Postgraduate Studies

1997-98

EPARTMENT OF

Mechanical Engineering

THE HONG KONG UNIVERSITY OF
SCIENCE AND TECHNOLOGY
香港科技大學

CONTENTS

Introduction

Mechanical engineering is a broad-based discipline that applies technical skills to design the most efficient mechanical and thermal systems, and manufacture components of these systems at the lowest possible costs. Mechanical engineers can find employment in almost every industry including, for example, building services, power generation, textiles, electronics, computer, marketing, management and sales. The Mechanical Engineering Department at HKUST offers four degree programmes, namely, Bachelor of Engineering (BEng), Master of Science (MSc), Master of Philosophy (MPhil), and Doctor of Philosophy (PhD). The BEng in Mechanical Engineering is a three-year programme that prepares students to enter professional practice or to continue advanced study in mechanical engineering and/or management field after graduation.

The MSc and MPhil programmes normally take two years to complete. The MSc and MPhil programmes focus on strengthening the students' background in mechanical engineering and exposing them to engineering research and development. The MSc is a taught degree whereas the MPhil programme is a research degree programme which requires both course work and a research thesis. The PhD degree requires a minimum of three years' study and research after a BEng or BSc degree, including the successful completion of a PhD thesis. The PhD programme aims at imbuing students with in-depth knowledge in mechanical engineering and the capability of conducting independent and original research in their chosen specialisation.

Academic Staff

Head of Department:
Ping CHENG (PhD, Stanford)

Professors:
Jay-Chung CHEN (PhD, Caltech)
Pin TONG (PhD, Caltech)
Tong-Xi YU (PhD, Cambridge)

Associate Professors:
Chin-Tsau HSU (PhD, Stanford)
See-Chun KOT (PhD, Cornell)
Matthew Ming-Fai YUEN (PhD, Bristol)
Tong-Yi ZHANG (PhD, Sci. & Tech. Beijing)

Assistant Professors:
Lilong CAI (PhD, Toronto)
Yongsheng GAO (PhD, Birmingham)
Jang-Kyo KIM (PhD, Sydney)
David Chuen-Chun LAM (PhD, California)
Steve Hong-Keung LEE (PhD, Rutgers)
Ricky Shi-Wei LEE (PhD, Purdue)
Yang LENG (PhD, Virginia)
Wei-Ping LI (PhD, MIT)
Hui-He QIU (PhD, Erlangen)
Qing-Ping SUN (PhD, Tsinghua)
Wai Ming TO (PhD, London)
Jing-Shen WU (PhD, Sydney)
Tian-Shou ZHAO (PhD, Hawaii)
Yitshak ZOHAR (PhD, Southern California)

Adjunct Professor
Yiu-Wing MAI (PhD, Hong Kong)

Postgraduate Programmes

The Department offers postgraduate programmes leading to the degrees of Master of Science (MSc), Master of Philosophy (MPhil), and Doctor of Philosophy (PhD) in Mechanical Engineering. The normal duration of residence and the course and thesis requirements for the degrees are described below.

There are three areas of concentration in postgraduate instruction and research in the Mechanical Engineering Department: (1) Mechanics and Materials, (2) Mechatronics and Manufacturing., and (3) Thermal and Environmental Engineering.

Master of Science (MSc) in Mechanical Engineering
The MSc programme is for students who intend to pursue further postgraduate studies or advanced work in industry. The MSc degree is a taught degree which normally requires one and a half years of full-time study. A student is required to complete 30 credits of approved courses. Up to six of the credits can be an MSc project under the supervision of a qualified adviser from either the University or industry.

Master of Science (MSc) in Environmental Engineering
This is an interdisciplinary degree programme which is part of the MSc in Environmental Science and Engineering programme at HKUST. The participating engineering departments in this programme are the Chemical, Civil and Structural, and Mechanical Engineering departments. Several science departments also contribute to the overall programme. Students are required to take the General Core Courses (9 credits) which include Environmental Management, Environmental Chemistry and Microbiology and Measurements of Pollutants. In addition, 12 credits of the engineering foundation courses, 3 to 6 credits of electives and 3 to 6 credits of MSc project are required. Part-time enrolment is welcome.

Master of Science (MSc) in Materials Science and Engineering
This multi-disciplinary programme is jointly offered by the Departments of Chemistry, Physics, Chemical Engineering, Electrical and Electronics Engineering, and Mechanical Engineering. For details, please contact the programme co-ordinator, Professor Hiroyuki Hiraoka of Chemistry Department.

