STRUCTURAL DYNAMICS GROUP

1. Introduction

Stemming from our mission to be locally relevant and internationally competitive, the Department of Mechanical Engineering, Mechatronics and Industrial Design at Tshwane University of Technology (TUT) places high emphasis on quality research, and considers the creation, application and transfer of knowledge as one of its major functions. The Department responds to the needs of the country by proactively contributing to the shaping of the future.

In today's competitive, high-tech society, noise and vibration are constantly present. Noise causes serious problems both at home and in the workplace, and the task of reducing noise and vibration is a subject currently focused on by authorities in many countries. Hence, the ever-growing demand for reducing community noise by designing better quality, low-noise emission products that can withstand severe dynamic conditions have increased drastically and will continue to do so as legislation on noise emission standards become higher. Similarly, manufacturers of mechanical products with vibrations causing acoustic noise, increasingly find themselves forced to compete on the noise levels of their products. Such competition has so far occurred predominantly in the automotive industry and in the rail and aeronautical industries to a lesser extent. However in Europe, domestic appliances and power tools are now being increasingly marketed stressing low noise levels. Hence, the prediction of noise and vibration characteristics of a product at its early stage of development is highly desirable.

In response to this, TUT has been active in research on dynamical systems since 2003. These activities eventually culminated in the establishment of the Structural Dynamics Group (SDG) in 2012. The SDG focuses primarily on structural sound and vibration (vibro-acoustics) and structural dynamics. These activities have gradually expanded to include a specialist Sound and Vibration laboratory at the Pretoria campus, with the aim of expanding these activities even further to the broader field of structural sound and vibration including biomechanics in collaboration with UNISA.

The SDG strives to provide quality-driven postgraduate training, industry-relevant research and development work to master's and doctoral students on the basis of postgraduate projects. These projects are completed in partial or complete fulfilment of the requirements for the particular master's or doctoral degree programmes. The aim is to produce highly competent, value-adding research graduates capable of supporting industry and the community in relevant problems and projects. The group actively collaborates with industry, the CSIR, University of Pretoria (UP), Eskom, UNISA and

many others with its projects and programs supported through both internal and external funding.

2. Research focus areas

Structural dynamics is a field which describes phenomena such as resonance in structures and how connecting structures together affect the resonances, etc.

Acoustics is a discipline close to noise and vibration analysis as the causes of acoustic noise is often vibrations.

Biomechanics understanding and modelling (FEA) the material behaviour of tissues in order to solve health challenges and various diseases.

Within this sphere, the SDG currently entails a range of activities which include:

Theme 1: Noise, vibration and harshness reduction of transportation systems

Sound & vibration prediction and control, reduced-scale and similitude modeling, design & development, mathematical & numerical modeling (finite element analysis - FEA), experimental validation, correlation, evaluation, design sensitivity analysis and optimization of systems, technologies and products to reduce noise and vibration emissions of transportation systems. Typical examples are the reduction of interior noise levels in the passenger cabin and door panel vibration; analysis of road-tyre interaction of rolling tyres and its subsequent spindle forces; mathematical modeling of a reliable, automated, CAD-based volume generation algorithm of enclosed complex, three-dimensional cavities or domains; sensitivity analysis of different automotive door mount architectures on vibration and interior noise levels and the analysis and influence of absorbent poro-elastic components, such as interior trim, on the interior sound field.

Theme 2: Dynamic characterization of materials including composites

Modal analysis & numerical modeling, experimental validation, correlation and evaluation of natural frequencies. Experimental characterization of damping. Examples include the analysis of polymer and composite materials in terms of their dynamic behaviour (natural frequencies and damping characteristics) and applications.

Theme 3: Sound radiation analysis and characterization of dynamical systems

Sound & vibration prediction and control, reduced-scale modeling, design & development, mathematical & numerical coupled acoustic-structural modeling (finite element analysis), modal analysis, experimental validation, correlation, evaluation, design sensitivity analysis and optimization of the vibro-acoustic behaviour of small products and components such as automotive engine covers and automotive door hinge design/architectural studies.

