Please Note: some of our courses are run every year and some alternate years. This is the most recent brochure available. We are planning to run this course next in June 2007.

NUMERICAL MODELLING IN MATERIALS ENGINEERING

20 – 24 June 2005

THE COURSE

This course introduces numerical modelling in materials engineering, with particular emphasis on Finite Element modelling. The course is suitable for those with no formal prior training in the field. The aims of the course are to provide an explanation of the underlying principles of finite element analysis, to introduce models for the constitutive behaviour of materials under different conditions, to demonstrate the application of finite element analysis in modelling the processing of materials and the behaviour of structural materials/components under a range of loading situations. The material covered will be generic rather than package-specific. Linear and non-linear problems will be considered and a range of applications will be drawn from all the main classes of engineering materials. Lectures will be given by experts in the field with experience of teaching to practising engineers and materials scientists on post-experience courses. Supervised practical sessions (primarily using the FEA code ANSYS) and exercise classes will enable delegates to work on carefully structured problems, designed to explore the potential and limitations of the technique, and to discuss these with the lecturers.

WHO SHOULD ATTEND?

The course would be invaluable for scientists and engineers seeking an introduction to numerical modelling and also those with a working knowledge in a particular area seeking a wider overview. It will be suitable for recent graduates in science or engineering disciplines and others who are entering the field.

PRE-REQUISITES

No prior knowledge or experience of numerical modelling is assumed, but the course will be taught at the graduate level. It should be readily understood by graduates in science or engineering. Candidates seeking to enrol on the Modular MSc should be of graduate status.

MODULAR MSc IN MATERIALS FOR ENGINEERING APPLICATIONS

The course is also offered as a credit bearing module in the University of Surrey Modular MSc programme in Materials for Engineering Applications. Further information on the programme is given towards the end of this brochure.

The development of this module was supported by the EPSRC via a Masters Training Package.

COURSE FORMAT

The course will commence mid-morning Monday 20th June and conclude in the afternoon of Friday 24th June. It is designed to be intensive and each day there will be at least six hours of classes.

ENROLMENT
Each intending participant should complete the registration form at the back of this brochure and return it with the appropriate remittance. Additional forms may be photocopied as required. The Basic Course Fee will be £995 and includes tuition and one set of lecture notes. There will be an additional charge for meals of £50 for the week to provide coffee, lunch and tea each day. Full joining instructions will be sent to delegates two weeks before the course. Cheques should be made payable to the "University of Surrey" in £ sterling. **Companies sending two delegates may send a third delegate for the price of their meals and accommodation only.**

If there are a number of people in your company who would benefit from a course in this field, please contact us to discuss the possibility of an in-house, customised, course to meet your requirements.

ACCOMMODATION
Accommodation is available on campus in recently built single study bedrooms with full en suite facilities. The cost of accommodation is £40 per night, including breakfast. The course is designed to be residential but non-residential enrolments will be accepted. Bed and breakfast will also be available for the night of Sunday, 19 June for those needing to travel on that day for an additional £40 per night.

LOCATION
The course will be held in Seminar Room 45, top floor, Building AZ, University of Surrey, Guildford. The campus has direct access from the A3 and is served by a link bus service from the railway station/town centre, which is otherwise about 20 minutes walk distant.

COURSE LECTURE NOTES
Each enrolled student will be provided with a comprehensive set of lecture notes. These notes include all the principal visual material presented during the course. It must be emphasised, however, that they are merely notes intended to supplement the oral presentations, and not intended as a substitute for text books. Copies are therefore made available only to those attending the course.

DISCLAIMER
The organisers reserve the right to amend the sequence of lecture topics, and to cancel lectures or substitute lectures, if necessitated due to circumstances beyond their control.

LECTURE CONTENT

1. **Introduction to Finite Element Analysis** — **Professor A D Crocombe**
Course structure. Brief historical background to numerical modelling. Development of FEA. Underlying principles of FEA. Types of element. Classes of analysis (static, dynamic, buckling). Optimisation. Equation solvers. Range of applications to be covered within the course.

