping ratio, and improvement of disc thickness variation of the brake disc by laser surface grooving.

Keywords Brake disc · Bionic design · Laser machining · Disc thickness variation · Residual stress · Friction and wear · Vibration and noise

激光表面加工汽车制动盘的性能表征

王书文[1] ● 郭旺[1] ● 曾康[1] ● 张雪刚[1]

【摘要】在汽车和交通运输行业，摩擦制动噪声和振动是持续存在且难以控制的问题。汽车工程师和研究人员正在努力克服这些问题，并已经在这一领域取得了重大突破。本研究在仿生设计的基础上，利用激光加工设备将M-形沟槽加工在四个汽车制动盘的摩擦面上，并通过多种实验测试来表征激光沟槽加工前后制动盘的物理、机械以及振动和噪声等性能的变化规律。实验结果表明，与未经表面激光加工的制动盘相比，激光沟槽加工后制动盘的表面硬度显著提高，同时表面残余应力大大降低。此外，激光加工后的制动盘在厚度差、摩擦磨损以及减振降噪方面也有显著改善。最后，本文探讨了激光加工沟槽对制动盘制动性能产生正面影响的机理。

关键词 制动盘 · 仿生设计 · 激光加工 · 制动盘厚度差 · 残余应力 · 摩擦磨损 · 振动噪声

✉ Shuwen Wang, shuwenwang66@163.com

1 College of Mechanical Engineering, University of Shanghai for Science and Technology, Shanghai 200093, China

Innovative Electric Vehicle Body Design Based on Insurance Institute for Highway Safety Side Impact Conditions

Xinchun Liu[1] · Maoyan Liang[1] · Qiang Luo[1]

Abstract

A version of an electric vehicle was developed and designed for the US market on the basis of the required domestic body structure. When compared with the original car, the new car body design leads to two major technical difficulties. First, the installation of high-voltage components such as the battery pack and other new energy sources increases the vehicle weight and occupies a great deal of its structural space; this limits the impact paths and the use of traditional structural designs, which greatly increases the design difficulty. Second, the USA, as an advanced automobile-using country, has well-developed laws and regulations for collision standards, vehicle operating conditions and evaluation standards. Using a combination of butterfly diagram analysis, bending moment management, section forces and other computer-aided simulation and analysis techniques, this paper presents a body structure design that can achieve a "GOOD" evaluation under the US Insurance Institute for Highway Safety (IIHS) side impact body structure conditions by optimizing the force transfer path, the B-pillar deformation mode and the threshold support structure. The threshold support structure supports realization of the "GOOD" rating for IIHS side impact and helps the body to meet the crash requirements of the Federal Motor Vehicle Safety Standard FMVSS214 and the US New Car Assessment Program (NCAP) requirements for side impact at 32 km/h and 75° angular pole impact.

Keywords IIHS · Side impact · Electric vehicle · Top Safety PICK+ rating · Car body structure

基于美国公路安全保险协会侧碰的创新型电动汽车车身设计

刘新春[1] • 梁茂燕[1] • 罗强[1]

【摘要】某车型美版电动汽车是在其国内版车身的基础上开发设计，相对原车型，新的车身设计主要存在以下两大技术难点1.电池包等新能源高压零部件部件的安装，不仅增加了整车重量，还占据大量的结构空间，其中地板下面Y向空间被动力电池全部占据，使的碰撞传力路径及传统结构设计受限，严重增大设计难度；2.美国作为汽车强国，其相关碰撞标准法规完善，工况及评价标准非常严苛，显著高于国内碰撞安全法规，其中尤以美国高速公路协会的IIHS评价为甚。本文结合蝶形图分析、抗弯弯矩管理、截面力等计算机辅助仿真分析技术，通过对传力路径、B柱变形模式和门槛支撑结构的优化，设计出一款可以获得美国IIHS侧碰车身结构GOOD评价的车身结构，其中的门槛支撑结构不仅支撑了IIHS侧碰车身结构GOOD评价的实现，还很好的兼顾了FMVSS214和USNCAP 75°&32 km/h 侧柱碰工况，保证了车内乘员和电池在各工况下的安全。

