2010 年主要研究项目介绍
Introductions of Main Projects in 2010

1. “高性能科学计算研究”中课题“材料物性的多物理多尺度计算研究”

国家重点基础研究计划（973 计划）项目课题， 编号：2005CB321704, 2005-2010

负责人：钟万勰, 张洪武, 杨海天, 陈飙松, 朱祎国

项目的主要研究内容包括：1) 辛对偶理论及其计算体系。2) 利用分子动力学模拟来研究材料界面断裂的方法。3) 材料非线性分析的多尺度计算方法, 发展基于现代微力学理论的材料非线性分析以及安全性评估的高复杂度问题的高阶计算理论。4） 不同尺度层次的材料与结构一体化优化设计理论与方法, 具有多物理耦合特征的复合材料与结构数值模型与优化设计。5) 有效的数值计算方法和大规模软件实现技术。

The Multi-Scale and Multi-Physics Simulation for Physical Properties of Materials

The National Key Basic Research and Development Program of China (973 Program), No. 2005CB321704, 2005-2009

Wanxie ZHONG, Hongwu ZHANG, Haitian YANG, Biaosong CHEN, Yiguo ZHU

Main topics of the project include: 1) Framework of symplectic theory and the corresponding computational algorithm. 2) Molecular dynamics method to investigate nanometer-scale interfacial mechanical behavior and interfacial failure and fracture mechanisms of composite materials. 3) Multiscale method for nonlinear analysis of heterogeneous materials and the higher order computational theory and model for failure prediction of materials based on the modern mechanics theory. 4) Integrated design optimization of materials and structures, numerical modeling and design optimization for composite materials and structural systems considering interrelations of meso-macro scale with multi-physics coupling effects. 5) Effective numerical algorithm and technique for the development of large scale software system in engineering science computation.

2. “超轻多孔材料和结构创新型的多功能化基础研究”中课题“超轻多孔材料与结构创新构型设计优化新理论”

国家重点基础研究计划（973 计划）项目课题， 编号：2006CB601205, 2006-2010

负责人：刘书田, 张卫红, 陈浩然, 郭旭, 吴承伟, 王跃方

研究结构与材料并发设计、特定性能（如零热膨胀, 负泊松比, 特异力、电、磁、热耦合性能等）材料细观结构创新设计、高比耗能超轻质高强韧结构设计、以及与其相关的多尺度参数并存的优化问题的提法和求解方法等关键科学问题, 研究建立超轻多孔材料结构创新构型设计的新理论。根据汽车、高速列车等高耗能运输工具对结构和材料的性能和功能的特殊要求, 提供一系列新的工具和理论, 帮助设计人员发现、认定和提出超轻质高强韧结构的新构型。通过设计结构的宏观构型, 使结构充分发挥材料的特性, 在具有所要求的性能和功能的同时达到减重的目的；设计材料的微观构型, 以

使材料具有轻质和特殊性能;特别是，要通过材料的微观构型和结构的宏观构型的并发设计，达到材料和结构几何的合理配合，提高结构性能、减轻重量。

Advanced Design Optimization Theory of Ultralight Porous Materials and Structures

The National Key Basic Research and Development Program of China (973 Program), No.2006CB601205, 2006-2010

Shutian LIU, Weihong ZHANG, Haoren CHEN, Xu GUO, Chengwei WU, Yuefang WANG

The main purpose of this project is to investigate the integrated design of materials and structure, the innovative design of material's microstructure with prescribed properties (such as zero-thermal expansion, positive Poisson ratio, specific mechanics, electricity, magnetism, thermal couple), ultralight structure design with high energy to weight ratio and strength to weight ratio, and with stiffness to weight ratio and to propose the formulation and corresponding solving method of the related optimization problem with the design variables in different scales. The advanced theory of designing the innovative configuration of ultralight porous materials and structure will be presented. To meet the special performance and functional demands of materials and structure in transportation facilities with high energy dissipation (such as automobiles, high speed trains), the new method and theory will be provided that can help designer to find, cognizance and give the new ultralight structural configuration design with high strength to weight ratio and stiffness to weight ratio. By designing the configuration of the macrostructure, the properties of materials can be utilized sufficiently and the aim of reducing the structural weight can be realized based on meeting the demands of performance and function. By designing the configuration of the microstructure, the materials with lightweight and prescribed properties can be gained. Especially, the integrated design strategy of material's microstructure and structural configurations, the reasonable configure of materials and structural geometry can be attained, the performance of whole structure is improved and the weight of whole structure is reduced.

3. “巨型重载操作装备的基础科学问题”中课题“非连续工况下重载装备的界面行为与力学特性”

国家重点基础研究计划（973 计划）项目课题， 编号：2006CB705403, 2006-2011

负责人：李刚

本课题属于国家“十一五”973 计划项目“巨型重载操作装备的基础科学问题”。重载操作装备的运动副间隙、摩擦与机构运动和变形之间，刚体运动与弹性变形之间都存在着耦合效应，而且冗余驱动和超静定结构还可能引起奇异偏载等不确定力学行为。同时在巨型重载操作装备主轴轴承中存在着复杂的界面行为。这些界面行为与力学特征不

仅会导致振动增大、运动精度丧失、运动副失效，影响装备的操作性能和操作精度，而且还会导致构件疲劳与损伤，影响装备的可靠性和使用寿命。本课题主要开展以下研究： (1) 多自由度刚柔体系统的非线性动力学行为； (2) 巨型重载操作装备的力流传递规律与构件拓扑优化； (3) 非稳态力场下润滑状态转换规律； (4) 交变重载界面的摩擦磨损规律及表面结构优化。

Surface behaviors and mechanical properties of f huge heavy-weight manipulator under discontinuous movement

The National Key Basic Research and Development Program of China (973 Program), No.2006CB705403, 2006-2011

Gang LI

This project is one of the seven projects of the 973 program “Basic scientific problems of huge heavy-weight manipulators”. There are generally considerable couplings between the surface behaviors of the pairs (friction and clearance) and deformation of the members, the rigid movement and elastic the deformation of the huge heavy-weight manipulators. The redundant motivations and indeterminate structures may cause some uncertain and singular mechanical behaviors. Furthermore, the surface behaviors of the main shafts are extremely complicated. All these factors may affect the performance, accuracy of the manipulator, cause the damage and fatigue of the members, reduce the reliability and fatigue life. This project mainly focuses the studies on (1) nonlinear mechanical behaviors of flexible multibody system; (2) rule of force transformation and topology optimization for members of the huge heavy-weight manipulator; (3) transformation of lubrication state under the unsteady force field; (4) rules of friction and wear on the surface and surface structure optimization of f huge heavy-weight manipulator.

4. “基于蛋白质结构与相互作用的计算生物学研究”中课题“蛋白质动态行为和相互作用模拟新方法研究”

国家重点基础研究计划（973计划）项目课题，编号：2009CB918501, 2009.1-2013.12

负责人：钟万勰

本课题研究蛋白质动态行为和相互作用模拟新方法，发展新的分子动力学模拟、蛋白质复合体三维结构模建和蛋白质－蛋白质(配体)相互作用热力学(Thermodynamic)和动力学(Kinetic)参数计算方法，提高分子模拟的空间和时间尺度。重点进行分子模拟的新策略、新方法和新技术研究，并建立计算生物学公共技术平台，为本项目的其他课题研究提供必要的计算方法和技术支持。

The research of novel simulation methods of protein dynamic and interaction behaviors

The National Key Basic Research and Development Program of China (973 Program), No.2009CB918501, 2009.1-2013.12

Wanxie ZHONG

This project aims to research novel simulation methods of protein dynamic and interaction behaviors, and develop new methods of molecular dynamic simulation, protein complex 3D structure modeling and protein (ligand) interaction thermodynamic and kinetic parameters calculation, so to improve the time-scale and space-scale of molecular simulation. The focus is on researching new strategies, methods and techniques of molecular simulation, establishing public technology platform of computational biology, and affording necessary support of computation methods and techniques for other projects of this program.

5. “核主泵制造的关键科学问题”中课题“转子组件超长使役特性及安全评估方法”

国家重点基础研究计划（973计划）项目课题, 编号: 2009CB724302, 2009.1-2013.12

负责人：王德忠，关振群

本课题属于国家“十一五”973 计划项目“核主泵制造的关键科学问题”。 核主泵作为核岛唯一不间断动力源，在 60 年超长使役时间内，经受各种极端工况考验。如何保证其长期安全运行是必须解决的关键科学问题。本课题针对转子组件，建立有效的安全性评估方法，研究转子的非线性动力行为，掌握冲击、高压密封力与流体激振等作用下转子组件动态响应规律和失稳机理；研究屏蔽部件电磁热流固多场耦合作用以及热损耗、热传递、水动力、电磁激励、碰磨问题及构型稳定性问题，揭示核主泵屏蔽部件的功能退化机理；研究极端工况下主轴与叶轮的结构安全评估方法；研究随机突变工况下惰转飞轮等惯性附件的作用机理；评价飞轮结构对转子结构安全性的影响。为核主泵系统安全性评估与性能预测提供理论依据和技术手段。

本课题主要开展以下研究： 1）核主泵转子组件动力学分析原理；2）转子组件失效机理分析与寿命预测；3）核主泵屏蔽部件的功能退化机理；4）随机突变工况下惯性附件作用机理。

Characteristics of the Rotor System of Reactor Coolant Pump and Safety Assessment Method

The National Key Basic Research and Development Program of China (973 Program), No. 2009CB724302, 2009-2013

Dezhong WANG, Zhenqun GUAN

The project belongs to the 973 Program "The key scientific problems of Reactor coolant pump manufacturing." As the only continuous source of power in Nuclear Island, Reactor coolant pump withstands the test of a variety of extreme conditions. How to ensure its safety is the key scientific issue which must be resolved. Rotor system is the key subsystem of Reactor coolant pump. This project tries to establish effective analysis methods, and provides theoretical basis and techniques for safety assessment and performance prediction for Rotor system.

This project mainly focuses the studies on 1) the dynamics analysis method of the rotor

system of the reactor coolant pump; 2) the failure mechanism of the rotor component and life prediction; 3) the degradation mechanism of the shielding component of reactor coolant pump; 4) the mechanism and function of the inertial attachment in the conditions of accident case.

6. 复杂装备研发数字化工具中的计算力学和多场耦合若干前沿问题

国家重点基础研究计划（973计划）项目，编号：2010CB832700, 2010.1-2014.12

负责人：张洪武

本项目以国家经济建设和国防建设中重大装备设计数字化工具的需求为背景，围绕重大工业与国防装备设计、制造与运行中计算力学共性前沿问题、高端算法与软件系统的开展研究。主要内容包括：（1）在强动荷载作用下多物质响应分析理论、数值方法及高应变率下材料动态行为，（2）材料与结构热力耦合的非线性多尺度本构模型和高性能多尺度算法，（3）多场耦合下考虑不确定性度量与传播的结构优化与工程反问题理论和高效算法，（4）面向多场耦合与多尺度分析的新一代计算力学软件平台研发，（5）多场耦合分析及不确定性优化在车辆覆盖件成形及碰撞安全性设计中的应用研究以及（6）特种装备结构服役过程和冲击载荷下毁伤的数值模拟、目标结构的防护分析等。研究成果将为国防与民用高技术装备自主创新设计提供关键建模理论、先进数值分析方法和技术支撑，形成自主知识产权的新一代大规模计算力学和多场耦合软件系统与研发平台。

Some Frontier Problems of Computational Mechanics and Multi-Field Coupling in Digital Tool for Development of Complex Equipment

The National Key Basic Research and Development Program of China (973 Program), No. 2010CB832700, 2010.1-2014.12

Hongwu ZHANG

This project aims at the common frontier problems, advanced algorithms and software packages of computational mechanics in the design, manufacturing and service of major civil and defense equipments. The main research contents include: (1) theories and numerical analysis of multi-material responses subject to high dynamic loads, material constitutive models under high strain rate, (2) nonlinear multi-scale constitutive model of thermal-structure coupling and high-performance algorithms, (3) structural and multidisciplinary optimization and engineering inverse problems considering uncertainty propagation and multi-field coupling, (4) development of new-generation integrated software platform of computational mechanics, (5) application of multi-field coupling analysis and non-deterministic optimization in metal forming and crashworthiness design of automobile structures, (6) destroy and damage simulation of special-purposed equipment under severe condition and impact loading, defense analysis of target structures. The project

will provide essential modeling theories and numerical methods for novel design of civil and national defense high-tech equipments, and realize self-owned copyright new-generation large scale platform for computational mechanics and multi-field analysis.

7. “复杂装备研发数字化工具中的计算力学和多场耦合若干前沿问题”中课题“考虑多场耦合与不确定性的结构优化设计和反问题方法”

国家重点基础研究计划（973计划）项目课题，编号：2010CB832703, 2010.1-2014.12

负责人：亢战

本课题围绕考虑不确定性和多功能的结构与多学科优化方法开展研究。主要研究内容包括重大装备结构优化设计前沿研究领域中具有挑战性的不确定性结构优化问题、考虑多尺度、多场耦合行为的结构与多学科优化问题、复杂结构反问题等。考虑不确定性及多场耦合的结构多功能优化和反问题理论与方法的研究，将在大规模非线性结构优化问题的理论和算法得到有重要应用价值的研究成果，推进结构优化和工程反问题的学科前沿。

Structural and Multi-disciplinary optimization methods considering uncertainty and multi-function

The National Key Basic Research and Development Program of China (973 Program), 2010CB832703, 2010.1-2014.12

PI: Prof. Zhan KANG

This project aims at investigating Structural and Multi-disciplinary optimization methods considering uncertainty and multi-function. It will mainly focus on (1) challenging non-deterministic optimization methods in the frontiers of structural optimization of major industrial equipments; (2) structural and Multi-disciplinary optimization problems with multi-scale and multi-physics coupled behaviors; (3) complex inverse problems. Research on theories and methods of optimal multi-functional design and inverse problems considering uncertainty and multi-physics will contribute to innovation of engineering design and promote application of structural optimization methods.

8. “复杂装备研发数字化工具中的计算力学和多场耦合若干前沿问题”中课题“新一代集成化计算力学软件平台设计理论和方法”

国家重点基础研究计划（973计划）项目课题，编号：2010CB832704, 2010.1-2014.12

负责人：张洪武，陈飙松

本课题是国家 973 计划项目“复杂装备研发数字化工具中的计算力学和多场耦合若干前沿问题”的第四课题。围绕关键科学问题“集成化计算力学软件平台的体系结构与设计模式”开展研究，充分利用软硬件技术的最新成果，吸收已有的科学与工程计算软件成果，对计算力学研究中的最新成果进行集成，实现跨越式发展，初步建立

一个具有自主知识产权的集成化计算力学软件平台。主要研究内容包括：1) 开展计算力学软件平台支撑技术研究;2)发展结构-多场耦合与多尺度有限元分析软件设计理论与实现技术;3) 研究集成化计算力学软件平台设计方法。

Design theories and methods for new generation integrated software platform for computational mechanics

The National Key Basic Research and Development Program of China (973 Program), No.2006CB705403, 2006-2011

Hongwu ZHANG, Biaosong CHEN

This project is one of six projects of the national 973 program “Some frontier problems of computational mechanics and multi-field coupling in digital tool for development of complex equipment”. The project aims at the key scientific problem “architecture and design patterns of integrated software platform for computational mechanics”. The project plans to employ advanced techniques and methods of computer software and hardware, and to assimilate the good results of current software systems for scientific and engineering computation, and to integrate up-to-date methods for computational mechanics. The objective of the project is to realize pursuant and leap-forward development in this regard and then to implement an integrated software platform with copyright for computational mechanics. Main researches include: 1) research on the enabling technologies of software platform for computational mechanics; 2) Software design methods and techniques of finite element analysis for structural-multidisciplinary and multiscale problems; 3) Design methods of integrated software platform for computational mechanics.

9. “复杂装备研发数字化工具中的计算力学和多场耦合若干前沿问题”中课题“车身钢板轻量化与碰撞安全性的数字化设计”之协作内容“车身钢板热成形理论与方法”

国家重点基础研究计划（973计划）项目课题, 编号：2010CB832705, 2010.1-2014.12

小武：黄颜色部分应该统一翻译。

负责人：胡平

车辆轻量化制造所涉及的结构件高强度板热成形理论和仿真方法的研究日益受到国内、外学术界的关注。本项目从汽车车身轻量化制造工艺与碰撞安全性的数字化优化设计两个方面进行深入系统的研究。研究内容包括：汽车车身结构件热成形工艺的微观相变特性，多场耦合本构理论，热－力－相变相关及热边界接触非线性大变形有限元计算方法等。

Theories and methods on hot forming of auto body high strength steel (HSS) which is belong to the project entitled “Digital design of auto body lightweight and crash safety”

The National Key Basic Research and Development Program of China (973 Program), No. 2010CB832705, 2010.1-2014.12

Ping HU

Hot forming theory and simulation methods of automobile load-bearing parts involving with lightweight manufacture have being widely paid close attention to researcher and engineer in the world. The present project focuses on the research of formability and manufacturability of auto body load-bearing parts with hot formed by HSS, and optimization design of the parts based on crash safety. Main research issues include: experiments and analysis of phase transformation and hardness of the load-bearing parts, constitutive models of multi mechanical field coupling, FEA algorithms of elastic-viscoplasticity involving with thermo-mechanics and phase transformation and thermo contact on boundaries, and so on.

10. “重大工程地质灾害的预测理论及数值分析方法研究”中课题“地质体渐进破坏过程的演化机理及计算模型”

国家重点基础研究计划（973计划）项目课题，编号：2010CB731502, 2010.1-2014.12

负责人：李锡夔

本课题致力于研究地质体由局部性材料破坏到贯穿性结构破坏的发展过程，揭示地质体由连续向非连续状态转化的细观机理并建立相关的判别准则，通过研究地质体渐进破坏过程中的声发射机制，确定地质灾害成形阶段内部破坏状态与宏观可测物理量之间的对应关系及理论框架，并建立它们与工程和环境扰动之间的联系，发展描述地质体由连续到非连续渐进破坏过程的数学、力学模型与数值方法。

Project “Evolution mechanisms and computational model for modeling of progressive failure process of geo-structures” under the program entitled “Theoretical and numerical studies for prediction of failure process of infrastructures due to geologic disaster”

The National Key Basic Research and Development Program of China (973 Program), 2010CB731502, 2010.1-2014.12.

Xikui LI

The project aims (1) to study the progressive failure process from local material damage to perfoliate structural damage occurring in geological media; (2) to reveal microscopic mechanisms of the transition of the geological media from continuous to discontinuous states and then to formulate the corresponding criterion for determining the transition; (3) to present the relationship between intrinsic microscopic failure state variables and measurable macroscopic physical quantities at the stage of geologic disaster formation and relevant theoretical frame through the modelling of acoustic emissions generated by sliding friction caused in the progressive failure process, furthermore, to establish the relation between the microscopic and macroscopic internal state variables describing the failure evolution and engineering and environmental disturbances of the geologic medium;

(4) to develop mathematical and mechanical models and numerical methods for describing the failure evolution process from continuous to discontinuous state of geologic media.

11. “南海深水油气勘探开发关键技术及装备”中课题“深水海底管道铺设技术”子课题“深水海底管铺设托管架设计及专用设备国产化技术研究”

国家“863”计划项目子课题，编号：2006AA09A105-2, 2006.10-2010.12

负责人：岳前进

深海管道铺设曾一度认为应采用 J 形，但随着技术的发展目前认为 S 形也可以实现深海管道铺设。在采用 S 形铺设的时候托管架是关键设备之一，通过托管架来实现对管线的支撑和引导管线按照所需要的角度入水，实现管线铺设时管线有合理的变形保证管线安全。本子课题研究 3000 米深水铺管船的关键装备之一的托管架。

子课题的目的就是消化吸收深水托管架设计的技术并实现国产化。基于深水托管架的基本原理子课题将对计划在建的3000米深水铺管船的托管架的设计进行技术审查，配合相关部门完成托管架的详细设计，并对设计的托管架结构进行模型试验，通过托管架结构的比尺物摸试验来验证托管架设计，为最终托管架的详细设计提供依据。通过托管架设计流程的研究和模型试验的总结，按照对深水托管架在深水管线铺设中的原理和作用的分析，提出深水托管架设计的优化方案，包括托管架结构设计的优化、托管架的相关的配套系统的选择、相关的软件系统的匹配等，并且要通过总结已有的经验形成一套完整的深水托管架的设计流程，包括托管架的设计要求、分析手段、技术规程。

The researches on designing pipelay stingers for deepwater sub-sea pipeline-lay barge and its homemade technology

Sub-Project of National High Technology Research and Development Program, No.2006AA09A105-2, 2006.10-2010.12

Qianjin YUE

There are different methods adopted to install marine pipelines, such as S-lay, J-lay, Tow-lay and Reel-lay. Traditionally J-lay is considered to be suitable in deep water and ultra-deepwater. However with the development of the installation technique in recent years, S-lay has been extended to deep water and ultra-deepwater pipelaying, too. For S-lay, stinger is one of the key equipments, which provides a suitable curved envelope and a smooth transition to protect the pipeline when the pipeline leaves the firing line to enter the launching ramp. And this project funded by National High Technology Research and Development Program of China is to research the ultra-deep water stinger on the pipelaying vessel that can lay pipe up to 3000 m depth

The purposes of this project are to comprehend the design concept and technology of deepwater pipelaying stinger and to achieve self-innovative design.

