Course Outline

Semester 2 2015

MECH9223

MACHINE CONDITION MONITORING

Contents

1. Staff Contact Details

Contact details and consultation times for course convenor

Name:	Wade Smith
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I will be available to answer your questions for one hour per week outside class time; the time and exact location for this consultation slot will be advised during the first lecture. If you need to see me outside this time, it is preferable that you make prior arrangements via phone or email.

Contact details and consultation times for additional lecturers/demonstrators/lab staff

Please make arrangements beforehand, via phone or email, if you need to see the following teaching staff outside scheduled class times.

Lecturers

Dr Sangarapillai Kanapathipillai
Room: ME 408J (J17)
Tel: (02) 9385 4251
Email: s.kanapathipillai@unsw.edu.au

Associate Professor Zhongxiao Peng
Room: ME 408B (J17)
Tel: (02) 9385 4142
Email: z.peng@unsw.edu.au

Demonstrators

Dr Lav Deshpande
Email: l.deshpande@.unsw.edu.au

Mr Chongqing Hu
Email: chongqing.hu@.unsw.edu.au

2. Course details

Credit Points

This is a 6 unit-of-credit (UoC) course, and involves 3 hours per week (h/w) of face-to-face contact.

The UNSW website states “The normal workload expectations of a student are approximately 25 hours per semester for each UoC, including class contact hours, other learning activities, preparation and time spent on all assessable work. Thus, for a full-time enrolled student, the normal workload, averaged across the 16 weeks of teaching, study and examination periods, is about 37.5 hours per week.”

This means that you should aim to spend about 9 h/w on this course. The additional time should be spent in making sure that you understand the lecture material, completing the set assignments, further reading, and revising for any examinations.

Contact Hours

The contact hours for this course will be as outlined in the following table. Lectures will begin in Week 1 (Friday 31 July), and demonstrations will begin in Week 2 (Friday 7 August).

	Day	Time	Location
Lectures	Friday	11am – 1pm	MechEng Room 102
Demonstrations	Friday	1pm – 2pm	MechEng Room 102 (unless advised otherwise)

Summary of the Course

This course is intended to provide the necessary tools and basic knowledge in the field of monitoring the health of rotating and reciprocating machines, primarily through vibration analysis.

Aims of the Course

The course starts with an introduction to the whole field of machine condition monitoring (MCM), including methods other than vibration analysis, as applied to the efficient maintenance of operating machines without disturbing their normal operation. It demonstrates the benefits of Condition Based Maintenance (CBM), which allows maintenance to be carried out at the optimum times, rather than after failure (which may be catastrophic, and therefore very expensive and potentially dangerous) or at intervals based on the minimum time to failure rather than mean time to failure, which in general is much longer. It then concentrates on the most powerful condition monitoring technique, which is based on analysis of the vibration signals in both normal and faulty condition. Vibration analysis is useful in all three phases of MCM, namely fault detection, fault diagnosis, and prognosis (prediction of remaining useful life).

The course discusses the vibration signals generated by machines and machine components, such as gears and bearings, in both healthy and faulty condition, and then the signal processing techniques that can be used to extract symptoms of individual faults in individual components from the overall vibration signal.

The course applies the dynamic system modelling concepts that you learned in MMAN2300 and MMAN3200 and the Fourier methods introduced in MATH2019 (or their equivalents). A basic knowledge of mechanical vibration, as covered for example in the present MMAN2300 or in former courses MMAN3300 and MECH4305-9305, would be highly beneficial.

Student learning outcomes

This course is designed to address the below learning outcomes and the corresponding Engineers Australia Stage 1 Competency Standards for Professional Engineers as shown. The full list of Stage 1 Competency Standards may be found in Appendix A.