关键词 美国公路安全保险协会 · 侧碰 · 电动汽车 · 最高安全等级 · 车身结构

✉ Xinchun Liu, 370040284@qq.com

[1] BYD Auto Industry Co., Ltd, Liujiao Building Area B, No.3009, BYD Road, Pingshan, China

Hardware Design and Test of a Gear‑Shifting Control System of a Multi‑gear Transmission for Electric Vehicles

Feng Tian[1] · Liqi Sui[1] · Yuanfan Zeng[1] · Bo Li[1] · Xingyue Zhou[2] · Lijun Wang[3] · Hongxu Chen[3]

Abstract

The performance of electric vehicles is affected by the shift quality of multi-gear transmission. The realization of dual-target tracking control requires the transmission control unit (TCU) to accurately measure and process the input signals of the gear-shifting control system and precisely control the drive motor torque and the position of shift motors. An electric-vehicle-dedicated TCU was designed to meet the above design requirements. Its function modules included a single-chip control circuit, shift position signal sampling circuit, signal conditioning circuit of the rotational speed and angle, controller area network communication circuit, and shift motor drive circuit. A hardware-in-the-loop simulation test system showed that the TCU design scheme met measurement accuracy requirements and coordinated the actions of the shift actuator and motor control unit to achieve fast and smooth shifting before the road test. The power interruption time of the shifting process was within 350 ms. The reliability of the TCU design was further verified in a 150,000-km vehicle road test.

Keywords Electric vehicles · Transmission control unit · Multi-gear transmission · Dual-target tracking control · Hardware design · Gear-shifting control

电动汽车多挡变速器换挡控制系统的硬件设计与测试

田丰[1] · 隋立起[1] · 曾远帆[1] · 李波[1] · 周星月[2] · 王立军[3] · 陈红旭[3]

【摘要】电动汽车的性能受多挡变速器的换挡品质影响。实现双目标跟踪换挡控制需要变速器控制器（TCU）准确测量和调理变速器控制系统的输入信号，并精确控制驱动电机扭矩和换挡电机位置。为了符合以上设计要求，本文设计了电动汽车专用TCU，其功能模块包括单片机控制电路，换挡位置信号采样电路，转速和角度信号调理电路，控制器局域网通信电路以及换挡电机驱动电路。硬件在环仿真测试系统表明，TCU设计方案满足测量精度要求，并能协调换挡执行机构和电机控制器的动作，在路试之前实现快速、平稳换挡，换挡过程的动力中断时间在350毫秒内。TCU设计的可靠性在15万公里的车辆道路测试中得到了进一步验证。

关键词 电动汽车 · 变速器控制器 · 多挡变速箱 · 双目标跟踪控制 · 硬件设计 · 换挡控制

✉ Liqi Sui, suiliqi@126.com

1 State Key Laboratory of Automotive Safety and Energy, School of Vehicle and Mobility, Tsinghua University, Beijing 10084, China

2 Beijing Spacecrafts, China Academy of Space Technology, Beijing 100080, China

3 Yibin Fengchuan Power Technology Co., Ltd., Yibin 644600, Sichuan, China

Multiphysics Field Co-Simulation Research Based on Electric Drive System for a Specific Type of Car

Chuanfu Wang[1] · Yubo Lian[1] · Heping Ling[1] · Hua Pan[1] · Yuxin Zhang[1]

Abstract

Electric drive systems for new energy cars are complex systems that should have multivariate, strong coupling, and nonlinear characteristics and should also involve the multiphysics field. The singular simulation software used at present in the modeling of electric drive systems cannot simulate the influences of all the physics fields on the operating system. The co-simulation model used in this paper was based on a specific type of car. The motor control algorithm model was built in MATLAB/Simulink, the electromagnetic finite element model of the motor was built in ANSYS EM-Maxwell, and the motor controller hardware circuit was built in ANSYS EM-Simplorer. To make real-time connections among these software platforms, a multi-software co-simulation platform was built, and the co-simulation platform's simulation results were input into STAR CCM+ software to enable finite element modeling of the motor and running of thermal analysis. When compared with the electric drive system model built using single Simulink software, the simulation results from this co-simulation platform were more realistic and were shown to be closer to reality when the dynamic characteristics of the electric drive system's power semiconductor switching devices and the motor's electromagnetic characteristics were considered. Finally, by benchmarking the multiphysics field co-simulation platform simulation results using dyno bench test results, the validity of the co-simulation platform was verified and the development of the multiphysics field co-simulation of the basic electric drive system was complete.