Based on the basic principle of stinger and S-lay, the project focuses on checking the design of the designed stinger by GUSTO firstly, and makes some detailed check in

cooperation with related departments then. Subsequently the scaled model experiment of the designed stinger system is to be developed, which can be useful to validate the design and assess the system performance. Finally, technical supports are provided for the final design of a novel stinger.

According to the study of stinger design and model experiment, an optimal scheme of the novel stinger design is to be provided, which covers the structural optimization of stinger design, the choice and arrangement of attached facilities, corresponded software system, and so on. Simultaneously, an integrated design flowchart should be concluded including design demands, analysis methods, and technical regulations.

12. “高效能计算机及网格服务环境”中课题“新药研发网格”

国家“863”计划项目课题，编号：2006AA01A124, 2007-2010

负责人：王希诚

发展大规模分布式计算方法及其在网格上的实现。在网格技术方面，将研究网格资源分配方法，任务的可靠性调度方法和网格计算的多级搜索算法。针对创新药物设计，将研究精细分子对接方法，研究考虑蛋白质柔性的多目标蛋白质柔性分子对接方法和优化算法，编制可用于药物虚拟筛选的应用程序；同时，建立考虑蛋白质柔性的反向分子对接方法，建立无冗余蛋白质结构数据库，编制相应的软件，应用于药物作用新靶标的发现。将上述应用模块在新药研发网格体系平台上部署使用。

The grad for innovating and developing drugs

Sub-Project of National High Technology Research and Development Program, No.2006AA01A124, 2007-2010

Xicheng WANG

This project is to develop the massively distributed computing methods and their implementation on grid, which involves data mining techniques for massive database with billions of compounds. For grad research, the main work is: grid resource management methods, transmitting methods of data on grid, and reliable task scheduling for grid computing and multi-level searching algorithm based on grid computing. For innovative drug design, the main research work includes: refined molecular docking methods, fast virtual screening methods based on multi-object optimization and flexibility docking. To be oriented with innovative drug research and development, the above-mentioned methods will be finally integrated to produce applied software for drug molecular design, and seal them on the grid to serve for innovative drug design.

13. “南海深水油气勘探开发关键技术及装备”中课题“深水半潜式钻井船设计与建造关键技术”

国家“863”计划项目课题，编号：2006AA09A104, 2007.4-2010.12

负责人：欧进萍，黄一

平台水动力性能与运动性能预报技术：完成目标平台的水动力性能分析，开发半潜式平台总体性能分析及优化集成软件系统，开发深水半潜式平台、隔水管系统、锚泊定位系统水动力性能和运动性能的时域非线性耦合分析技术及分析软件。

平台结构强度与疲劳寿命分析技术：在完成目标平台规范要求的结构强度计算校核与疲劳寿命分析的基础上，重点开展深水恶劣海况下的平台立柱、横撑等重要结构碰撞计算分析，特殊结构型式目标平台结构关键部位疲劳寿命计算分析，特殊结构型式目标平台结构冗余度分析计算，以及平台"虚拟载荷条件-结构响应数据库"计算机软件系统的开发。

平台全寿命期长效防腐技术：依托目标平台，研究基于涂层防护、牺牲阳极防护以及外加电流防护的联合防腐措施的全寿命期长效防腐技术；针对目标平台，确立平台主体结构的全寿命期长效防腐技术及设计方案。

Pivotal technique for Design and Construction of Deepwater Semi-submersible drilling platform

Project of National High Technology Research and Development Program, No.2006AA09A104, 2007.4-2010.12

Jinping OU, Yi HUANG

Prediction technique for hydrodynamic performance and movement performance of the platform: Analysis of hydrodynamic performance of the objective platform will be completed; An integrated software system for analysis and optimization of collective performance of a semi-submersible drilling platform will be developed; The time domain nonlinear coupling analysis technique and the analysis software for hydrodynamic performance and movement performance of the semi-submersible drilling platform, the riser system as well as the mooring system will be developed.

Analysis technique for structural strength and fatigue life of the platform: On the basis of the structural strength checking and fatigue life analysis according to the criterion by certain code, analysis of impact for some important structures such as platform column and brace, etc. under deepwater condition will be carried out, analysis of fatigue life of some pivotal local structures in the objective platform will be carried out, analysis of structural redundancy of the objective platform will be carried out, and finally a “Dummy load conditions-structural response databases” software will be developed.

Full life long term effective anticorrosion technique: A full life long term anticorrosion technique based on combinative utilization of coatings protection, sacrificial anode cathodic protection and impressed current cathodic protection will be studyed rely on the objective platform; The full life long term anticorrosion technique and a scheme of the corrosion protection system for objective platform will be established.

14. “海洋油气勘探开发技术”中课题“海洋工程防腐系统数值模拟优化设计技术”

国家“863”计划项目课题，编号：2007AA09Z320, 2007.12-2010.12

负责人：黄一，吴建华

本项目的研究目标是：针对复杂海洋工程的防腐系统，研究先进的防腐系统数值模拟计算技术并完成软件系统研制，形成海洋工程防腐系统优化设计的核心技术，建立基于数值模拟计算的复杂海洋工程防腐系统设计技术体系，能够针对复杂海洋工程中的电偶腐蚀和杂散电流腐蚀问题制定出确切可靠的解决方案，显著提高海洋腐蚀的控制水平，研究成果应用于海洋平台及海底管道等实际工程的防腐系统优化设计。主要研究内容包括：复杂海洋工程腐蚀与防腐系统数值模拟计算技术研究及集成化软件系统研制，防腐系统数值模拟及实验研究，海洋平台与海底管道防腐设计参数研究，防腐设计参数敏感性研究，海洋工程防腐设计数据库建立，复杂海洋工程防腐系统数值模拟设计技术研究及集成化软件系统研制。

Numerical simulation optimization design technique of anticorrosion system for ocean engineering

Project of National High Technology Research and Development Program, No.2007AA09Z320, 2007.12-2010.12

Yi HUANG, Jianhua WU

As the objective of the project, an advanced numerical simulating calculation technique of the anticorrosion system for a complex ocean engineering will be studied, and the computing software system will be developed, so that the core technique for optimization design of the anticorrosion system for ocean engineering is achieved, on the basis of which, the design technique system based on numerical simulating calculation of the anticorrosion system for a ocean engineering is founded, and then a reliable measure corresponding to problems of the galvanic corrosion and the corrosion resulted from stray current occurs in a complex ocean engineering will be able to be realized, therefore the control level for ocean corrosion would be improved remarkably, the research achievement will be applied to the optimum design of the anticorrosion system for a real engineering object such as a ocean platform or a seabed pipeline. The major research work of this project includes: Study on numerical simulating calculation technique for corrosion and anticorrosion system of complex ocean engineering and development of the integrated computing software system; Numerical simulation and experimental research of anticorrosion system; Study on design parameter for anticorrosion system of ocean platform and seabed pipeline; Study on sensitivity of anticorrosion design parameter; Foundation of the databases for anticorrosion design of ocean engineering; Study on numerical simulating design technique for corrosion and anticorrosion system of complex ocean engineering and development of the integrated computing software system.

15. “重大产品和重大设施寿命预测激素和专题”中课题“大型离心压缩机叶轮疲劳寿命可靠性设计与分析”

国家“863”计划项目课题，编号：2007AA04Z405, 2007.12-2010.12

负责人：吴承伟

本项目主要研究大型离心压缩机叶轮叶片的疲劳可靠性问题，包括可靠性设计方法、分析软件等，为我国大型离心压缩机的可靠性设计提供分析方法和专用软件。

Project of National High Technology Research and Development Program, No.2007AA04Z405, 2007.12-2010.12

Chengwei WU

This project studies the fatigue reliability of large scale centrifugal compressors, including the reliability design method, analysis software, and etc. The main aim is to provide the basic design method and special software.

16. 台风浪耦合作用下跨海峡桥梁动力模拟及防灾减灾技术

国家“863”计划项目课题，编号：2007AA11Z101, 2008-2010

负责人：张亚辉，赵岩

跨海峡桥梁跨径大，桥位处水深浪高，气候、水文、地质、地震等海洋环境因素异常复杂。台风以及台风掀起的巨浪破坏力极大，而且两者之间在强度、方向以及频谱等方面具有复杂的相关关系，对跨海峡桥梁的作用具有强烈的动态特性、随机性和耦合性。在许多情况下，通常将瞬态的强风和波浪激励看作等效静力作用。但对于跨海峡桥梁，台风以及台风掀起的巨浪动态特性显著且具有强烈的耦合效应。因此，考虑台风以及台风掀起巨浪这种破坏性环境荷载的实际动力特征、随机性和耦合性，将为跨海峡桥梁的设计获取非常显著的改善，而与之相应结构抵抗台风浪耦合作用的结构构造措施及振动控制技术将成为跨海峡桥梁建设面临的一项关键技术难题。

本项申请根据项目组成员和依托单位、协作单位的研究积累和设备优势，针对跨海桥梁设计和建设技术瓶颈问题，开展如下研究工作：1）考虑跨海峡桥梁下部结构分别在随机风浪耦合、畸形波、涌浪作用下的特征荷载确定技术，有效的波浪消减技术及相应构造装置开发。2）基于风、波浪和随机振动等相关工程理论、方法，建立风浪耦合作用下桥梁－海水相互作用体系随机响应预测方程，进一步提出有效的数值求解技术，使之能快速、并较为精确地预测跨海峡桥梁动力性能。3）跨海峡桥梁台风浪耦合作用下桥塔（墩）消减波浪和风荷载的关键构造技术及振动控制技术研究。

本课题的总体目标是，通过对跨海峡桥梁风浪耦合作用的动力模拟领域的一些基本、共性的问题进行较为系统地研究，解决跨海峡桥梁在风浪恶劣自然环境下需要面对的防灾减灾技术问题，为未来跨海峡桥梁工程建设提供技术支持与储备。

Disaster prevention and reduction and dynamic analysis of long-span oversea bridge under giant wind and wave loads

Project of National High Technology Research and Development Program,

No.2007AA11Z101, 2008-2010

Yahui ZHANG, Yan ZHAO

Cross-Strait bridge span, and the bridge located at the depth of the waves, climate, hydrology, geology, earthquakes and other factors in the marine environment is very complex. Typhoon as well as the typhoon whipped up waves of great destructive power, but also between the two in the intensity and direction as well as the spectrum has a complex correlation between the cross-Strait bridge dynamic characteristics have a strong, random, and coupling. In many cases, usually transient excitation to strong winds and waves as equivalent static force. But for cross-Strait bridge, typhoons as well as the typhoon whipped up waves of significant and dynamic characteristics of a strong coupling effect. Hence, in consideration of the typhoon, as well as the typhoon whipped up waves of this destructive environment for the actual power load characteristics of randomness and coupling for the design of cross-Strait bridge access to very significant improvement in the structure of the resistance with the corresponding coupling of typhoon waves structure vibration control measures and technology will be faced with cross-Strait bridge construction, a key technical problems.

The application is made under the project team members and support unit, cooperative research units and equipment for the accumulation of advantage, in view of the sea bridge design and construction of technical bottlenecks, to carry out research work as follows: 1) to consider cross-strait bridge in the lower part of the structure of random wave coupling, abnormal waves, swell under load to determine the characteristics of technology, effective technology and the corresponding reduction wave device development structure. 2) based on wind, wave and associated works, such as random vibration theory, methods, and the establishment of a bridge under the waves coupling - water interaction system randomly in response to the forecast equation, and further put forward an effective numerical solution of technology, so that it can quickly and more accurately predict Cross-Strait bridge dynamic performance. 3) Cross-Strait bridge under typhoon waves coupling the bridge towers to reduce wave and wind loads are the key structural vibration control technology and technical studies.

The overall objective of this project is a bridge of cross-strait momentum coupling wave simulation in the field of basic, common issues of a more systematic study to address the cross-strait bridge in the worst storms to face natural disaster prevention and mitigation of technology issues for future cross-Strait bridge construction projects to provide technical support and reserve.

17. “先进制造技术领域”中课题“汽车概念车身数字化设计新方法与新技术”

国家“863”计划项目课题，编号：2009AA04Z101, 2009-2012

负责人：胡平

本课题属于国家在先进制造技术领域急需的关键技术，旨在解决我国在车身概念设计阶段的技术“空心化”问题，推动行业的技术发展。本项目研究一种全新的汽车车身概念设计方法和集成软件平台技术。主要研究内容包括：(1) 概念车体的等几何分析方法，(2)车身数据库与知识工程、（3）空间自由曲面的参数化设计、以及 （4）知识导航与模板技术。

New methods and new technologies for digital design of concept auto body

Project of National High Technology Research and Development Program in Advanced Manufacture field, No. 2009AA04Z101, 2009-2012

Ping HU

The project is one of imperative key technologies in national 863 projects,aimed at solving so-called “bottleneck” of automobile body concept design with parametric CAD/CAE integration，in order to promote technical progress of automobile concept design field. The project will develop a fully new and powerful design and analysis methodology of auto body concept design and closer integration software platform between CAD and CAE technique. This project mainly focuses the studies on (1) Iso-geometric analysis method of concept auto body; (2) Auto body data-base and knowledge-based engineering; (3) Parametric design with morphing and deformation constraints of auto body; (4) knowledge navigation and template technique.

18. “海洋油气资源勘探开发技术”中课题“水下生产系统脐带缆关键技术研究”子课题“水下生产系统脐带缆结构设计的软件开发及实验研究”

国家“863”计划项目子课题，编号：2009AA09Z301-2，2009-2010

负责人：岳前进

应用于水下生产系统石油开发动态脐带缆的设计与制造技术在国内仍是空白。本课题研究目标是研究深水动态脐带缆的设计的关键技术。动态脐带缆结构的力学行为比较复杂，采用理论与数值方法进行模拟达不到设计的要求。本课题的任务是面向动态脐带缆设计，开展相应的理论研究，数值分析及实验方法研究。包括截面初步设计，截面加强设计，脐带缆的整体分析，动态与静态实验方法研究等。

Study of key mechanical problem of deep water dynamical umbilical design

Sub-Project of National High Technology Research and Development Program, No.2009AA09Z301-2，2009-2010

Qianjing YUE

The design and manufacture of dynamical umbilical used for oil exploitation by subsea system has not been carried out in China. The aim of this project is to study mechanical problem of designing deep water umbilical. The structure of dynamical umbils is quit complicated and could not be simulated by analytical and numerical approachings. The

task of the project will conduct the research for primary design, section enhance design and global design with the numerical and prototype test in laboratory.

19. “机械系统动力学CAE平台”子课题“基础数学算法库研究及机械零部件结构分析与优化模块开发”

国家“863”计划项目子课题, 编号：2009AA044501，2009-2011

负责人：姚伟岸

面向多领域复杂机械系统仿真，研究微分-代数方程（DAE）相关基础算法对离散事件支持、对刚性问题的适应性调整策略；针对结构分析与结构优化问题，提供大规模数值计算的高效算法。最终为多领域复杂系统的仿真求解提供稳定可靠的通用基础算法库。开发机械零部件结构分析与优化模块，并与机械系统动力学 CAE 平台集成。

The software development on fundamental algorithm library and structural analysis and optimization for mechanical components

Sub-Project of National High Technology Research and Development Program, No.2009AA044501，2009-2011

Weian YAO

To achieve the simulation of multi-domain complex mechanical systems, a solver on differential-algebraic equations (DAE) is designed which possess the functions of discrete event handling and self-adaptive adjustment for stiffness problems, while the large scale computations with high efficiency on structural analysis and optimization are investigated. The ultimate objective of this project are, (1) to provide a general algorithm library for simulation of multi-domain complex mechanical systems; (2) to develope the function module on structural analysis and optimization for mechanical components, and integrate it with CAE platform on mechanical systems.

20. “镁合金防护与连接工程技术研究开发”子课题“镁合金连接部位喷涂微/纳米涂层及其应力分析”

国家科技支撑计划项目子课题, 编号：2006BAE04B05-4-1, 2007.6-2008.12

负责人：周霞

结合车辆、航空航天等领域对镁合金连接结构的防护要求，开展镁合金连接结构高速电弧喷涂微/纳米涂层技术研究，本项目主要是根据涂层/基体系统的受力情况和有限元软件平台，建立了镁合金涂层/基体系统应力分析模型，并基于该模型对复合涂层系统的应力和变形情况进行了三维有限元分析。探讨了涂层厚度、涂层/基体弹性模量比值对系统应力和变形分布的影响情况，旨在提高涂层/基体结合强度及耐腐蚀性能，为镁合金连接部位防护技术提供完善的应力状态分析。此外，为验证镁合金连接结构表面涂层耐磨耐蚀性，应用有限元软件对具有超硬微/纳米陶瓷涂层的镁合金试样进行了纳米压痕试验模拟。结果表明超硬微/纳米陶瓷层的显微硬度为93.7GPa，为镁合金基

体显微硬度（2.52GPa）的37.2倍。说明具有微/纳米超硬涂层的镁合金构件将更具耐磨蚀性。

Micro / nano-coating spray and stress analysis of magnesium alloy connecting parts

Sub-Project of National Science & Technology Support Program, No.2006BAE04B05-4-1, 2007.6-2008.12

Xia ZHOU

High velocity arc spraying technology of micro/nano-coating was studied on the surface of magnesium alloy connected components according to the protection requirements for magnesium alloy structure in vehicles, aerospace and other fields. In the project, a magnesium alloy coating / substrate system stress analysis model was established on the basis of the force conditions of the coating / substrate system and finite element software platform. In addition, a three-dimensional finite element analysis on the stress and deformation of the composite coating system. The influence of coating thickness, elastic modulus ratio of the coating / substrate on the distribution of stress and deformation of the system was also discussed. The aim of the study is to increase the bonding strength and corrosion resistance of the coating / substrate system, at the same time, to provide better analysis of the stress state for magnesium alloy protection technology. In order to verify wear and corrosion resistance of the micro/nano-coating on the surface of magnesium alloy connected components, nanoindentation test simulation was carried out on a magnesium matrix sample with super-hard micro/nano-ceramic coating materials. And the results show that the microhardness (93.7GPa) of the coating will be 37.2 times of the microhardness (2.52GPa) of the magnesium matrix. This shows that magnesium alloy connected components with coating will be more wear resistant.

21. **渤海海冰资源开发利用关键技术及试验研究**

国家科技支撑计划项目子课题, 编号：2006BAB03A03，2007.6-2010.8

负责人：宗智

海水变成海冰是一个天然的淡化过程。海冰的含盐量不到海水的 20%。海冰结冰时间越长，其含盐量就越低。因此，如果将海冰从海中捞起，放到储冰的地方，等到天气转暖，海冰溶化后就变成了淡水。在渤海湾，有丰富的海冰资源。本项目研究渤海海冰资源开发的装备开发研制任务。研究采冰船的工作机理，完成采冰船的原理样机并在水池进行试验，验证样机原理的可行性；在此基础上，完成海上中试模型采冰船的开发、设计和制作，并进行海上试验。为实现产业化提供技术支持。

Key equipments and experimental study for utilization of sea ice resources present in Bay Bohai

Sub-Project of National Science & Technology Support Program, No. 2006BAB03A03,

2007-2010

Zhi ZONG, Shaoxin WANG, Jun MA, Shaoling NI

The phase change from sea water to sea ice is a natural desalation. The amount of salt in a unit volume of sea ice is below 20% that of sea water. The longer the sea ice is, the less salt it contains. Therefore, if we were able to collect sea ice from the sea in winter and stored it until the summer, sea ice could be desalted by use of natural resources. The Bohai area is proud of ice resources. In this project we will study the mechanism of how to collect ice from the sea using vessel; and then manufacture a vessel model to be tested in the towing tank with purpose to examine the feasibility of ice-collecting mechanism; after that, design and manufacture another large-scale vessel to be sea-trialed, providing necessary technical support for putting the project into industry.

22. “中国高速列车关键技术研究及装备研制”中课题“高速列车车体技术”中任务“高速列车车体结构强度设计技术及规范研究”

国家科技支撑计划项目子课题, 编号：2009BAG12A04-A08, 2009-2012

负责人：赵国忠

该项研究属于“十一五”国家科技支撑计划“中国高速列车关键技术研究及装备研制”的课题四“高速列车车体技术”的子课题。高速列车车体是关键的人机界面部件和承载部件，车体的技术状态影响车体的安全可靠性和舒适性。由于速度等级的提升，车体承受的静动态载荷更为复杂，并且在高速条件下车体的振动和疲劳问题更为突出。目前，国内外对时速 380 公里以上高速列车的车体设计，可供参考的标准和规范很少，国内时速 380 公里以上高速列车车体的相关研究急需补充和完善。本子课题共有 3 个研究任务：1）高速列车车体关键设计技术及规范研究；2）高速列车车体静强度、刚度的试验技术及试验规范研究；3）基于车体结构的安全评估技术。

Structural strength of high-speed train body

Sub-Project of National Science & Technology Support Program, 2009BAG12A04-A08, 2009-2012

Guozhong ZHAO

The study belongs to the fourth subject “high-speed train body technology”, in National Science & Technology Pillar Program ‘the research of the key technologies and equipment of the Chinese high-speed train’ in the 11th Five year Plan of china. High-speed train body is the key man-machine interface components and load carrying structures. The technical condition of the car body effects on the safety and reliability and comfort. Because of the increase in level of speed, the static and dynamic loads are more complex and the body's vibration and fatigue problems are more serious. Currently, on the design standards and criterions for the car body of high-speed train more than 380 kilometers per hour，very little domestic and abroad references can be found. The domestic research of the car body of the

high-speed train speed is urgently needed to be supplemented and improved. There are three project tasks: 1) The key design techniques and criterions of high-speed train body; 2) Experiment techniques and standards of static strength, stiffness of the high speed train body; 3) The safety assessment of body structure.