After successfully completing this course, you should be able to:

Learning Outcome		EA Stage 1 Competencies
1.	Understand the concept of machine condition monitoring and develop familiarity with the technology used in this field	PE1.1, PE1.2, PE1.3
2.	Apply vibration analysis techniques to diagnose faults in rotating and reciprocating machines and take proper actions	PE1.1, PE1.2, PE1.3, PE1.5, PE2.1, PE2.2
3.	Prepare appropriate reports to communicate the results of analysis (both at an executive level and at a professional engineering level)	PE1.6, PE3.1, PE3.2, PE3.4
4.	Know the different systems used to measure and analyse vibration signals	PE1.2, PE1.3, PE2.2

3. Teaching strategies

There are a number of different areas to be covered in this course, which imposes a variety of teaching strategies. The topics in general are first introduced through PowerPoint® presentations during the lecture time. Demonstration sessions are designed to provide you with feedback and discussion on the assignments, and to investigate problem areas in greater depth to ensure that you understand the application and can avoid making the same mistake again. Due to the fact that there are a number of mathematically based concepts and theories that you will need to absorb, demonstration sessions have been devised to help you develop your theoretical understanding. This will be done through a number of problems that will be provided during the demonstration time, and through a number of MATLAB® examples. Lab demonstrations will be scheduled to illustrate signal capturing and a number of case studies/histories will be presented.

4. Course schedule

The following course schedule is an indication only, and may be adjusted slightly throughout the Semester.

Week	Date	Lecturer	Topics covered
1	31 Jul	Dr Wade Smith	Overview of condition monitoring and vibration analysis Maintenance practices. Condition monitoring methods; vibration analysis, oil analysis, performance analysis, thermography etc. Vibration transducers. Permanent vs intermittent monitoring. Signal classification and signals produced by machines and components in healthy and faulty condition. Vibration criteria.

Week	Date	Lecturer	Topics covered
2	7 Aug	Dr Wade Smith	Basics of mechanical vibrations. Vibration signal measurement and display. Introduction to signal processing. Frequency analysis using filters. Fourier analysis and the Fast Fourier Transform (FFT). Assignment 1 (15%) given (due Week 6 – 4 September).
3	14 Aug	Dr Wade Smith	Convolution and the convolution theorem. Practical FFT analysis; sampling theory, FFT pitfalls, aliasing, leakage, windowing. Scaling. Fault detection using constant percentage bandwidth (CPB) spectra on log frequency scales.
4	21 Aug	Dr Wade Smith	Advanced signal processing techniques; Hilbert transform, demodulation, cepstrum analysis, time-frequency analysis, cyclostationary analysis.
5	28 Aug	Dr Wade Smith	Order tracking to compensate for speed fluctuations. Separation of deterministic and random signals.
6	4 Sep	Dr Wade Smith	Diagnostics of rolling element bearings. Vibrations generated by local and extended faults. Envelope analysis by amplitude demodulation. Spectral correlation. **Assignment 1 (15%) due – 11:00 hours.**
7	11 Sep	N/A	**Mid-Semester Exam (15%) – during lecture time.** Assignment 2 (30%) given (due Week 12 – 23 October).
8	18 Sep	Dr Kana Kanapathipillai	Introduction to rotor dynamics. The Jeffcott rotor. More complex rotors. Critical speeds; forward/backward whirl. Unbalance; misalignment.
9	25 Sep	Dr Kana Kanapathipillai	Hydrodynamic bearings and their interaction with rotor dynamics. Reynolds equation and solutions.
	2 Oct	N/A	Mid-semester break
10	9 Oct	Dr Wade Smith	Gear diagnostics; time synchronous averaging (TSA), residual analysis, cepstrum analysis, time/frequency analysis.
11	16 Oct	A/Prof Zhongxiao Peng	Condition monitoring by oil analysis and wear debris analysis.
12	23 Oct	Dr Wade Smith	Diagnostics of IC engines and other reciprocating machines; torsional vibration, time/frequency analysis. **Assignment 2 (30%) due – 11:00 hours.**
13	30 Oct	Dr Wade Smith	Review of course material.

5. Assessment

You will be assessed by way of two MATLAB®-based assignments and two examinations, all of which will generally involve a combination of calculations and written descriptive material.

The various assessments contribute towards the overall grade as follows:

Task	Weight	Learning outcomes assessed	Assessment criteria	Due date, time, and submission requirements
Assignment 1: Fourier Analysis	15%	1, 3, 4	Technical content	11am, 4 Sep 2015, online submission via Moodle
Assignment 2: Diagnostics Project	30%	1, 2, 3, 4	Technical content and report writing skills	11am, 23 Oct 2015, online submission via Moodle
Mid-Semester Exam	15%	1, 4	All course content from weeks 1-5	11am, 11 Sep 2015
Final Exam	40%	1, 2, 4	All course content from weeks 1-12	Exam period, date TBA

In order to pass the course, you must achieve an overall mark of at least 50%.