Keywords Multiphysics field co-simulation · Electric drive system · MATLAB · ANSYS EM · Thermal analysis

基于某车型电驱动系统的多物理域联合仿真研究

王传福[1] • 廉玉波[1] • 凌和平[1] • 潘华[1] • 张宇昕[1]

【摘要】新能源汽车的电驱动系统是一个多变量、强耦合、非线性 ,涉及多个物理域的复杂系统。使用单一仿真软件对电驱动系统进行仿真已不能满足当前需求。本文基于某车型平台 ,通过在Matlab-Simulink软件下搭建电机控制算法模型 ,在ANSYS EM-Maxwell软件下搭建电机电磁有限元模型 ,在ANSYS EM-Simplorer软件下搭建电控硬件电路模型 ,建立了多软件协同运算的联合仿真平台 ,使用STAR CCM+软件对电机有限元模型建模进行热场分析。该联合仿真平台相比以往建立在单一Simulink软件下的电驱动系统模型 ,在保证控制算法模型不变的前提下 ,将电驱动系统中的功率开关器件动态特性与电机电磁等特性考虑到了仿真运算中 ,使得仿真结果更加真实 ,贴合实际。最后 ,通过对标同工况下多物理域联合仿真平台与台架试验结果 ,验证了联合仿真平台的有效性 ,为电驱系统多物理域联合仿真平台的发展建立了基础。

关键词 多物理域联合仿真 · 电驱动系统 · MATLAB · ANSYS EM · 热场分析

✉ Yuxin Zhang, zhang.yuxin1@byd.com

[1] BYD Auto Industry Co. Ltd., Shenzhen, China

Systematic Synthesis of Dedicated Hybrid Transmission

Lin Li[1] · Haijun Chen[1] · Ferit Küçükay[1]

Abstract

The great diversity of dedicated hybrid transmissions (DHTs) requires a method to identify solutions among all potential concepts involved in each structure. Therefore, a DHT synthesis tool is developed on the basis of general transmission synthesis. In the first synthesis step, transmission structures are generated with only conventional functions such as driving with only the internal combustion engine. Electric machines are then installed in the transmissions to achieve further hybrid functions, including boosting, eCVT and electric driving modes. The number of generated transmission concepts increases exponentially with each synthesis step. Various evaluations are carried out successively to identify the most suitable DHT concepts among the many possible solutions. The generated DHT concepts are evaluated in terms of structural feasibility, driving modes, drivability and load factors on transmission components. An example of DHT synthesis involving planetary gear sets is explained in detail. The best five DHT structures are identified out of more than 120 billion solutions.

Keywords Dedicated hybrid transmission · Transmission design · Synthesis · Structural evaluation

专用混合动力变速器（DHT）方案优选方法

李琳[1] • 陈海军[1] • Ferit Küçükay[1]

【摘要】专用混合动力变速器（DHT）的多样性对其方案的选型提出了极高的要求。为了从众多的可能方案中挑选出最优的DHT方案，我们以成熟的传统变速器的优选方法为基础，开发出了针对于专用混合动力变速器的优选工具。首先，针对专用混合动力变速器中的传统功能，例如发动机直驱等，优选工具生成不同的变速器结构。针对每种结构，优选工具在变速器内嵌入一个或多个电机，以实现混合动力功能，包括电机辅助驱动、无极变速驾驶（eCVT）、纯电动驾驶等。在方案生成的过程中，方案的数量成指数增长。优选工具在此过程中会从不同方面对已生成的方案进行逐一评估，包括结构的可用性、实现的驾驶模式、驾驶性及各个变速器部件上的载荷。本文以行星齿轮组结构的专用混合动力变速器为例展示了方案优选的方法，并从1200亿个可能方案选出了最优的5个方案。

关键词 专用混合动力变速器 · 变速器设计 · 方案优选 · 结构评估

✉ Lin Li, lilin.obasic@gmail.com

[1] Institute of Automotive Engineering, Technische Universität Braunschweig, Brunswick 38106, Germany

Driving Space for Autonomous Vehicles

Diange Yang[1] · Xinyu Jiao[1] · Kun Jiang[1] · Zhong Cao[1]

Abstract

Driving space for autonomous vehicles (AVs) is a simplified representation of real driving environments that helps facilitate driving decision processes. Existing literatures present numerous methods for constructing driving spaces, which is a fundamental step in AV development. This study reviews the existing researches to gain a more systematic understanding of driving space and focuses on two questions: how to reconstruct the driving environment, and how to make driving decisions within the constructed driving space. Furthermore, the advantages and disadvantages of different types of driving space are analyzed. The study provides further understanding of the relationship between perception and decision-making and gives insight into direction of future research on driving space of AVs.