23. “中国高速列车关键技术研究及装备研制”中课题“高速列车车体技术”中任务“高速列车车体弹性随机振动响应分析平台”

国家科技支撑计划项目子课题，编号：2009BAG12A04-A03, 2009-2012

负责人：赵岩

本课题属于国家“十一五”国家科技支撑计划项目“中国高速列车关键技术研究及装备研制”。 由轨道不平度造成的高速列车随机振动是影响乘坐舒适性和车辆易损部件疲劳寿命的最重要因素之一。 但是由于常规随机振动计算方法效率太低，通常都是采用若干条路面不平度的样本函数，应用逐步积分并对计算结果进行简单统计处理的方法来求得随机振动的近似解。不但计算量仍然很大，而且精度较差。虚拟激励法已经在承受地震、风、海浪等多种随机荷载作用下的水坝、桥梁、海洋平台等许多复杂结构随机振动计算中获得了广泛的应用。近年来对于车-轨系统用虚拟激励法进行随机振动分析也已被证明是十分有效的。虚拟激励法最重要的优点则在于其极高的计算效率。 在个人台式计算机上可实现具有百万自由度的车体有限元模型严格的随机振动计算。基于虚拟激励法随机振动仿真平台的研发对于我国高速列车车体弹性体动力性能设计更具有现实意义，也是本课题的重要研究内容之一。

Enhance design capability for the train using pseudo-excitation method

Sub-Project of National Science & Technology Support Program, No.2009BAG12A04-A03, 2009-2012

Yan ZHAO

This project is one of the national key technology R&D program “Key technology and equipment development for China high-speed train”.

The random vibration of high speed trains is one of the most important factors that affect the ride comfort and the fatigue life of some parts of the train. The conventional random vibration methods are too inefficient to deal with such complicated computation, therefore a few samples of the trail irregularity are usually taken to perform step-by-step integration, and the results are statistically proceeded to give the approximation of random vibration results. This process is not only very costly, but also less accurate. The pseudo-excitation method (PEM) has now been widely used in many fields, e.g. dams, bridges, platforms, many other kinds of structures subjected to the random action of earthquakes, wind-gusts, ocean waves, and so on. Its use in the random vibration analyses of train/track systems has also been proved to be quite effective. The most important advantage of PEM is its extremely high efficiency. The computational time for a strict random vibration

analysis required for a vehicle-body FEM model with one million degrees of freedom is only about one hour on a personal desk computer. The simulation platform of random vibration based on PEM is very important for dynamic performance design of high-speed trains, and also is important aspect of research project.

24. “大型油气田及煤层气开发”—“南海深水油气勘探开发示范工程项目”中课题“荔湾3-1气田工程设计、建造、安装技术课题”子课题“浮体结构有限元分析技术研究”

国家科技重大专项子课题, 编号：2008ZX05056-03-04, 2008.8-2010.12

负责人：李刚

通过对典型浮式平台浮体结构强度、局部构件疲劳及其整体性能进行综合研究，形成浮体结构精细化有限元建模技术和方法；发展一套面向设计的浮体结构有限元分析技术，为深海平台浮体结构的设计、建造提供依据和理论基础。主要研究内容包括（1）结构有限元快速建模方法及其精度控制技术研究；（2）子结构方法在浮体结构有限元建模中的应用技术研究；（3）浮体结构多尺度多目标有限元分析

Research on Technology of finite element analysis of floating structures

Sub-Project of Major National S&T Program, No. 2008ZX05056-03-04, 2008-2010

Gang LI

This project studies the strength of typical floating structures of deep-sea platforms, local fatigue problem and global properties, and develops the methodology and technology of the fine finite element (FE) modeling and design-oriented technology FE analysis of floating structures, which will be provide the theoretical foundation for the design and manufacturing of the deep-sea platforms. The project covers: (1) Fast FE modeling method and error control technology; (2) Applications of sub-structure technology in FE modeling of floating structures; (3) Multi-scale and multi-objective FE analysis of floating structures.

25. “大型油气田及煤层气开发”课题“大型FLNG/FLPG、FDPSO关键技术”子课题“FLNG/FLPG储液晃荡问题及FDPSO运动抑制技术研究”

国家科技重大专项子课题， 编号：2008ZX05026-006-02, 2008-2010

负责人：岳前进

本课题属于国家科技重大专项“大型油气田及煤层气开发”下属子课题“大型FLNG/FLPG、FDPSO 关键技术”。由于船体的运动引起储液的运动液体本身的晃荡会影响储液安全、船上工艺系统、船体姿态。所以液舱内晃荡载荷十分必要,本课题通过模型试验方法和数值模拟方法对晃荡力分布形式及最大冲击力的统计分析为我国今后的 FLNG/FLPG 自主设计提供技术储备。本课题主要开展以下研究：(1) FLNG/FLPG 储罐晃荡的实验装置及实验技术研究； (2) FLNG/FLPG 储罐晃荡模型试验研究； (3) 极限强度分析中的最大晃荡冲击载荷统计特性好时空分布； (4) 疲劳分析中的晃荡载

荷时间历程及其统计特性； (5) 不同液舱内晃荡载荷的数值模拟研究；

DPSO 是融合了多种功能于一体的新型深远海开发模式，具有多种概念形式。钻井月池内甲板与船体间的相对运动会影响钻井工作效率，以及导致钻具损坏、打井失败。本课题主要展开以下研究：（1）FDPSO 运动补偿的仿真研究；（2）FDPSO-TLD 样机实验研究；

Sub-Project of Major National S&T Program, No. 2008ZX05026-006-02, 2008-2010

Qianjin YUE

The project is one of thenational science and technology program “The key issues in Large FLNG/FLPG 、FDPSO” which belongs to “Large Oil , Gas Fields and Coal Bed Methane Development Program”. Ship motion will result in liquid sloshing in the tank and affects the safety of the tank. So the study of sloshing in the tank is very necessary.

This project mainly focuses the studies on (1) The study of liquid sloshing experimental equipment and technology in the FLNG/FLPG tank; (2) The study of liquid sloshing model test; (3) The temporal and special distribution of maximum sloshing impact load in ultimate strength analysis; (4) The characteristics and time history of sloshing load in fatigue analysis; (5) Numerical study about liquid sloshing in different type of tanks;

FDPSO is a new concept of exploring deep high sea that fused all functions together. The movement between deck in drilling moon pool and ship can reduce the efficiency of drilling job, even break the drilling equipment. This project mainly focuses the studies on: (1) Simulation Research of FDPSO-TLD system’s heave control; (2) The research of FDPSO-TLD’s model experiment

26. “大型油气田及煤层气开发”课题“深水平台工程技术”子课题“深水浮式平台现场监测技术研究”

国家科技重大专项子课题, 编号：2008ZX05026-002-05, 2008-2010

负责人：岳前进

浮体、锚泊、立管系统一起组成深海油气开发的浮式生产系统。目前，我国在深水浮式平台的设计方面尚不成熟，也缺乏深水开发的经验。为了发展深水结构设计理论，提高深水浮式平台结构作业的安全可靠性，开展深水浮式平台系统监测是非常必要的。

本课题开发面向深水浮式平台结构的监测技术，并在我国已有的浮式平台中应用。本课题的研究成果将为检验我国深水平台的设计理论、指导平台的安全生产，同时将促进我国深水结构的监测技术，促进我国在深水浮式结构设计方面的技术进步，提高国际竞争力。

Monitoring of deep water floating platform.

Sub-Project of Major National S&T Program, No.2008ZX05026-002-05, 2008-2010

Qianjin YUE

Floator, mooring line and riser composite deep water floating production system. At present, the design of floating platform has not well studied and lack experience of deep water oil exploitation. In order to design and operate a deep water platform it is necessary to conduct monitoring research.

The project will study the monitoring technology of deep water floating platform and use for exist the platform is Southsea of China. The research will be used to check the design theory, guideline the platform operation.

27. “大型油气田及煤层气开发”课题“深水海底管道和立管工程技术”子课题“海底管道超声导波检测样机研发”

国家科技重大专项子课题，编号：2008ZX05026-005-06, 2008-2010

负责人：武湛君，岳前进

本课题属于国家科技重大专项“大型油气田及煤层气开发”。海洋油气田的开发是我国能源战略的一个重要组成部分，海底管道石油输送是海洋油气田开发的命脉。海底管道服役条件复杂恶劣，容易发生腐蚀及开裂等损伤，如果不能及时发现，就会导致重大的经济损失甚至生态环境的巨大破坏。本课题主要开展针对海底管道腐蚀损伤的超声导波检测与监测技术研究，建立海底管道超声导波检测的成套技术与开发平台，设计开发海底管道超声导波检测样机。

Research and Development of Prototype for Submarine Pipelines Inspection

Sub-Project of Major National S&T Program, No.008ZX05026-005-06, 2008-2010

Zhanjun WU，Qianjin YUE

This project is one of the many sub-projects of the Major National S&T Program “Development of large oil/gas field and coalbed methane”. The development of ocean oil and gas field is playing a key role in Chinese energy strategy. Submarine pipelines serve as the arteries of the oil and gas transportation. These pipelines typically work under harsh and complex environmental conditions and hence are prone to damage like corrosion and cracks. If pipeline damage can not be found in time, the failure of the pipeline may result in great economic loss and even severe environmental disasters. In this project we are aiming at carrying out research for submarine pipeline corrosion inspection and monitoring using guided wave technologies. Through the research, we will set up a research platform enabling systematic research activities involving guided ultrasonic wave inspection and monitoring. Meanwhile, we will develop a prototype of submarine pipeline inspection instrument.

28. “高档数控机床与基础制造装备”中课题“面向动静热特性的机床数字化设计及其软件”

国家科技重大专项课题，编号：2009ZX04014, 2009-2010

负责人：马雅丽，**刘书田**，王德伦

以形成完全自主知识产权的机床行业版数字化设计与分析软件为目标，为提高机床设计质量、创新能力和设计水平，推动机床行业技术进步提供软件支持。研究机床类型与系列化参数驱动受力分析模型以及载荷约束算法，揭示不同类型和系列机床在力-热等多场耦合条件下的静动热性能，建立面向静动热特性的机床部件拓扑优化设计方法，实现机床结构专用的静动热特性及其多功能协同结构优化设计，建立机床静动热特性分析设计知识库，结合实验数据修正理论模型，提高数字化设计软件的可信度与可靠度，形成面向静动热特性的机床专用数字化设计软件。

Software development and research on digital design of Machine Tool for static-dynamic-thermal behaviors

Project of Major National S&T Program, No. 2009ZX04014, 2009-2010

Yali Ma, **Shutian Liu** and Delun Wang

This project is targeted at forming industry version software on digital design and analysis of Machine Tool with fully independent intellectual property, providing software support for improving the quality, innovation ability and level in Machine Tool's design, and promoting the technical progress of Machine Tool industry. Both the mechanical model driven by machine type and serialization parameters and the load constraint algorithm are analyzed to reveal the static, dynamic and thermal performance of different types and series of Machine Tools under mechanical-thermal multi-field coupling condition. In the mean time, topology optimization of the static, dynamic and thermal characteristics of machine parts is established to realize the optimal design of static and dynamic thermal characteristics and multi-functional collaborative structure. In addition, knowledge base of static and dynamic thermal analysis and design for Machine Tool is built, and the theoretical mode is modified according to the experimental data to improve the credibility and reliability of this digital design software, in order to obtain a digital design software special for machine tool with static and dynamic thermal characteristics.

29. “高档数控机床与基础这早装备”课题“开合式大型热处理设备”子课题“开合式热处理设备结构计算及优化”

国家科技重大专项子课题，编号：2009ZX04008-011-004, 2009-2011

负责人：张小鹏

本课题属于国家科技重大专项课题。开合式大型热处理设备主要是针对百万千瓦核电转子生产设计的。大型核电机组中发电机转子、汽轮机转子是重要部件，由于发电机和汽轮机转子锻件体积和重量超大，国内无法制造，只能依赖进口。受国外供货能力，甚至国际政治因素的影响，而且进口价格昂贵，极易为国外的设备供应商限制。

核电发电机转子性能热处理的特点是立式加热＋立式喷淬，核电转子超重、超大，长度达到 18 米、重量达 300～400 吨，必须进行热处理设备的相应技术开发和技术攻

关，提升超大型热处理淬火加热设备和冷却设备能力。而国外大型热处理设备价格昂贵，涉及到国家经济安全的重大技术装备国外对我国出口限制较严，尤其是制造核电转子的热处理关键重大技术装备国外根本不出口，必须立足国内自主设计制造。

本课题主要对开合式大型热处理设备主架结构进行计算分析与优化，以达到经济、合理、适用。

Large heat treatment equipment structure calculation and optimization

Sub-Project of Major National S&T Program, No. 2009ZX04008-011-004, 2009-2011

Xiaopeng ZHANG

This topic is a national science and technology major special subject. Large heat treatment equipment is mainly aimed at 1000MW nuclear power production design of the rotor. Large nuclear power units of generator rotor, turbine rotor are important components, because generator and steam turbine rotor forgings bulk and weight oversized. That can not be made, in domestic and only rely on imports. Affected by foreign supply capacity, even the international political factors, the price of imports is expensive, for foreign equipment suppliers extremely limited. Nuclear power generator rotor performance heat treatment is characteristic of the vertical heating + vertical quenching injection. Nuclear power rotor, length of overweight and oversized rotor to 18 meters, weight of 300 to 400 tons, must undertake the corresponding heat-treatment equipment technology development and technology research, and promote super-large heat treatment quench heating equipment and cooling equipment ability. But large foreign heat treatment equipment is expensive, related to national economic security, especially the restriction of heat treatment of key manufacturing nuclear power rotor major technical equipment. So it is important to independent design and manufacturing.

This topic is large heat treatment equipment main frame structure analysis and optimization, in order to achieve economic and reasonable and applicable.

30. 分析结构力学与相关问题的研究

国家自然科学基金（重点项目），编号：10632030, 2007-2010

负责人：钟万勰

保守体系可用哈密顿体系描述，其特点是保辛，保辛是保持体系结构最重要的特性。本项目以分析结构力学的研究为主线，建立应用力学多学科、多领域的保辛算法。首先，建立和完善分析结构力学的基本理论，并突破传统时间差分格式的限制，构造出一整套具有更高求解精度和更好数值稳定性的保系统特性的空间—时间有限元序列，并用于线性和非线性保守系统的数值分析。其次，通过对应用力学势能、混合能的保辛摄动性能的研究，建立基于正则变换和矩阵乘法的辛矩阵保辛摄动方法，为短波近似、反问题与参数识别问题等许多不同的研究领域提供更为丰富、性能良好的有效数值分析手段，开展高振荡问题的保结构计算的理论与应用研究。形成某些特殊函数高精度、

高效算法，为非线性系统的积分奠定坚实的基础，同时给出时间滞后最优控制系统的有效分析手段。本项目的研究将传统分析力学进一步发展到分析结构力学阶段，并在哈密顿体系的基础上推广应用力学的辛数学方法。

Analytical Structure Mechanics and Related Problems

Major Program of the National Natural Science Foundation of China, No.10632030, 2007-2010

Wanxie ZHONG

The conservative system can be described by using Hamilton system and its main feature is symplectic preservation, so conserving the symplectic structure of the system is the most important features. Based on the analytical structural mechanics, the project will establish symplectic algorithms for applied mechanics. Firstly, the project will establish and improve the basic theories of analytical structural mechanics, and broken through the traditional constraints of the time difference scheme and construct a set of space-time finite element sequences with higher precision and better stability for numerical analysis of conservative linear and non-linear system. Secondly, through the research of symplectic perturbation for potential energy and mixed-energy, the project will establish symplectic matrix perturbation method based on the canonical transformation and the matrix multiplication which will provide rich and better numerical analysis method with effective performance for the short-wave approximation and parameters identification problem and will begin the preserving structural theories and application research for the high oscillation problem. Finally, the project will establish high-precision and highly efficient algorithms for some special functions which will lay a solid foundation for the numerical integration of nonlinear systems and give effective analysis tools for the optimal control system with time delay. This research of the project will develop the traditional analytical mechanics to the analytical structural mechanics level and promote symplectic mathematical methods of applied mechanics on the basis of Hamiltonian system.

31. “计算力学与工程科学计算”国家自然科学基金委创新研究群体科学基金

国家自然科学基金委创新研究群体科学基金，编号：10721062, 2008-2010

张洪武，钟万勰，程耿东，陈震，杨海天，吴承伟，刘书田，齐朝晖，郭旭等

以先进结构与材料的分析与优化设计理论和方法为主要方向，研究力-热-声-电磁多物理场耦合作用与极端环境下的多尺度计算与宏细观一体化优化设计的基本理论与数值方法，发展和建立系统的创新性理论、模型、算法以及基础软件。主要研究内容是：（1）多物理场耦合作用下结构分析的创新性理论和计算方法；（2）多场耦合条件下结构与材料细观构型的优化与创新设计理论和方法；（3）材料非线性和结构安全性问题的多尺度分析理论和方法；（4）结构与材料的宏细观一体化优化理论和方法；（5）多相多物理场耦合作用下材料力学分析的基本理论；（6）相关的基础性高性能算法和

软件平台。使计算力学与工程问题更有机的结合，进而推动计算力学特别是结构与多学科优化理论和方法的发展。争取为解决先进装备制造、空天飞行器、微电子机械、新材料设计、生物医学工程中的重大工程问题做出贡献。

Computational Mechanics and Engineering Scientific Computations

NSF Project for Innovative Research Team in China, No. 10721062, 2008-2010

Hongwu ZHANG, Wanxie ZHONG, Gengdong CHENG, Zhen CHEN, Haitian YANG, Chengwei WU, Shutian LIU, Zhaohui QI, Xu GUO, et al.

The principle research direction of the project is the computational method and design optimization theory for advanced structures and materials. The aim is to investigate the fundamental theory and numerical methods of multi-scale computations and macro-micro integrated design optimization with multi-physics coupling and extreme environment, and to develop systemic and innovative theories, models, algorithms and software system. The research contents include the advanced computational method and structural optimum design under multi-physics coupling effects, design optimization of material micro-structures, multi-scale nonlinear analysis of materials, macro-micro integrated structure-material concurrent design optimization, multi-medium and multi-physics coupling material computations and multiscale simulation of nano-materials, and basic high-performance computational algorithms and software platform. The project is to promote the combination of computational mechanics with engineering, and the advances of computational mechanics as well as, in particular, the theories and methods of structural and multidisciplinary design optimization. The applications in the fields of advanced manufacture, aerospace vehicles, MEMS/NEMS, new materials, biomedical engineering, and etc. are also fended.

32. 重大工程动力灾变数值模拟平台软件的设计与开发

国家自然科学基金重大研究计划（重点项目），编号：90715037，2008-2011

负责人：张洪武

本项目设计与开发重大工程动力灾变数值模拟平台软件，进行面向大规模计算的工程数据库、开放式结构有限元软件系统框架、可扩展的高性能数值算法库、基于网格的先进计算技术的研究工作。研究工程数据库系统的体系结构、数据存储管理、内存管理、文件管理机制；研究开放式有限元系统设计方案、面向对象有限元系统的类库设计，开放接口及实现技术、有限元分布式计算技术及耦合场问题有限元系统的设计方案；研究高性能数值算法库的设计方案、泛型编程技术、大规模代数方程的算法类设计方案、通用矩阵类库设计方案及分布式计算技术；研究基于网格计算的任务和资源管理机制、数据传输机制、安全机制、优化设计算法及移动代理技术。研究内容构成重大工程动力灾变软件平台的基本要素，是重大工程动力灾变软件模拟系统集成

平台的基础性研究工作，总体目标是为将来重大工程动力灾变数值模拟平台软件与应用软件的集成化开发奠定基础。

An numerical software platform for dynamic harzards analysis of key engineeirng structures

Major Program of the National Natural Science Foundation of China, No. 90715037, 2008-2011

Hongwu ZHANG, Biaosong CHEN, Wanxie ZHONG, Yunpeng LI, Mingchu LI, Sheng ZHANG, et al.