2. **Modelling with Finite Elements** — **Professor F J Guild**
Assessment of accuracy, mesh refinement, application of constraints and loading, use of symmetry conditions, coupling and constraint equations, mixing element types, sub-structuring, sub-modelling,

3. **Material models for elastic behaviour and fracture** **Professor P A Smith**
Elastic properties of materials. Stress/strain relations for isotropic materials. Plane stress and plane strain. Stress/strain relations for anisotropic materials (composite laminae/laminates). Generalised plane strain. Linear elastic fracture mechanics - stress intensity factor and energy release rate parameters. Implementation of elastic models within FE codes.

4. **Typical Finite element codes** **Mr D Sinclair**
Key features of FE software (graphics display and manipulation, labeling, logical menu structure, grouping) FE model generation (geometry import vs geometry creation, mesh generation techniques, mesh modification techniques, assessing mesh quality) FE solution (external vs internal solvers) FE postprocessing (deformed plots, contours, graphing, listing, vectors, advanced visualization methods)

5. **Introduction to non-linear analysis** **Professor A D Crocombe**
Sources of non-linearity (material, geometric and boundary), non-linear finite element equations, non-linear solution methods, solution procedure for non-linear FEA, assessing and monitoring convergence, methods for enhancing solution convergence, automatic step-sizing, brief details of non-linearitries not considered (hyperelasticity, geometry and contact).

6. **Material elasto-plasticity: constitutive behaviour** **Dr M A Wahab**
Typical material responses, measures of stress and strain (engineering and true), yield criteria (von Mises, Tresca), yield surface, hardening (isotropic vs kinematic), flow rules (associated vs non-associated), integration of rate equations, analytical solutions (pressurized cylinder), pressure dependent yielding.

7. **Implementing plasticity-related non-linearity within FE models** **Dr M A Wahab**
Restatement of NLFE equations, typical plasticity models available, typical hardening models, tangent modulus matrix (continuum and consistent), tangent stiffness matrix, limit loading, displacement control, arc length methods, illustration through presentation of non-linear benchmark tests.

8. **Material non-linearity - time dependent phenomena (creep, visco-elasticity, visco-plasticity): constitutive behaviour** **Professor P A Smith**
Simple spring-dashpot models, characteristic time-dependent response (constant strain rate, creep, and relaxation and recovery), creep models (uniaxial and multiaxial), steady state power law creep and analogy to elasto-plasticity, illustrative analytical solution (relaxation, beam bending fixed load), simple overstress visco-plasticity.

9. **Implementing time-dependent non-linearity within FE models** **Professor A D Crocombe**
Overview of time dependent models available within FE codes (creep, visco-elasticity, rate dependent yield), governing FE creep equations, time integration procedures, stability, illustrative benchmarks, implementation of user models, illustrative example for overstress based visco-plasticity.

10. **Computer Simulation of Microstructure Evolution Part A** **Dr J Pan**
Various computer simulation techniques for microstructure evolution will be critically reviewed using a series of examples. The techniques under review include the variation based technique, the Monte Carlo technique and the Phase Field

technique. The examples used include phase transform, solidification, creep deformation and creep failure, superplastic deformation, grain-growth, sintering of powder compacts and etc.

11. **Computer Simulation of Microstructure Evolution Part B** **Dr J Pan**
A critical review of the atomistic modelling of the behaviour of nano-scale structures and processes via molecular dynamics simulation method is presented. Three areas of application in condensed matter are considered: i) adhesive and indentation properties of the solid surface in nano-contacts, ii) the nucleation and growth of nano-phase metallic and semi-conducting atomic and molecular films on supporting substrates and iii) sintering of nano-sized particle compacts.

12. **Modelling impact events** **Dr M S Neale**
Numerical modelling, and in particular finite element analysis is used extensively in the field of vehicle crash safety. It is used to predict the behaviour of vehicles when they collide with each other, to predict the response of crash test dummies within those vehicles and also to understand the mechanisms by which the human body sustains injury in such accidents. In all of these applications, simulation technology has advanced at a dramatic pace and further progress is now limited by available computer hardware and by the accuracy with which material behaviour can be represented. This is most apparent when modelling the human body where the problem is compounded by the difficulties of measuring suitable material data as well as implementing such data.

13. **Finite element analysis of adhesively bonded joints** **Professor F J Guild**
The acceptance of adhesive bonding as a reliable joining technology relies on full understanding of the stresses and strains in and around the joint. This understanding can best be gained using finite element analysis. Examples of analysis of adhesive joints will include metal and composite adherends, and the analyses will highlight issues including non-linearity, constitutive material modelling and element type.