Master of Philosophy (MPhil) in Mechanical Engineering
The MPhil programme differs from the MSc programme in that students are required to complete only 12 credits of postgraduate coursework. In addition, students must complete a thesis to demonstrate competence in engineering research. If the student participates in an industrial project and writes a thesis on a work-related topic, the thesis will be supervised jointly by a faculty member of the

Department and a representative from the participating company. The MPhil degree normally takes two years of full-time study.

Doctor of Philosophy (PhD) in Mechanical Engineering

The PhD degree is awarded upon the successful completion of an advanced study programme which includes a minimum of 24 credits of postgraduate courses and a thesis of significant original research. If a student enters the PhD programme with an MPhil/MSc degree, he/she should complete 12 credits of postgraduate courses, together with a PhD thesis.

The doctoral degree normally takes four years of full-time study at HKUST beyond a bachelor's degree, or a minimum of two years at HKUST beyond a master's degree.

After a student enters the PhD programme, an advisory committee will be established to supervise the programme of study and thesis. To become a doctoral candidate, the student must pass a qualifying examination (oral) no later than the end of the third semester of postgraduate study at HKUST. If the student fails in the oral qualifying examination, he/she can re-take it once in the following semester. Prior to the oral examination, the student must submit a written report on his/her research work accomplished since he/she has enrolled in the PhD programme and a proposal for future work. The purpose of the qualifying examination is to evaluate the student's ability in conducting independent research and his/her preparation for postgraduate study in the chosen area of concentration.

Upon completion of the postgraduate study programme and the thesis, the candidate is required to defend the thesis in front of a thesis examination committee.

Postgraduate Courses

Postgraduate courses are offered in the major research areas described in this prospectus, supplemented by engineering mathematics courses. Postgraduate courses are numbered at 500 level or above. The instructional hours per week and the course credits are represented by course vector using the format : [lecture hours - tutorial hours - laboratory hours : course credits]. The following is a planned course list for the next two academic years. Courses will be offered upon enough enrolment.

MECH 501 Foundation of Solid Mechanics [3-0-0:3]
Continuum concept for deformation of solids; analysis of stress and strain; constitutive equations; solution of problems relevant to materials processing, fracture mechanics and structural analysis; energy methods and numerical solutions.
Background: MECH202, MECH303

MECH 502 Engineering Plasticity [3-0-0:3]
Macroscopic descriptions of plastic behaviour of materials; inelastic and visco-plastic deformation in non-metals; macroscopic 3-D constitutive relations; simple elastic-plastic problems; mechanics of metal forming; limit analysis; plastic instability.
Background: MECH202, MECH303

MECH 507 Mechanical Vibrations [3-0-0:3]
Normal mode analysis for lumped parameter and continuous systems; forced vibrations; whirling, receptance analysis; approximate and numerical methods; experimental modal analysis; random vibrations
Background: MECH102

MECH 509 Impact Engineering [3-0-0:3]
Elastic stress waves; 1-D elastic-plastic waves; rate dependency of dynamic behaviour of materials; characterization of intense dynamic loads; dynamic response of structures to impact and pulse loading; dynamic failure of structures; impact energy absorbers.
Background: MECH102, MECH202

MECH 521 Fluid Dynamics [3-0-0:3]
Tensor notation, derivation of Navier-Stokes equations, viscous flow, flow separation, boundary layer, flow instability, turbulent boundary layer, stratified flow.
Prerequisites: MECH121 and MATH101

MECH 522 Turbulent Flow [3-0-0:3]
Emphasis on engineering methods. Averaged (Reynolds) equations for momentum, energy, heat and species transfer; turbulence: production, dissipation, and scaling laws; free and bounded turbulent shear flows in jets, pipe and channel flows, boundary layers, plumes, dispersion problems, etc. Introduction to more complex closure schemes and statistical methods in turbulence.
Prerequisite: MECH 521

MECH 523 Computational Fluid Dynamics [3-0-0:3]
Numerical analysis techniques for simulation of viscous incompressible flows; finite-difference, finite-element, spectral methods; time-step size; accuracy, stability, and generality considerations; diffusion, dispersion; stream function and primitive-variable formulations; examples from internal and external flows, and heat transfer.
Prerequisite: MECH 521