The project is to design and develope an numerical software platform for dynamic harzards analysis of key engineeirng structures. The research consists of four main tasks: a) design of engineering database system for large scale computation, b) developement of open software system for structural finite element analysis, c) construction of extensible high performance numerical algorithm library and d) investigation of grid based advaced computational techniques. In the design of engineering database system, key problems are system architeture design, high performance management of large scale data, computer memory and storage devices. In the development of finite element system, main attentions are paid to system framework design, implementations of software application interfaces, distributed computation and object-oriented design for coupled mulitiphysical problems. In the construction of numerical algorithm library, research work includes object-oriented design, generic programming techniques, numerical objects design of large scale algebraic equations, general purpose matrix class design and distributed computation. The investigations of grid computation techniques include management of tasks and resources, data transport, security strategy and mobile agent technique. The software platform in the project will play a solid foundation for the development of overall integrated computational software system. The overall software system will be employed to integrate the theory and numerical algorithms for dynamic harzards analysis of key engineeirng structures.

33. 强动荷载下土体地基破坏过程分析的多尺度方法

国家自然科学基金重大研究计划（面上项目），编号：90715011，2008-2010

负责人：李锡夔

以超大尺度重大工程结构的土体地基为工程背景，基于平均场理论的均匀化方法，发展在细、宏观尺度上分别采用含液离散颗粒模型（和离散元法）与含液Cosserat连续体模型（和有限元法）的颗粒材料在动载下力学行为数值模拟的多尺度分析模型与相应的高效和精确的计算方法。在细观尺度上发展导致高阶宏观Cosserat连续体的二阶计算均匀化途径。推导高阶均匀化下细、宏尺度运动学与动力学变量之间的关系，及表征元的边界条件。建立颗粒材料细、宏观本构模型及参数之间关系的均匀化过程和公式。研究颗粒集合体的塑性、损伤、破碎及其耦合和动力材料失稳等宏观破坏过

程的细观机理。基于热动力学理论框架和细、宏观材料失稳条件之间的一致性建立基于细观力学过程的宏观破坏本构模型及其参数识别。揭示大尺度土体地基在复杂动力荷载条件下在宏观上以由材料软化、刚度退化等因素引起的应变局部化为特征的动力灾害现象的细观损伤机理和破坏机制。

Multi-scale method for failure analysis of soil foundations subjected to dynamic loading

Project of National Science Foundation of China, No. 90715011, 2008.1-2010.12

Xikui LI

Aiming at the soil foundations of key engineering structures with large scales as engineering background, a multi-scale model and corresponding computational methods with high accuracy and efficiency for numerical simulations of mechanical behaviors in geotechnical structures of granular materials subjected to dynamic loadings are to be developed, in which saturated discrete particle model (with the discrete element method) and saturated Cosserat continuum model (with the finite element method) are respectively adopted. A gradient enhanced computational homogenization procedure in microscopic level leading to high-order macroscopic Cosserat continuum models is intended to develop. The relations between kinematic and kinetic variables in microscopic and macroscopic levels and the RVE boundary conditions for the high order homogenization procedure are derived. The homogenization procedure and corresponding formulations for macro-structural constitutive models including the parameters used in the models are to be established for granular materials on the basis of a micro-mechanical approach. The micro-mechanical mechanisms for macroscopic failure phenomena characterized by coupled plastic, damage and breakage processes and dynamic instabilities of granular assemblages are to be studied. Based on the theoretical framework of thermodynamics and the consistency conditions between micro-structurally and macro-structurally based constitutive responses macroscopic constitutive model for the failure description and the identification of its parameters are delivered from the micro-mechanical process. It is desired to explore the mechanisms of micro-structurally damage and failure, resulting in dynamic disaster phenomena occurring in the soil foundations with large scales subjected to complex dynamic loadings, characterized by the strain localization due to strength softening and stiffness deterioration observed in the macroscopic level.

34. 新型高强、防热、宽频透波多孔氮化硅陶瓷的制备及性能分析

国家自然科学基金重大研究计划（面上项目），编号：90816018，2009.1-2011.12

负责人：王红洁，王博

针对高速近空间飞行器天线罩用多孔透波材料强度与介电性能、使用温度与高温下力/电/热性能稳定性之间的矛盾，提出一种新型高强、防热、宽频透波多孔氮化硅陶

瓷的显微结构设计新思路：即以Si3N4、纳米非晶Si3N4为原料，采用凝胶注模成型，①通过烧结过程中纳米非晶Si3N4的晶化，形成纳米Si3N4相；②控制有机单体的含量，利用凝胶分子造孔，形成均匀弥散的微孔。从而形成一种性能协同的、无晶间玻璃相的纳米Si3N4结合Si3N4多孔透波陶瓷。该材料的性能特点是轻质、高强、防热/隔热、低介电常数、高透波率，显微组织特点是无晶间玻璃相、气孔率高、气孔尺寸细小、分布弥散、均匀，从而实现材料高强度、高透波率的目的。通过对其力学、热学性能的综合分析，建立表征多孔陶瓷宏观力学、热学性能的数学模型，识别陶瓷微观结构、孔隙率与宏观性能的关系。为高速近空间飞行器天线罩材料的设计、制备提供理论依据和实验数据。

Preparation and performance of new high-strength, heat-resistance and broad band wave-transmitting porous Si3N4 ceramics

Project of National Natural Science Foundation of China, No. 10802018，2009-2011

Hongjie WANG, Jian ZHANG, **Bo WANG**

According to the contradiction between strength and dielectric properties, application temperature and its heat stability, a new idea of micro-structural design and preparation method of high-strength, heat-resistance and broad band wave-transmitting porous Si3N4 ceramics was proposed, which was used in antenna redome of near space vehicle(NSV).In this work, the Si3N4 and non-crystal nano-Si3N4 powder was used as raw material, and the gel-casting method was applied. First, the nano-Si3N4 phase was prepared in Si3N4 ceramics through the crystalline process of non-crystal Si3N4, then, through controlling the monomer content, the micropores was homogeneously dispersed in the ceramic body. This new material has the merit of lightweight, high strength, excellent heat-resistance, low dielectric coefficient and high wave transmissivity. At the mean time, there is not glassy phase in the grain boundary, so it has excellent thermal properties, which satifies the properties of antenna redome of NSV. Through analyzing the mechanical and thermal properties, for the porous ceramic, some mathematics models on characterizing the related performance are to be developed and effect of micro-structure, morphology and relative density on the macro-performance is to be identified.

35. 面向近空间飞行器多功能超轻质结构设计优化理论

国家自然科学基金重大研究计划（重点项目），编号：90816025，2009.1-2012.12

负责人：程耿东

本项目以近空间飞行器轻量化设计为目标，采取结构/材料一体化设计和多功能协同设计的途径，研究实现这一目标和途径的结构优化理论和方法。探讨不同尺度参数并存的分析模型和优化模型的建模、敏度分析和优化求解，建立材料性能预测、结构分析、敏度计算和优化问题求解等多尺度算法，开拓和发展多尺度设计优化。研究超轻质多功能材料的性能表征方法，探讨轻质材料的制造工艺与试验技术。

DESIGN OPTIMIZATION THEORY OF ULTRA-LIGHT MULTIFUNCTIONAL STRUCTURES ORIENTED TO NEAR SPACE VEHICLE

Major Program of National Natural Science Foundation of China, No.90816025，2009.1-2012.12

Gengdong CHENG

Theory of The present project aims at light weight design of near space vehicle by the approaches of integrated and/or multifunctional structure/material design and develops structural optimization theory and method to realize the goal and the approaches. Multi-scale design optimization theory will be developed. Performance characterization, manufacturing and experimental techniques of a number of ultra light multifunctional material will be also touched.

36. 超高层建筑的动力失效模式及抗灾-分灾优化设计研究

国家自然科学基金重大研究计划（重点项目），编号：90816023，2009.1-2012.12

负责人：李刚

随着我国经济的飞速发展和城市化水平的不断提高，越来越多具有超高、柔性、体型复杂、平面不规则等超高层建筑出现；超高层建筑在地震和风载等动力荷载作用下，灾变行为十分复杂，具有动力、非线性、不确定性等特点，引起结构安全性、设备适用性与人员舒适性等问题。因此，在对超高层建筑动力失效模式充分认识的基础上，不断寻求创新的设计思想、理念，设计并优化超高层建筑的传力路径与失效模式，以提高其整体防灾能力，具有很大的挑战性，同时具有重要的理论与工程意义。本项目针对指南“重大工程结构失效模式与整体抗灾能力优化”，开展超高层建筑的动力失效模式及抗灾−分灾优化设计研究，包括：超高层建筑的动力失效模式与整体防灾能力表征、超高层建筑的动力抗灾优化设计、超高层建筑的动力分灾优化设计、动力荷载下超高层建筑整体防灾能力的可靠性与鲁棒性分析。为提高超高层建筑等重大工程结构的整体抗灾能力提供相关的理论与方法基础。

Research on dynamic failure modes and hazard-resistant / hazard-transferred optimum design for tall buildings

Major Program of the National Natural Science Foundation of China, No.90816023, 2009.1-2012.12

Gang LI

With the rapid development of ecomonomy in China, there are more and mor flexible, complex-shaped and irregular super high buildings, whose hazard evolution under the earthquake and wind loads is dynamic, nonlinear and uncertain in nature. These hazard behaviours may cause the problems of structural safety, equipment servicibility and human comfort. Thus, it is an challenging task with both theoretical and practical significance to improve the global hazard-resistant capacity of tall buildings.by seeking the innovative

design concept, designing and optimizing the load path and failur modes of tall buildings, based on the comprehensive understanding of the dynamic failur modes of tall buildings. This project will perform the research on dynamic failure modes and hazard-resistant / hazard-transferred optimum design for tall buildings, according to the guideline of NSFC, optimization of structural failure modes and the global hazard-resistant capacity of major civil infrastructures. The contents of this project include: 1) description of the dynamic failure modes and the global hazard-resistant capacity of tall buildings; 2) hazard-resistant optimum design for tall buildings; 3) hazard-transferred optimum design for tall buildings; 4) reliability and robustness of the global hazard-resistant capacity of tall buildings under dynamic loads. The results of the project will provide the relevant foundation of theory and methoology to improve the global hazard-resistant capacity of tall building as well as other major civil infrastructures.

37. 高强度钢板热成形关键力学问题研究

国家自然科学基金重点项目，编号：10932003，2010.1-2013.12

负责人：胡平

高强度钢板的热成形技术，是当今制造更节能、更安全轿车车身的最佳途径。本项目将针对轿车车身关键结构零部件轻量化设计制造所亟待解决的关键力学问题，诸如：涉及热－力－相变耦合多物理场和本构方程的建立，具有尺度效应的微观与宏观材料与力学参数的实验测定，相变膨胀、应变率和热边界摩擦相关的多物理场弹塑性大变形有限元方法，以及轻量化车身典型结构件的碰撞安全性力学分析与性能优化等，开展多学科的联合研究。

Research on key mechanical problems of hot forming for high strength steel

Major Program of the National Natural Science Foundation of China, No.10932003, 2010.1-2013.12

Ping HU

At present, Hot forming of high stregth steel is thought to be the best way to improve safety of car and manufacture lightweight loadbearing parts in auto body. The present preject is focus on multi-disciplinary research, including establishment of constitutive equation involving with Multi mechanical field coupling (thermo, force, phase transformation) and multi-scale coupling, experimental measure of macro-micro material and mechanical parameters related to scale effect, FEA formulation of elastic and plastic large deformation depending on phase volume expansion, strain rate, hot friction on boundary, and so on. Mechanical analysis and performance optimization on crash safety are also studied for some typical auto body load-bearing parts used the hot forming technique.

38. 结构优化

国家杰出青年科学基金，编号：10925209，2010.1-2013.12

负责人：郭旭

39. 多体系统中铰约束反力生成机理研究

国家自然科学基金，编号：10972044，2010.1-2012.12

负责人：齐朝晖

作为一种连接机构，铰的失效往往意味着整个机械系统功能的丧失，甚至会导致灾难性的后果。同时，高频的交变应力和几乎不可避免的磨损，使铰成为最容易破坏的部件之一。了解铰在工作状态时其内部复杂的接触形式和接触力大小是工程实际的迫切需求。传统理论将铰的运动学约束解除，通过系统中物体的运动分析铰内物体的接触模式，进而确定铰内物体的接触力。然而，由于铰内物体在间隙内的相对运动幅度与物体整体运动幅度相差好几个数量级，计算误差的干扰有时会对分析结果产生明显的影响。铰是维持物体运动学约束的机制，同时也是约束反力的生成机制。本项目拟通过对铰约束反力的生成机理的深入研究，提出一种由铰约束反力确定铰内物体接触位置和接触力大小的理论及其方法，从而能够在保持铰的运动学约束的前提下分析多体系统中铰内复杂力学行为，有效地提高分析结果的可靠性，为复杂机械系统的设计提供技术储备。

Mechanism for Reaction Forces of Joints in Multibody Systems

Project of National Natural Science Foundation of China, No.10972044

Qi Zhaohui

Joints link bodies in multibody systems, and their malfunction can result in the failure of whole system, or disasters in some cases. Meanwhile, stresses in them usually vary in high frequency, making them become easy to damage. Therefore, the understanding of contact situation and contact forces in joints is urgently needed in engineering. According to traditional theories, the constraint of a joint has to be released in order to detect the contact situation and to calculate the contact forces with the relative motions between bodies. However, it often results in tremendous difficulties in ruling out the computational errors because of great difference in the order of magnitude between tiny relative movements of bodies in the clearances and the movements of bodies themself. Joints not only maintain their kinematic constraints, but also generate reaction forces. Through the investigation of the deep insight about how the reaction forces are generated, this project will present a method to determine the contact locations and contact forces in joints without the necessity to release the joint constraints, which can improve the reliability and efficiency of the contact analysis.

40. 日地系统平动点附近混合编队飞行动力学与控制

国家自然科学基金，编号：10972045，2010.1-2012.12

负责人：蔡志勤

平动点附近轨道卫星系统在深空探测中有巨大的应用前景，研究多个航天器在平动点附近轨道上的自由编队以及绳系卫星编队的动力学与控制，在国内外都是新课题。本项目拟对基于平动点附近轨道上的自由卫星与绳系卫星的混合编队系统动力学与控制进行研究，基于 Hill 限制性三体问题，采用柔性系绳模型，建立描述母卫星轨道运动，子卫星相对母卫星的姿态运动以及系绳振动的耦合动力学模型；通过无控制力作用下系统动力学的数值仿真，研究影响系统稳定性的各种关键因素，深入了解平动点附近混合编队系统运动的特点；结合自由编队的轨道控制以及绳系卫星的姿态与系绳振动的控制方法，探索高效、精密、实时、易行的非线性系统控制方法，实现对轨道运动，构型保持以及系绳振动的混合控制，进一步还可考虑编队重构阶段的动力学与控制。为我国未来的深空探测、空天安全提供理论与技术储备，促进动力学与控制的基础理论与应用研究。

Dynamics and control of hybrid tethered and free-flying formations near libration points of the Sun-Earth system

Project of National Natural Science Foundation of China, No.10972045，2010.1-2012.12

Zhiqin CAI

The satellite system near the libration point orbits has the fabulous potentiality for the future deep space exploration. The dynamics and control of either free-flying formations or multi-tethered formations on libration point orbits are the new scientific research at home and abroad. In this project , the dynamics and control of Hybrid tethered and free-flying systems on libration point orbits will be investigated. Firstly, Based on the Hill’s restricted three-body problem and flexible tether model, a new dynamical formulation of the hybrid formation systems will be developed, which can be utilized to describe the coupling dynamics of the orbital motion of the parent satellite, the attitude motion of the subsatellites and the vibration of the tethers. Secondly, in order to deeply investigate the characteristics of the Hybrid formation systems near libration points, the key facts relevant to the system stability will be studied by numerical simulations of the uncontrolled dynamics. Finally, in order to carry out the hybrid control on the orbital motion, configuration-keeping, and the vibration of tethers simultaneously, a fast, precise, real-time and easy-operation nonlinear system controller will be developed by combining the independent control methods on the relative position control of free-flying formation and attitude control of tethered subsatellites and vibration control of tethers. Furthermore, the dynamics and control for reconfiguration stage can be considered. The above work will not only provide the reliably theoretic and practical foundation for our nation’s deep space exploration and safety, but also facilitate the fundamental theories and applications of dynamics and control.

41. 基于时间反转方法进行噪声源定位和声场重构及控制的理论和实验研究

国家自然科学基金，编号：10972046，2010.1-2012.12

负责人：黎胜

噪声源定位和声场重构是噪声控制的关键问题。本项目拟采用时间反转（相位共轭）方法来进行噪声源定位和声场重构及控制研究，发挥时间反转方法可实现声波的反向传播和自适应聚焦特点，建立一种新的将实验和计算相结合的声场分析技术。

Location of noise source and reconstruction of acoustic field based on time reversal

Project of National Natural Science Foundation of China, No.10972046, 2010.1-2012.12

Sheng LI

Location of noise source and reconstruction of acoustic field is the key to noise control. This project concerns the location of noise source and reconstruction of acoustic field based on time reversal (phase conjugation) and tries to develop a new technique by making use of the focusing property and the two-way travel capacity of the acoutic time reversal and by combining the acoustic field measurement and computation techniques.

42. 聚合物基纤维复合材料界面应力传递及脱粘失效行为的微尺度实验力学研究

国家自然科学基金，编号：10972047，2010.1-2012.12

负责人：雷振坤

本项目对聚合物基纤维复合材料界面应力传递及失效行为进行微尺度实验力学研究和探索。发展微拉曼光谱微尺度精细测试和全场光力学分析手段，从纤维和基体两个层面来提供典型界面微力学测试过程中纤维/基体界面上的应力/应变分布，研究试样几何构形参数以及界面化学粘结性对界面应力分布、应力集中和热残余应力等界面微力学特性的影响，探讨纤维/基体界面脱粘的物化及力学机制，为建立微尺度界面剪应力与宏观界面拉拔力的跨尺度关联提供实验依据，从微尺度实验力学角度发展纤维复合材料界面应力传递及失效模型。本项目是在探索微尺度测试方法在各学科交叉领域的应用空间，也是为复合材料界面力学问题研究提供必要的微尺度力学实验测试和全场观测工具，对实验力学学科的发展以及与相关学科的交叉融合具有积极意义。

Microscale Experimental Mechanics Study on Interfacial Stress Transfer and Debonding in Polymer-matrix Fibrous Composite

Project of National Natural Science Foundation of China, No.10972047, 2010.1-2012.12

Zhenkun LEI

The objective of this project is to investigate and explore interfacial stress transfer and failure behavoir of polymer-matrix fibrous composite in microscale expeimental mechanics. Some key problems studied by means of micro-Raman spectroscopy and full-field

photomechanics method, such as stress distribution on interface between fiber and polymer provided from matrix and fiber levels in typical microscopic mechnical tests, the influence of specimen geometry and interfacial chemical bonding on interfacial micromechanical characters (interfacal stress distribution, stress concentration and thermal residual stress), discussion of physic-chemical and mechanical mechanism on interface debonding, providing expeimental evidence of relationship of interfacial shear stress in microscale and interface pullout force, developing interface stress transfer and failure model of fibrous composite in the view of microscale experimental mechanics. The significance of this project manifests on providing essential microscale experimental mesurement and full-field observation tool for study of interface mechanical problems in composite and other related applications.

43. 多点地震作用下车桥耦合系统随机动力性态研究

国家自然科学基金，编号：10972048，2010.1-2012.12

负责人：张亚辉

随着铁路设计标准的提高，特别是高速铁路的迅猛发展，桥梁在线路中所占的比重越来越大，使得地震发生时列车在桥上的机率大为增加。车桥耦合系统本身是一个具有时变性的动力学系统，系统内部存在时频非平稳和非线性作用关系，而高柔性、低阻尼的动力特性使其对地震作用更为敏感。一方面必须处理地面运动随机场的非均匀性和非平稳性，有时又要考虑梁、柱单元的材料非线性，支座、伸缩缝、挡块等边界及联接单元的非线性以及地基、土壤的非线性等。结构型式的复杂性、材料和联接的复杂性、与非结构系统的耦合性以及荷载的复杂性，这些因素都对车桥耦合系统的抗震分析提出了更高的要求。本项研究将以发展基于混合能与混合变量方法的广义模态综合法为突破口，发展多点地震作用下车桥系统耦合随机动力学行为分析方法，研究车辆与桥梁之间力的传递方式，探索多点地震作用下车桥系统损伤机理和破坏机制，开发多点地震作用下车桥系统耦合随机动力学分析软件系统。

Stochastic dynamic behavior of vehicle-bridge coupled systems under multi-support seismic excitations

Project of National Natural Science Foundation of China, No.10972048, 2010.1-2012.12

PI: Yahui ZHANG

The proportion of bridges in the whole railway is growing with the improvement of the design standards, in particular the rapid development of high-speed railways. Therefore, the chances of the train on the bridge have increased considerably during an earthquake. The vehicle-bridge coupling system is a time-varying dynamic system, with non-stationary and non-linear properties. Moreover, the high flexibility and low damping of the dynamic properties make them more sensitive to seismic actions. The non-uniformity and nonstationary nature of the ground motions should be considered in the design. On the other

hand, the material non-linearity of the beam and column elements, expansion joints, block boundaries and connections as well as the foundation also plays an important role. Due to the complexity of the structural type, materials, connection with non-structural systems, as well as the complexity of load, the seismic analysis of the vehicle-bridge coupling system has been paid considerable attention. In this study, a new algorithm for the seismic analysis of the vehicle-bridge coupling system subjected to multi-input seismic actions will be developed based on a hybrid method of generalized modal synthesis method. The force transfer mode of the vehicle-bridge coupling system will be investigated. The mechanism damage and failure of the coupling system will also be explored. Furthermore, a software system of the stochastic dynamic analysis of the vehicle-bridge system under multi-input earthquake actions will be developed.

