Mechanical Engineering Postgraduate Programme in Asset Integrity Management

Department of Mechanical and Aeronautical Engineering

Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

Universiteit van Pretoria
University of Pretoria
Yunibesithi ya Pretoria

Centre for Asset Integrity Management

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Make today matter

Mechanical engineers can contribute significantly to optimising the reliability, structural integrity and performance of physical assets. This unique programme equips engineers with expertise in fields such as mechanical design, finite element analysis, fatigue, condition monitoring, reliability engineering and maintenance practice.

A Mechanical Engineering approach to Asset Integrity Management

The cost of managing the physical assets of a business is a significant component of the total operating cost. These physical assets include items such as plant equipment, machinery, buildings, vehicles or any other physical assets of value to the business. In addition, the non-availability of such assets often impact negatively on the customer, usually in the form of services or products not being delivered on time due to production equipment break down.

Asset integrity management ensures fitness-for-service of mechanical assets over their entire life cycle, while extending their remaining life in the most reliable, safe, and cost-effective way.

In order to optimally manage such complex assets requires a profound understanding of asset management principles in general, and specifically the importance of the technical mechanical engineering aspects related to asset integrity, i.e. the fitness for purpose of such assets. This draws heavily on expertise in fields such as mechanical design, finite element analysis, fatigue, structural testing, condition monitoring, non-destructive testing, residual life modelling, fault and failure prognostics, and reliability-centred maintenance, all within the context of the asset life cycle phases.

The above represents unique and interesting opportunities for mechanical engineers interested in optimising the reliability and performance of physical assets through integrating these specialised technical principles into the life cycle management and decision environment.

Objectives and structure of the Programme

This postgraduate programme consists of a course-based honours degree followed by a research dissertation for masters degree purposes. The honours degree can be completed full-time over a one-year period, or on a part-time basis, typically over two to three years. Completion of the masters degree dissertation normally requires one year full-time, or two to three years' part- time research. The programme is structured to achieve specific objectives.

Objectives of the Postgraduate Programme

The Honours Degree

- Theoretical understanding of the technical and management aspects of asset management.
- Exposure to the application of theoretical concepts through industry relevant case studies and assignments.
- Direct exposure to thought leaders in various disciplines.
- Interaction with a broad range of students.

Masters Degree

- Achieve specialisation in a specific area.
- Produce novel research – publication of research results in a journal is required.
- Career enhancement by conducting research on industry/company related issues.
- Supervision by leaders in Asset Management.

Students who have completed a BEng, BSc or BTech degree can apply for admission.

The first part (honours degree) of the programme is course-based, with the student expected to complete at least eight 16-credit modules (128 credits in total). This is in line with the SAQA standard of 1280 notional hours of study, and typically consists of 20 lecture hours per module. The balance of study time made up of homework assignments. The second part of the programme entails extensive research which culminates in a dissertation.

A student will be awarded an honours degree, i.e. either a BEng (Hons,) or BSc (Hons)(App) (Sci) after completion of the courses, and a masters degree, i.e. either an M.Eng or MSc (App) (Sci) degree after completion of the research dissertation.

This programme is unique in that students can choose from a large number of course modules related to asset integrity management during the honours year, in preparation for the masters dissertation.

Honours degree modules

Students must construct a curriculum totalling 128 credit modules, selecting from the following 16 and 32 credit modules related to asset integrity management. It is advised that the modules are selected in conjunction with the student's supervisor, and considering possible research topics for the second-year masters dissertation.

MEE 781 Advanced finite element methods (16 Credits)

Linear and geometrically non-linear finite element formulations. Continuum mechanics: deformation gradient, Green-Lagrange strain, objectivity and hyperelasticity. Contact, multi-point constraints and arc-length control. Mixed formulations for incompressibility. Small strain plasticity and the radial return algorithm.

MBB 780 Control systems (16 Credits)

Introduction to state space methods, full state feedback design, disturbances and tracking systems, linear observers, compensator design by the separation principle, linear quadratic optimum control, Kalman filter, linear quadratic Gaussian compensator.

MSV 780 Fatigue (16 Credits)

Fatigue principles addressing both elasticity and plasticity; notch effects; variable amplitude loading conditions; multi-axial fatigue and weld fatigue.

MSF 780 Fracture mechanics (16 Credits)

Historical development, Linear Elastic Fracture Mechanics (LEFM): Stress concentrations and singularities, stress intensity factor, stability of crack propagation, elasto-plastic fracture mechanics: crack tip plasticity, small scale yielding, measurement of Kic, J-integral, Fatigue crack growth: Paris Law, life prediction, combined mode fracture, strain energy density methods.