Keywords Autonomous vehicle · Driving space · Drivable area · Environment perception · Autonomous vehicle decision

自动驾驶汽车的行驶空间

杨殿阁[1] • 焦新宇[1] • 江昆[1] • 曹重[1]

【摘要】自动驾驶汽车行驶空间是自动驾驶感知层与决策层的衔接，一方面是集成感知结果的环境抽象表达，一方面是驾驶决策过程的环境输入。行驶空间的形式代表了对环境理解认知的方式，现有的感知研究与决策研究对于行驶空间的理解存在较大差异。本文在系统性地总结现有行驶空间研究的基础上，聚焦于两个问题进行了研究：一是针对感知层构建行驶空间，研究不同形式的行驶空间的构建方式、表达方式及其优劣势，二是针对决策层运用行驶空间，研究不同类型的决策算法对行驶空间的利用。通过以上研究，本文以行驶空间的角度梳理了自动驾驶感知与决策的关系，并指出行驶空间的未来研究方向应集中于弥合感知与决策对行驶空间理解的差异，加强自动驾驶技术链条上下游的协调性与系统性。

关键词　自动驾驶汽车 · 行驶空间 · 行驶区域 · 环境感知 · 驾驶决策

✉　Diange Yang，ydg@mail.tsinghua.edu.cn

[1]　State Key Laboratory of Automotive Safety and Energy, Department of Automotive Engineering, Collaborative Innovation Center of Intelligent New Energy Vehicle, Tsinghua University, Beijing 100084, China

Comprehensive Analysis and Optimization of Dynamic Vibration-Absorbing Structures for Electric Vehicles Driven by In-Wheel Motors

Yechen Qin[1,4] · Zhenfeng Wang[2] · Kang Yuan[3] · Yubiao Zhang[4]

Abstract

Distributed-drive electric vehicles (EVs) replace internal combustion engine with multiple motors, and the novel configuration results in new dynamic-related issues. This paper studies the coupling effects between the parameters and responses of dynamic vibration-absorbing structures (DVAS) for EVs driven by in-wheel motors (IWM). Firstly, a DVAS-based quarter suspension model is developed for distributed-drive EVs, from which nine parameters and five responses are selected for the coupling effect analysis. A two-stage global sensitivity analysis is then utilized to investigate the effect of each parameter on the responses. The control of the system is then converted into a multiobjective optimization problem with the defined system parameters being the optimization variables, and three dynamic limitations regarding both motor and suspension subsystems are taken as the constraints. A particle swarm optimization approach is then used to either improve ride comfort or mitigate IWM vibration, and two optimized parameter sets for these two objects are provided at last. Simulation results provide in-depth conclusions for the coupling effects between parameters and responses, as well as a guideline on how to design system parameters for contradictory objectives. It can be concluded that either passenger comfort or motor lifespan can be improved to 15% and 36% by properly changing the IWM suspension system parameters.

Keywords Global sensitivity analysis · IWM suspension · Parameter optimization · Electric vehicle

轮毂电机驱动车辆动力吸振构型系统参数分析与优化研究

秦也辰 [1,4] ● 王振峰 [2] ● 袁康 [3] ● 张玉彪 [4]