14. **Modelling of Polymer Flow** **Dr C Lekakou**
Polymer flows in polymer processing are laminar flows at traditionally low Reynolds numbers. The lecture will present the general flow problem in terms of momentum and continuity equations, different types of boundary conditions and numerical methods. Constitutive rheological models will cover non-Newtonian pseudoplastic fluids and will include the Power-Law, Carreau model and viscoelastic models. Case studies will be presented on extrusion and injection moulding.

15. **Modelling of composites processing** **Dr C Lekakou**
This includes the modelling of the following stages: drape/forming of fibre reinforcement, resin infiltration, heat transfer and resin curing. Different approaches and applications will be presented for the modelling of drape/forming, including the “fishnet”, solid mechanics finite element and viscous approach. Darcy’s law is applied in the numerical modelling of infiltration. Numerical case studies will cover resin transfer moulding (RTM) and processing of thermoplastic matrix composites.

16. **Numerical modelling of composite laminates with through-thickness reinforcements: a suitable modelling strategy** **Dr M Grassi**
Different modelling levels of analysis where the finite element method can be applied. From the simulation of a composite micro-mechanical failure process to the modelling of a composite coupon test up to modelling of a large aerospace component.

17. **State of the art modelling of hot metal forming processes Dr J Talamantes-Silva**
Industrial drivers for modelling. Current status of finite element modelling for hot metal processes with emphasis on its integration with other techniques, particularly those for predicting microstructural evolution. Incorporation of physically based models, including internal state variable approach. Modelling techniques, including CAFE (Cellular Automata Finite Element) and artificial neural networks. Future developments, including neuro expert systems, grey box and fuzzy techniques.

PRACTICAL SESSIONS AND TUTORIALS

The four afternoons of the course will include practical classes, in which delegates will have the opportunity to work through various problems using a finite element package. These sessions will include linear problems, covering both isotropic and anisotropic materials, and non-linear problems. Tutorial sessions will also be timetabled for discussion and application of constitutive models.

LECTURERS

Joint Course Directors

Professor Andrew Crocombe: Professor in Mechanics of Structural Bonding. Professor Crocombe gained BSc(Eng) and PhD in Mechanical Engineering at the University of Bristol. Principal area of research involves experimental and numerical analyses in structural adhesive bonding, simulating typical service conditions including: creep, fatigue and environmental degradation. Research is also being carried out in soft tissue and skeletal bio-mechanics. Extensive use is made of both in-house and commercial non-linear FEA in all of this work , which has been published widely.

Professor Paul A Smith: Professor of Composite Materials in the School of Engineering at the University of Surrey. Professor Smith graduated from the Engineering Department at the University of Cambridge where he subsequently gained his PhD working on joints in composite materials. He joined the University of Surrey in 1986 and his current research interests are concerned with experimental characterisation and analytical modelling of failure processes in a range of materials, in particular composites, with a major aim being to develop mechanism-based models for use in engineering design. He has published extensively and lectured in the UK and overseas. He is Editor-in-Chief of the journal Composites Part A.

Lecturers

Dr Marcello Grassi: After gaining a degree in Aerospace Engineering at the University of Naples (Italy), Marcello Grassi completed a PhD at Cranfield University where he successfully carried out numerical modelling studies of novel composite material architectures. He then joined QinetiQ in the Future Systems Technology Division, where he is involved in research and consultancy programmes looking at design, modelling and simulation aspects of composite materials and structures for the Ministry of Defence and some of the major commercial aerospace companies. He has been author and co-author of many conference and journal papers.

Professor Felicity Guild: Professor of Composite Materials in the Department of Materials Queen Mary, University of London. She has published widely in the fields of composite materials and finite element analysis. Her research has included the use of finite element analysis to study mechanical properties and fracture of composite materials and adhesive joints on both the microstructural and macrostructural scales.

Dr Tina Lekakou: Senior Lecturer in the School of Engineering at the University of Surrey. She gained her PhD at Imperial College working on reaction injection moulding. After a further period of research on multi-phase systems in the Mechanical Engineering Department at Imperial College, she took up her present appointment in 1989. Her current research focuses on the study of polymer and composite processing including specifically Resin Transfer Moulding, injection moulding of liquid crystalline polymers and processing of polymer blends. She has also research projects on vascular grafts, polymer scaffolds and microfluidic device fabrication for biomedical applications.