Theme 4: Asset integrity management

Vibration analysis and development of predictive (FEA) models applied to power stations, transmission and distribution utilities such as transformers, voltage switch gear, power

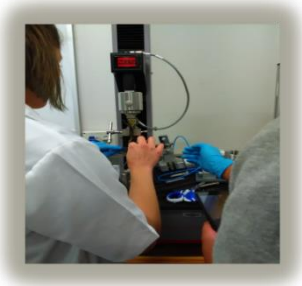
line structures (pylons), capacitor banks, grinding mills, boiler tubing and pipes, steam turbines/blades, generator stators, mill gearboxes. Specific FEA modeling topics relate to boilers, natural frequencies of rotors on turbo-generators, fatigue & creep of turbine discs and residual stresses in turbine blades and rotor attachments.

Theme 5: Biomechanics (in collaboration with UNISA: Prof. F Nemavhola)

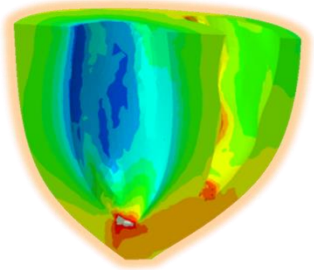
Our research investigations includes theoretical and experimental work that are aimed at understanding various mechanisms of medical conditions. Research projects are designed to achieve scientific insights to better prevent human diseases and better under the healing processes and the mechanisms medical conditions. The nature of this research requires a multidisciplinary approach research including medical specialists, biologists, material engineers and scientists etc. Biomechanics is the study of biological systems through mechanical principles. Biomechanics is closely related to engineering, because it often uses traditional engineering sciences to analyze biological systems.

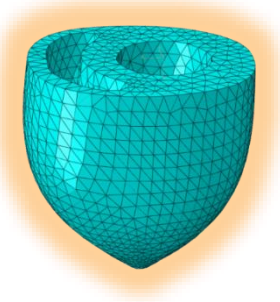
Research Areas:

- Experimental characterisation of soft biological tissues and biomaterials
- Hard tissue mechanics
- Mechanobiology of eye diseases
- Soft tissue mechanics and mechanobiology
- Cellular and viral mechanobiology in physiology and disease
- Mechanobiology of cardiovascular diseases and therapies
- Soft tissue regeneration



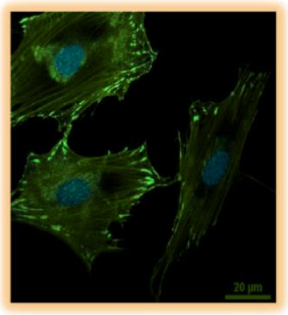
Experimental Biomechanics





Computational Biomechanics

Soft Tissue Mechanics

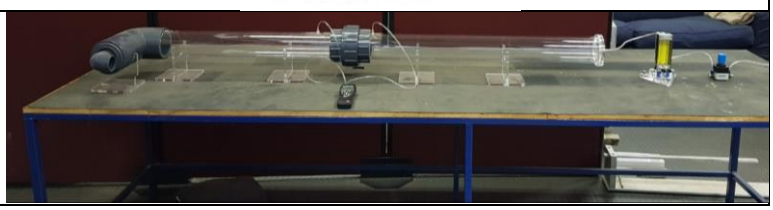


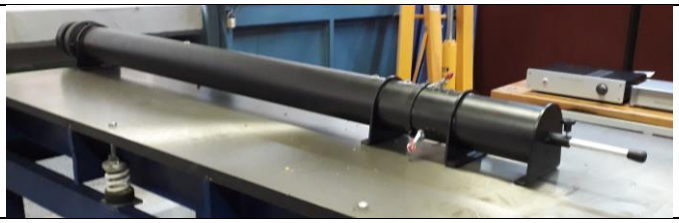
Mechanobiology

3. Facilities

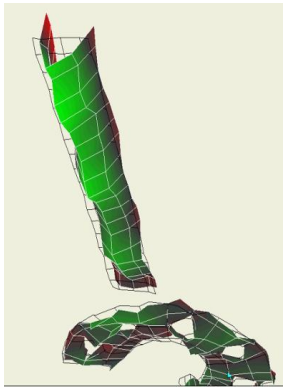
Some (not all) of the research facilities/equipment currently available at TUT are shown below:

Item	Brief specification	Visual
Dynamic FFT signal/spectrum analysers	Various models available	
Electro-dynamic shakers	High precision modal exciter - 100N Sentek Dynamics – 1000N	
Impact (modal) hammers	Bruel & Kjaer 8206 22.7mV/N Bruel & Kjaer Type: 8202 21.04 mV/N	
SVantek Portable sound and vibration analyser	912 AE	
Current mode power amplifiers	Various models available	

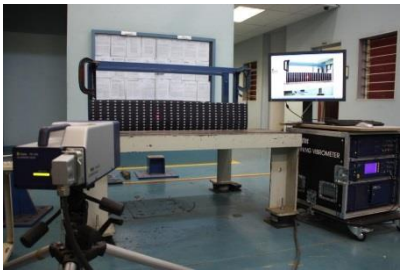
Acoustic sound calibrator	MVI Technologies Cal 21 01dB Stell	
Miniature ½″ & ¼″ condenser microphones pressure field	BSWA MPA 401, 418, 416 50mV/Pa, 436 12.5mV/Pa with pre-amp circuitry, MP 206 30mV/Pa with pre-amp circuitry	
Force transducers	Various models available	
Accelerometers: sub-miniature tri-axial, teardrop, various sizes	Various models available	
Sweep/Function Generator	FG-7005C	
Rigid shaker tables	Various models available	
Infrared thermography cameras	Various models available	
Airflow resistivity meter		

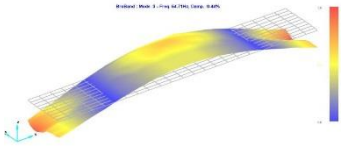
Impedance tube		
DS - ABAQUS FEA simulation software	Full research edition V6.14	
DS software: FeSafe, Isight, Tosca	Full research edition	
MODENT modal analysis software		
BSWA signal & data acquisition software	VA-Lab4 Base 4 channels	

4. Some of the facilities available at the University of Pretoria's Sasol Laboratory for TUT students on collaborative projects

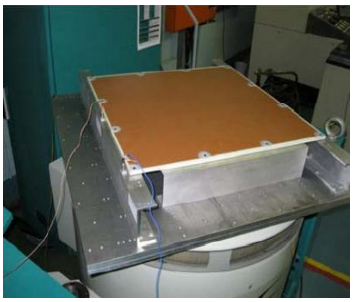


Laser vibrometry for development of turbo machine blade damage detection algorithms

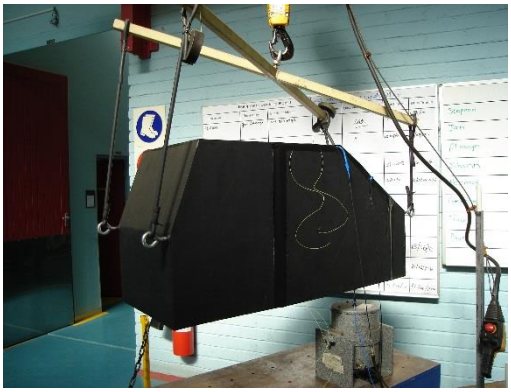


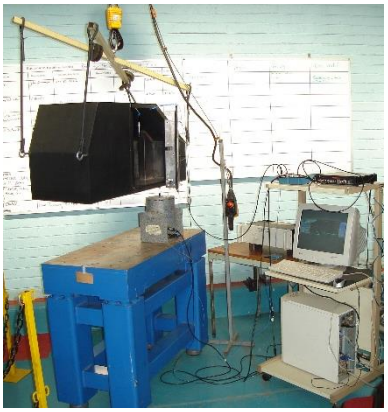


Scanning laser vibrometry for damage detection studies on composite structures



Durability investigations on composite panels





Dynamic testing of an automotive vehicle model

(Pictures: Courtesy of the Department of Mechanical and Aeronautical Engineering, University of Pretoria)
Link to University of Pretoria's Sasol Lab: Sasol Laboratory for Structural Mechanics

5. Some of the facilities available at the University of South Africa on collaborative projects

This Lab is based at UNISA, School of Engineering, Department of Mechanical and Industrial Engineering. The Lab is equipped with sophisticated equipment including newly developed biaxial machine and cellculture.