【摘要】分布式驱动电动汽车利用多个分布式布置电机取代了传统内燃机，此种新结构导致了诸多车辆动力学问题。为提升轮毂电机驱动车辆悬架系统动力学性能，本文针对基于动力吸振构型的悬架-轮毂电机系统开展参数-响应耦合分析与优化研究。针对单轮系统，本文首先建立悬架-轮毂电机系统四自由度动力学方程，并从中选取9个系统变量参数以及5个与车辆动力学评价密切相关的系统响应。基于以上参数与响应，本文采用一种"两步式"的全局灵敏度分析架构开展了系统参数-响应耦合分析。在上述结果的基础上，本文进一步将悬架-轮毂电机控制问题转化为多目标优化问题，并以与电机以及悬架相关的三个响应作为系统约束。利用粒子群优化方法实现汽车乘坐舒适性的提升以及衰减轮毂电机的振动，并给出了这两个目标的两个优化参数集。仿真结果为参数与响应之间的耦合效应提供了深入的分析，也为如何针对矛盾目标设计系统参数提供了方向。通过适当改变IWM悬架系统参数，乘客舒适性和电机寿命可分别提高约15%和36%。

关键词 全局灵敏度分析 · 悬架轮毂电机系统 · 参数优化 · 电动汽车

✉ Yechen Qin, qinyechenbit@gmail.com; qinyechen@bit.edu.cn

1   Beijing Institute of Technology, Beijing, China

2   China Automotive Engineering Research Institute Co. Ltd., Tianjin, China

3   Chongqing University, Chongqing, China

4   University of Waterloo, Waterloo, Canada

A Comparative Study of Charging Voltage Curve Analysis and State of Health Estimation of Lithium-ion Batteries in Electric Vehicles

Xuebing Han[1] · Xuning Feng[1] · Minggao Ouyang[1] · Languang Lu[1] · Jianqiu Li[1] ·

Yuejiu Zheng[2] · Zhe Li[1]

Abstract

Lithium-ion (Li-ion) cells degrade after repeated cycling and the cell capacity fades while its resistance increases. Degradation of Li-ion cells is caused by a variety of physical and chemical mechanisms and it is strongly influenced by factors including the electrode materials used, the working conditions and the battery temperature. At present, charging voltage curve analysis methods are widely used in studies of battery characteristics and the constant current charging voltage curves can be used to analyze battery aging mechanisms and estimate a battery's state of health (SOH) via methods such as incremental capacity (IC) analysis. In this paper, a method to fit and analyze the charging voltage curve based on a neural network is proposed and is compared to the existing point counting method and the polynomial curve fitting method. The neuron parameters of the trained neural network model are used to analyze the battery capacity relative to the phase change reactions that occur inside the batteries. This method is suitable for different types of batteries and could be used in battery management systems for online battery modeling, analysis and diagnosis.

Keywords Lithium-ion battery · Capacity fade · Charging voltage curve · Neural networks · Electric vehicle

电动车用锂离子电池充电曲线分析与健康状态估计对比研究

韩雪冰[1] · 冯旭宁[1] · 欧阳明高[1] · 卢兰光[1] · 李建秋[1] · 郑岳久[2] · 李哲[1]

【摘要】锂离子（Li-ion）电池在循环后会衰减，表现为其容量逐渐下降，而其电阻会逐渐增加。锂离子电池的衰减是由于其内部多种物理和化学反应导致的，并且受到包括所用电极材料、工作条件和电池温度等因素的影响。目前，充电电压曲线分析方法已广泛用于电池特性的研究，基于恒流充电电压曲线以及增量容量（IC）等方法，可以分析电池老化机理，估算电池的健康状态（SOH）。本文提出了一种基于神经网络的充电电压曲线分析方法，并与已有的数点法和多项式曲线拟合方法进行了比较。经过训练后的神经网络模型的神经元参数可以对应于电池内部各相变反应相关的电量。该方法适用于不同类型的电池，并且可以在电池管理系统中用于在线的电池建模仿真、分析和诊断。

关键词 锂离子电池 · 容量衰减 · 充电电压曲线 · 神经网络模型 · 电动汽车

✉ Minggao Ouyang, ouymg@tsinghua.edu.cn

1 School of Vehicle and Mobility, State Key Laboratory of Automotive Safety and Energy, Tsinghua University, Beijing 100084, China

2 College of Mechanical Engineering, University of Shanghai for Science and Technology, Shanghai 200093, China

3D Vehicle Detection Based on LiDAR and Camera Fusion

Yingfeng Cai [1] · Tiantian Zhang[2] · Hai Wang[1] · Yicheng Li[1] · Qingchao Liu[1] · Xiaobo Chen[1]

