The University of Western Ontario
Faculty of Engineering
Department of Civil and Environmental Engineering

CEE 9720a – Introduction to Pipeline Design and Assessment
Course Outline – Fall 2011

Objective

Pipelines are the safest and most economical means to transport large quantity of hydrocarbons. There are about 500,000 km and 100,000 km of onshore natural gas transmission pipelines in the US and Canada, respectively. The safe operation of these vast pipeline networks is the top priority for the pipeline operators in the US and Canada, and has significant social and economic implications. The design and integrity assessment of pipelines is a multi-disciplinary undertaking and involves a broad spectrum of engineering knowledge such as basic structural mechanics, elasticity and plasticity, soil mechanics, fracture mechanics, fatigue, reliability and risk assessments, and corrosion.

The objective of the course is to introduce the basic principles and methodologies employed in the design and assessment of onshore pipelines. Students who successfully complete this course should be able to perform the basic technical tasks carried out by pipeline integrity engineers. In particular, the students should be able to

- categorize pipelines based on their geographic locations, materials, function, and product carried;
- know the key material properties of line pipe steels;
- grasp the basic principles of plasticity and fracture mechanics;
- identify the class location of an onshore natural gas pipeline and use the design factor approach to determine the wall thickness of the pipeline;
- understand the basic tools and technologies used to conduct pipeline inline inspections;
- carry out integrity assessment of pipelines that contain metal-loss corrosion defects and planar defects, and
- understand the basic principles and methodologies of pipeline risk assessments.

Prerequisites

None.

Corequisites

None.

Antirequisites

None.

Contact Hours

2 lecture hours per week: Monday, 10 am to 12 pm.

Instructor

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Administrative Support: Ms. Cindy Cao, SEB 3010

Textbook

None.

Selected References

1. Anderson, T.L. 1995. *Fracture Mechanics: Fundamentals and Applications. 2nd Ed.* CRC Press, Boca Raton.
2. Barsom, J. and Rolfe, S.T. 1999. *Fracture and Fatigue Control in Structures: Application of Fracture Mechanics*. ASTM, PA.
3. Broek, D. 1988. *The Practical Use of Fracture Mechanics*. Kluwer Academic Publishers, Dordrecht.
4. Chen, W.-F. and Han, D.-J. 2007. *Plasticity for Structural Engineers*. J. Ross Publishing, Fort Lauderdale, FL.
5. Canadian Standard Association (CSA). 2007. *Oil and Gas Pipeline Systems, CSA Z662-07*. CSA, Mississauga.
6. Hutchinson, J.W. 1979. *A Course on Nonlinear Fracture Mechanics*. Technical University of Denmark.
7. Kiefner, J.F. and Clark, E.B. 1996. *History of Line Pipe Manufacturing in North America*. CRTD-Vol. 43, American Society of Mechanical Engineers, New York.

Lecture Notes

Prepared lecture notes will be made available to the students at the beginning of the course. Students should bring the notes to each lecture.

Laboratory

NA

Units

Both SI and Imperial units will be used in lectures, assignments and examinations

Specific Learning Objectives:

1. *Introduction*. At the end of this section, the students should be able to
    a. distinguish various pipeline categories;
    b. know the basic pipeline construction methods, and
    c. know the basic material properties of line steel pipe including yield strength, tensile strength, engineering and true stress-strain relationships, charpy v-notch toughness, and ductile-to-brittle transition temperature
2. *Pipeline Design*. At the end of this section, the students should be able to

a. know commonly used pipeline design standards in the US and Canada;

b. identify the location class for an onshore gas pipeline according to the Canadian pipeline standard CSA Z662-07, and

c. apply the design factor approach to determine the wall thickness for onshore pipelines.

3. *Pipeline Integrity Assessment*. At the end of this section, the students should be able to

   a. know the basic concepts and principles of theory of plasticity including the yield criterion (e.g. the von Mises and Tresca yield criteria), plastic flow rule and hardening rule;

   b. apply the incremental theory of plasticity to calculate the stress and strain in the pipeline due to internal pressure and/or axial load under different boundary conditions;

   c. know the commonly-used pipeline corrosion protection and inspection techniques;

   d. apply the ASME B31G, B31G Modified and RSTRENG methods to determine the acceptability of a given metal-loss corrosion defect on a pipeline;

   e. know the basic concepts and principles of fracture mechanics including the stress intensity factor, J-integral, crack tip opening displacement (CTOD), small-scale yielding (SSY), large-scale yielding, fracture toughness, plane strain and plane stress conditions;

   f. apply the Battelle model (i.e. Log-secant approach) and failure assessment diagram (FAD) approach to evaluate the integrity of pipelines containing cracks or planar defects;

   g. know the basic concepts and principles related to fatigue including Paris law, S-N curve, Miner's rule, variable amplitude loading and cycle counting method (e.g. rainflow counting), and

   h. apply the fatigue principles to evaluate the remaining life of pipelines containing planar defects.

4. *Pipeline Risk Assessment*. At the end of this section, the students should be able to

   a. know the common integrity threats for pipelines and basic steps for carrying out a pipeline risk assessment;

   b. estimate the average pipeline failure statistics using the pipeline failure databases in the US and Europe including the DOT, EGIG and CONCAWE databases;

   c. evaluate the failure consequences of onshore gas pipelines using the simplified pipeline ignition and thermal radiation models, and

   d. know various risk measures in the pipeline risk assessment such as the societal and individual risks, and various risk criteria such as the as low as reasonably practicable (ALARP) criterion.

Assignments
Four assignments during the term. Students must turn in one solution to each assignment to Ms. Laurence by the specified due date. The penalty for late submission is 10% per day late.

Examinations
One 3-hour **Open Book** Final Examination.

Evaluation
The final grade is computed as follows:

Assignments	40%
Final Examination	60%
TOTAL	100%

English
In accordance with Senate and Faculty Policy, students may be penalized up to 10% of the marks on all assignments, tests and examinations for the improper use of English. Additionally, poorly written work with the exception of final examinations may be returned without grading. If resubmission of the work is permitted, it may be graded with marks deducted for poor English and/or late submission.

Scholastic Offence
Scholastic offences are taken seriously and students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence, at the following Web site:
http://www.uwo.ca/univsec/handbook/appeals/scholastic_discipline_grad.pdf

Consultation
Students are encouraged to discuss problems with their teaching assistant and/or instructor in tutorial sessions. Other individual consultation can be arranged by appointment with the instructor.