44. 生物微纳米锯齿针的超级刺切机理研究

国家自然科学基金，编号：10972050，2010.1-2012.12

负责人：吴承伟

The superpiercing and cutting mechanism of biomicronanotoothed needles

Project of National Natural Science Foundation of China, No.10972050, 2010-2012

Chengwei WU

45. 炸药爆轰合成碳包覆纳米金属粒子与其机理研究

国家自然科学基金，编号：10972051，2010.1-2012.12

负责人：李晓杰

由于炸药爆轰能产生数千度高温与数万大气压的高压，在爆轰波反应区内可以合成出包覆紧密的碳包覆纳米金属粒子。据此，本项目提出了采用炸药爆轰法合成碳包覆金属纳米颗粒这一类新材料的思路，研究还针对爆轰合成CEMNPs的特点，提出了对其平衡态宏观机理和纳米粒子聚合的细微观机制的研究方法，以最终实现主动控制CEMNPs的目的。在项目研究中，首先参考其他CEMNPs合成方法已取得的研究成果，选用代表性铁族元素进行爆轰包覆研究，同时探讨其他元素的掺杂合金化对碳包覆作用的影响，以先进的材料学研究手段表征产物；在此基础上，研究爆轰反应区中的状态参数分布，以化学平衡态理论建立爆轰反应区的相图模型，确定爆轰反应的各相分布，从而构成爆轰合成CEMNPs的宏观平衡态机理；然后，建立纳米晶粒在爆轰反应区的成核生长动力学模型，结合对爆轰产物膨胀区的粒子演变历程研究，最终构成爆轰合成CEMNPs微细观机制。

The Synthesis of Carbon-encapsulated Metal Nanoparticles by Detonation and the Corresponding Research on Mechanism

Project of National Natural Science Foundation of China, No.10972051, 2010.1-2012.12

Xiaojie LI

As the detonation of explosives can synchronously produce 1000~4000K high temperature and 1~30GPa high pressure, Carbon encapsulated metal nano-particles (CEMNPs) can be synthesized in the detonation wave reaction zone，this new idea of CENMPs' synthesis was proposed in this project.According to the characteristics of detonation synthesis CEMNPs, a macro-mechanism of equilibrium state and a micro-mechanism based on the impacting aggregation of nano-particles will be built up for the ultimate purposes artificially controlling CEMNPs.

Firstly, investigate other synthesis methods of CEMNPs, choose representational iron group elements to synthesize CEMNPs by detonation and also explore other elements doping and alloying effects on carbon-coated particles. Then, based on the results, build up a phase diagram model of detonation wave reaction zone with equilibrium state theory,make confirm the distribution of various phases in detonation wave reaction zone, use above researches to constitute the macro equilibrium state mechanism of detonation synthesis. Establishing the nucleation and growth kinetics model of nano-particles in the detonation reaction zone , combined with the evolution of the particles in the expansion zone of detonation products, eventually constitute the micro-mechanism of detonation synthesis CEMNPs.

46. 近断层地震动的持时效应和强度参数研究

国家自然科学基金，编号：50978047，2010.1-2012.12

负责人：杨迪雄

近断层地震动的强烈破坏作用引发了地震工程学界的密切关注。考虑地震事件的不同震源机制，并针对近断层脉冲型地震动的持时作用和强破坏性特点，深入研究其影响高层建筑结构损伤破坏的持时效应和强度参数。分别从一般的层次和具体的层次，研究近断层地震动持时对不同周期的建筑结构损伤破坏的影响，考察结构滞回耗能和低周疲劳累积损伤的持时效应，并建立相应的非弹性设计谱；针对脉冲型近断层地震动和长周期高层建筑结构(含基础隔震和被动消能结构)，提出与结构动力特性有关的基于非弹性反应谱的地震动强度参数，分析确定最佳的强度参数；高效地实现高层建筑结构的概率抗震需求分析和地震易损性分析，获得结构对于各种破坏状态的条件概率及倒塌概率。

Duration effects and intensity measure parameters of near-fault ground motions

Project of National Natural Science Foundation of China, No.50978047, 2010.1-2012.12

Dixiong YANG

The severe damage action of near-fault ground motions attracts the close attention of researchers in earthquake engineering. Considering the different source mechanism of

earthquake events and duration action and intensive damage property of near-fault impulsive ground motions, this project deeply investigates their duration effects and intensity parameters affecting the seismic damage of high-rise building structures. From the general and specific perspective, this project respectively explores the duration effects of near-fault motions on the dynamic damage of building structure with different periods, and structural hysteretic energy and low-cycle fatigue cumulative damage. Furthermore, the corresponding inelastic design spectra are established. For the impulsive near-fault motions and long-period high-rise buildings (including the base isolated building and passive energy dissipation structure), the intensity parameters of ground motions related to the structural dynamic performance based on the inelastic response spectrum are proposed, and the optimal intensity indices are determined. Moreover, probabilistic seismic demand analysis and seismic fragility analysis of high buildings are conducted efficiently, and the structural condition probability and collapse probability to the various damage states are obtained.

47. 分层各向异性晶体中波传播的辛分析理论与数值方法研究

国家自然科学基金，编号：10902020，2010.1-2012.12

负责人：高强

高效高精度和具有良好性态的数值分析方法是分层各向异性晶体波传播问题中的关键问题。本项研究在吸取国际先进理论方法的基础上，特别注意立足于我们自己创立的独具特色的优秀研究成果，如哈密顿系统的辛几何理论、精细积分法、扩展W-W算法和保辛算法，以期在这一重要领域建立自己的理论方法和技术优势。其最有特色之处是综合运用和发展近年来由申请人及其所属研究团队所发展的辛几何理论和一系列计算力学研究成果，从而实现：(1) 在哈密顿体系下建立起分层各向异性晶体中波传播问题的辛几何理论；(2) 基于混合变量和两端边值精细积分法，建立稳定性好、精度高的传递矩阵计算方法，并在此基础上联合应用精细积分法和扩展Wittric-Williams算法，建立起求解分层各向异性晶体中表面波的精确高效算法；(3) 在上述辛几何理论和数值方法的基础上，进一步建立周期分层各向异性晶体能带分析的高精度保辛算法。

Symplectic theories and numerical methods for the wave in the anisotropic layered materials

Project of National Natural Science Foundation of China, No.10902020, 2010.1-2012.12

Qiang GAO

Efficient and accurate numerical methods are the key issues for wave propagation in layered anisotropic crystal. Based on the advanced theoretical methods, this project uses own outstanding research results, such as symplectic theories, precise integration method, extended W-W method and symplectic-preserving methods, to establish advanced

theoretical and numerical methods in this area. The most important feature of this project is integrate a series of symplectic theories and numerical methods developed by our research team to achieve the following: (1) establish the symplectic theories for the wave propagation in the anisotropic crystal based on Hamiltonian system; (2) base on the mixed variables and precise integration method for two points boundary value problem, develop the transfer matrix method with high stability and precision, and on this basis, by combining precise integration method and extended Wittric-Williams algorithm, develop efficient methods for the surface waves in layered anisotropic crystals.; (3) based on the above symplectic theories and numerical methods, establish the symplectic-preserving methods for periodic layered anisotropic crystals.

48. 乳化炸药爆轰合成纳米氧化物的研究

国家自然科学基金，编号：10902023，2010.1-2012.12

负责人：王小红

本课题属于国家青年科学基金项目的应用基础研究。本项目提出了采用乳化炸药爆轰合成纳米氧化物粉体的方法，其基本思路是将硝酸盐作为前驱体盐溶入液相中代替传统炸药中的硝酸铵作为主氧化剂制备乳化炸药，使目标产物的前驱体盐在炸药爆轰过程中发生分解化合反应而生成纳米粉体。该方法是乳化炸药的一个全新的应用尝试，它作为一种廉价低耗的方法，适用于多种复式氧化物的合成，在某些方面具有替代其它合成方法的潜能。本项目主要开展以下研究：（1）添加元素在纳米晶胞中的掺杂特性及材料物化性能；(2) 研究特种炸药的制备工艺，热稳定性以及爆轰特性；(3) 研究爆轰产物的材料性能与爆轰参数之间的对应关系。(4) 研究特种炸药的爆轰反应结构，判断爆轰反应区（或高温高压状态下）纳米晶粒的存在状态以及纳米晶粒在爆轰反应区的成核生长机制及在爆轰产物膨胀区的形成演变历程。

Research of nano-oxides synthesis by detonation of emulsion explosives

Project of National Natural Science Foundation of China, No.10902023, 2010.1-2012.12

Xiaohong WANG

The project is the applied basic research of National Youth Science Foundation in which the method of nano-oxide powders synthesis by detonation of emulsion explosives is developed. Its basic idea is that ammonium nitrates are substituted by metal nitrates as oxidants in emulsion explosives which are decomposed, recombined and then gennerated into nano-powders in detonation reaction. It is a brandly new application for emulsion explosives and is applicable for synthesis of many complex oxides. As a low-cost and low-consumption method, it has the possibility and superiority of replacing some of other synthesis methods. Following researches in the present project are

carried out: (1) The characteristic of the nano-crystals with the dopping elements, (2) The preparing process, thermal stability, detonation characteristic of these special explosives. (3) The relationship between materials' properties and detonation parameters; (4) The detonation structure of the explosives, the state and nucleation mechanism of nano-crystals in detonation reaction zone, and their developing track during the course of expansion of detonation products.

49. 多功能结构布局与构件拓扑协同优化设计

国家自然科学基金，编号：10902019，2010.1-2012.12

负责人：张永存

结构拓扑优化已经成为创新设计的重要工具，在先进工业装备结构的轻量化和多功能设计中具有重要的应用前景。目前结构拓扑优化主要针对单一构件，而实际工程结构中往往是由梁、板、壳等构件组成的复杂多构件结构，各构件的最优拓扑与构件布局（构件的布置和相互连接关系）有关，同时构件的拓扑形式又影响构件布局。因此，多构件结构布局与构件拓扑应同时考虑。本项目主要针对多构件结构，研究建立构件最优布局设计与最优拓扑设计协同的设计理论和方法。研究能够清楚表征构件几何构型和连接关系的布局描述方式，以使在优化过程中能够准确描述应力、局部稳定性等局部状态量以及全局状态量（如位移、频率等），其优化设计结果能够直接应用于工程；研究考虑以结构重量、刚度、强度、稳定性等性能为约束条件或目标的构件布局优化问题的数学提法和求解方法；研究结构拓扑与布局耦合的设计策略，建立构件布局与拓扑协同优化设计的理论和方法。

Concurrent optimum design for the layout of multi-component structure and topology of components

Project of National Natural Science Foundation of China, No.10902019, 2010.1-2012.12

Yongcun ZHANG

Structural topology optimization has already been a significant way for innovative design, and is widely used in the design of lightweight and multifunctional advanced industry equipment structures. However, topology optimization is mainly used to design a single component currently. The practical engineering structures are usually complex structure which is assembled with beams, plate, shells and others. Every optimal design of components is determined by the layout of multiple components(the collocation and the connection of each components), and the different topology also affect the optimal layout of structure. So, we should consider the concurrent optimum design for the layout of multi-component structure and topology of components. In this project, a theory will be presented for designing the optimal layout of multi-component structure and the topology of components collaboratively. The geometry of components and the connective relationship

with others must be clearly described, in order that the local parameters (stress, local stability) and the global(displacement, frequency) parameters can be exactly described in the process of optimization. By this way, the results of optimization can be used in practice directly. The mathematic models of optimization and the corresponding solving methods will be built considering the multiple constraints(for example: weight, stiffness, strength, stability, etc).The strategy for the concurrent optimum design of the layout of multi-component structure and the topology of components will be researched, and the corresponding theories or methods will be presented.

50. 层级杆系结构的优化设计

国家自然科学基金，编号：50878038，2009-2011

负责人：程耿东

工程中著名的埃弗尔铁塔、金门大桥等巨型结构，都是具有丰富层次、表观密度相当低的层级结构，历史证明了它们具有优异的力学性能。受到这些优异的层级结构启发，本申请旨在深研究将结构拓扑优化、形状优化和尺寸优化混合起来的层级杆系工程结构的优化设计方法，在给定结构重量的条件下，考虑结构的刚度强度和破坏等力学条件的约束，实现工程层级结构的优化设计，并用实验验证若干优化设计。

OPTIMUM DESIGN OF HIERARCHICAL SKELETAL STRUCTURES

Project of National Natural Science Foundation of China, No. 50878038, 2009-2011

Gengdong CHENG

The well known Eiffel tower, Golden Gate bridge are examples of giant hierarchical macro structures and have very low relative density. Their superior mechanical properties have been verified during their long historical service. Inspired by these superior hierarchical structures, the present project aims at developing optimization method for hierarchical skeletal structure by integrating structural topology, shape and size optimization approaches. Optimum design of one or two engineering hierarchical structures will be studied and verified by laboratory experiment.

51. 考虑界面破坏的压电智能复合材料结构的失效机理

国家自然科学基金，编号：10878038，2009-2011

负责人：白瑞祥

本课题属于国家自然科学基金面上项目。基于静/动态实验、高速图像处理和电镜技术等宏、细观观测手段，观察压电元件与被控结构间的界面裂纹起裂和扩展特征，提出反映裂纹前缘细管损伤特征的跨尺度损伤模型，并建立相应的起裂和扩展准则；发展研究复合材料智能结构的界面损伤起裂、扩展和失效分析的多场耦合有限元方法，通过典型复合材料智能结构分析，讨论压电智能复合材料相物理与几何、粘弹性界面

层强度对界面裂纹起裂、扩展特征和控制行为劣化的影响。在此基础上，通过数值仿真分析和小型压电智能复合材料结构的实验研究相结合的方法，为大型复杂压电智能复合材料工程结构的虚拟设计和实验系统提供依据，并对该类结构的失效防范提出意见。

Failure mechanism of piezoelectric smart composite structure considering interfacial fracture

Project of National Natural Science Foundation of China, No. 10872038, 2009-2011

Ruixiang BAI

This project is the national natural science foundation of China. Based on experiment observation and numerical simulations, the interfacial failure behavior of piezoelectric smart composite structure will be observed and the corresponding analysis model and method will be developed. The effect of physical and geometric parameters, interfacial strength on the crack initiation, growth and degradation of control ability of piezoelectric smart composite structure will be investigated systematically.

52. 三维动态混合网格自适应移动与重剖分方法研究

国家自然科学基金，编号：10872040，2009-2011

负责人：关振群

面向流固耦合过程数值模拟，研究三维动态混合网格自适应移动与重剖分方法，提出高性能算法，建立三维动态混合网格自适应生成通用平台，解决流固耦合数值模拟中动态网格更新的难点问题。研究三维混合网格移动方法，提出基于点-面模型的拉普拉斯自适应移动算法，解决经典网格移动方法在边界大位移与变形时的网格畸变问题和计算效率问题；研究混合网格重剖分方法，提出基于优化的三维混合网格局部与全局精化算法，解决经典网格重剖分方法的适应性问题；研究建立基于黎曼度量张量与平衡叉树的动态自适应网格尺寸控制的基本框架，将各向同性/各项异性、先验/后验网格尺寸控制纳入统一架构；提出基于拓扑连接的动态网格数据结构，配合平衡叉树，提高底层数据操作效率。将上述研究应用于一类流固耦合数值模拟中以验证算法。建立面向对象的网格生成通用平台，为CAE自主知识创新体系提供支撑技术。

Adaptive motion and refinement method for 3D dynamic hybrid mesh

Project of National Natural Science Foundation of China, No. 10872040, 2009-2011

Zhenqun GUAN

In this research project, adaptive moving and remeshing approach of three-dimensional dynamic hybrid-mesh is studied for the numerical simulation of fluid-solid interaction problem. We will propose some high-performance algorithms, and establish a common platform of three-dimensional dynamic hybrid-mesh adaptation to address the meshing difficulty in the numerical simulation of fluid-solid interaction process. At study of

three-dimensional dynamic hybrid mesh moving approach, a new vertex-ball topology model and a Laplacian-like adaptive algorithm will be presented to overcome the mesh distortion and low efficiency problems of the classical mesh moving method in the cases of large boundary displacement and large deformation. At study of three-dimensional dynamic remeshing approach, local/global mesh refinement algorithms based on the optimization approach will be presented to solve the adaptability of classical remeshing methods. Based on Riemann metric tensor and balance-tree, the basic framework of the mesh size control in dynamic mesh adaptation process will be built, in this way, isotropic/anisotropic, priori/posterior mesh size control will be brought into unified framework. With balance-tree, the dynamic mesh data structure based on the topological connection is designed to improve the bottom data operation efficiency. This research works will be applied to the numerical simulation a class of fluid-solid interaction problem to verify algorithm. The establishment of the object-oriented universal platform of mesh generation will provide important support technique for independent knowledge innovation CAE system.

53. 开放式面向对象结构有限元分析软件的设计与开发

国家自然科学基金，编号：10872042，2009-2011

负责人：陈飙松

研究和设计面向对象结构有限元分析软件。使用C++程序设计语言，综合利用面向对象方法和UML等技术，设计适于有限元数值模拟研究的开放式软件体系，解决有限元软件的可维护性和可扩展性问题。设计完备的有限元分析类库，探索相关的设计模式；研究非线性有限元的面向对象设计方案；研究非线性数值模型与数值算法库的设计，实现算法库的独立性。建立有限元数据库，实现大规模计算中海量数据的有效管理，研制专用数据管理工具，提高数据管理的效率。提出有限元软件的XML数据标准，实现有限元计算数据共享。提出有限元分析软件各功能模块的接口设计方案和标准，研究软件动态功能扩展的实现机制，建立插件式开放接口，逐级拓展新功能。研究结构有限元分析软件的多核及局域网分布式计算的任务和资源管理算法。研究分布式有限元计算的软件实现技术。

Design and Development of Open Object Oriented Software System for Structural Finite Element Analysis

Project of National Natural Science Foundation of China, No.10872042, 2009-2011

Biaosong CHEN

The project is to develope an object oriented software system for structural finite element analysis(FEA). With the employment of C++, Object oriented design methods and UML, it is planned to propose an open software architecture and improve the software maintainability and extensibility. Main tasks include: design of general class library for FEA and investigation of relevant design patterns, software framework design for nonlinear FEA,

construction of data-independent numerical algorithm library. In order to meet the requirements for large scale compuations, a specific database management system with high efficiency for FEA is planned to developed. It is aimed to propose a XML protocol of FEA data description, and its applications will realize data sharing among FEA softwares. One prominent feature of the proposed system is to construct an open architecture based on plugins technology, tasks of which include design of module interface standards, design of plugin interfaces and dynamic management mechanisms. Attentions will be also paid to the investigations of task and resources management algorithms and software technology for FEA distributed computation based on multi-CPU and local network.

54. 人中耳生物力学模型及人工中耳的基础研究

国家自然科学基金，编号：10872043，2009-2011

负责人：刘迎曦

耳聋居人类各种类残疾之首。在我国听力障碍和听力残疾的发病率约为 11.35％和 3.86％，其中传导性听力损失为 14％。由于在活体上很难随时测量耳的传导功能,研究活体中耳传声功能，建立逼真高效的中耳生物力学数值模型，倍受人们关注。有限元方法可以全面模拟中耳复杂几何形态各向异性的生物特性,定量研究任何位置的力学行为,是其它分析方法难以做到的。但模型“内边界”（中耳与内耳结合部位）的设定，即卵圆窗镫骨底板两侧的力学行为描述，分别牵涉到“声固”“液固”等多场耦合，至今未得到满意的解决，成为构造中耳生物力学数值模型无法回避而十分棘手的问题，直接关系到模型的真实性。为此，本项目拟提出“虚拟耳蜗”的方法，将复杂问题简单化，使中耳生物力学数值模型能较精确描述活体中耳的声学功能，为中耳传声疾患机理的研究和临床个性化干预（诊断、医疗方案优化和疗效预测评估）提供依据，也为人工中耳的设计和评估提供高效的数值分析平台

The biomechanical model of human middle ear and the base of middle ear implant

Project of National Natural Science Foundation of China, No.10872043, 2009-2011

Yingxi LIU

Deafness is on the first place of various disabilities. In our country, the incidence rate of hearing disorder is about 11.35% and of the hearing disability is about 3.86％, 14% of these diseases are conductibility problems. Because it is difficult to measure the ear conduction momentarily in vivo, we hope to establish a vivid and high efficient computational biomechanics model for the researching of sound transmission of middle ear. The Finite Element Method can solve the problems which can not be fulfilled by any other analytical method, including totally simulating the complicated geometry forms and anisotropic characteristics of middle ear as well as quantitating the mechanics behaviors of any position. But the setting of the ‘inner boundary’ (the binding site of middle and internal ear), the mechanics behaviors description for the both sides of oval window and base of stapes

including many couplings such as “the acoustic-structure coupling” and “the liquid-solid coupling”,has not been solved satisfactorily and become the key problem to the validity of the model. The “virtual cochlea” simplifying the complicated issue was proposed to make the acoustics function of middle ear in vivo be precisely described so that the pathogenesis and the intervention（including diagnosis, optimization of the treatment and prognosis）will be studied and the efficient numerical analysis platform for the design and evaluation of the artificial middle ear will be provided as well.

