Problem-Based Learning using an eBook?

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Abstract*: As more and more material becomes available in electronic form and readily accessible from the WWW it is necessary that students develop the skills necessary to make effective use of the material. One of the attributes required of engineering graduates is that they have life long learning skills and unit descriptions often include this as one of the planned outcomes. This paper describes the use of an eBook on the topic of vibration as the basis for a problem-based assignment aimed at developing the desired skills.*

Introduction

In 2004 Stone and Pan (2004, 2007) produced an eBook for vibration. The contents of this eBook cover basic vibration theory and some more advanced material. The chapter headings of the eBook are,

Introduction: This discusses the importance of vibration and introduces the animation programs, equilibrium position and degrees-of-freedom.

Chapter 1: One degree-of-freedom vibration. This covers simple vibration theory and introduces many of the terms and concepts that are used in more complex vibration situations.

Chapter 2: Two degree-of-freedom vibration. This extends vibration theory and introduces the concepts of modes of vibration and illustrates some methods for reducing vibration.

Chapter 3: Beam on springs. This is another example of a two degree-of-freedom system that includes rotation as well as translation. Together with the axial system considered in chapter 2 it provides useful illustrations for the next chapter.

Chapter 4: Analysis methods. A variety of methods that are used for finding natural frequencies and mode shapes is presented.

Chapter 5: Multi degree-of-freedom vibration. The analysis of systems with increasing numbers of degrees-of-freedom is presented.

Chapter 6: Modal analysis. The use of modal characteristics to find transient and steady state solutions.

Chapter 7: Continuous systems The axial and torsional vibration of beams are presented.

Chapter 8: Continuous systems. The transverse vibration of beams is presented.

Chapter 9: Receptances - a systems approach. The systems approach is useful in gaining understanding and finding solutions. It allows a building block approach to generate complex systems.

The main advantage of the eBook is the links to 78 animation programs that illustrate the material and allow the 'reader' to investigate the effects of parameter variation. Some of these programs were written previously (Scott et al., 2000, 2001, 2004) and others were purpose written for the eBook.

The authors of the eBook teach (in lectures) some of the material in a third year unit. This material is from chapters 1, 2, 6, 7 and 8. It was realised that the eBook could also be used as the basis for a range of assignments that would involve students mastering some of the remaining material in the eBook. It was anticipated that this would/should develop life long learning skills and that this assignment could involve elements of problem-based learning.

The literature on problem-based learning is extensive, see for example the extensive list of references in Walton and Matthews (1989) and since then there has been much more. The objectives of problem-based learning vary somewhat depending on the discipline but the main elements are (from Bridges and Hallinger, 1997)

1. Address a problem that future professionals *predictably* will encounter.
2. The content of the curriculum is organised around these problems rather than around disciplines.
3. Students work in small groups and take responsibility for their own learning.
4. The instructor creates or selects the problems that are the focal point for learning but does not take an active role in presenting the content.

The assignments based on the eBook involved elements of the above (1, 3 and 4).

The Assignments

The students (around 140) that elect to take the third year vibration unit are made up of both single and double degree students. Their engineering major is normally mechanical or mechatronics engineering. Double degree students will often have mathematics or computing as their second major. The unit is regarded as ‘hard’ (see Outcomes below) and has a large mathematical content. Any realistic vibration problem will inevitably involve a great deal of mathematics and will require a computer for its solution. This was the major concern in setting the problem, would the students have sufficient computing skills?

The general topic area chosen for the assignments was the systems approach to vibration analysis. This was not part of the current vibration unit. However in the 1980’s a final year unit had the systems approach as half the content. In those days students were taught in a traditional lecture mode and found the concepts involved in the systems approach difficult. Since a systems approach to engineering is currently encouraged it was considered that a problem requiring a systems approach could prove challenging. The eBook has a chapter on ‘Receptances - a systems approach’ and it was therefore of interest to see how the students would perform on a problem-based assignment involving systems.