MWN 780 Numerical methods (16 Credits)

Solving systems of linear algebraic equations using direct and iterative methods from small to large scale systems. Numerical solutions of non-linear systems of equations. Solving eigenvalue problems. Numerical approximation strategies. Numerical differentiation. Numerical Integration. Numerical solutions to initial -value problems for ordinary differential equations. Numerical solutions to boundary-value problems for ordinary differential equations.

MIC 780 Condition-based maintenance (16 Credits)

Theory and practical applications of condition based maintenance techniques. Pitfalls of the various condition based maintenance techniques. Acoustic emission, wear debris monitoring, oil analysis, thermography and non-destructive testing, standards.

MIP 782 Maintenance logistics (16 Credits)

Introduction to logistics, systems engineering and supportability analysis, inventory, aspects of logistical design, LEAN Production, Facility Layout, Job Design and Work Measurement, Logistics from the development to the retirement phase, planning and scheduling, project management.

MEV 781 Vibration-based condition monitoring (16 Credits)

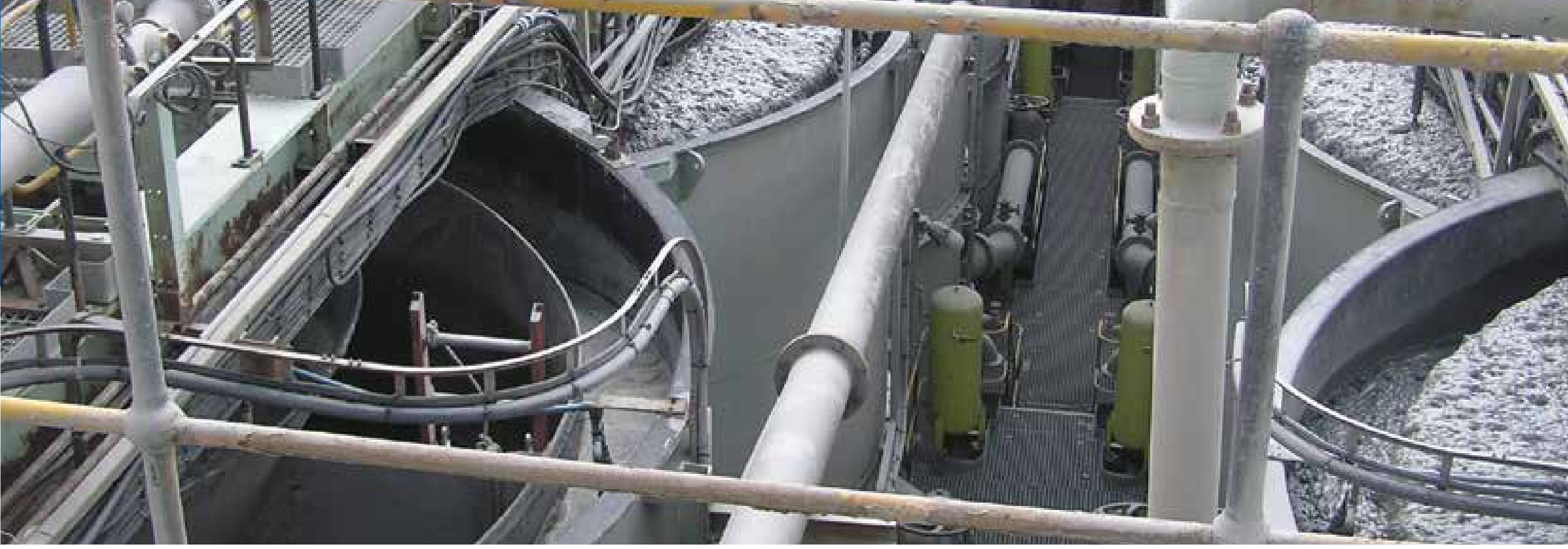
Vibration measurement: conventional and optical technique, digital signal processing in vibrations, vibration monitoring: diagnostics and prognostics, artificial intelligence in vibration monitoring, human vibration.

MSY 783 Experimental structural dynamics (16 Credits)

Spatial, modal and response models of structures, frequency response functions and the relationships between spatial, modal and response models for single degree of freedom systems and multi-degree of freedom systems, modal analysis, operational modal analysis, updating finite element models.