MECH 526 Micrometeorology and Atmospheric Diffusion [3-0-0:3]
Atmospheric boundary layer, lapse rate, stability classification, atmospheric turbulence, dispersion modelling, boundary layer wind-tunnel.
Prerequisite: MECH 521

MECH 528 Two-Phase Flow [3-0-0:3]
Topics include: boiling, cavitation, condensation, and atomisation; dynamics and thermodynamics of forced-convection two-phase flow with boiling and/or evaporation; thermal and hydrodynamic stability of two-phase flows; applications to water and liquid metal.
Prerequisite: MECH 221

MECH 531 Advanced Heat Transfer [3-0-0:3]
Heat transfer in solids and fluids; similarity between heat, momentum, and mass transfer in forced and buoyancy driven flows; diffusion, internal and external forced and natural convection, boiling, condensation, and radiative heat transfer; heat, momentum, and mass transfer with phase change in liquid-solid and liquid-vapour systems.
Prerequisites: MECH 231 and MECH 521

MECH 532 Convective Heat and Mass Transfer [3-0-0:3]
Predictions of heat and mass transfer based on analytical and numerical solutions, comparison of predictions and experiments; laminar and turbulent boundary layer heat transfer by similarity, integral and superposition methods; effects of roughness, curvature, transpiration and high turbulence on heat transfer; forced and free convections for duct flows, boundary layer flows, free-shear flows and buoyant flows; numerical methods and computer applications in heat and mass transfer.
Prerequisites: MECH 231 and MECH 521

MECH 533 Thermo Fluid Flows in Porous Media [3-0-0:3]
Derivation of governing equations in transport phenomena in porous media; closure modelling, Darcian and non-Darcian flows, convective heat and mass transfer, thermal dispersion; thermally non-equilibrium models; onset of instability.
Prerequisite: MECH 231

MECH 535 Combustion [3-0-0:3]
Comprehensive treatment of combustion principles; flammability and explosion limits; diffusion and premixed flames; laminar and turbulent combustion, ignition, propagation, and combustion instability; exothermic hypersonic flows; supersonic combustion; droplet, jet and coal combustion; engine combustion; modelling and numerical simulation of combustion processes.
Prerequisites: MECH 121 and MECH 231

MECH 541 Advanced Mechanical Behaviour of Materials [3-0-0:3]
Discussions of relationships between microstructure and mechanical behaviour in crystalline materials; temperature-dependent deformation in elasticity, viscosity and creep; embrittlement, fatigue and fracture of engineering materials; strengthening mechanisms in crystalline materials.
Prerequisite: MECH 242

MECH 542 Engineering Fracture Mechanics [3-0-0:3]
Linear elastic fracture mechanics; energy concept, J-Integral and fracture criteria; mixed mode problems; elastic-plastic fracture; fracture of composite materials; computational methods and experimental techniques; fatigue and damage tolerance.
Background: MECH202, MECH303, MECH501

MECH 543 Theory of Dislocations [3-0-0:3]
Basic treatment of the structure and properties of dislocations in crystals; stresses and energies of straight and curved dislocations; dislocation dynamics; effects of crystal structure on dislocations; interactions between dislocations and point defects; groups of dislocations; applications to the mechanical properties of materials.
Prerequisite: MECH 101

MECH 544 Thermodynamics of Solids [3-0-0:3]
Advanced treatment of thermodynamics of solutions, heterogeneous reactions, and associated topics of interest in metallurgy; free energy, activity and phase equilibria.

MECH 545 Physical Metallurgy [3-0-0:3]
Structure-property relationships in metallic alloys; phase transformation and strengthening mechanisms in metals and alloys; mechanical properties. Structural features such as structural stability, grain size, interstitial and substitutional solutes, precipitates, second-phase particles, eutectics and composites.
Prerequisite: MECH 241

MECH 547 Composite Technology [3-0-0:3]
The behaviour of filamentary composite materials composed of boron, graphite, glass, and Kevlar fibres embedded in a matrix; metal and ceramic matrix composites; material properties of fibres and matrices; micromechanics, anisotropic elasticity, and laminated plate theory; failure analysis, buckling, sandwich construction, thermal and moisture stresses, and interlaminar stresses; design concepts and cost-effective applications.
Prerequisite: MECH 241

MECH 548 Tribology [3-0-0:3]
Geometric, chemical, and physical characterisation of surfaces; theories of friction and wear of metals, polymers, and ceramics; delamination theory, erosion, boundary lubrication and solid film lubrication; rolling contact problems; tribological problems in magnetic recording and electrical contacts; monitoring and diagnosis of friction and wear.
Prerequisite: Permission of instructor

MECH 552 CAE Systems [3-0-0:3]
Computer graphics; data structures; geometric modelling; NC cutting path planning; process planning; mesh generation techniques for analysis; computer integrated manufacturing; intelligent CAD systems.