55. 不连续平面点阵夹层结构的承载性能与构型优化设计研究

国家自然科学基金，编号：10802016，2009-2011

负责人：王博

不连续平面点阵夹层结构是一种新型的轻质夹层结构，由于它既有可设计的内部流道又有优良的承载性能，有可能应用于高速飞行器热防护系统。本申请采用理论、数值与实验相结合的方法，基于拓扑优化、多目标优化等先进设计方法，通过设计"连接柱"拓扑形状、排布方式与空间位置，优化结构承载性能。主要包括：分析典型"连接柱"形状和排布方式下的结构刚度、破坏强度和热防护性能，识别不同构型参数对不同性能的优化特征；发展针对刚度、隔热性能的"连接柱"构型设计拓扑优化方法；建立分层次优化模型，采用拓扑优化、响应面代理优化技术优化夹层构型，分步实现"局部刚度-隔热"、"主动冷却散热"和"整体抗弯刚度"等性能目标；探讨制备工艺，引入可制造性约束调整优化模型，开展典型结构在典型载荷作用下的承载性能实验研究。国际上对该构型夹层结构的研究尚在起步阶段，本项目的研究成果对促进该结构设计方法的发展以及与工程应用的密切结合具有重要意义。

Research on loading capacity and optimum configuration design of non-continuous 2D lattice sandwich structure

Project of National Natural Science Foundation of China, No. 10802016, 2009-2011

Bo WANG

Non-continuous 2D lattice sandwich structure is a new type ultra-light sandwich structure. Because of its designable inner channel and excellent loading capacity, it is to be used as a Thermal Protection System (TPS) for hi-speed aircraft. Theoretical analysis, numerical simulations and experimentations are studied respectively in this application. Based on the topology optimization and multi-objective optimization technique, the structural loading capacity is optimized through designing the topology, size and layout of the supports. The main works of the application are as follows: aiming at some typical supports, to study the relationship between the supports' geometrical parameters and structural stiffness, strength and thermal performance, and to study the optimum morphological characteristic; to develop topology optimization method for the configuration design of supports aiming at the structural stiffness and heat insulation performance. To build up multi-level optimization

model in order to achieve 'stiff-heat insulation', 'active cooling' and 'maximize bend stiffness' through topology optimization or respond surface methods. Some fabrications are to be studied and classical mechanical experiments are to investigate for loading capacity test. It is still in the initial stage on the international study of this kind of sandwich structure, the project research results to promote the development of methods of structural design and engineering application.

56. 搅拌摩擦焊接的多尺度计算方法研究

国家自然科学基金，编号：10802017，2009-2011

负责人：张昭

本课题是国家自然科学青年科学基金项目。搅拌摩擦焊接是1991年由英国焊接所发明的一种新型固态焊接工艺，具有接头性能好、缺陷少、环保等优点，已经开始广泛应用于航空航天、船舶制造、汽车、列车制造等工业领域。在搅拌摩擦焊接过程中，搅拌头周围的材料在大变形和热的共同作用下，发生一系列微观结构的变化，搅拌摩擦焊接过程中微观结构的演化直接影响搅拌摩擦焊接构件的力学性能，因此，开发基于宏观连续尺度和微观晶体尺度的搅拌摩擦焊接多尺度力学模型对于搅拌摩擦焊接的理论研究是非常必要的。本项目基于晶体塑性理论，建立考虑再结晶和沉淀相演化的搅拌摩擦焊接多尺度计算模型，进而预测焊接构件的力学性能。通过对宏观连续尺度和微观晶体尺度搅拌摩擦焊接的数值模拟，建立和完善考虑再结晶和沉淀相演化的晶体塑性理论，并研究不同尺度搅拌摩擦焊接力学模型之间的内在联系，为搅拌摩擦焊接的研究提供理论支持，并进一步从不同尺度解释焊接缺陷的形成机理。

Research on multiscale computational methods in friction stir welding

Project of National Natural Science Foundation of China, No. 10802017, 2009-2011

Zhao ZHANG

This project comes from the National Natural Science Foundation of China. Friction stir welding (FSW) was invented as a new solid state joining technology by the welding institute in UK in 1991. FSW has many advantages such as high quality weld, low defects, environment friendly, etc. and has been applied to aerospace, ship, automobile, and train industries. In FSW process, microstructures are changed due to the effects of large deformation and heat. The microstructural evolutions in the friction stir welding process can obviously affect the mechanical properties of the friction stir welds. So, it is necessary to develop the numerical models on macro continuum scale and micro crystal scale for the theoretical researches on friction stir welding. The objective of the current work is to establish the multi scale model of friction stir welding with consideration of the recrystallization process and the variations of the precipitations. Based on the established model, the mechanical properties of the friction stir welds can be predicted. By the simulations of the friction stir welding on macro continuum scale and micro crystal scale,

the internal relations between the two models on micro and macro scales can be further studied and then the investigations on the mechanism of friction stir welding can be improved. Based on the numerical models established, the formations of the friction stir welds can be explained based on the developed theory.

57. 电毛细驱动微通道可控流动研究

国家自然科学基金，编号：10802019，2009-2011

负责人：马国军

本课题属国家自然科学基金(青年基金项目)。微流体(微流控)系统因具有微型化、集成化、高效率和低成本等特点，在MEMS、微全分析系统和生物芯片技术领域有着广泛的应用前景，相关微通道内流体的驱动与控制是其关键。Prins等人(Since,2001,291:277-280)展现了电毛细对微通道(微通道阵列)中连续性流体的优异操控功能，有着十分诱人的应用前景，但目前还缺乏该技术的系统研究。本项目拟首先建立电毛细驱动微通道流动的流体力学模型和计算方法，并对模型和方法的准确性与有效性进行必要的实验验证，然后通过详尽的数值分析揭示电毛细与微通道自身各参数强耦合作用下的微通道流动特性与规律，为利用电毛细实现微流体的驱动与控制提供理论依据。

Research on the fluid flow induced by electrocapillary effects

Project of National Natural Science Foundation of China, No. 10802019, 2009-2011

Guojun MA

Microfluidics system, due to its miniaturization, integration, high efficiency and low cost, has many potential applications in MEMS, micro-total analysis system and so on. However, how to drive and control the fluid in microchannel in microfluidics system is still a key problem. In 2001, Prins, et. al., revealed that the fluid in microchannel (arrays of microchannels) can be controlled by electrocapillary effects. These findings show that electrocapillary effects probably can be used in the control of microfluidics. Unfortunately, there are still many problems in this technique. Therefore, in this program, we will firstly establish a fluid mechanics model of the fluid in the microchannel induced by electrocapillary effects, and then give the corresponding numerical algorithm of this problem. At the same time, experiments will be carried on to investigate the accuracy and efficiency of the model and algorithm. Finally, detailed numerical analyses will be carried out to reveal the influences of various parameters on the fluid in the microchannel induced by electrocapillary effects. We hope this work can be useful to improve our knowledge of the behavior of fluid in the microchannel induced by electrocapillary effects.

58. 先进复合材料网格结构共固化工艺与软模成型参数优化分析

国家自然科学基金，编号：10702012，2008-2010

负责人：任明法

参加人：陈浩然，曲牡，许士斌，张志峰，黄其忠，徐浩

采用理论分析、数值模拟和试验验证相结合的方法，研究先进复合材料网格结构在共固化成型工艺过程中的应力场、温度场和固化度场的多场耦合问题,其研究内容包括：

（1）建立具有试验基础的复合材料网格结构成型工艺共固化阶段的多场耦合分析模型；

（2）推导复合材料网格结构成型过程的多场耦合分析的有限元列式；

（3）开发先进复合材料网格结构软模设计和共固化成型过程仿真分析的软件包；

（4）通过对采用几种典型工艺参数的复合材料格栅结构共固化成型工艺过程的多场耦合分析结果的比较与参数讨论，研究芯模网格材料的热物理和力学性质、网格模具的特征尺寸以及纤维缠绕、复合材料固化和复合材料网格结构脱模过程中的工艺参数对复合材料网格结构制品质量（几何和承载能力）的影响。

本项目的研究成果将为先进复合材料网格结构成型过程工艺力学分析和工艺参数优化设计提供理论和方法以及工程软件。

The optimization anasysis for co-curing and soft-mold technics factors of advanced grid-stiffened structure during manufacture process

Project of National Natural Science Foundation of China, No. 10702012，2008-2010

Mingfa REN, Haoran CHEN, Mu QU, Zhifeng ZHANG, Qizhong HUANG, Hao XU

By theoritical analysis and numerical simulation in conjuction with experimental study, a multi-fields coupling analysis problem between stess, temperature and curing extent fields during the co-curing manufacture process for advance composite grid structures (AGS) is investigated in the project, which main contents involve as:

(1) Establish a muti-fields coupling analysis model based on testing observation during the stage of AGS's co-curing manufacture process;

(2) Deduce some Finite Element formulas for analyzing the multi-fields coupling problem of co-curing process;

(3) Develop a software package for designing soft-mould and simulating the co-curing manufacturing process.

(4) Discuss the effects of thermal and mechanical properties for constituets of AGS, mould characteristic dimensions and technics parameters during the fiber winding, curing and demoulding stages upon the qulity of AGS product,such as geometry, loading capacity and etc. form some typical parametric studies.

The theory ,methods and engineering software provided in this projet should be valuable to engineering designers and researchers for studying on mechanism and designning optimum technical parameters of AGS's manufacture process.

59. 高性能碳纳米管/聚合物复合材料纤维的力学行为及增强机理

国家自然科学基金，编号：10702013，2008-2010

负责人：阮诗伦

本项目以碳纳米管增强超高分子量聚乙烯复合材料为研究对象，采用实验与理论相结合的方法，研究本体材料分子高度取向的情况下碳纳米管对复合材料机械性质的影响以及该新型复合材料的增强机理。面用工业应用，以凝胶纺丝法制备纳米复合材料纤维。通过实验找出最佳的工艺条件和纳米管含量，制备出具有优越机械性能的特种纤维。借助现代电子显微镜，观察聚乙烯分子取向不同情况下碳纳米管的形态变化，分析本体材料与纳米管之间的取向联系，理解结构与性能的关系。在此实验基础上，建立合适的分子模型，通过分子动力学的方法，研究聚合物分子取向不同的情况下,界面的形态变化和对应的剪切强度并模拟该结构的复合材料机械性质。与实验数据相比较,真正理解碳纳米管在高性能复合材料纤维中的增强机理，达到控制高性能纤维制备的目的。

Mechanical behavior and reinforcement mechanism of high performance CNT/UHMWPE composite fiber

Project of National Natural Science Foundation of China, No. 10702013, 2008-2010

Shilun RUAN, Chunqiu YANG, et al.

This project will focus on the carbon nanotube reinforced ultra high molecular weight polyethylene composite fiber. Using the traditional process,gel-spinning, this nano composite fiber can be fabricated for the industrial application in the future. By characterizing the mechanical behavior of this composite fiber with the highly oriented polymer chains, the effect of carbon nanotube on the mechanical properties can be investigated to find the best conditions used in the fabrication of fibers. With the help of electron microscopy, the relation between mechanical properties and the structure of the composite fiber can be researched. Based on the experimental results, the molecular model for this composite with the different orientation of polymer chains can be set up and used to investigate the effect of interface on the mechanical properties of composites and understanding the reinforcement mechanism. Once the reinforcement mechanism is known, this technology can be used in the industrial fabrication of high performance fibers.

60. 多宗量分数阶导数反问题的数值求解－粘弹性

国家自然科学基金，编号：10772035，2008-2010

负责人：杨海天

近年来分数阶导数在力学、物理、控制、金融、生物医学等领域得到越来越多的应用。如何确定分数阶导数有关参数，是其应用的前提；另一方面，在分数阶导数相关场问题中，如何确定未知的分数阶导数相关的物性参数、源项、边界条件等，是场问题求解首先需应对的问题。本项目拟从粘弹性问题入手，从分数阶导数相关场多宗

量反问题求解的角度，提供确定这些宗量的数值方法。内容主要包括：1.发展基于积分变换和敏度分析的象空间反问题数值模型及求解方法；2.发展基于时段离散和智能类优化算法的时域反问题数值模型及求解方法；3.计算效率研究;4.多宗量情形下抗不适定性及附加信息影响等研究。本项目研究可为解决分数阶导数粘弹性相关的实际问题、为分数阶导数在粘弹性领域的应用，提供必要的前提条件，为其它领域分数阶导数的反问题研究提供有益的借鉴参考。此外国内外分数阶导数反问题研究的直接报道似很少，为本项目获得创新性的研究成果提供了良好契机。

Numerical modeling of multi-variables inverse problems with fractional derivatives: Viscoelasticity

Project of National Natural Science Foundation of China, No. 10772035，2008-2010

Haitian YANG

The theory of fractional derivatives has received considerable interests in the recent years, and been successfully applied in various areas such as mechanics, physics, system control, finance, and biomedical engineering etc. One of the important aspects of the application of fractional derivatives theory is to determine the relevant parameters in a model or a field formulated by fractional derivatives, such as the unknown constitutive coefficients, and the unknown terms related to source and boundary conditions. Unfortunately it seems pretty less progress directly relevant to this issue has been reported, we therefore propose a proposal to carry out a study providing numerical methods to determine the above items by solving the inverse fractional derivative problems with multi-variables. The major points of the proposal include: 1.Developing a numerical model based on integral transformation and the sensitivity analysis in the Phase-Space. 2. Developing a numerical model in the time domain, which facilitates the application of intelligent optimization methods. 3. Investigating the computing accuracy and efficiency of the proposed numerical models. 4. Investigating the influence of the ill-posed behavior and the additional information on the solutions.

The study will initiate from the inverse viscoelastic problems with fractional derivatives, and hopefully make some fresh contributions.

61. 非概率模型下结构可靠性优化若干问题的研究

国家自然科学基金，编号：10772037，2008-2010

负责人：郭旭

62. 随机激励下结构和声场耦合系统的数值分析和优化设计

国家自然科学基金，编号：10772038，2008-2010

赵国忠，丁彦闯，石磊，王悦东等

本项目寻求通过随机振动声场数值分析和优化设计相结合的研究方法来达到这个

目的。研究随机激励下声结构耦合系统的有限元/边界元分析的高效求解算法，优化设计的数值建模技术和求解方法，基于统计信息的灵敏度分析理论和实用的优化设计方法。建立声固耦合系统的结构和声学一体化的优化模型，提出随机激励下耦合系统非对称矩阵的灵敏度分析新理论，结构振动声辐射系统有限元和边界元相结合的灵敏度分析新算法，给出耦合系统尺寸、形状与拓扑多层次优化方法，解决程序实现的关键技术。对结构声场设计中阻尼材料和吸声材料的优化布置问题，提出有效的设计准则和数学模型，并采用拓扑优化理论和最新的优化算法进行求解。通过典型算例来验证上述理论和方法的正确性，并为该项技术的实际工程应用提供一个软件原型系统。

Numerical analysis and design optimization of structure and sound coupling system under random excitation

Project of National Natural Science Foundation of China, No.10772038, 2008.1-2010.12

Guozhong ZHAO, Yanchuang DING, Lei SHI, Yuedong WANG et al

The numerical analysis and design optimization are used to decrease the structural noise in this project. The project studies high effiency solving algorithms of the finite element/boundary element for acoustic-structural coupling system, numercial modelling and solving techniques of design optimization, the theory of the sensitivity analysis based on the statistical behaviors, and the practical optimization methods.An integrated acoustic-structure design optimization model for coupling system will be bulit. A new sensitivity analysis theory of the non-symmetrical matrix under the random load will be proposed and a new sensitivity analysis algorithm of the strucyural vibration acoustic radiation, based on finite element and boundary element,will be presented. This project also will give a multi-level optimization method including the size, shape and topology designs. Some key program techniques will be discussed .For the optimal locations of the dammping and absorptive materials, the optimization criterions and mathematic model of optimal placement will be proposed. The topological optimization theory and the advanced optimization algorithms will be used to solve it. Some typical examples will be presented to demonstrate the the validity of the methods and theory. A basic software prototype system will be provided for the application of this technique.

63. 基于辛空间的板弯曲解析奇异单元及其应用

国家自然科学基金，编号：10772039，2008-2010

负责人：姚伟岸

带有应力奇性板弯曲问题的分析求解具有重要的工程实用价值。项目研究目标是将辛对偶体系的优秀方法论应用于一整套薄板、中厚板弯曲解析奇异单元的构造，给出带有应力奇性的板弯曲问题的高精度、高效率的数值求解和分析手段，为该领域的研究提供新的求解方法和理论。首先将板弯曲问题导入极坐标辛对偶体系，并在由挠

度、转角以及它们的对偶变量组成的辛空间里，通过分离变量和辛本征展开法给出具有任意顶角和任意侧边边界条件的扇型板弯曲问题的解析解，并以此为基础构造出系列基于辛空间理论的能严格满足域内控制微分方程和边界条件的板弯曲奇异单元，该类解析奇异元能精确描述奇异点附近的应力场和位移场的特性。然后通过变分原理形成奇异单元的单元刚度阵并与常规弯曲板单元相结合，从而可应用于带有应力奇异性的有限尺寸弯曲板问题的数值分析。本项目的研究将辛对偶体系推广到数值应用领域，具有十分重要的理论价值和广阔的应用前景。

Analytic Singular Elements for Plate Bending in Symplectic Space and its Applications

Project of National Natural Science Foundation of China, No. 10772039，2008-2010

Wei-an YAO

Solutions of plate bending with stress singularity have significant engineering practicability. In this project, a set of analytical singular elements for thin plate and middle-thick plate are constructed by applying the excellent methodology -symplectic dual system, so high precision and efficient numerical technique for plate bending with stress singularity can be presented. The project shows a new numerical solution and theory for plate bending problem. Firstly, plates bending problem is introduced into the polar symplectic dual system, so analytical solutions of sector plate bending problem with arbitrary vertex angle and boundary conditions can be give by separation of variables and symplectic eigenfunction expansion in the symplectic space which consist of deflection, rotational angle and their dual variables. On basis of their solutions, a set of singular elements for plate bending problem are formed. The elements can strictly satisfy all differential equations in domain and boundary conditions, and accurately describe the characteristic of stress and displacement fields near singular point. Then stiffness matrixes of singular elements can be obtained and connected with conventional plate bending ones by applying variational principle, thereby they can be applied to numerical solution of plates bending problem with stress singularity. This project extends symplectic dual system into numerical method, which is greatly significant in theory and has wide application foreground.

64. 颗粒介质类固－液相变过程的微观－宏观力学行为研究

国家自然科学基金，编号：10772041，2008-2010

负责人：季顺迎

颗粒介质的类固-液相变过程是其独特的宏观性质之一，并广泛地存在于不同研究领域。颗粒介质的宏观力学行为与其微观尺度下颗粒间的碰撞接触过程是密切相关的。为此，本项目将通过对颗粒体的碰撞、压缩和剪切实验，建立不同形态颗粒体在微观尺度下的非线性粘-弹-塑性碰撞接触模型；在此基础上对不同密集度、剪切速率和约束应力下颗粒介质的宏观流动特性进行离散元模拟和剪切流动实验；通过微观尺度下

颗粒单元之间力链的强度、持续时间和空间方位的统计分析来研究颗粒介质的宏观力学行为，确定其发生类固-液相变的理论判据，建立一个适用于颗粒介质不同流动相态的粘弹塑性本构模型。

Mechanical behaviors of granular materials of quasi-solid-liquid phase transition at Micro-macro scales

Project of National Natural Science Foundation of China, No. 10772041, 2008-2010.

Shunying JI

The quasi-solid-liquid phase transition, which appears in various fields widely, is one unique property of grnaulr materials at macro-scale. The mechanical behaviors of granular materials at macro-scale have a close relationship with their contact processes at micro-scale. Therefore, a non-linear viscous-elastic-plastic contact force model for irregular-shape particles will be established with the aids of collision, contact, compression and shear tests at micro-scale. Based on this contact force model, the rehological properties of granular matter at macro-scale will be modeled with the discrete elememt model (DEM), and also be validated with shear cell tests in physical lab. Through the statistical analysises of strength, duration and orientation of force chains between particles at micro-scale, the macro-mechanical properties of granualr matter will be investigated to determine a theoritical criterion for quasi-solid-liquid phase transition. The main target of this project is to establish a viscoelastic-plastic constitutive law for granular materials under various flow phases.

