Creative Design Course Syllabus

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MECH5601F(33712) Creative Problem Solving and Design (SEM) 2013

The class will be held 6:00 PM to 9:00 PM Monday evenings for the fall term of 2014 at Carleton University in room ?3356? Mackenzie Engineering Building.

1 Overview

The course deals with software support for the process of designing complex systems such as a nuclear reactor, aeroplane or pipeline; with particular emphasis on computational mechanics, i.e., the mechanical behaviour of such designs. How much of the technology is captured, analyzed and simulated by the software? How is the design process for large complex systems organized, managed and regulated? What is the vision, the attack strategy or road map? What are the qualifications of the people and the availability of resources for a project? How does one balance the tension between the devil we know and the devil that we do not know, i.e., older more tested and trusted technology and newer, relatively less tested and trusted technology? Are design decisions based on evidence or judgement? Today, social, political and environmental issues can be just as important to a design as technical issues. There's a flea on the wing on the fly, on the frog on the bump on the log, in the hole in the middle of the sea.

The course is motivated by the changing role of computer hardware and software in designing, manufacturing, operation and maintenance of complex systems. Twenty years ago, computer-aided-design was largely limited to specifying the geometry of parts and assemblies. Analysis of performance was almost entirely done by analysts, not designers. In the next ten to twenty years, designers of most mechanical systems will rely on software that captures most the physics, mechanics and behaviour relevant to the production and operation of the product or system. Such computational models are sometimes called holistic models. The way design will be done will be quite different than the way it is done today and different skill sets and knowledge sets will be required at all levels from senior management to junior designers and technologists.

2 Outline

1. Historical Perspective: Designer Driven Analysis. Until the 1960s, design practice separated the design process into stages such as drawing-drafting or CAD design, analysis of the performance of a design, the planning for manufacturing, production planning, scheduling and supervision, system operation and plant de-commissioning into separate silos with little communication, interaction or feedback. Since the development of computers in the 1950s, increasingly sophisticated computer models have been developed to capture more and more of these stages and to integrate them into higher level more holistic computer computer models. NC Machining and Computer Aided Drafting were two of the earliest examples of computational models to have a major impact on Mechanical Engineering. The Silicon Compiler for VLSI design is perhaps the best example of a holistic model for the design process. In the past fifteen years ASME has developed standards for Verification and Validation of Computer Models for Solid and Fluid Mechanics. AWS has developed a standard for Verification and Validation of Computer Models for Computational Weld Mechanics. These standards provide guidelines for the use of computer models for decision making in the design process.

2. Optimization and Optimal Design of Experiments. Starting in the 1940s and 1950s, Taguchi and Geoge Box applied the mathematics of statistics to improving given designs using experimental data. Statistics had been used primarily to assess the performance of completed designs. Taguchi and Box's innovation was to incorporate statistics into the design process. Their methods dramatically changed industries, e.g., Toyota. In the last thirty years this has been evolving to apply similar ideas to computer models to compute the optimal design of experiments. The Large Hadron Collider project used to determine that the Higgs boson exists is perhaps the best and most widely known example of optimal design of an experiment.

3. Evidence based decision making, e.g., use of sensor data, big data, data mining and the role of statistics, stochastic processes and probability theory are beginning to play an important role in the design process.

4. Risk and Reliability Engineering. Probabilistic Design. Response surfaces, kriging and reduced order models in design. Design from the Viewpoint of Government Regulators.

5. Computer models for stress analysis. Prager-Synge's Hyper-Circle Theorem for upper and lower bounds in stress analysis and Eshelby's mechanics are quite different from

the stress analysis theory usually taught in undergraduate courses.

6. Computer models for Fracture Mechanics and Design that are used in the design stage to reduce the risk of failure by brittle or ductile fracture to acceptable levels. Some famous examples of such failures will be discussed. The concept of Fitness For Service (FFS) will be discussed.

7. Computer models for failure by fatigue and corrosion that are used in the design stage to reduce the risk of failure by brittle or ductile fracture to acceptable levels. Some famous examples of such failures will be discussed.

8. Computer models for design for failure by fatigue and creep, shake down analysis that are used in the design stage to reduce the risk of failure by brittle or ductile fracture to acceptable levels. Some famous examples of such failures will be discussed.

9. Computer models for design for welded structures; transient temperatures, microstructure evolution, distortion, residual stress, weld repairs, failure modes. The overlay weld repair of AECL's NRU reactor in 2009-2010 will be discussed as a example.

10. NDT Technolgy, training, licensing and regulation. Similar issues apply to highly qualified personnel in all areas of society. Search www for Have Crack, Will Travel. An example of NDT for low cycle thermal fatigue due to stratified flows in the start up of PWR nuclear reactors will be discussed.

11. ASME code Rule Based Design vs Design by Analysis will be illustrated by a review and discussion of the design case described in the paper, Radoslav Stefanovic, Alicia Avery, Kanhaiya Bardia, Reza Kabganian, Vasile Oprea, Trevor Seipp, USERS DESIGN SPECIFICATION PREPARATION FOR 214Cr-1Mo-14V REACTORS IN ACCORDANCE WITH ASME SECTION VIII, DIVISON 2 AND CODE CASE 2605, PVP2013-97720, Proceedings of the ASME 2013 Pressure Vessels and Piping Conference PVP2013 July 14-18, 2013, Paris, France.

12. Health monitoring. The Internet of Things.