MECH 561 Modern Control Theory [3-0-0:3]
Modelling of physical systems; introduces modern system and control theory; basic systems concepts; state-space and I/O representation; controllability; observability; stability; state and output feedback; observer; Kalman filters; linear optimal regulators; applications to mechanical system.
Prerequisites: MECH 261 and MATH 152
(This course is co-listed with ELEC 560)

MECH 562 Multivariable Control Systems [3-0-0:3]
Integrated state-space and frequency domain description; analysis and synthesis of linear multivariable control systems; closed-loop stability; performance and robustness trade-offs; multivariable Nyquist criterion; singular-value decomposition and application; tracking and disturbance rejection; linear quadratic optimal control.
Prerequisite: MECH 261
(This course is co-listed with ELEC 561)

MECH 563 Digital Control Systems [3-0-0:3]
Computer interfaces and data acquisition; sampling, z-transform and digital filters and discretisation of continuous compensation; analysis and synthesis of sampled-data control systems using frequency and state-space design techniques; sample rate selection; problems with discretisation and numerical roundoff; laboratory project emphasise practical digital techniques.
Prerequisite: MECH 261
(This course is co-listed with ELEC 563)

MECH 571 Robot Design and Control [3-0-0:3]
Analysis, design, and control of robot manipulators; geometry kinematics, statics, and dynamics of manipulators; sensors and actuators, arm design; position and trajectory control, compliant motion control; robustness and adaptation in robot control and performance trade-offs.
Prerequisites : MECH 261, MECH 503, and MECH 505

MECH 581 Experimental Methods in Solid Mechanics [2-0-2:3]
Introduction to instrumentation and principles of measurement; data acquisition and processing; error analysis; strain gauge techniques; theory and application of optical methods; nondestructive inspection and evaluation; fracture testing methods.
Background: MECH202, MECH303

MECH 582 Experimental Methods in Thermofluid [2-0-2:3]
Methods of experimental design; data acquisition and processing in thermofluid areas; advanced remote sensing and optical diagnostic methods for flow velocity; particle dynamics and properties; temperature field measurements and flow visualization.

MECH 583 Experimental Methods in Air Pollution [2-1-4:3]
Methods of experimental design, sampling and measurement of particulate and gaseous pollutants. Emphasis is on field measurement techniques: data acquisition and sampling systems, instrument calibration, and particle characterisation.
Prerequisite: MECH 525

MECH 591 Applications of Complex Variables [3-0-0:3]
Complex numbers, analytic functions, contour integrals, conformal mapping, special functions, asymptotic analysis, integral transforms, applications.
Prerequisite: MATH 101

MECH 593 Finite Element Methods [3-0-0:3]
Finite element formulation; variational principles for structural and continuum mechanics; numerical interpolation and integration; plane stress and plane strain analysis; plate bending and three dimensional solids; solution of large systems of algebraic equations.
Background: MECH202, MECH303.
Exclusion: CIVL512

MECH 609 Seminar in Mechanical Engineering [1-0-0:0]
Technical seminars in various disciplines of mechanical engineering; presentations are given by students, faculty, or guest speakers; all full time students are required to participate every semester.

MECH 691 Special Topics in Mechanical Engineering [3-0-0:3]
Selected topics in mechanical engineering of current interest to the Department and not covered by existing courses.

MECH 697 MSc Project I [0-1-6:3]
An independent project carried out under the supervision of an ME faculty member.

MECH 698 MSc Project II [0-1-6:3]
Continuation of MECH 697.
Pre-requisite: MECH697

MECH 699 MPhil Thesis Research

MECH 799 PhD Thesis Research

Facilities

The Department of Mechanical Engineering has engineering workstations and graphic terminals in the computation laboratory and extensive state-of-the-art facilities. The Department has the following laboratories available for instruction and research:

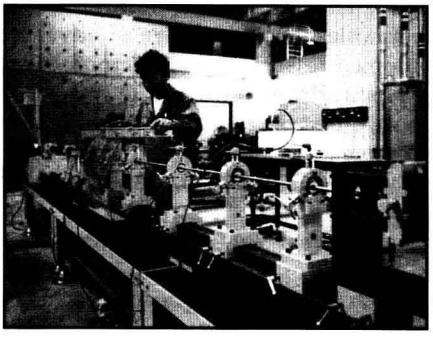
Automation/Manufacturing Laboratory
CAD Research Laboratory
Controls & Robotics Laboratory
Design Project Laboratory
Energy Technology Laboratory
Experimental Method Laboratory
Fluid Engineering Laboratory
Materials Laboratory
Micro Machine Laboratory
Solid Mechanics Laboratory
Structural Dynamics Laboratory

In addition to departmental facilities, students and staff have access to the University's central facilities which include: Electronic Support Shop, Instrumentation Pool, Machine Shop, CAD/CAM Laboratory, Centre for Advanced Engineering Materials, and Materials Characterisation and Preparation Laboratory. The University also maintains state-of-the-art academic computing facilities.

Major Research Areas

Research in the Department focuses on three areas which are relevant to the economic development of Hong Kong. These areas are described below.

1. Mechanics and Materials Engineering



Research in mechanics involves the application of mathematics, theoretical mechanics and computational skills to the design and analysis of mechanical components and systems. Work includes technical assessments, computer modelling and testing the static and dynamic behaviour of structures and continua, the mechanical behaviour of materials, computational mechanics for analysing solids and structures, and the study and control of vibration and failure of mechanical components and systems.

Materials engineering focuses on characterising new materials, developing processes for controlling their properties and their economical production, generating engineering data necessary for design, and predicting the performance of products. Potential research topics include: interface properties of composites; fracture and fatigue; residual life assessment; thermo-mismatch of electronic board metal forming; plastics flow in injection molding; instrumentation and measurement techniques.

2. Mechatronics and Manufacturing

Manufacturing and mechatronics are the heart of mechanical engineering in which engineers conceive, design, build and test innovative solutions to "real world" problems. The activities include Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM), mechatronics, intelligent systems for design, manufacturing, inspection and maintenance.

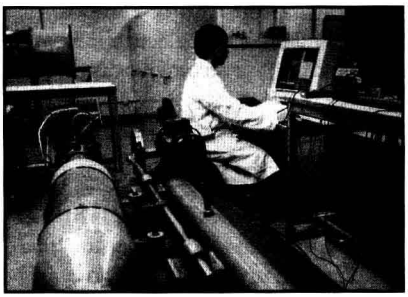
Scientific research covers topics such as control theories, motion control, sensor and measurement technologies, process mechanics, rapid part manufacturing, precision engineering, design analysis and theory, and geometric modeling.

Research efforts are integrated to focus on a number of application areas: polymer processing, electronic packaging, garment manufacturing, intelligent manufacturing systems, mechatronics, and CAD/CAM.

The group runs the CAD research, automation, control and robotics, manufacturing laboratories which have a wide range of advanced engineering, control and CAD/CAM software. The laboratories also have advanced equipment such as microprocessor development systems, CNC machines, robots, metrology and measurement equipments. Some of them are provided by the University's CAD/CAM Centre.

3. **Thermal and Environmental Engineering**

Research in thermal engineering includes (i) the investigation of heat transfer and fluid flow in porous media with applications to geothermal recovery and heat pipes, (ii) the study of oscillatory flow and heat transfer with applications to Stirling machines and cryocoolers, (iii) the innovative design of heat pumps for thermal control of indoor environment, and (iv) the development of new technology for the cooling of electronic equipment and waste heat recovery. Research activities in environmental engineering include the development of new waste-treatment methods to reduce the discharge of pollutants and technologies to halt the degradation of and/or to rejuvenate already polluted surroundings. Work includes technical assessments, computer modeling, studies of the phenomena involved, and studies of environmental control for options. Field work will also undertaken to collect critical data needed to evaluate systems, concepts and models.



Faculty Profiles

Academic staff currently on board are presented below. When the department becomes mature, more than 25 academic staff are expected to have joined the department.