Dr Michael Neale: First degree in Mechanical Engineering, MSc in Biomedical Engineering and a PhD in Thermal Physiology developing and applying numerical techniques to simulate the human thermal response. Currently he is Head of the Numerical Simulation Group at the Transport Research Laboratory (TRL) in Crowthorne, Berkshire. At TRL he has worked on a variety of transport safety related research projects, applying numerical techniques in the investigation of vehicle occupant and pedestrian safety, motorcycle helmet concept developments, vehicle crashworthiness, occupant restraint system development and injury biomechanics, and has authored a number of published papers on this work.

Dr Jingzhe Pan: Lecturer then Senior Lecturer in the Solid Mechanics Group of the School of Engineering at the University of Surrey since 1994. Prior to that (1991-1994), he was a Research Associate in the Materials Group at the Engineering Department of Cambridge University. His major research interests include (a) Computer simulation of microstructure evolution of materials, (b) Modelling of the sintering process of fine powder compacts, (c) Modelling of creep failure of engineering alloys and (d) Modelling of thermo-shock of ceramics.

Mr Darrel Sinclair: Darrel was sponsored by British Aerospace (Space Systems) during his BEng in Aeronautics and Astronautics at Southampton University. He subsequently gained an MPhil at the University of Surrey. This work included the development of specialised pre and post processing for the analysis of adhesively bonded structures. Since 1995 Darrel has worked in customer support and training for MSc Software Ltd, who develop leading engineering analysis software such as Patran and Nastran).

Dr Jesus Talamantes-Silva: PhD, University of Sheffield; works in the Department of Mechanical Engineering at the University of Sheffield. His research involves the development and use of finite element and related techniques for engineering simulations. In particular, those linking the microstructure to the properties of the material. His major research interests include: (a) Finite element modelling of thermo-mechanical processes, (b) CAFE modelling (Cellular Automata Finite Element), (c) Hybrid modelling and (c) Tribology of hot metal forming.

Dr Magd Abdel Wahab: Senior Lecturer in Mechanics of Materials and Structural Bonding in the School of Engineering, University of Surrey. He received his BSc, 1988, in Civil Engineering and his MSc, 1991, in Structural Mechanics, both from Cairo University. Dr Wahab completed his PhD in Fracture Mechanics in 1995 at KU Leuven, Belgium, before joining UniS as a lecturer in 1999 and promoted to Senior Lecturer in 2003. He has published more than 100 papers and technical reports in fracture mechanics, finite element, bonded joints and dynamics of structures. His research interests include fracture, creep and fatigue of adhesively bonded joints and vibration of structures.

UNIVERSITY OF SURREY

The University of Surrey is a Technological University with approximately 8,500 students in Schools of Engineering, Science and Human Studies. The campus is situated on the outskirts of Guildford, below the Cathedral and just 20 minutes walk from the shopping centre and the main line railway station.

Guildford is a thriving business and shopping centre, easily accessible from London, 35 minutes by fast train (two each hour) and 30 miles by car on a fast road. Both London airports are just 40 minutes by car; with good public transport connections.

A large Research Park has been established on University land on the other side of the A3 from the main campus. This provides facilities for industrial companies to conduct research, and operates in conjunction with the research schools already established at Surrey. Several major research establishments are also within a few miles and many collaborative research projects with the University have resulted from this proximity.

RESEARCH IN THE SCHOOL OF ENGINEERING

Within the Composites Research Group work on the properties of composites encompasses characterisation and associated analytical and finite element modelling at the constituent, laminate and structural element level. A number of polymer, metal and ceramic composite materials and reinforcement types (short fibre, continuous fibre and a range of woven fabric architectures) are under investigation. Smart technologies for composites are also being developed. Another major area of interest is processing of polymers (notably blends and liquid crystalline polymers) and polymer matrix composites, especially with regard to the effects of resin flow and the drape of fibre mat on final microstructure and properties.

Research within the Solid Mechanics group is undertaken in two main areas; Adhesive science and structural bonding and Micro-structural evolution due to solid state diffusion. In the first, research is directed towards predicting the response of bonded structures to service loading conditions. These include quasi-static, creep and fatigue loading and the effect of environmental degradation. The general approach involves combining materials and structural testing with numerical modelling at both the micro-structural and macroscopic level. Materials modelling involved with this activity includes the development of visco-plastic models for polymers, progressive material rupture and damage mechanics. Research in solid state diffusion seeks to link general constitutive laws to the material behaviour at the microstructural level. This has found application to a wide range of problems from the sintering process of the fine powder compact to the creep failure of engineering alloys. This work has fundamentally changed aspects of classical sintering theory and has resulted in the second generation of constitutive models.