Assignments will be handed out in hardcopy in class, and will be available on the UNSW Moodle website in case you miss the hand-out in class. Any data required for you to complete the assignments will be supplied to you via Moodle or email.

Assignments

Presentation

All submissions should have a standard School cover sheet which is available from this subject's Moodle page.

All submissions are expected to be neat and clearly set out. Your results are the pinnacle of all your hard work. Presenting them clearly gives the marker the best chance of understanding your method, even if the numerical results are incorrect.

Submission

Assignments are due by the commencement of class on the dates nominated above. Assignments should be submitted electronically via Moodle.

Late submissions will be penalised 5 marks per calendar day (including weekends). An extension may only be granted in exceptional circumstances. Where an assessment task is worth less than 20% of the total course mark and you have a compelling reason for being unable to submit your work on time, you must seek approval for an extension from the course convenor ***before the due date***. Special consideration for assessment tasks of 20% or greater must be processed through https://student.unsw.edu.au/special-consideration.

It is always worth submitting late assessment tasks when possible. Completion of the work, even late, may be taken into account in cases of special consideration.

Assessment Criteria

The following criteria will be used to grade assignments.

For report-style assignments the following criteria will be used:

- Identification of key facts and the integration of those facts in a logical development.
- Clarity of communication—this includes development of a clear and orderly structure and the highlighting of core arguments.
- Sentences in clear and plain English—this includes correct grammar, spelling and punctuation.
- Correct referencing in accordance with the prescribed citation and style guide.

Assignments involving numerical calculations will be assessed using the following criteria:

- Accuracy of numerical answers.
- All working shown (see Presentation above).
- Use of diagrams, where appropriate, to support or illustrate the calculations.
- Use of graphs, were appropriate, to support or illustrate the calculations.
- Use of tables, where appropriate, to support or shorten the calculations.
- Neatness.

Considerable effort will be made to provide constructive feedback on your assignments, and there will be opportunities (e.g., during the demonstrations and staff consultation times) for you to discuss your assignments, both before submission and after marking, with the teaching staff.

Examinations

There will be one two- or three-hour examination at the end of the semester, covering all material.

You must be available for all tests and examinations. Final examinations for each course are held during the University examination periods, which are June for Semester 1 and November for Semester 2.

Provisional Examination timetables are generally published on myUNSW in May for Semester 1 and September for Semester 2

For further information on exams, please see Administrative Matters.

Calculators

You will need to provide your own calculator, of a make and model approved by UNSW, for the examinations. The list of approved calculators is shown at https://student.unsw.edu.au/exam-approved-calculators-and-computers

It is your responsibility to ensure that your calculator is of an approved make and model, and to obtain an “Approved” sticker for it from the School Office or the Engineering Student Centre prior to the examination. Calculators not bearing an “Approved” sticker will not be allowed into the examination room.

Special Consideration and Supplementary Assessment

For details of applying for special consideration and conditions for the award of supplementary assessment, see Administrative Matters, available on the School website and on Moodle, and the information on UNSW’s Special Consideration page.

6. Expected Resources for students

All material corresponding to the lectures, demonstrations and their solutions, and assignments will be provided in UNSW Moodle. Extra handouts and further useful material will be posted periodically in UNSW Moodle. You are advised to check it regularly.

All essential material for you to complete the course will be provided; the following references are mentioned in case you would like to investigate certain topics in further detail. The ‘recommended text’, in particular, would be very useful for the course.

Recommended text

Randall, R. B., Vibration-based Condition Monitoring: Industrial, Aerospace and Automotive Applications, 1st Edition, Wiley, 2011. (Available in electronic form from the UNSW Library.)

Suggested references

Brandt, A., Noise and Vibration Analysis: Signal Analysis and Experimental Procedures, 1st Edition, Wiley, 2011.

Braun, S., Discover Signal Processing: An Interactive Guide for Engineers, 1st Edition, Wiley, 2008.

Rao, S.S., Mechanical Vibrations, 5th Edition, Prentice Hall, 2011.

Shin, K. and Hammond, J. K., Fundamentals of Signal Processing for Sound and Vibration Engineers, 1st Edition, Wiley, 2008.

Smith, D., Gear Noise and Vibration, 2nd Edition, Marcel Dekker, 2003.