The first assignment was set in 2005 and is shown in Appendix 1. In the first trial the assignment was one of two assignments (the other being set on what was taught in lectures). Also each student was required to work independently which is not commonly the case for problem-based learning. This assignment problem was similar to one described in the eBook but was very challenging requiring the optimisation of a frequency response that was dependent on three variables. It was soon apparent that the majority of students did not have the necessary computing skills and therefore the assignment took much longer to complete than anticipated. The result, however, was that most students felt they had developed life long learning skills and they had mastered the systems approach to vibration problems. It was evident to the author that students had achieved a much better comprehension than had been achieved in the earlier course when the topic was lectured. This conclusion was based on a comparison of the exam results from the lectured course and the content of the assignment reports

The experience gained from the first assignment led to some changes in 2006. There were still two assignments but the first assignment (Appendix 2) had an increased weight and required students to work in self-selecting groups with at least one ‘programmer’ in each group. In order to widen the scope of the problem the context was changed to the unstable vibration called ‘chatter’ that occurs in machining. Another eBook was in the process of being written and basic chatter theory was covered in it. This assignment was much closer to the problem-based learning approach in that teams were involved. To encourage active participation of all team members the teams (around 40) were informed that five teams selected at random would be required to have a viva. This assignment was also done well though more students sought advice (mainly on chatter theory) than had been the case with the 2005 assignment. Also the lack of computing skills was not so evident.

The most recent (2007) assignment was the result of the experience gained from the first two and students were surveyed about their reaction to the unit including the assignment. As it was clear that the problem-based assignment involved a major time commitment it was the only assignment required and its weight was increased to 20% of the unit. This assignment arose from a consulting enquiry and so was ‘a problem that future professionals *predictably* will encounter’. It required a systems approach and there was not a similar problem in the eBook. Teams were again self-selecting with a viva to be held for five teams. The results of this assignment have been more thoroughly investigated and are described in the next section.

Outcomes for Students

The University of Western Australia has various means available to staff for determining student evaluations. Individual lecturers may request a SPOT (Student Perceptions Of Teaching) questionnaire to be administered at the end of a lecture series with the lecturer not present. The results of these surveys are not made available to Heads of School/Department. There is a SURF (Students' Unit Reflective Feedback) questionnaire on the entire unit but this is not very detailed. Recently the Head of the School of Mechanical Engineering has had an independent and in depth survey done on selected units, which included the one containing the assignments described. This was done online using a survey provider called "Survey Monkey" and was anonymous and entirely optional. The 15 questions were not determined by the lecturers. In the event 68 students out of 140 completed the survey. The survey covered the whole unit and the four lecturers who were involved. At the time of the survey only 3 lecturers had presented material to the students and one of these was a 'Postgraduate teaching intern' who gave 4 lectures. The survey results on the lectures/lecturers were as follows,

Overall, the lectures in this unit were a useful part of the course.

Strongly agree 35; Agree 29; Neither agree or disagree 3; Disagree 1; Strongly disagree 0;

The lecturers showed enthusiasm in lectures

Strongly agree 36; Agree 29; Neither agree or disagree 3; Disagree 0; Strongly disagree 0;

It is evident that as far as lectures and lecturing goes the standard was high. This is encouraging since 43 of the students used the words 'hard' and 'difficult in describing the unit. The most colourful comment was, *The lecturers in this unit were great I really appreciate their dedication and enthusiasm. The unit is bloody hard though, and I wouldn't recommend anyone do it for 'fun' when there are other more easy to pass units out there. If you like maths, then it's a good unit to do.*

In fact one of the questions addressed the issue of recommending it to others as it was an elective unit.

This unit was a worthwhile educational experience and I would recommend it to other students

Strongly agree 13; Agree 32; Neither agree or disagree 16; Disagree 5; Strongly disagree 1;

Also the students were asked, **Please describe your educational experience in this unit (enjoyable, poor, etc) and why this was the case**. Enjoyable was the word used by 43 of the 68 students. A typical response was, *Very enjoyable, I learnt a lot from the lectures, and my self learning ability increased.*

The question relating to the assignment was, **Tell us about the major assignment in this unit and what you got out of doing it. What value was there for you in doing this activity?** Half the responses were negative complaining that too much computing was involved.. The most extreme was "*nothing!!!! one of the worst assignments ive ever done, it is not a programing unit, i dont want to program nor do i want my assignments to be based around. if i wanted to do computer science i would have done it"*. However the other half of the respondents were much more positive and indicated that some of the goals of problem-based learning had been achieved. Typical of these comments were the following,

"It was a bit tricky, and since none of it was covered in lectures it was hard to grasp the concepts. also the programing part of the assignment was hard as nobody in our group was really good at computer programming."

"This was a large project that forced you to learn a large amount of material. Since it involved a few people, if you were lacking in one aspect you could (rely on)/(learn from) other members."

"Valuable - tested our knowledge of the material while extending us in finding a solution. Also very interesting as it related to real life situations."

"Major assignment was difficult and hard to visualise. A deeper understanding of receptances was a value of the activity."

"The major assignment was a very good learning experience. It was a good way to get to fully understand vibration principles and a good excuse to get to play with MATLAB. Learning MATLAB programming will be handy for a future unit I am enrolled in. It also reinforced some learning from previous maths units about optimisation."