65. 药物分子优化设计的网格计算方法研究

国家自然科学基金，编号：10772042，2008-2010

负责人：王希诚

研究基于诱导契合理论的药物分子优化设计方法，在深入分析当前各类分子打分体系的基础上，用数学规划的多目标优化理论整合药物分子设计领域基于力场、经验和知识的传统打分模式，建立同时考虑受体和配体柔性的新型分子精细对接优化模型。将演化类算法、聚类分析方法和代理模型基优化算法相结合，发展求解多场、多尺度问题的高效、快速黑箱类优化设计算法，并用于药物分子优化设计，形成药物分子的网格级并行虚拟筛选方法，克服当前在考虑受体大分子柔性的精细对接时的计算瓶颈。以中国药物研发网格为依托，研制适应于百万量级的大型化合物数据库高通量精细虚拟筛选的药物分子设计软件，为我国的新药研发服务。

Study of optimization methods for drug molecular design using grid computing

Project of National Natural Science Foundation of China，No. 10772042，2008-2010

Xicheng WANG

This project is to study the optimization methods based on the induced fit modeling for

drug molecular design. Multiobject optimization methods of mathematical programming will be developed to establish a refined molecular docking model considering protein receptor and ligand flexibility simultaneously, which will consist of force-field-based, empirical and knowledge-based score functions. The noval model will be used to optimize drug molecular design. Some efficient black algorithms will be developed to solve the above optimization model with multi-field and multi-scale problem by combining the evolutionary algorithms、clustering analysis, surrogate modeling methodology together with traditional optimization methods. Then parallel virtual screening methods based on grid computing will be developed to overcome the computational bottleneck of the refined molecular docking considering protein receptor flexibility. To be oriented with drug design and development, the above-mentioned methods will be finally integrated to produce applied software for drug molecular design to do high-throughput virtual screening to billions of compounds.

66. 结构优化和可靠性分析

国家自然科学基金，编号：10728205，2008.1-2010.12

负责人：仝立勇，张洪武

Samutaneous design of actuators and host structures for shape adaptive flexible structures

Project of National Natural Science Foundation of China, No.10728205, 2008.1-2010.12

Liyong TONG, Hongwu ZHANG, Zhan KANG, Biaosong CHEN, Guozhong ZHAO, et al.

A shape adaptive structure can employ either mechanical actuators or smart material based actuators to provide actuation authority to the host structure. Compared to the mechanical actuators, the smart material based actuators are typically compact and lightweight and may provide a balanced stroke, bandwidth and force thus a higher energy density when adequate amplifiers are built-in. Research into such a scietific challenging problem is starting as there exists very limited literature. The overall objective of this project is to develop a generic algorithm for simultaneous design optimization of shape adaptive flexible structures and to explore new smart material based compact actuators. The expected outcomes are: (1) to develop novel concepts and formulations for simltaneous design optimization of shape adaptive flexible structures; (2) to develop understanding of the solid-fluid coupling in the nastic movements of plants, and to develop relevant models for two-phase solid-fluid cellular active materials and actuators for shape adaptive structures. This project is scientifically challenging and has an important engineering potential. It will contribute to the development of shape morphable wing technology and its research.

67. 船舶与海洋结构物全寿命长效防腐蚀关键技术研究

国家自然科学基金，编号：50779002，2008-2010

负责人：黄一

68. 工程海冰预报技术研究

海洋公益性行业科研专项经费项目，编号：200805009, 2008.7-2011.6

负责人：刘煜，季顺迎

海冰是渤海冬季最主要的海洋环境灾害之一。本项目以预防和减轻海冰灾害为目标，以渤海石油平台海冰环境安全保障为示范，开展工程海冰参数预报技术研究。通过海冰力学参数预报技术研究，海冰对海上工程结构物作用机理研究，小区域海冰精细化预报以及风险冰块识别和漂移轨迹预报技术开发，建立工程海冰预报技术示范系统，为冰区海上油气开发的海冰环境安全保障系统的建立奠定基础。

Study on Forecasting Techniques of Engineering Sea Ice

Special funding project for Marine Commonweal Trades, No.200805009, 2008.7-2011.6

Yu LIU, **Shunying JI**

Sea ice is the one important disaster in winters of the Bohai, China. In this project, the object is to prevent and reduce the sea ice disaster, to set an example to protect the oil/gas exploration in the sea ice environments of Bohai Sea, and to develop the forecasting techniques of engineering sea ice. Under the following studies: (1) the forecasting techniques of sea ice parameters, (2) the interaction mechanism between sea ice and offshore structures, (3) the prediction of sea ice conditions with high precise in local zone, (4) the identification of hazardous ice floes, (5) the simulation of drifting trance of ice floes, a demonstrating system will be established for forecasting techniques of engineering sea ice. It can be applied in the Safety Guarantee System (SGS) of oil/gas exploration in the ice-covered zone.

69. 高速铁路综合试验技术研究——受电弓和接触网耦合系统的动力和波动性能分析

铁道部科技研究开发计划，编号：2010T001-C, 2010-2011

负责人：高强

本项目拟采用参变量变分原理和精细积分方法对受电弓和接触网耦合系统进行动力和波动性能分析，并分析列车运行速度对受电弓和接触网耦合系统动态行为的影响。参变量变分原理和以此为基础的二次规划算法在处理非线性问题时具有明显的优势，可精确地处理接触问题，准确判断出受电弓与接触线的接触状态，同时能有效解决弦索结构拉伸和压缩模量不同导致的非线性问题。精细积分方法可给出非常精细的数值结果，并能有效地避免积分的刚性问题，从而解除对时间积分步长的限制，可精确地反映弓网系统的波动特性。在以上基础上，对受电弓和接触网耦合系统进行动力和波

动性能分析。

The dynamics analysis for the coupled system of Pantograph and catenary

Scientific Research and Development Project of the Ministry of Railways, No.2010T001-C, 2010-2011

Qiang GAO

In this project, the parametric variational principle and the precise integration method are used to analyze the wave behavior of the coupled system of pantograph and catenary, and analyze the effect of the speed of the train to the dynamic behavior of the coupled systems of pantograph and catenary. The parametric variational principle and the corresponding quadratic programming algorithm are the powerful tools for the analysis of the nonlinear problems. They can be used to handle the contact problems precisely, to determine the accurate contact states, and to effectively solve the nonlinear problems results from the different tension and compression modulus of the droppers. Precise integration method can give very precise numerical results and can avoid the rigid problems effectively, so breaks the restrictions on the time step and can reflect accurately the wave characteristics of the coupled system. Based on the above methods, the dynamic and wave behaviors of the coupled pantograph and catenary system are analyzed.

70. “渔业节能关键技术研究与重大装备开发”中课题“玻璃钢渔船船型优化及施工工艺关键技术研究”

公益性行业（农业）科研专项，编号：201003024, 2010.7-2014.12

负责人：林焰

71. 分布式空间系统的编队控制方法研究

高等学校博士学科点专项科研基金, 编号：20070141067, 2008.01-2010.12

负责人：吴志刚

Formation flying control of distributed space system

Specialized Research Fund for the Doctoral Program of Higher Education, 20070141067, 2008.01-2010.12

Zhigang WU

72. 新型计算力学软件系统设计理论研究

教育部新世纪优秀人才支持计划，编号: NCET-07-0128, 2008-2010

负责人：陈飙松

本项目计划综合运用当前软件设计技术和工具，利用网络及高性能计算机硬件条件，研究新型计算力学软件系统的设计理论。主要研究工作：面向大规模计算的工程数据库设计理论，研究适合于有限元、有限差分、有限体积、无网格等多种数值方法

的通用数据存储技术及检索算法，研究大型矩阵存储方案，研究计算数据的跨文件、跨分区、分布式数据存取技术；面向对象有限元程序设计技术，研究结构有限元分析的面向对象设计方案(类图、模块、设计模式等)，研究有限元分析中计算任务的管理技术和开放接口技术，研究耦合物理场问题的面向对象有限元程序设计技术；高性能数值方法的实现技术，研究面向适合于有限元、有限差分、有限体积、无网格等多种数值方法的数值算法(线性/非线性代数方程、特征值、数值积分)的范型实现技术，研究面向分布式/并行计算环境的计算技术。

Design theory research for new generation software system of computational mechanics

Program for New Century Excellent Talents in University, Ministry of Education of People's Republic of China, NCET-07-0128, 2008-2010

Biaosong CHEN

The Project plans to develop design theory for new generation software system of computational mechanics by employing updated software techniques and tools, hardware devices such as networks and high performance computers. The main work includes: 1) Design methods of engineering database system for large scale computation, which covers general purpose data retrieving techniques for FEM, FDM, FVM; storage managements for large scale matrix; and data accessing methods among multi-files, multi-partitions and multi-disks; 2) Object oriented Finite Element Software System, which covers designs of object class, software modules and design patterns; management of computational tasks and Application Programming Interfaces(APIs); design methods for multi-physics Finite Element Software System; 3) High performance numerical algorithm libraries, which covers numerical generic programming techniques(such as algorithms of linear/nonlinear algebraic equations, eigen problems and numerical integration methods) for FEM, FDM, FVM; software techniques for distributed and parallel computation.

73. 重大土木水利工程防灾减灾学科创新引智基地

教育部、国家外国专家局高等学校学科创新引智计划项目，编号: B08014, 2008.1-2010.12

负责人：张洪武（联合负责人）

本项目由教育部、国家外国专家局“高等学校学科创新引智计划”资助，与海外大学及研究机构的知名专家进行合作与交流。研究内容包括：1）重要大型工程结构防灾减灾方面的合作研究与信息交流。2）工程结构灾害预防的数值模拟与多尺度计算。3）地震及风等动荷载条件下的工程结构优化及稳定性分析。4）结构控制的先进理论与数值方法。

Introducing talents of discipline for disaster prevention and reduction in civil engineering

Project supported by the Programme of Introducing Talents of Discipline to Universities in China, No. B08014, 2008.1-2010.12

Hongwu ZHANG (CO-PI), Gengdong CHENG, Wanxie ZHONG, Gang LI

This project was supported by the Program of Ministry of Education of China for Introducing Talents of Discipline to Universities. It covers the following activities: 1) collaborative research and exchange of information in the research on disaster prevention and reduction for important and large scale engineering structures. 2) studies on the numerical simulation and multiscale computation of disaster prediction for engineering structures. 3) structural optimization and reliability analysis of engineering structures under dynamic loading conditions such as earthquake and wind loads. 4) advanced theory and numerical algorithm for structural control.

74. 基于多椭球凸模型的结构与材料非概率可靠性拓扑优化

高等学校博士学科点专项科研基金，编号: 200801410013, 2008-2010

负责人：亢战

在具有非确定性的结构系统中，采用优化设计手段进行结构最佳拓扑设计，将得到在参数变化条件下仍满足性能指标要求的结构构型，此即考虑不确定性的结构拓扑优化设计所要解决的问题。

本项目将研究非概率可靠性约束下的结构拓扑优化设计问题。将采用区间模型和凸模型理论，完善非概率可靠性指标的定义，分别对离散结构和连续体结构建立非概率可靠性拓扑优化设计的数学模型，并利用基于函数梯度的数学规划算法求解。

Non-probabilistic reliability-based topology optimization of materials and structures using multi-ellipsoid convex model.

Specialized Research Fund Project for the Doctoral Program of Higher Education, No. 200801410013, 2008-2010

Zhan KANG

The topology optimization considering material and parameter uncertainties will attain the best performance even in presence of system variations. This project will investigate the structural topology optimization with non-probabilistic reliability constraints. Interval and convex models will be used the design problem will be formulated into a optimization problem with constraints on reliability. Mathematical programming methods will be employed for solution of the problem.

75. 杆系层级结构的承载性能与优化设计研究

高等学校博士点基金新教师项目资助课题，编号: 200801411053, 2008-2010

负责人：王博

受到生物和工程中优异的层级结构启发，本课题旨在深入研究若干典型工程层级

结构，分析它们在特定层次上的各种破坏模式和破坏强度，研究特定层次的结构拓扑布局、形状与尺寸参数对这些破坏模式和破坏强度的影响，在可能的条件下给出解析表达式以得到规律，从而理解这些结构优异的力学性能及其本质；在此基础上，研究将结构拓扑优化、形状优化和尺寸优化混合起来的层级杆系工程结构的优化设计方法，在给定结构重量的条件下，考虑结构的刚度强度和破坏等力学条件的约束，实现工程层级结构的优化设计，并用实验验证若干优化设计，分析可能的缺陷的影响。争取获得工程层级结构优化设计的若干规律性认识。

Structural performance and optimization of hierarchical skeletal structure

Specialized Research Fund Project for the Doctoral Program of Higher Education, No. 200801411053, 2008-2010

Bo WANG

Inspired by superior hierarchical structures of biology and engineering, the project aims at studying a number of typical engineering hierarchical structures, analyzing their various failure modes and strength at specific level, discussing the effect of structural topology, shape and size parameters on the failure mode and strength at specific level. Analytic formula for failure criterion will be attempted wherever is possible in order to study their general law and deepen the understanding of their superior mechanical and multifunctional properties. Based on the above study, optimization method for hierarchical skeletal structure is developed by integrating structural topology, shape and size optimization approaches. Under the given constraints on structural material volume, structural rigidity, strength for various failure modes, optimum design of one or two engineering hierarchical structures will be studied and verified by laboratory experiment. The impact of structural defect on structural performance will be examined to gain general understanding.

76. 基于Cosserat介质模型的轻质结构与材料一体并发优化设计

高等学校博士点基金新教师项目资助课题，编号: 200801411052, 2008-2010

负责人：阎军

随着线性金属蜂窝材料、类桁架材料等具有周期性排布特点的轻质多孔材料越来越多的应用于工程实践，人们发现在某些情况下这种材料表现出明显的边界层效应和尺度效应。而传统的柯西介质理论不能考虑微单胞绝对尺度的影响，不能有效地解释实验中发现的尺度相关力学行为。Cosserat介质理论（微极理论）建立了非局部化本构关系，用来考虑这种尺度效应则相对准确。本项目主要研究将此类轻质多孔材料等效为Cosserat连续介质的方法，研究依据宏观等效分析结果快速映射计算微单胞构件应力的多尺度算法。在此基础上，运用拓扑优化技术，研究基于Cosserat介质模型的宏观结构拓扑优化方法以及具有特定性能的微单胞构型设计方法，研究以结构刚度及应力分布最优为目标的结构与材料一体化并发设计模型及高效求解算法。研究成果将为轻质结构与材料的分析、设计提供新型理论模型和设计方法。

Analysis and Concurrent Optimization for Light Structures and Materials based on Cosserat continuum model

Specialized Research Fund Project for the Doctoral Program of Higher Education，No.200801411052, 2008-2010

Jun YAN

More and more experiments on the cellular or truss-like materials showed that the equivalent mechanical properties depend on the ratio of characteristic lengths of macrostructure to microstructure, especially in the neighbor of boundary layers. The classical continuum theory can't consider the effect from the characteristic length of cell, so can not explain the size–dependent mechanical properties observed in the experiments. As a result, micropolar or Cosserat theory is adopted as a general theory of continuum mechanics to account for these effects. A new united approach to formulate the equivalent micropolar constitutive relation of 2-D periodic cellular materials is developed and the multi-scale algorithm for the micro-stress of cellular materials is researched based on the results of macro effective analysis. The optimal macro structural configuration and microstructure with specified properties are obtained based on the Cosserat continuum representation with topology optimization techniques. The concurrent optimization models for the structures and materials with the objective of maximum stiffness and optimum stress distribution are developed and the corresponding effective algorithm is established. This research will help to probe the new theoretical model and designing technique for ultra-light materials and structures.

77. 颗粒离散介质的基本力学行为及其工程应用

教育部新世纪优秀人才支持计划，编号：NCET-08-0072, 2009-2011

负责人：季顺迎

颗粒介质广泛地存在于不同研究领域并在过去几十年中得到受到了系统地研究。为揭示颗粒材料复杂的运动规律和表现形式，更好地理解并解决不同研究领域所面临的颗粒材料动力学问题，需要对颗粒介质在微观(颗粒)尺度下的碰撞接触模型和宏观尺度下的流变特性进行深入研究。为此，首先在微观-宏观尺度下研究颗粒介质的基本力学行为，通过对离散介质在微观(颗粒)尺度下碰撞接触模型的数值分析和实验验证，确定其在宏观尺度下的动力特性，建立适用于颗粒介质不同流动状态的粘弹塑性本构模型。在此基础上将颗粒介质的基本力学模型应用于以下两个研究领域：一是对不同尺度海冰动力学的离散元数值模拟以提高海冰数值模拟的计算精度，二是对铁路有碴道床的动力特性进行离散元分析以确定其破坏机理。因此，本项目既是颗粒介质在微观和宏观尺度下力学行为的基础理论的研究，同时又是颗粒介质理论在海冰动力学和铁路有碴道床动力特性等两个不同领域的应用研究。

Fundamental mechanical behaviors of discrete granular matter and its

applications in engineering

Program for New Century Excellent Talents in University, Ministry of Education of People's Republic of China, No.NCET-08-0072, 2009-2011

Shunying JI

The granular matter exists in various research fields and has been invesitigated comprehensively in the past couple decates. To undersatnd its complex intestine mechanisum and extrinsic behaviors, and to sovle the different granular problems, the contact force model on micro-scale (particle scale) and the rehological properties on macro-scale should be investigated. In this project, the fundamental mechanical behaviors of granular matter are studied firslty. With both of numerical and experimental approaches, the contact force model of single particle is improved on micro-scale, and the motion characteristics of granular matter are analyzed on macro-scale to establish the visco-elastic-plastic constitutive model. Based on the research above, the applications of granular mechanical theory are applied in two aspects. The one is to model the sea ice dynamics with discrete element model (DEM) on various scales to improve the precision of sea ice numerical results. The other one is to study the dynamic behaviors and failure process of railway balast. Therefore, this project is the fundamenal reaserch of granular matter on micro-macro scales, and also the engineering applications of granular matter theory in the dynamics of sea ice and railway balast.

78. 基于边界等效阻抗计算的复杂结构中频振动响应预报研究

教育部留学回国人员科研启动基金资助项目，2009.3-2011.3

负责人：黎胜

对复杂结构系统的振动响应分析，一般根据所考虑的频率范围将分析频段分为低频段、中频段和高频段，并针对不同频段采取不同的分析方法。本课题基于边界等效阻抗进行复杂结构中频振动响应预报研究，主要开展以下研究：（1）中频问题的杂交方法建模；（2）柔性构件对刚性构件的边界等效阻抗特性分析；（3）等效阻抗的灵敏度分析；(4)等效阻抗的不确定性所引起的响应变异性分析。

Research on mid-frequency vibration analysis based on the effective impedance methods

Scientific Research Foundation Project for the Returned Overseas Chinese Scholars, State Education Ministry, 2009.03-2011.03

Sheng LI

The frequency spectrum where simulation methods can be utilized for vibration analysis can be divided into three regions: low, mid and high frequency. This project concerns the mid-frequency vibration problems and the effective impedance methods to solve such problems. This project mainly focuses the studies on: (1) Hybrid methods for mid-frequency

vibration; (2) Effective impedances between flexible members and stiff members; (3) Sensitivity analysis of the effective impedance; (4) Response variance induced by the uncertainty of the effective impedance.

79. 考虑热效应的压电智能结构的优化和控制

教育部新世纪优秀人才支持计划项目，编号：NCET-09-0259，2010-2012

负责人：赵国忠

研究考虑热效应的压电智能结构的优化设计和控制系统的数值建模、理论与数值分析方法，压电作动器、传感器优化配置方法，以及该类耦合系统的灵敏度理论和算法。提出含有结构、电场、温度场和控制设计参数的优化和控制的一体化设计模型和给出求解这一多学科复杂系统的基于灵敏度分析的优化求解算法。通过典型算例来验证上述理论和方法的正确性，并为该项技术的实际工程应用提供一个软件原型系统。

Design optimization and control of piezoelectri intelligent structures considering heat effect

Program for New Century Excellent Talents in University, Ministry of Education of People's Republic of China, No.NCET-09-0259, 2010-2012

Guozhong ZHAO

This project studies the numerical model, theory and numerical analysis method of the design optimization and control system of piezoelectric intelligent structures considering heat effect, optimal location method of piezoelectric actuators and sensors, and the theory and methods of sensitivity analysis for the coupling system. An integrated control-structure design optimization model with design parameters of structure, electrical field and heat field will be proposed. Based on the sensitivity analysis, an optimization algorithm will be presented for multidisciplinary complicated system. Some typical examples will be presented to demonstrate the the validity of the methods and theory. A basic software prototype system will be provided for the application of this technique.

