深地科学论坛（第六十一讲）：深地科学前沿热点问题探究

时间：2023 年 7 月 6 日 15：00-17：00

地点：腾讯会议直播

邀请人：刘江峰

报告人	报告人单位	报告题目
Andrey P. Jivkov	英国曼彻斯特大学	Development of Finite Mechanics and Physics of Solids （有限力学和固体物理学的发展）
Majid Sedighi	英国曼彻斯特大学	Coupled Processes in Clays Barriers in Deep Geological Disposal of High Level Nuclear Waste （高放废物深地质处置中粘土屏障的耦合过程）

欢迎全校教师及同学参加！

深地工程智能建造与健康运维全国重点实验室

深部地下工程学科创新基地

《深地科学（英文）》

力学与土木工程学院

2023.06.28

报告人简介：

Andrey P. Jivkov is a Professor of Solid Mechanics and currently Head of Department of Solids and Structures in the School of Engineering, University of Manchester, UK. He obtained an MSc in Structural Engineering in 1994 from the University of Architecture, Civil Engineering and Geodesy in Sofia, Bulgaria, and a PhD in Mechanics in 2002 from Lund University, Sweden. His research since 1997 has been dedicated almost exclusively to the civil nuclear sector, both in academia and industry, first on the safe operation of NPPs and more recently also on the safe disposal of nuclear waste. He joined the School of Engineering at Manchester in 2010 as Research Lecturer, was promoted to Senior Lecturer in 2015, and to full Professor in 2017. His expertise is in modelling the performance of materials subject to different, often coupled, physical processes, such as deformation, damage, fracture, mass, and heat transport. He has experience with different classes of metallic materials, such as ferritic and austenitic steels, nickel, copper, and aluminum alloys, as well as different classes of quasi-brittle materials, such as cement-based composites, nuclear graphite, and geological. His research has always been focused on understanding the relations between the internal structures of materials and their performance in engineering structures and translating this understanding into advanced mathematical models. Since 2017 he has been working on new mathematical formulations that can expedite the discovery of such relations and the talk will make an overview of these developments. Prof Jivkov has published over 180 peer-reviewed papers, of which more than 110 journal articles, graduated 21 PhD students, supervised 13 post-doctoral research associates, and delivered 14 invited, keynote, and plenary lectures at international conferences. He serves as expert reviewer to the funding agencies in several countries in Europe and North America and chairs the Technical Committee 2 on Micro-mechanisms of Fracture and Fatigue of the European Structural Integrity Society.

报告摘要：

Development of Finite Mechanics and Physics of Solids

有限力学和固体物理学的发展

The approximation of materials as continuous solids leads to the classical formulations of conservation of scalar (mass, energy, charge) and vector (linear and angular momentum) quantities in terms of their densities. Such formulations do not allow for describing localisations of properties and processes by underlying material structures. One approach to address the deficiency of the classical formulations is to consider explicitly the internal structures of engineering materials as assemblies of discrete, finite cells. Calculus on such cell complexes was born at the same time as our current students. It offers great opportunities for revisiting and reformulating the descriptions and analyses of real materials.

The talk will show the development of discrete analogues of the conservation laws relevant to the analysis of materials with complex internal structures. These are based on the notion of combinatorial differential forms on cell complexes, introduced by Forman [1], and on operations with such forms, formalised by Berbatov [2]. Topological, i.e., metric-independent, operations include exterior derivatives and exterior products of forms. Metric operations arise from the introduction of metric tensors used to define inner product of forms canonically, and consequently co-differentials.

An example for conservation of scalar quantities using co-differentials has been recently given by Berbatov et al. [3]. It has been shown how the new formulation can be used to analyse materials where sub-structures with different dimensions from the bulk (3D), specifically carbon nanotubes (1D) and graphene-oxide sheets (2D), coexist and have vastly different properties. The talk will discuss an extension to conservation of momenta, which has been proposed by Jivkov et al. [4]. Notably, the formulation that will be discussed integrates the mathematic, physics, and computation. This must be contrasted with the classical approach, which involves a long list of approximations: continuum approximation leading to weak or strong formulation using densities of quantities – discretisation approximation – and discretisation of operators (FDM, FVM) or continuum fields (FEM, BEM).

[1] Forman R (2003). Combinatorial Novikov-Morse theory. International Journal of Mathematics 13: 333–368.

[2] Berbatov K (2023). Discrete Approaches to Mechanics and Physics of Solids. PhD Thesis, The University of Manchester. (https://pure.manchester.ac.uk/ws/portalfiles/portal/261212897/FULL_TEXT.PDF)

[3] Berbatov K, Boom PD, Hazel AL, Jivkov AP (2022). Diffusion in multi-dimensional solids using Forman's combinatorial differential forms. Applied Mathematical Modelling 110, 172-192.

[4] Jivkov AP, Berbatov K, Boom PD, Hazel AL (2023). Microstructures, physical processes, and discrete differential forms. Procedia Structural Integrity 43, 15-22.

报告人简介：

Majid Sedighi is a Reader at the University of Manchester. He is a Civil Engineer with more than 20 years of work experiences in academia and industry. Majid has been an academic member of School of Engineering at the University of Manchester since 2015. Prior to that he was a UNESCO Research Fellow at Cardiff University for 5 years. He also worked for five years between 2002 and 2007 as a Design then Senior Design Engineer in various industrial projects in three consulting engineers. He is currently the Discipline Lead for Engineered Barrier System at the Research Support Office of the UK's Nuclear Waste Services. His expertise and research interests cover areas of geo-engineering with a focus on multiphysics/coupled phenomena and reactive transport processes. He leads the geoenvironmental engineering team and the research focus of the team is currently on containment systems for geological disposal of HLW and emerging contaminants of concerns. His research extends to the application of phyllosilicate minerals and carbonaceous materials for environmental applications.

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报告摘要：

Coupled Processes in Clays Barriers in Deep Geological Disposal of High Level Nuclear Waste

高放废物深地质处置中粘土屏障的耦合过程

Deep geological concepts are currently the preferred long term solution for the management of high level radioactive waste (HLW) in most countries. Bentonite barriers are proposed for buffer, backfill and sealing components in the disposal concepts. The physical processes involved in bentonite-based barrier in geological disposal of nuclear waste are often interdependent and inherently coupled. Understanding such coupled processes and multiphysics phenomena are critical to ensure the development of a robust safety assessment case. Such coupled phenomena that are observed in the behaviour of swelling clays originate mainly from the microstructure, geochemical composition and electrified surfaces of clay minerals. Interactions between the multiple ionic species, clay mineral and accessory minerals present in the clay-water system can induce profound microscopic and macroscopic effects on transport phenomena. The focus of this talk will be on how such coupled processes would operate at microscopic scale while affecting the overall performance at larger scales. Thermally coupled phenomena will be discussed in this talk; looking into how elevated temperature affects the swelling and erosion behavior at different scales.