"Major assignment was excellent. Learnt a lot and very challenging, but took up a lot of time, and ran into a few brick walls doing it. glad when it was over."

"This assignment was very valuable as it improved my understanding of matlab. We also had to teach ourselves new concepts to do the assignment. This involved reading the online book and understanding how to apply those concepts to the project."

As far as the author was concerned the final reports, with one exception, arrived at the required optimised absorber (appendix 3). The mastery of the systems approach was much better than that demonstrated in exams when the topic had been covered in lectures but not in an assignment.

Conclusions

The experience over three years of setting a problem-based assignment has shown that students find this challenging and time consuming. The mathematical nature of vibration analysis requires complex equations to be solved. All three assignments involved an optimisation process that required the use of a computer. This clearly posed problems for many students and begs the question of whether engineering graduates need to be able to use/program computers for such tasks. It would be preferable to remove the need for programming but this would then restrict the range of problems to much simpler ones that would not be typical of those predictably encountered by professional engineers. Overall it was apparent that despite the difficulties many aspects of problem-based learning were achieved using a problem based on part of the eBook.

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Appendix 1

Assignment 2005 - 12% of unit

A boring bar may be represented by a clamped/free round bar and chatter occurs when the bar vibrates in a transverse manner. Such bars are prone to chatter because they have little damping. It is proposed to design a damped cantilever bar by employing a tube with another bar inside as shown below.

The first mode of transverse vibration is to be damped by inserting some damping material (red) between the tube and bar at their free ends. Both bars are made of steel (E = 2.0e11 N/m^2; Density =7800 kg/m^3) and have negligible damping.

The design objective is to minimise the maximum response at the free end of the tube by adjusting the characteristics of the damping material and the diameter of the solid bar.

Each student will be given (on request) individual values for the overall length and diameter of the boring bar to be optimised. The clearance between the tube and the solid bar is to be 1mm, ie the bore diameter of the tube is to be 2mm greater than the diameter of the solid bar. The damping material should be assumed to have both stiffness and hysteretic damping. The optimum values of the stiffness and damping are to be determined as well as the diameter of the solid bar.

An investigation should be made of a source of damping material with the required stiffness and damping.

Report

Your report should include your analysis and optimisation method and a possible source for the damping material. It should be less than 1000 words. The deadline for submission is Monday 23rd May at noon.

Background material

One of the objectives of this assignment is to develop life long learning skills so you will have to learn off the WWW. The transverse vibration of bars will be covered in Professor Pan's lectures and notes are available on the WWW at,

http://www.mech.uwa.edu.au/bjs/eVib/Transverse.pdf

Also there is material available on a systems approach to vibration. This includes an analysis of two solid clamped/free bars mounted in parallel and with damping material connecting them at the free end. This may be found at,

http://www.mech.uwa.edu.au/bjs/eVib/Receptances.pdf

an optimising program is available for parallel solid bars at

http://www.mech.uwa.edu.au/bjs/eVib/Programs/Complex/Prog11/Transverse.html

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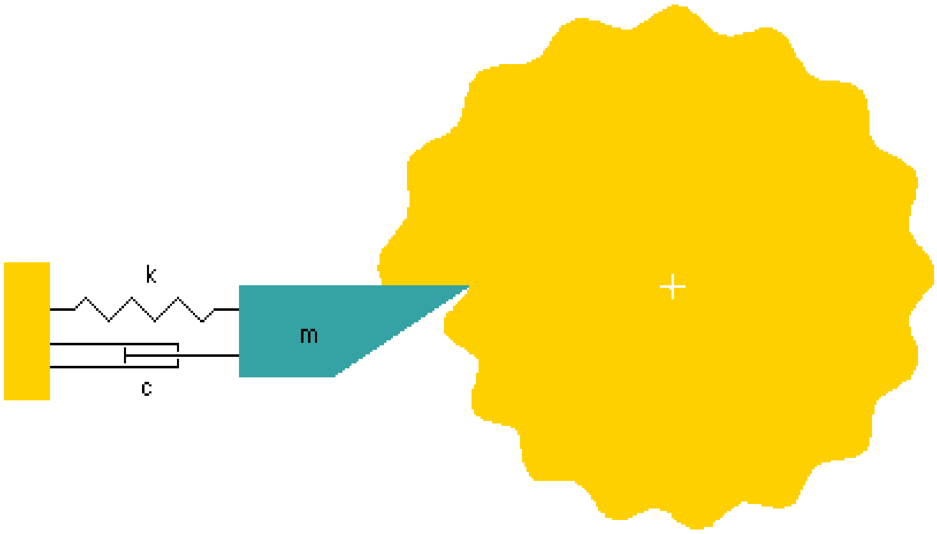
Appendix 2

Assignment 2006 - 16% of unit



A lathe is found to chatter and its response is measured and found to be well modelled by a single degree of freedom system. You are required to stop chatter by the addition of a vibration absorber. You will be expected to work in teams of 3 or 4. Each team must have a member who can program and to that end only one double degree student with Maths or Computing can be in a team. If there is any difficulty in forming teams assistance will be provided.