80. 可变体构型与控制系统一体化协同优化设计理论

高等学校博士学科点专项科研基金，编号：20090041110023，2010.1-2012.12

负责人：刘书田

81. 爆轰合成碳包覆金属纳米粒子机理研究

高等学校博士学科点专项科研基金，编号：20090041110024，2010.1-2012.12

负责人：李晓杰

Mechanism of Carbon-encapsulated Metal Nanoparticles Synthesized by Detonation

Specialized Research Fund Project for the Doctoral Program of Higher Education,

No.20090041110024，2010.1-2012.12

Xiaojie LI

82. 低温贮箱结构健康监测方法研究

教育部留学回国人员科研启动基金资助项目，2010.12-2012.12

负责人：武湛君

本项目研究高超声速航天器复合材料低温液体燃料贮箱的结构损伤识别方法与监测技术，形成一套理论基础完备，并在一定程度上解决低温液体燃料复合材料贮箱液固耦合系统损伤识别所面临主要问题的方法，提供一套工作环境激励下复合材料贮箱结构液固耦合系统的模态分析和损伤识别软件系统与贮箱结构模态监测技术,应用于该类重要结构中，为保障其服役安全、避免重大事故发生提供了先进实用技术。主要研究内容有：（1）采用理论推导、数值分析和试验研究的方法研究复合材料贮箱液固耦合系统的动力特性，包括基本动力特性以及在外部激励作用下的动力响应特征；（2）针对考虑液面高度变化的充液复合材料贮箱发展基于随机子空间算法及统计理论的损伤识别算法。（3）建立一套动态应变测量的结构模态识别技术。

Research on the method of structure health monitoring on cryogenic tank

Scientific Research Foundation Project for the Returned Overseas Chinese Scholars, State Education Ministry, 2010.12-2012.12

Zhanjun WU

This project researchs the structural damage identification method and monitoring technology on cryogenic liquid fuel composite tank of hypersonic spacecraft. The method is built to solve the main problem about liquid-solid coupling system damage identification of cryogenic liquid fuel composite tank to a certain extent. Structure modal monitoring technology and a set of software system about the liquid-solid coupling system modal analysis and damage identification of composite tank are provided to be applied to such important structures. These provide advanced practical technology to ensure the safety and avoid serious accident. This project mainly focuses the studies on (1) The methods of theoretical derivation, numerical analysis and experiment are employed to study the dynamic properties of composite tank liquid-solid coupling system, including the basic dynamic characteristics and dynamic response characteristics in external excitation; (2) Aiming at the filling liquid composite tank, considering the liquid level height variable, the damage identification algorithm based on the random subspace algorithm and the statistic theory is developed. (3) A set of structure modal identification technology about dynamic strain measurement is established.

83. 考虑Fail-safe性能要求的结构拓扑优化方法

高等学校博士学科点专项科研基金，编号：20100041110012，2011-2012

负责人：亢战

该项目研究以不确定性结构系统 fail-safe 性能为目标的拓扑优化设计方法。将采用凸模型或区间模型描述不确定性参数或荷载，并将可靠性或鲁棒性约束列入优化问题中。将针对双层优化问题发展有效的数值求解方法。

Structural topology optimization methods for fail-safe requirements

Specialized Research Fund Project for the Doctoral Program of Higher Education, No.20100041110012, 2011-2012

Zhan KANG

This project investigates structural topology optimization methods for acquiring fail-safe performance of structural systems subject to damage or uncertain parameter variations. Uncertain variations of structural parameters and loading conditions will be models with convex sets and intervals. Reliability and robustness constraints will be incorporated into the design problem. Special strategies for efficient solutions of the resulting double-loop optimization problem will be developed.

84. 智能仿生机器鱼控制机理与优化设计

高等学校博士学科点专项科研基金，编号：20100041110013，2011-2012

负责人：徐新生

该项目研究和优化设计一种超磁仿生机器鱼。实现以鱼形合金薄板模拟鱼体骨架，以板体表面贴或镀的超磁材料模拟鱼体肌肉，以外磁场模拟神经用以控制超磁材料的伸缩，从而达到由外磁场控制仿生鱼游动的目的。揭示外磁场强度和频率等因素与机器鱼游动的基本规律的基础上，掌握超磁材料分布，鱼尾形状和外磁场等对机器鱼游动速度和机动性能等的影响，获得超磁仿生机器鱼设计的关键技术。为其在工业和医疗器械等方面的应用提供理论依据和设计思路。

The controlling mechanism and optimization design of intelligent bionic fishes

Specialized Research Fund Project for the Doctoral Program of Higher Education, No.20060141008, from 2011 to 2012

Xinsheng XU

This project researches a subminiature robot fish aid the method of optimization design. For the subject, a new analytical method is presented for a subminiature robot fish, which is controlled by external magnetic fields. In the method, the alloy sheet is simulated as the framework of the fishtail and the giant magnetostrictive material (GMM), which is attached the sheet, as the muscle of fish. In this wise, the mechanics model is given. Base on studying the mechanism of fish swimming, GMM actuator (GMMA) of the robot fish is devised and can be simulated as the nerve to control the swing of the fishtail, or fish swimming, by the external magnetic field. Results show that the average propulsion depends upon material constants, geometrical parameters and the frequency of the magnetic field. Especially, the

propulsion is the larger when the frequency of the external magnetic field is close to the natural frequencies of the system. This conclusion can be used for the primary idea to control and drive the fishtail of the robot fish.

85. 微纳尺度界面摩擦阻力控制

辽宁省博士启动基金, 编号：20071082, 2008-2010

负责人：马国军

在微纳尺度下，由于大的表面积体积比，使得界面摩擦力的作用成为导致微纳系统性能下降甚至完全失效的关键因素之一，如何减小这种有害力的作用已成为微纳米科技研究领域中的一个热门方向。本项目着重研究微纳尺度下利用流体流动的边界滑移来实现界面摩擦阻力控制的理论和方法。首先，建立具有不同滑移性质表面发生边界滑移时的计算模型并给出相应计算方法；其次，研究表面几何拓扑对流体边界滑移行为的影响规律，并以减小表面摩擦阻力为目标，对表面几何拓扑进行优化设计。

Control on the friction at the solid-liquid interface on micro/nano scale

Doctoral research fund of Liaoning Province, No. 20071082, 2008-2010

Guojun MA

Because the surface- volume ratio is usually very large on micro/nano-scale, the friction at the interface becomes one of the most unfavorable factors that decrease the properties of MEMS. In recent years, how to decrease such harmful effect has received more and more attentions in the MEMS. In this program, we focus on the how to take advantage of boundary slip to decrease the friction force at the interface. Firstly, we will create the calculation model and numerical algorithm of the boundary slip problem when the solid wall has heterogeneous slip/no-slip properties. Secondly, we will study the influences of the geometry topology on the behavior of boundary slip at the interface. Finally, an optimal design will be carried out to decrease the friction force.

86. 先进复合材料网格结构共固化工艺参数优化分析

辽宁省博士启动基金, 编号：20071093, 2008-2010

负责人：任明法

采用理论分析、数值模拟和试验验证相结合的方法，研究先进复合材料网格结构在共固化成型工艺过程中的应力场、温度场和固化度场的多场耦合问题,其中包括建立具有试验基础的复合材料网格结构成型工艺共固化阶段的多场耦合分析模型；推导复合材料网格结构成型过程的多场耦合分析的有限元列式；通过对采用几种典型工艺参数的复合材料格栅结构共固化成型工艺过程的多场耦合分析结果的比较与参数讨论，研究纤维缠绕、复合材料固化和复合材料网格结构脱模过程中的工艺参数对复合材料网格结构制品质量（几何和承载能力）的影响。

Optimization analysis of advanced composite grid structures co-curing manufacture parameters

Doctoral research fund of Liaoning Province, No.20071093, 2008-2010

Mingfa REN

By theoritical analysis and numerical simulation in conjuction with experimental study, a multi-fields coupling analysis problem between stess, temperature and curing extent fields during the co-curing manufacture process for advance composite grid structures (AGS) is investigated in the project, which main contents involve as:

(1) Establish a muti-fields coupling analysis model based on testing observation during the stage of AGS's co-curing manufacture process;

(2) Deduce some Finite Element formulas for analyzing the multi-fields coupling problem of co-curing process;

(3) Discuss the effects of thermal and mechanical properties for constituets of AGS, mould characteristic dimensions and technics parameters during the fiber winding, curing and demoulding stages upon the qulity of AGS product,such as geometry, loading capacity and etc. form some typical parametric studies.

87. 高效板式小温差换热器的开发及其传热性能强化研究

辽宁省自然科学基金，编号：20072180, 2008-2010

负责人：卞永宁

研究目的是通过实验和数值模拟的手段，揭示各种形状二维流路内的流体力学性能和热质传递性能。基于上述实验研究结果，描述流动及传递强化过程的机理，为开发设计适用于海水温差发电系统的高效小温差换热器提供参考。

Development and study on heat transfer enhancement for an effective plate heat exchanger with small temperature difference

Natural Science Foundation Project of Liaoning province, No. 20072180, 2008-2010

Yongning BIAN

In this study, the performance of fluid flow and heat and mass transfer are explored experimentally and numerically. Based on the above experimental results, the mechanism of flow and transfer enhancement could be described, which will be an important reference for the development of effective heat exchanger with small temperature difference applied to the ocean thermal energy conversion system..

88. 复杂船体曲面钢板高频感应加热成形过程机理研究

辽宁省自然科学基金项目，编号：20072186, 2007.10-2010.10

负责人：刘玉君

本项目主要是船体曲面板感应加热过程的感应加热系统的研究开发，研究内容包

括：钢板感应加热成形过程中工艺参数的实验和数值研究，钢板感应加热过程中变形和工艺参数关系的数学建模，以及钢板感应加热过程加热路径和加热参数的优化控制研究。

本项目的研究可以实现船体曲面外板在高频感应热源下的自动弯曲成形，使复杂曲面成型过程得以精确控制，以缩短船舶建造周期。同时，该研究项目为高频感应热源代替氧乙炔热源应用于双曲率船体板的弯曲加工工艺奠定理论和技术基础，促进船厂生产技术的革新，使高频感应热源应用于船厂的复杂曲面钢板成型设备中，该设备将大幅提高曲面钢板的生产效率，提高我省造船企业的造船产量和市场竞争力。

Research on the Mechanism of the Ship-hull Curved Plate Forming Process by the High Frequency Induction Heating

Natural Science Foundation Project of Liaoning province, No.20072186, 2007.10-2009.10

Yujun LIU

The project is aimed to develop an induction heating system for the ship-hull curved plate. The major researching tasks include the following aspects: the experimental and numerical research on the technical parameter of the steel plate induction heating process, building the mathematical model between the deformation and technical parameters of the steel plate induction heating process, and optimization control of heating path and heating parameters in the steel plate forming by induction heating.

The project will actualize an automatic bending forming process for the ship-hull curved plate under induction heating resource. Thus, the complex curved plate forming process will be under accurate control, and the ship building period will be shortened. Meanwhile, the project will build the theory and technical basis for the replacing oxyacetylene flame with high frequency heating resource in the double curved ship-hull plate bending forming technology. The project will promote the production technology reform, and high frequency heating resource will be adopted in the complex curved plate forming facility in shipyard. The forming facility will evidently promote the production efficiency of ship-hull curved plate, and increase the shipbuilding output and the market competition ability of the shipyard.

89. 大型离心压缩机结构优化设计与制造中的关键力学问题

辽宁省高校优秀人才支持计划, 2008-2010

负责人：吴承伟

The key mechanics problems in structure optimization design and manufacturing of large centrifugal compressors

The support plan of outstanding scientists of Liaoning Province, 2008-2010

Chengwei WU

90. 分层各项异性晶体总波传播的辛分析理论与数值方法研究

辽宁省博士科研启动基金，编号：20081091, 2009.1-2012.12

负责人：高强

本项目在哈密顿体系框架下建立起分层各向异性晶体中波传播问题的辛几何理论，并建立起相应的精细高效保辛数值算法。主要开展以下研究：1．建立起分层各向异性晶体中体波、声表面波、光波以及周期晶体能带分析的辛几何理论。2．基于哈密顿体系的辛几何理论、混合能和本征值记数的概念，建立起联合应用精细积分法和扩展 Wittric-Williams 算法的高效精确算法，实现对周期分层各向异性晶体能带分析的保辛精确算法。3．在上述辛几何理论和数值方法的基础上，进一步建立分层各向异性晶体声表面波和光波频散特性分析的保辛精确算法。

Symplectic theory and numerical method for wave propagation in layered anisotropic crystal

Doctoral research fund of Liaoning Province, No. 20081091, 2009.1-2012.12

Qiang GAO

In this project, based on the Hamiltonian theory framework, the symplectic theory and the efficient symplectic numerical methid will be established for layered anisotropic material. This project mainly focuses on: 1 the symplectic theory of body wave, surface wave and enegy band of periodic structure; 2 the efficient numerical method for the enegy band analysis of periodic structure based on the symplectic theory, the concept of mixed enegty and the eigenvalue count; 3 the symplectic algorithm for the surface wave of layered anisotropic material.

91. 基于有限元/统计能量分析杂交方法的船舶动力响应预报

辽宁省自然科学基金项目，编号：20082170, 2009.01-2010.12

负责人：黎胜

本项目拟针对船舶结构中柔性构件与刚性构件的典型连接方式，采用连接点的约束模态和柔性构件的主模态基于模态综合法来计算连接点的等效阻抗，然后通过连结点的阻抗将求解刚性构件的有限元方法和求解柔性构件的统计能量分析进行杂交结合，实现船舶结构中频段的振动响应分析。本项目将基于满足精度要求的有限元计算结果和实验结果来进行预报方法的比较和验证。项目研究成果将对船舶结构的动力响应预报和设计具有重要意义。

Predication of ship dynamic response using FEM/SEA hybrid approach

Natural Science Foundation Project of Liaoning Province, No. 20082170, 2009.01-2010.12

Sheng LI

Flexible structural members and stiff structural members coexist in a ship and the typical connections between flexible members and stiff members will be identified. The

effective impedance between the flexible members and the stiff members will be calculated using component mode synthesis method based on the constraint modes and the principal modes. The hybrid FEM/SEA approach combines the conventional FEM models with SEA models for analysis of ship structural vibration. Conventional FEM are employed for modeling the behavior of the stiff members and SEA for the flexible members, they are combined by the effective impedance between them to solve the mid-frequency vibration problem in ships. The proposed method will be compared and validated by accurate FEM results with very dense FE mesh and experimental results. The application of the new development in this project to the prediction and design of ship dynamic response is very promising.

92. 装备结构的多源不确定性量化及可靠性优化设计方法

辽宁省高校创新团队支持计划项目，编号：2009T014, 2009.1-2011.12

负责人：亢战

本课题将基于多椭球凸模型，提出工业装备结构多源不确定性参数和荷载的非概率描述方法。研究不确定性结构非概率可靠性优化设计的数学模型和约束条件的正则化方法，提出双层优化问题的高效数值算法，完成典型工程应用实例。

Description of multi-sourced uncertainty of equipment structures and reliability-based optimization

Innovation Team Project of Universities of Liaoning Province, No.2009T014, 2009.1-2011.12

Zhan KANG

This project will propose non-probabilistic description methods for uncertain parameters and loads of industrial equipments from multiple sources. Mathematical models and regularization of constraints of non-probabilistic reliability-based structural optimization will be investigated. Efficient numerical algorithms for double-loop optimization problem will be developed and practical engineering design problems will be treated.

93. 动力学仿真分析系统级求解器的研究及开发

辽宁省高校科研项目计划重点实验室项目，编号：2009S018, 2009.1-2011.12

负责人：姚伟岸

动力学仿真分析是提高我国装备制造业产品竞争力和自主创新能力的关键技术之一，它所涉及的常微分方程和微分-代数方程等系统级求解器的分析算法和程序研发是其核心内容之一。本课题主要开展以下研究及开发： (1) 动力学系统常微分方程求解器实现； (2) 保守动力系统的算法研究和求解器实现； (3) 不等式约束动力系统的积分算法研究和求解器实现。

The development of system-level solver in simulative dynamic calculation

Key Laboratory Project of Universities of Liaoning Province, No.2009S018, 2009-2011

Weian YAO

The simulative calculation is one of the important technologies in increasing the competitiveness and improving the self-renovation capability of the equipment manufacturing industry, in which numerical algorithm and development of system-level solver for ordinary differential equation (ODE) and differential-algebraic equations (DAE) is one of the core elements. This project mainly focuses the studies on (1) implement of solver for ODE in dynamics; (2) numerical algorithm and implement of solver for conservative dynamical system; (3) integral arithmetic and implement of solver for dynamical system with inequality constrain.

94. 铁路列车车体结构分析和优化技术

辽宁省教育厅创新团队项目，编号：LT2010018, 2010-2012

负责人：赵国忠

本课题研究与高速列车和重载列车运行安全性和舒适性相关的车体关键技术，包括车体静动强度分析、车体减振降噪设计和结构优化设计技术等研究任务。

Structural Analysis and design optimization of railway train body

Innovation Team Project of Universities of Liaoning Province, No.LT2010018, 2010-2012

Guozhong ZHAO

This project Studies the key design techniques of the car body effects on the safety and reliability and comfort for high-speed train and heavy haul train. Some main research tasks are static and dynamic strength analysis, structural design optimization of the car body considering vibration and noise performances.

95. 计算力学集成化软件平台的研发

辽宁省教育厅创新团队项目，编号：LT2010019, 2010-2012

负责人：陈飙松

本项目面向计算力学集成化软件平台研发，重点研究软件平台的体系结构及相关设计理论和方法，以及探索适合于计算力学软件的设计模式及软件技术。主要工作：研究适用于计算力学软件的插件管理系统和软件平台体系结构；研究适用计算力学数值算法库的框架设计方案和数值算法设计模式；研究面向科学与工程计算的异构软件系统的集成技术；研究集成平台的脚本语言技术及集成平台的典型应用。

Development of integrated software platform for computational mechanics

Innovation Team Project of Universities of Liaoning Province, No.LT2010019, 2010-2012

biaosong CHEN

The project aims at the development of integrated software platform for computational mechanics. Focuses of the project are architecture of software platform and its relevant design methods, design patterns and techniques of software system for computational mechanics. Main researches are plug-in management system and software architecture for computational mechanics; design methods of framework of numerical algorithm library and its design patterns; software integration techniques for heterogeneous systems for scientific and engineering computation; script language techniques for the integration software platform; and typical engineering applications.

96. 机车制造中焊接热变形预测、控制与矫正计算平台

辽宁省教育厅重点实验室项目，编号：LS2010033, 2010-2012

负责人：张昭

本项目的主要目的是基于有限元计算平台，开发机车制造中在相关焊接(TIG, MIG, FSW)工艺过程中热变形的系统性理论和热变形有效控制方法，通过对机车典型结构焊接件的过程仿真，计算不同工艺条件下的热变形的机理，相关计算结果将与工厂直接加工的结果进行对比，在验证计算可靠性的前提下，研究热变形控制工艺，改进机车制造中现有的焊接工艺，减少由于焊后残余热变形不合格而导致的后续矫正的相关工作。基于上述工作，建立不同矫正工艺下的计算平台，提高矫正工艺的效率和准确性。这项工作的开展将有利于简化现有机车制造中的焊后处理工作，并显著提高焊接构件的可靠性，这将有益于机车制造成本的进一步降低以及焊接质量的进一步提高。该项成果不仅仅可以应用于机车制造领域，也会对相关涉及焊接的装备制造业产生显著影响，推动我省装备制造业中焊接工艺的进一步发展。

Computational platform for prediction, controlling and recovery of distorted weld in locomotive manufacture

Key Laboratory Project of Universities of Liaoning Province, No.LS2010033, 2010-2012

Zhao ZHANG

The major objective of this project is to develop methods for controlling of weld distortions and systematic theory on weld distortions in different welding technologies in locomotive manufacture based on FEM computational platform. The mechanism of weld distortions in different process parameters can be calculated with comparison to the experimental tests. After validations, the controlling of weld distortions can be studied and then the current welding technologies can be improved to obtain the distortion. The specific computational platform can be then established for improvement of welding technologies in locomotive manufacture. This work can be useful for the improvement of weld qualities and

reduction of the manufacture costs. This work can be also beneficial to the other manufacturing industries related to welding and joining, which can be useful to the development of industrial equipments in Liaoning province.

97. 平地造船过驳过程实时智能配载系统

辽宁省教育厅重点实验室项目，编号：LS2010046, 2010-2012

负责人：林焰

98. 船体分段制造工艺耦合残余应力问题的应用基础研究

辽宁省自然科学基金，编号：20102028, 2010-2012

负责人：刘玉君

本课题属于辽宁省自然科学基金资助项目。完整的船体建造周期包含一系列加工工艺，其中热切割、水火弯、焊接等热加工过程将分别在工件内形成残余应力。当船体构件在经历连续复合加工时，由于多种工艺综合作用进而生成耦合残余应力，相对于单项工艺残余应力，耦合残余应力分布形式更复杂，对结构可靠性的影响也更难预测，因此本课题针对船体分段制造过程中的工艺耦合残余应力问题开展研究。主要研究内容如下：（1）三类典型工艺耦合残余应力（切割与焊接、水火弯与焊接、多道焊接）分布规律的有限元数值分析与实验研究；（2）前序工艺残余应力对后序工艺残余应力与变形的影响；（3）基于残余应力与变形联合控制的分段装配优化方法研究。

Applied basic research on coupled residual stresses induced by multi-technology in hull section construction

Natural Science Foundation Project of Liaoning province, No. 20102028, 2010-2012

Yujun LIU

This project is supported by the Natural Science Foundation of Liaoning Province. The integral life cycle of ship building involves a series of technology processes, including the cutting, line heating, and welding, which all belong to hot working and will generate residual stresses in workpieces. While the hull structural component is undergoing the multi-technology processes, the coupled residual stresses will be generated caused by combined effects of different technologies. Compared with the residual stresses induced by single technology, the coupled residual stresses have the more complex distributions and the less predictable influences of structural reliability. Therefore, this project will carry out the research on the coupled residual stresses induced by multi-technology in hull section construction, and mainly focuses the studies on: (1)the numerical and experimental studies on the distributions of three typical coupled residual stresses caused by cutting-welding, line heating-welding, and multi-pass welding; (2)the influence of the residual stresses induced by pre-technology on the residual stresses induced by post-technology; (3)the block assembly optimization based on the combined control of residual stresses and distortions.