Thomson, W. T., Theory of Vibration with Applications, 4th Edition, Chapman & Hall, 1993.

Other Resources

If you wish to explore any of the lecture topics in more depth, then other resources are available and assistance may be obtained from the UNSW Library. One starting point for assistance is: https://www.library.unsw.edu.au/servicesfor/index.html.

7. Course evaluation and development

Feedback on the course is gathered periodically using various means, including the Course and Teaching Evaluation and Improvement (CATEI) process, informal discussion in the final class for the course, and the School's Student/Staff meetings. Your feedback is taken seriously, and continual improvements are made to the course based, in part, on such feedback.

In this course, recent improvements resulting from student feedback include a reduction in the number of lecturers, which should ensure greater consistency of delivery, and an increase in the number of worked examples demonstrating the application of the theory. Another change has been the switch to a MATLAB®-based first assignment, which is intended to provide greater familiarity with MATLAB® and to give a practical introduction to Fourier Analysis, which forms the basis for many advanced condition monitoring methods.

8. Academic honesty and plagiarism

UNSW has an ongoing commitment to fostering a culture of learning informed by academic integrity. All UNSW students have a responsibility to adhere to this principle of academic integrity. Plagiarism undermines academic integrity and is not tolerated at UNSW. *Plagiarism at UNSW is defined as using the words or ideas of others and passing them off as your own.*

Plagiarism is a type of intellectual theft. It can take many forms, from deliberate cheating to accidentally copying from a source without acknowledgement. UNSW has produced a website with a wealth of resources to support students to understand and avoid plagiarism: https://student.unsw.edu.au/plagiarism The Learning Centre assists students with understanding academic integrity and how not to plagiarise. They also hold workshops and can help students one-on-one.

You are also reminded that careful time management is an important part of study and one of the identified causes of plagiarism is poor time management. Students should allow sufficient time for research, drafting and the proper referencing of sources in preparing all assessment tasks.

If plagiarism is found in your work when you are in first year, your lecturer will offer you assistance to improve your academic skills. They may ask you to look at some online resources, attend the Learning Centre, or sometimes resubmit your work with the problem fixed. However more serious instances in first year, such as stealing another student's work or paying someone to do your work, may be investigated under the Student Misconduct Procedures.

Repeated plagiarism (even in first year), plagiarism after first year, or serious instances, may also be investigated under the Student Misconduct Procedures. The penalties under the procedures can include a reduction in marks, failing a course or for the most serious matters (like plagiarism in an honours thesis) even suspension from the university. The Student Misconduct Procedures are available here:
http://www.gs.unsw.edu.au/policy/documents/studentmisconductprocedures.pdf

Further information on School policy and procedures in the event of plagiarism is presented in a School handout, Administrative Matters, available on the School website.

9. Administrative Matters

You are expected to have read and be familiar with *Administrative Matters*, available on the School website: https://www.engineering.unsw.edu.au/mechanical-engineering/sites/mech/files/u41/S1-2015_Admin-Matters.pdf

This document contains important information on student responsibilities and support, including special consideration, assessment, health and safety, and student equity and diversity.

Wade Smith
20 July 2015
(v2: 5 August 2015)
(v3: 20 August 2015)
(v4: 11 September 2015)
(v5: 15 September 2015)

Appendix A: Engineers Australia (EA) Professional Engineer Competency Standards

	Program Intended Learning Outcomes
PE1: Knowledge and Skill Base	PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals
	PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing
	PE1.3 In-depth understanding of specialist bodies of knowledge
	PE1.4 Discernment of knowledge development and research directions
	PE1.5 Knowledge of engineering design practice
	PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice
PE2: Engineering Application Ability	PE2.1 Application of established engineering methods to complex problem solving
	PE2.2 Fluent application of engineering techniques, tools and resources
	PE2.3 Application of systematic engineering synthesis and design processes
	PE2.4 Application of systematic approaches to the conduct and management of engineering projects
PE3: Professional and Personal Attributes	PE3.1 Ethical conduct and professional accountability
	PE3.2 Effective oral and written communication (professional and lay domains)
	PE3.3 Creative, innovative and pro-active demeanour
	PE3.4 Professional use and management of information
	PE3.5 Orderly management of self, and professional conduct
	PE3.6 Effective team membership and team leadership