Each team will be given (on request) individual values for the one degree of freedom parameters, the cutting geometry, the workpiece material and the absorber mass. The absorber damping material should be assumed to have both stiffness and viscous damping. The optimum values of the stiffness and damping are to be determined.

The design objective is to maximise the unconditional width of cut, ie the maximum width that may be cut without chatter independent of the workpiece speed. You should determine the unconditional width of cut for the lathe with and without absorber. You should also determine the maximum width (without chatter) in the speed range 1500 to 8000 rpm.

An investigation should be made to find a source of damping material with the required optimum stiffness and damping.

<u>Report</u>

Your report should include your analysis and optimisation method and a possible source for the damping material. It should be less than 1000 words. The deadline for submission is Monday 22nd May at noon.

<u>Background material</u>

One of the objectives of this assignment is to develop life long learning skills so you will have to learn from the WWW. Some material on chatter may be found on the WWW at,

Introduction: http://www.mech.uwa.edu.au/bjs/eChatter/Introduction.pdf

Basic theory: http://www.mech.uwa.edu.au/bjs/eChatter/Basic.pdf

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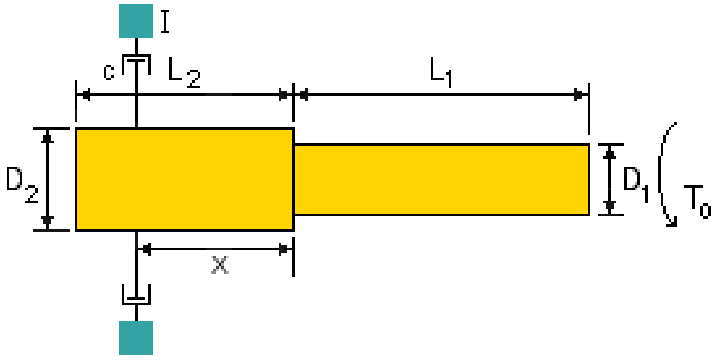
Appendix 3

Assignment 2007 - 20% of unit



A rotating system has a torsional vibration problem involving the first two non-zero modes of vibration. The system can be approximated to a stepped shaft made up of two undamped solid circular bars (yellow) excited at one end as shown. A torsional damper, comprising an inertia I and viscous damper c, is to be added to the second bar (L_2) in order to reduce the resonant response of the two modes as measured at the excited end. It is required to optimise both the absorber damper and the location of the absorber on the second bar. However, physical restrictions limit x to being greater than $0.1L_2$ and less than $0.9L_2$.

You will be expected to work in teams of 3 or 4. Each team must have a member who can program and to that end only one double degree student with Maths or Computing can be in a team. If there is any difficulty in forming teams assistance will be provided. Each team will be given (on request) individual values for the parameters L_1, L_2, D_1, D_2, I and the shear modulus G and density ρ of the material of the bars. The optimum values of x and c are to be determined to minimise the maximum resonant response (at the excited end) of the two modes.

Torsional dampers, of the kind modelled in this assignment, can fail and then the inertia of the damper is effectively fixed to the shaft. Investigate if the changes in the resonant frequencies that occur on failure could be used as a way of determining if the absorber has failed.

Report

Your report should include your analysis and optimisation method and an investigation of the changes in resonant frequencies if the absorber fails. It should be less than 1000 words. The deadline for submission is Tuesday 22nd May at noon. Several teams will be selected for a viva to ensure all team members have made an appropriate contribution.

Background material

One of the objectives of this assignment is to develop life long learning skills so you will have to learn from the WWW. Some useful material may be found in the eBook on the WWW at,

Receptances, a systems approach: http://www.mech.uwa.edu.au/bjs/eVib/Receptances.pdf

Continuous systems, axial and torsional vibration of bars:
http://www.mech.uwa.edu.au/bjs/eVib/Continuous.pdf

Teams should email me (bjs@mech.uwa.edu.au) with members' names, student ID's and type of degree. I will then send the system parameters for the team.

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