The School has a comprehensive range of equipment for mechanical testing, including fatigue, creep and environmental facilities. The MicroStructural Studies Unit (MSSU) has one of the most comprehensive ranges of electron microscopes and associated instrumentation to be found in any research institution. Likewise, the Surface Analysis

Laboratory, directed by Professor J F Watts, is recognised as one of the leading groups in the world.

MODULAR MSc PROGRAMME

This short course is offered as a module in our part-time or full-time Modular MSc Programme in Advanced Materials.

The **Advanced Materials Programme** aims to study the structure, processing and properties of a range of advanced materials and associated analytical techniques. The principal objective of the programme is that science and engineering graduates will be equipped with a thorough understanding of several classes of advanced materials and of means by which they can be characterised.

The modules available are set out below. Each module may be taken as an individual short course.

SE3M11	Introduction to Materials Science and Engineering
SE3M12	Introduction to Physical Metallurgy
SE3M41	Ceramics and Ceramic Matrix Composites
SE3M14	Polymers for Advanced Applications
SE3M15	Introduction to Composite Materials Science
SE3M16	Characterisation of Advanced Materials
SE3M56	Nanomaterials
SE3M18	Surface Analysis: XPS, Auger and SIMS
SE3M19	Scanning Probe Microscopy
SE0M20	Research Methods
SE3M26	Materials under Stress: An Introduction to Fracture Mechanics and Fatigue
SE3M27	Adhesive Bonding Technology
SE3M28	Managing Materials Cycles
SE3M29	Materials for Biomedical Engineering Applications
SE3M31	Surface Engineering
SE3M32	Numerical Modelling in Materials Engineering
SE3M37	Composite Materials Technology
SE3M38	Corrosion Engineering
SE3M39	Light Metals and Alloys
SE3M40	The Science of Adhesion

Candidates who choose to conduct a project need to complete 7 taught modules. Candidates who choose to conduct an independent study need to complete 9 taught modules.

If a student wishes to take ‘Introduction to Materials Science and Engineering’ it must be one of their first three modules. This module is not normally available to students who hold a degree in Materials Science and Engineering.

If a student wishes to take ‘Introduction to Physical Metallurgy’ and ‘Light Metals and Alloys’ they must take the introductory module first.
If a student wishes to take ‘Introduction to Composite Materials Science’ and ‘Composite Materials Technology’ they must take the introductory module first.

REGISTRATION FORM
NUMERICAL MODELLING
UNIVERSITY OF SURREY, GUILDFORD, UK
20 – 24 June 2005

Name .... Title ....

Company/Affiliation: ....

Address: ....

....

Tel. No: ....email address...

Name of Approving Manager: ....

			£
1.	**STANDARD COURSE FEE**		995.00
	each delegate will receive one set of Lecture Notes		
	Reduced fee for <u>registered</u> MSc students		970.00
2.	**MEALS - Coffee, Lunch and Tea**		
	from Coffee 23 June – Lunch 27 June	5 days	50.00
3.	**ACCOMMODATION**		
	Room + Breakfast 20-24 June (4 nights)		160.00
	Room + Breakfast 19/20 June (1 night)		40.00
4.	PARKING		
	Five days at £2 per day		10.00

Please complete the following as applicable:
Please charge to the following credit card No ....

Expiry Date ....

Name of Cardholder ....

Type of Card: Visa/ Mastercard / American Express / Other: ....

I enclose a cheque for £ ....

Please invoice myself/my company for £ ....

Order No or Reference/Invoice Address ....

Company VAT registration number ....

Special dietary requirements, if any ....

I am/am not registered for the MSc in Advanced Materials Technology/Materials for Engineering Applications
Cheques should be made payable to the "University of Surrey" in £ sterling.

<u>This form should be returned to:</u>

Derek Saunders, Manager of Continuing Education,
School of Engineering (D3) University of Surrey Guildford Surrey GU2 7XH
Tel: 01483 689612 - FAX: 01483 686671 - email: D.Saunders@surrey.ac.uk