MUU 781 Fossil fuel power stations (16 Credits)

Study of all mechanical systems and processes of a fossil fuel power station. The analysis of steam cycles, combined cycle power generation, fuels and combustion, combustion mechanisms, combustion equipment and firing methods, the draught group, steam generators, steam turbines, condenser, feedwater and circulating water systems, coal handling, ash handling, compressor plant, water treatment, the importance of HVAC, control and instrumentation, control philosophies and environmental considerations.



MIR 781 Reliability engineering (16 Credits)

Definition of Reliability, History, Relationship with Quality, Coherent Systems Analysis, Lifetime Distributions, Parametric Lifetime Models, Competing Risks, Proportional Hazards, Accelerated Life, Repairable Systems, Lifetime Data Analysis, Parametric Methods, Nonparametric Methods, Model Adequacy.

MCT 780 Non-destructive testing (16 credits)

Probability, design and management in non-destructive testing (NDT). Fundamental theory of commonly used NDT methods: Ultrasonic Testing, Electromagnetic Testing (MT and ACFM), Radiographic Testing, Penetrant Testing, Eddy Current Testing. Other NDT Technologies including phased array UT, Time-of flight diffraction, Digital RT and Acoustic Emission Monitoring.

MIP 780 Maintenance practice (16 Credits)

Introduction to Asset Management, Mechanisms of Failure, Quantitative descriptions of Failure, Maintenance Policies/ Strategies, Renewal Theory, Lubrication, Asset Management Strategy, Replacement Decision Making, RCM Principles, Maintenance & Failure Risk, A Business Case for Maintenance, Repairable Systems, Integrated Failure Data Analysis, Maintenance Profit Impact, Life Cycle modelling.

Asset life-cycle management (16 Credits)

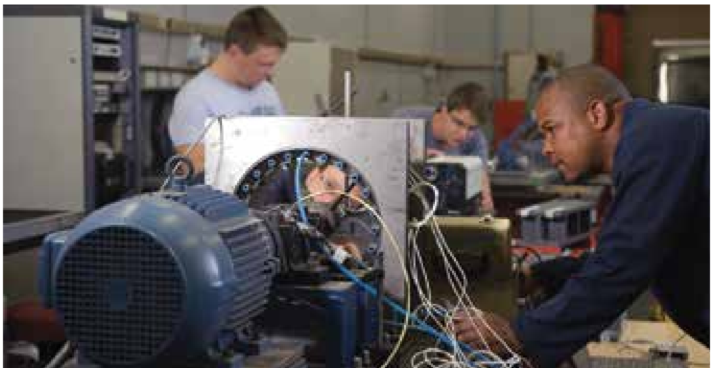
ALCM is the management of an asset throughout its life-cycle, including planning and support for the investment decision, acquisition, commissioning, utilisation and ongoing maintenance, as well as replacement or retirement planning. In ALCM, the emphasis is on efficiency and sustainability. The course includes topics such as, designing for reliability, early equipment management, Reliability-Availability-Maintainability (RAM) modelling, renewal analysis (optimal replacement modelling), Life Cycle Costing, integrity risk management and disposal management.

MOO 780 Optimum design (16 Credits)

Introduction to optimum design, optimum deterministic and optimum probabilistic inference problems in mechanical engineering. Overview of data analysis tools that include principal component regression, partial least square regression, radial basis function approximation, probabilistic inference Gaussian distributions, maximum likelihood estimation, regularisation, cross-validation, Bayesian model calibration, Bayesian optimisation. Numerical methods to solve unconstrained and constrained optimum design and data inference problems.

MSS 732 Research study (32 Credits)

This module allows a student to do research on a certain topic in mechanical or aeronautical engineering, as specified by a lecturer in the Department of Mechanical and Aeronautical Engineering, on an individual basis, under the supervision of that lecturer. The study should be seen as a precursor to the master's degree research that may follow the honours degree. The total volume of work that is to be invested in this module by an average student must be 320 hours. The body of knowledge studied must be of an advanced nature, at the level of the other postgraduate modules offered by the Department. Normal requirements for assessment that include the use of an external examiner apply to this module as well. The module is available in either the first or the second semester. A student may also do this module spread over two consecutive semesters. In such a case, the student should register the module for the second of these semesters.



Masters degree focus areas

The following diagram summarises the various focus areas of asset integrity management which can be the focus area of a masters degree dissertation.