Abstract

Nowadays, the deep learning for object detection has become more popular and is widely adopted in many fields. This paper focuses on the research of LiDAR and camera sensor fusion technology for vehicle detection to ensure extremely high detection accuracy. The proposed network architecture takes full advantage of the deep information of both the LiDAR point cloud and RGB image in object detection. First, the LiDAR point cloud and RGB image are fed into the system. Then a high-resolution feature map is used to generate a reliable 3D object proposal for both the LiDAR point cloud and RGB image. Finally, 3D box regression is performed to predict the extent and orientation of vehicles in 3D space. Experiments on the challenging KITTI benchmark show that the proposed approach obtains ideal detection results and the detection time of each frame is about 0.12 s. This approach could establish a basis for further research in autonomous vehicles.

Keywords Vehicle detection · LiDAR point cloud · RGB image · Fusion

基于激光雷达和摄像头融合的多车辆检测

蔡英凤[1] · 张田田[2] · 王海[1] · 李祎承[1] · 刘擎超[1] · 陈晓波[1]

【摘要】目前用于目标检测的深度学习算法受到了广泛关注，并在众多领域得到了应用。本文中提出了一种激光雷达与摄像头数据融合对车辆3D位置检测的算法，该算法充分利用了激光雷达采集的数据具有精确深度信息和摄像头能够保留更详细的语义信息的优势，可使检测精度更高。首先将LiDAR点云和图像RGB作为输入，分别对处理后的LiADR点云和图像生成相应特征图，以生成可靠的3D感兴趣区域并进行融合，最终对3D框回归以确定检测车辆的尺寸及方向。基于KITTI基准的实验表明，本文中提出的算法能获得理想的检测结果，每帧数据的检测时间约为0.12 s。该方法为自动驾驶车辆的进一步研究奠定了基础。

关键词 车辆检测 · 雷达点云 · RGB 图像 · 融合

✉ Hai Wang, wanghai1019@163.com

[1] Institute of Automotive Engineering, Jiangsu University, Zhenjiang 212013, China

[2] School of Automotive and Traffic Engineering, Jiangsu University, Zhenjiang 212013, China

High-Efficiency and Clean Combustion Natural Gas Engines for Vehicles

Fubai Li[1] · Zhi Wang[1,2] · Yunfei Wang[1] · Boyuan Wang[1]

Abstract

Natural gas engines have become increasingly important in transportation applications, especially in the commercial vehicle sector. With increasing demand for high efficiency and low emissions, new technologies must be explored to overcome the performance limitations of natural gas engines such as limits on lean or dilute combustion, unstable combustion, low burning velocity, and high emissions of CH_4 and NO_x. This paper reviews the progress of research on natural gas engines over recent decades, concentrating on ignition and combustion systems, mixture preparation, the development of different combustion modes, and after-treatment strategies. First, the features, advantages and disadvantages of natural gas engines are introduced, following which the development of advanced ignition systems, organization of highly turbulent flows, and the preparation of high-reactivity mixtures in spark ignition engines are discussed with a focus on pre-chamber jet ignition, combustion chamber design, and H_2-enriched natural gas combustion. Third, the progress in natural gas dual-fuel engines is highlighted, including the exploration of new combustion modes, the development of novel pilot fuels, and the optimization of combustion control strategies. The fourth section discusses after-treatment systems for natural gas engines operating in different combustion modes. Finally, conclusions and future trends in the development of high-efficiency and clean combustion in natural gas engines are summarized.

Keywords Natural gas engines · Pre-chamber jet ignition · Combustion chamber · Fuel reforming · Dual-fuel combustion · After-treatment

天然气发动机高效清洁燃烧研究综述

李富柏[1] • 王志[1,2] • 王云飞[1] • 王博远[1]

【摘要】天然气发动机在交通运输领域，特别是在商用车领域，变得越来越重要。随着人们对高效低排发动机需求的日益增长，探索改善天然气发动机稀燃稀释极限、提高燃烧稳定性和燃烧速度、降低CH_4和NO_x排放的新技术变得十分必要。本文阐述了近几十年来天然气发动机的研究进展，重点介绍了天然气发动机的点火与燃烧系统、混合气制备、不同燃烧模式的发展以及后处理策略。本文首先介绍了天然气发动机的特点和优劣势。其次，重点从预燃室射流点火、燃烧室设计和富氢天然气燃烧等三个方面阐述了点燃式天然气发动机先进点火系统、高湍流流动组织和高反应活性混合物的制备的研究进展。随后本文介绍了天然气双燃料发动机的研究进展，包括新型燃烧模式的探索、新型引燃燃料的开发和燃烧控制策略的优化。第四部分讨论了天然气发动机不同燃烧模式下的后处理系统。最后，总结了天然气发动机高效清洁燃烧的研究成果和未来发展趋势。

