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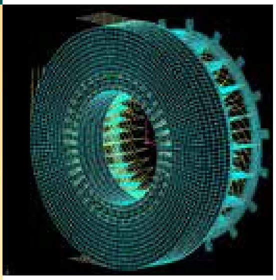
Mechanical Engineering Postgraduate Programme in Asset Integrity Management



Centre for Asset
Integrity Management (C-AIM)

Department of Mechanical
and Aeronautical Engineering

www.up.ac.za/caim

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 Physical Asset Management.

Students who have completed a B.Eng, 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 B.Eng (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.

MIP 780 Maintenance practice (16 Credits)

Failure characteristics, statistical analysis and optimal preventive maintenance. Maintenance economics, optimal inspection and condition monitoring intervals. Work force and resource management, maintenance contracting. Strategic capital strategies.

MIP 781 Maintenance practice (16 Credits)

Review of renewal theory, repairable systems, integrated failure data analysis, point processes, life cycle modelling, Monte Carlo analysis, mechanisms of failure, maintenance forensics, building a maintenance concept, maintenance diagnostics.

MIR 781 Reliability engineering (16 Credits)

Introduction to probabilistic distributions, computation of system reliability, building reliability models and optimisation of system reliability. Fault Tree Analysis, Failure Modes, Effects and Criticality Analysis (FMECA), Monte Carlo Simulation; probability-based design.

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.

MSY 732 Structural mechanics (32 credits)

Dynamics: Kinematics and kinetics of particles, plane kinematics and plane kinetics of rigid bodies
Mechanics of materials: Euler Beam Theory, stress and strain transformation, deflection of beams
Vibrations: Single and multidegree of freedom systems.

MSV 780 Fatigue 780 (16 Credits)

Introduction to fracture mechanics. Fatigue of material, stress-based approach: notched members, multi-axial fatigue, fatigue crack growth, plastic deformation behaviour of materials. Fatigue of material, strain-based approach.

MEE 780 Finite element methods (16 Credits)

Linear elastostatic and elastodynamic finite elements; strong and weak form mixed boundary value problem; isoparametric displacement and assumed stress elements; element defects (shear and volumetric locking); numerical integration; consistent nodal loads; multi-point constraints.

MEE 781 Advanced finite element methods (16 Credits)

Overview of non-linear geometric effects, continuum mechanics, deformation gradients, Lagrange strains and hyperelasticity. Contact, multi-point constraints and arc-length control. Mixed formulations for incompressibility. Small strain plasticity and radial return algorithm.

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, project management.

MII 780 Reliability Based Maintenance (RBM) (16 Credits)

Introduction to methodologies to eliminate or limit need for maintenance through proactive design. Topics covered include RBM in context, Total Productive Maintenance, FMECA, Equipment Criticality, Six Sigma, Root Cause Analysis, RCM and Risk Based Inspection.

MEV 781 Vibration-based condition monitoring (16 Credits)

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

MOX 781 Non-destructive testing (16 Credits)

Probability, design and management in non-destructive testing (NDT). Fundamental theory of commonly used NDT methods e.g. Ultrasonic Testing, Electromagnetic Testing (MT and ACFM), Radiographic Testing, penetrant Testing, Eddy Current Testing array UT, Time-of flight diffraction.

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.

MSE Theory of elasticity (16 Credits)

Mechanics of elastic deformable bodies, kinematics, balance laws, constitutive equations; classical small-deformation theory; formulation of boundary-value problems of linear elastostatics; plane problem of elastostatics; variational formulations, minimum principles.

MSY 783 Experimental structural dynamics (16 Credits)

Development of spatial, modal and response models of structures. Frequency response functions and relationships between spatial, modal and response models. Modal parameter extraction. Finite element model updating. Damage detection.

MOO 780 Optimum design (16 Credits)

Computer-aided optimum design; single and multi-objective optimum design problem formulation; optimality concepts of unconstrained and constrained optimization; interior-point methods; linear programming; sensitivity analysis; response surfaces; evolutionary algorithms; interpretation.

MWN 780 Numerical methods (16 Credits)

Solving linear and non-linear systems of equations. Solving eigenvalue problems. Numerical approximation strategies. Numerical differentiation and Integration. Numerical solutions to initial-value problems and boundary-value problems for ordinary differential equations. Interpolation.

MEG 780 Mechatronics (16 Credits)

Mechatronics is a multidisciplinary field of engineering that integrates mechanics, electronics, computer science, and control theory. Topics included are such as analogue electrical circuits, digital circuits, op amp, microcontroller, actuators, sensors, data acquisition and system response.