Ping CHENG (PhD, Stanford, 1965)
Department Head
Professor

Professor Cheng obtained his B.S. in Mechanical Engineering from Oklahoma State University, his M.S. in Mechanical Engineering from Massachusetts Institute of Technology, and his Ph.D. in Aeronautics and Astronautics from Stanford University. Prior to joining HKUST, he was Chairman (1989-94) and Professor (1974-1994) of the Mechanical Engineering Department at the University of Hawaii. Other academic experiences include appointments as a Visiting Professor at Stanford University 1976-77, and a Guest Professor at the Technical University of Munich in 1984. A Fellow of the American Society of Mechanical Engineers (since 1986), he has published more than 133 refereed papers, including review articles in the *Handbook of Heat Transfer and Advances in Heat Transfer*. Professor Cheng is an associate editor of the *AIAA Journal of Thermophysics and Heat Transfer*, and a member of the editorial broads of *Numerical Heat Transfer*, Experimental Heat Transfer, and Journal of Porous Media. He is also the recipient of 1996 Heat Transfer Memorial Award in Science given by the American Society of Mechanical Engineers.

Research interests:

Convection and phase change heat transfer in porous media; periodically reversing flow and heat transfer; radiative heat transfer.

Representative publications:

Zhao, T. and **Cheng, P.**, 1996, "The Friction Coefficient of a Fully-Developed Laminar Oscillatory and Reversing Flow in a Pipe", *Int. J. Heat and Fluid Flow*, Vol.17, pp.167-172.

Chao, B.T., Wang, H. and **Cheng, P.**, 1996, "Stagnation Point Flow In a Catalytic Bed", *Int. J. Heat Mass Transfer*, Vol.39, pp.3003-3019.

Hsu, C. T., **Cheng, P.** and Wong, K.W., 1995, "A Lumped Parameter Model for Stagnant Thermal Conductivity of Spatially Periodic Media", *J. Heat Transfer*, Vol.117, pp.264-269.

Chao, B. H., **Cheng, P.**, and Le, T., 1994, "Free-Convective Diffusion Flame Sheet in Porous Media", *Combustion Science and Technology*, Vol.99,pp. 221.

Malashetty, M., **Cheng, P.**, and Chao, B.H., 1994, "Thermal Instability in a Horizontal Porous Layer Filled with a Reacting Fluid", *Int. J. Heat Mass Transfer*, Vol.37, pp. 2901-2908.

Pop, I., Ingham, D. and **Cheng, P.**, 1993, "Transient Free Convection between Two Concentric Spheres Filled with a Porous Medium", *J. Thermophysics and Heat Transfer*, Vol.7, pp. 724-727.

Cheng, P., Hsiao, S. H. and Chen, C. K., 1992, "Nonuniform Porosity and Thermal Dispersion Effects on Natural Convection about a Heated Horizontal Cylinder in an Enclosed Porous Medium", *Int. J. Heat Mass Transfer*, Vol.35, pp. 3407-3418.

Pop, I. and **Cheng, P.**, 1992, "Flow Past a Circular Cylinder Embedded in a Porous Medium Based on the Brinkman Model", *Int. J. of Fluid Flow*, Vol.30, pp. 257-262.

Hsu, C. T. and **Cheng, P.**, 1991, "A Singular Perturbation Solution for Couette Flow over a Semi-Infinite Porous Bed", *Fluid Engineering*, Vol.113, pp. 137-142.

Hwang, T. H., **Cheng, P.**, and Lin, J. K., 1990, "Heat Transfer of Laminar Mist Flow in Concentric Annuli", *Numerical Heat Transfer*, Vol.18, pp. 243-258.

Hsu, C. T. and **Cheng, P.**, 1990, "Thermal Dispersion in a Porous Medium", *Int. J. Heat Mass Transfer*, Vol.8, pp. 1587-1597.

Cheng, P. and Vortmeyer, D., 1988, "Transverse Thermal Dispersion and Wall Channeling in a Packed Bed with Forced Convective Flow", *Chemical Engineering Science*, Vol.43, pp. 2523-2532.

Cheng, P., 1985, "Geothermal Heat Transfer", Chapter 11, *Handbook of Heat Transfer Applications*, edited by W. Rohsenow, J. P. Hartnett and E. N. Ganic, pp.11.1-11.54.

Cheng, P.., 1981, "Film Condensation about an Inclined Surface in a Porous Medium", *Int. J. Heat Mass Transfer*, Vol.24, pp. 983-990.

Cheng, P., 1978, "Heat Transfer in Geothermal Systems", *Advances in Heat Transfer*, Vol.14, pp. 1-105.

Cheng., P. and Minkowycz, W. J., 1977, "Free Convection about a Vertical Flat Plate Embedded in a Porous Medium with Application to heat Transfer from a Dike", *J. Geophysical Research*, Vol. 82, pp. 2040-2044.