关键词 天然气发动机 · 预燃室射流点火 · 燃烧室 · 燃料改质 · 双燃料燃烧 · 后处理

✉ Zhi Wang, wangzhi@tsinghua.edu.cn

1 State Key Laboratory of Automotive Safety Energy, Tsinghua University, Beijing 100084, China

2 Collaborative Innovation Center of Intelligent New Energy Vehicle, Beijing 100084, China

Ion Current Features of HCCI Combustion in a GDI Engine

Guangyu Dong[1] · Liguang Li[1] · Denghao Zhu[1] · Jun Deng[1]

Abstract

Homogeneous charge compression ignition (HCCI) gasoline engines have the merit of good fuel economy and very low NOx emissions. The ion current signal in a gasoline direct injection-HCCI engine is the main focus of this paper. Experiments showed that the ion signal is significant correlated with the combustion status. Fuel spray and air–fuel mixture motions significant decrease the signal-to-noise ratio of the ion current signal. However, the current waveforms still vary regularly as the boundary conditions change, and their phases have significant linear relationships with the combustion phases. By combining the analysis with cylinder pressure data, the current can be used to effectively detect the combustion phase when the air fuel mixture is not lean. When the mixture gets leaner, the signal amplitude diminishes dramatically, and the linear correlation decreases substantially. The ratio of two-stage fuel injection has a strong effect on signal amplitude and combustion stability, and the linear relationship between the signal and combustion characteristics becomes insignificant as the pre-injection fuel amount decreases. A reaction kinetics analysis of the mechanism for the ion current signal in the HCCI engine explains the experimental observations.

Keywords Fuel economy · Ion current · HCCI · GDI engine · Reaction kinetics

GDI发动机HCCI燃烧的离子电流特征

董光宇[1] · 李理光[1] · 朱登豪[1] · 邓俊[1]

【摘要】均质充气压缩点火（HCCI）汽油发动机具有良好的燃油经济性和极低的NO_x排放量的优点。汽油直喷HCCI发动机中的离子电流信号研究是本文的重点。实验表明，离子信号与燃烧状态显著相关。燃料喷雾和空气燃料混合物的缸内运动降低了离子电流信号的信噪比。但是，电流波形仍会随着边界条件的变化而有规律地变化，并且它们的相位与燃烧相位具有显著的线性关系。通过将离子电流信号与气缸压力数据的结合分析发现，当空气燃料混合物较浓时，该信号可有效检测燃烧阶段。当混合物变稀时，信号幅度急剧减小，线性相关性将会降低。两阶段燃料喷射的比例对信号幅度和燃烧稳定性也有很大的影响，随着预喷射燃料量的减少，信号与燃烧特性之间的线性关系变得不明显。 HCCI发动机中离子电流信号机理的反应动力学分析解释了上述实验观察结果。

关键词 燃油经济性 · 离子电流 · HCCI · GDI 发动机 · 反应动力学

✉ Jun Deng, eagledeng@tongji.edu.cn

1 School of Automotive Studies, Tongji University, Shanghai 200092, China

Experimental Study on the Combustion and Energy Flows of Vehicle Engine Under NEDC of Cold Start

Zhichao Zhao[1] · Zaiqiang Meng[1] · Lu Li[1] · Shuqian Wang[2] · Jianqin Fu[2] · Jingping Li[2]

Abstract

To enhance the fuel economy of a vehicle powered by a gasoline engine under road conditions, an energy flow test of a vehicle was performed experimentally under the New European Driving Cycle of cold start. The energy distributions and related influencing factors were analyzed using the test data. Results show that the effective power and thermal efficiency are mainly affected by the engine load except in the early stage of the New European Driving Cycle. Because of the retarded CA50 and longer CA10-90, the effective thermal efficiency is lower in the early phase of driving conditions. Initially, the heat transfer loss mainly comprises the loss of the heating, ventilation, and air conditioning system. The radiator then plays the major role, with its percentage affected by the engine load and decreasing under the extra-urban driving cycle. The exhaust gas loss is decided by the temperature and flow rate of the exhaust gas, while its percentage is mainly affected by the temperature of the exhaust gas. In the early phase of driving conditions, the retarded spark advance angle leads to a higher temperature of the exhaust gas and a greater exhaust gas loss. The pumping loss and its percentage are mainly determined by the engine speed under the urban driving cycle, and both decrease under the extra-urban driving cycle except at maximum vehicle speed.