MSS 781 Independent study (16 Credits)

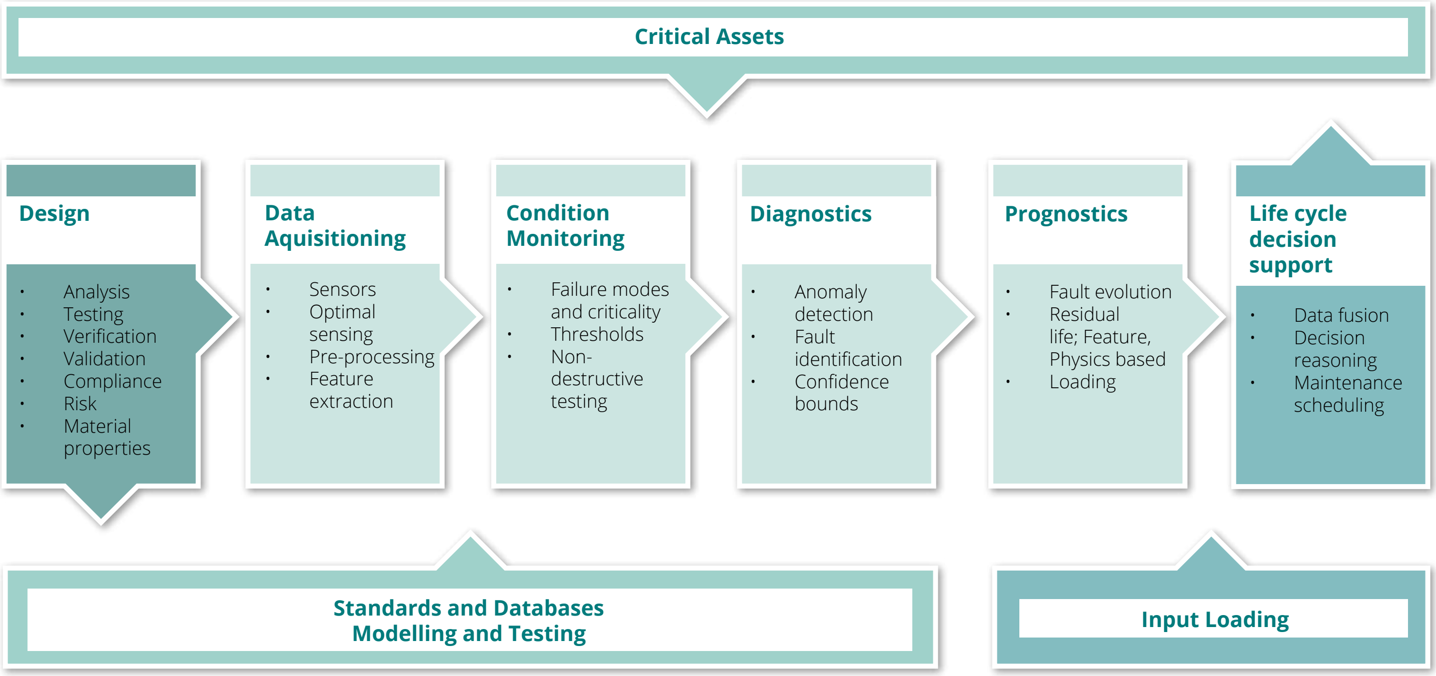
This module allows a student to study a certain body of knowledge, as specified by a lecturer on an individual basis, under the supervision of that lecturer. The total volume of work that is to be invested in this module by an average student must be 160 hours.

MIP 783 Maintenance operations (16 Credits)

Understanding the maintenance function, building a business case for maintenance, Computerised Maintenance Systems (CMMS), Maintenance Management Systems, Maintenance Cost Management, Total Productive Maintenance (TPM), strategic thinking in maintenance.

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.



Critical Assets

Design

- Analysis
- Testing
- Verification
- Validation
- Compliance
- Risk
- Material properties

Data Aquisitioning

- Sensors
- Optimal sensing
- Pre-processing
- Feature extraction

Condition Monitoring

- Failure modes and criticality
- Thresholds
- Non-destructive testing

Diagnostics

- Anomaly detection
- Fault identification
- Confidence bounds

Prognostics

- Fault evolution
- Residual life; Feature, Physics based
- Loading

Life cycle decision support

- Data fusion
- Decision reasoning
- Maintenance scheduling

Standards and Databases
Modelling and Testing

Input Loading

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.

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.

Further information

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