Identification of Critical Assets

Design
- Analysis
- Testing
- Verification
- Validation
- Compliance
- Risk

Manufacturing
- Material characterisation
- Surface treatment

Data acquisitioning
- Sensors
- Optimal sensing
- Pre-process
- Feature extraction

Condition monitoring
- Failure modes and criticality
- Thresholds
- Inspections
- NDT

Diagnostics
- Fault identification
- Confidence bounds
- Anomaly detection

Prognostics
- Fault evolution
- Residual life:
- Feature, Physics based
- Loading

Decision support
- Integrity
- Maintenance.
- Safety
- Life cycle management and costing

Environmental Interaction

Standards and Business Integration

Critical assets identification

Companies operate a huge variety of assets with diverse attributes. With limited human and financial resources it is imperative to focus on those assets that may have the most significant and immediate impact on key performance indicators, such as the unplanned capability loss factor. Utilising advances statistical analysis and modelling techniques, asset criticality is determined based on factors such as performance (and direct and opportunity cost of non-performance), reliability, as well as availability within the context of health, safety and the environment.

Design for reliability and performance

It is essential that both during the manufacturing phase, as well as the operational (consider modifications on existing assets) phase of assets, sophisticated techniques are used to ensure that asset design is optimal. Some of the sophisticated techniques that can be utilised are finite element modelling of complex structures, scanning laser vibrometry and digital imaging correlation, development of response reconstruction techniques for durability testing of plant assets using servo-hydraulic actuators, determination of material characteristics of tubular structures using bulge tests, as well as dynamic design of materials handling equipment.

Manufacturing

Determine material characteristics of complex materials such as composites or materials subject to high strains and strain rates. Surface treatments such as shot and shock peening are also investigated.

Data acquisition

Asset integrity and performance management increasingly require measurement of system parameters such as solids, liquids and gas flow rates, pressure, temperature, chemical composition, oil condition or vibration, together with detailed logs of the operating conditions. Some of the advanced techniques include the utilisation of non-contact sensors for turbomachinery condition monitoring, as well as acoustic emissions in specialist condition monitoring applications.

Condition monitoring

While significant progress has been made in the diagnostic analysis of complex industrial assets and imminent failures can often be identified, there are still significant research challenges to be addressed. Examples of these include having to deal with fluctuating operating and process conditions in systems, optimising of on-line condition monitoring and inspection techniques for equipment such as turbogenerators, pumps, gearboxes, pipes, mills, and more.

Diagnostics

Understanding failure modes and criticality is crucial in identifying optimal condition monitoring approaches. Detailed models to link features extracted from system response and performance measurements are indispensable in the diagnosis of system faults. Examples of research in this area are of computational models for turbo-generator rotor and journal bearing dynamic behaviour, condition monitoring techniques which separate deterministic and stochastic machine behaviour under widely fluctuating conditions, while at the same time being robust enough for in-field implementation.

Prognostics

Maintenance decisions based on the outcomes of condition-based time-to-failure estimates often contain a strong element of uncertainty which suggests a need to integrate traditional condition assessment and statistical reliability models. This requires evolving from making intuitive decisions based on experience, towards more sophisticated prognostic models capable of dealing with complex equipment with many interrelated failure modes. The focus here is to develop a range of models for predicting remaining useful life of power generation assets. These models range from simple knowledge-based models, to life expectancy models, artificial intelligence models and physical models.

Life cycle decision support

When considering life cycle management decisions, the focus starts to extend beyond immediate failure towards understanding the long-term operational and maintenance implications. An important aspect of the current research, therefore, entails integration of condition information with improved understanding of the degradation mechanisms, to manage maintenance interventions, risk, inventory and end-of-life decisions. This should all be done in the context of reliability, availability and safety.

Standards and databases

Realising the importance of optimal utilisation and life cycle management of scarce and expensive physical assets is rapidly growing in our cost-sensitive competitive society. Symptomatic of this is the emergence of new asset management standards such as PAS55 and ISO 55000. It is important to fully understand the implications of such standards on business.

The programme is hosted by the Centre for Asset Integrity Management (C-AIM), Department of Mechanical and Aeronautical Engineering.

Entrance requirements and considerations

Students with a BTech (Mechanical Engineering) or BSc undergraduate study background will be considered only if the student achieved a 75% or higher average final year mark.

A student will be awarded a Honours Degree, i.e. either a BEng (Hons,) or BSc (Hons) after completion of the courses, and a Masters Degree, i.e. either a MEng or MSc degree after completion of the research dissertation.

Bursaries

Various bursary options are available to students who have proven themselves academically.

Further information

Visit the website **www.up.ac.za/caim**, for more information on this programme as well as other postgraduate study opportunities, or contact:

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