Keywords Vehicle · New European Driving Cycle · Cold start · Energy flow · Energy loss

NEDC冷启动行驶工况下车辆发动机燃烧和能量流试验研究

赵智超[1] · 孟再强[1] · 李路[1] · 王书千[2] · 付建勤[2] · 刘敬平[2]

【摘要】为提升汽油车载路试工况下的燃油经济性，开展了NEDC冷启动行驶工况下的整车能量流试验。基于试验数据，对车辆发动机能量分布和相关影响因素展开了分析。研究结果发现，除NEDC循环初期外，有效功和有效热效率在其他时期主要受发动机负荷影响。在NEDC循环初期，由于50%燃烧位置点推迟，同时10%-90%燃烧持续期较长，导致此时期有效热效率较低。冷启动初期，传热损失主要由HVAC（heating, ventilation and air-conditioning）系统传热损失构成。随后，散热器传热损失占据传热损失的主要部分，其占比主要由发动机负荷决定，且在EUDC（extra-urban driving cycle）循环中，占比有所降低。排气损失主要由排气温度和流量决定，然而其占比主要由排气温度决定。在驾驶循环初期，点火提前角推迟导致排气温度较高，导致排气损失较大。泵气损失及其占比在UDC（urban driving cycle）循环中主要由发动机转速决定，而在EUDC循环中，除最高车速点外，两者均有所降低。

关键词 整车 · NEDC · 冷启动 · 能量流 · 能量损失

✉ Jianqin Fu, fujianqinabc@163.com; fujianqin@hnu.edu.cn

[1] China Automotive Engineering Research Institute Co., Ltd, Chongqing 401122, China

[2] State Key Laboratory of Advanced Design and Manufacturing for Vehicle Body, Hunan University, Changsha 410082, China

Reliability Growth Test Planning and Verification of Commercial Vehicles

Jicheng Liu[1] · Liyan Huang[1] · Renmin Zhou[1] · Markus Volmer[1]

Abstract

Reliability and durability are two important technical indicators in automobile research and development. A research-and-design and testing organization can increase inherent quality attributes by adopting a systematic approach based on statistical tools and clearly defined processes. The process affects the design phase, validation through testing, and quality assurance in production. On the basis of reliability growth theory and the Duane model, this study established an estimation method for the definition of the target mileage and specific test cycles in reliability growth testing. A construction method for defining test conditions was proposed that adopts the theory of the design of experiments. The simulation was conducted under a variety of typical test conditions including differing operation times, loads, and logistics modes to predict customer use and detect failures. Failure cases were then analyzed in detail. At the same time, a reliability growth prediction model was established on the basis of the initial test data and used for test process tracking and risk control.

Keywords Reliability · Duane model · Reliability growth prediction model · Failure rate

商用车可靠性增长试验与验证

刘继承[1]· 黄丽燕[1]· 周任民[1]·Markus Volmer[1]

【摘要】在汽车研发过程中,可靠性、耐久性是两个重要技术指标,是通过设计确立、试验验证、生产保证,并在使用中显现出来的产品的一种固有质量属性。本研究主要以可靠性增长理论和Duane模型为基础,建立可靠性增长试验里程和试验周期的推算方法;运用实验设计理论,提出试验工况构建方法,以不同的运行时间、载荷、物流模式为要素,预测用户使用率与失效率,并进一步分析失效原因;同时,根据初期试验数据建立可靠性增长预测模型,用于试验过程跟踪和风险管控。

关键词 可靠性 · Duane 模型 · 可靠性增长预测模型 · 能量流 · 失效率

✉ Huang Liyan, huangliyan@foton.com.cn

[1] Beiqi Foton Motor Co., Ltd., Beijing 102206, China

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