	PRODUCT DESCRIPTION
1	Biomaterial biaxial testing machine (BT 50 mm)
2	A micro-scale tension/compression test system
3	Mechano-Culture B1 (MCB1-200)
4	Versatile uniaxial bench top mechanical tester
5	In Vitro-indentation of bone to determine mechanical properties
6	Tensile Testing of Hair
7	Dental static and fatigue testing system
8	Static, Dynamic and Fatigue Test system for Orthopaedic

6. Summary of Research Areas (Prof. D Desai)

- Sound and vibration analysis
- Stress analysis – structural dynamics
- Coupled acoustic-structural analysis
- Thermo-mechanical stress analysis
- Infrared thermography
- Numerical simulation
- Characterization of dynamic properties of materials
- Asset integrity management – fatigue life prediction, vibration and modelling
- Biomechanics (in collaboration with Prof. F Nemavhola - UNISA)

7. Contact

Group leader: Prof D Desai

Tel: +27 (0)12 382 5886
Email: desaida@tut.ac.za

** *Some topics are mentioned below to serve as guidelines but students are welcome to propose their own topic more or less in line with the above areas:*

SPECIFIC RESEARCH TOPICS: Power Generation: Steam Turbines, Boilers & Transformers

1. Transient analysis of thermal bending and vibration of a turbine rotor with attached seals
2. Fatigue life prediction of mistuned steam turbine blades subjected to variations in blade geometry
3. Fatigue life prediction of steam turbine blades (variations in either damping or material properties…etc – a probabilistic approach.
4. Geometric optimisation of a boiler tube web fatigue member.
5. Prediction of transformer transport damage due to shock loading.
6. Vibration modelling/measurement/monitoring of a transformer core using infrared thermography.
7. Prediction of damping characteristics of a self-actuating Z-lock integral shroud mechanism
8. Investigation of micro-mechanism of material fatigue resistance induced by shot peening process (continuation of current research activities at TUT).
9. Online monitoring of residual stresses during shot peening process (continuation of current research activities at TUT).
10. Prediction of damping characteristics on laced blade-disk assemblies using infrared thermography (continuation of current research activities at TUT).

11. Online prediction of vibration characteristics of turbomachinery using infrared vibrothermography (continuation of current research activities at TUT).
12. Optimisation of the blade shot peening process in terms of location.
13. Optimisation of the blade shot peening process in terms of material selection.
14. Vibrational characterisation of internal components (eg. turbine blades) using novel techniques (hybrid X-ray/Infrared…etc).
15. Modal analysis of a municipal power transmission pylon: prediction and validation
16. FEA modeling methodology for prediction of boiler wall fatigue failure
17. Precipitator plate vibration
18. Information harvesting from blade tip time of arrival measurements
19. Boiler tube localized flaw sensitivity specification
20. Fatigue life prediction of steam turbine blades – a probabilistic approach
21. Prediction of long term benefits of compressive residual stresses in turbine blade roots and rotor attachments
22. Turbine blade stress response due high shaft lateral vibration
23. Estimation of generator rotor lateral and torsional stiffness by 3D FEM
24. Generator end winding vibration
25. Vibration behaviour of transformers. Can vibration monitoring be used to assess transformer condition?
26. Development of a material model to account for cyclic hardening and softening
27. Prediction of residual stresses in steam turbine blade subjected to shotpeening.
28. Low cost FEA and prediction of torsional natural frequencies of rotors with bladed discs.