Pipeline Education at Engineering Schools: What Is Needed?

Henry Liu
Capsule Pipeline Research Center, University of Missouri-Columbia, Columbia, MO, United States,
http://www.cclabs.missouri.edu/~cprc
Telephone: (573) 882-2779; FAX: (573) 884-4888; liuh@missouri.edu

Abstract: Many areas of engineering practice require a good working knowledge of pipeline. Yet, most engineering schools and universities teach little about pipelines, other than the most elemental knowledge in pipe flow of incompressible, Newtonian fluids, in the first course of fluid mechanics. This lack of education in pipeline limits the ability of college graduates to practice pipeline engineering without extensive on-the-job training. It also hinders the development and commercial use of advanced pipeline systems such as those for transporting solids. To solve this problem, it is recommended that all engineering schools enrich their curricula by offering at least one pipeline elective course that covers all basic aspects of pipelines including both principles and technology for all types of pipelines—liquid, gas, slurry, and capsule. Such a course taught at the University of Missouri-Columbia is described herein. In addition, schools that wish to become leaders in the pipeline field should provide additional courses in pipeline engineering described herein.

Keywords: education, pipeline engineering, transportation, universities

Introduction

Pipeline is a time-honored and preferred mode of freight transportation not only for various liquids and gases but also for many solids. At present, practically all the natural gas transported on land is by pipeline, and most of the liquids transported on land including water, sewage and various petroleum products are by pipeline. Pipeline has also been used throughout the world to transport hundreds of solids including coal, minerals, construction materials, plastics, fertilizers, mail, parcels, documents, foods and even library books. A recent review of the subject of freight pipelines covering various types of pipelines to transport solids is given in a task committee report of the American Society of Civil Engineers [1].

Pipeline is often the preferred mode of transportation due to the following advantages:

1. Economics—The cost for transporting liquid and gas by pipeline is often only a fraction of that by truck or train. Therefore, great cost savings can be accomplished by using pipeline instead of truck or train to transport any liquid or gas. Although using pipelines to transport solids is more costly than to transport liquids or gases, in many cases solids can also be transported at a lower cost by pipeline than by truck or train. This accounts for the use of pipelines for transporting certain solids in many cases around the world [1].
2. Safety—Pipeline is by far the safest mode of freight transport. This can be seen from a comparison of the average number of people killed each year by different transportation modes. According to statistics published by the U.S. Department of Transportation, while more than 800 people are killed by trucks and more than 500

people are killed by train per year in the United States, fewer than 30 people are killed by pipelines.

3. Underground—Most pipelines are constructed underground, at least 1 m below the surface of the ground. This means pipelines do not occupy land; the ground surface above pipelines can be used for other purposes such as farming, buildings or roads. Also, crossing of roads (railroads, highways, streets, etc.) by pipelines is done underground, and hence it does not interfere with traffic.
4. Reduction of Traffic Jam and Pollution—Use of pipelines to transport liquids, gases and solids reduces the need for trucks and freight trains. Consequently, highways and streets will not be as congested, and there will be fewer freight trains running on railroads. With fewer trucks and trains, air and noise pollution problems caused by trucks and trains will be reduced, resulting in a better environment.
5. Dependability—Pipelines being underground are protected from bad weather and operate 24 hours a day and 365 days a year. It is the most reliable mode of transportation. Also, theft of cargoes during transportation is very unlikely or rare for pipelines.

In spite of the great economic, safety and environmental values of pipelines, and in spite of the great technological advancements made in the pipeline field in the last three decades, many engineers and transportation planners have inadequate knowledge in pipelines and hence do not use pipelines for transportation when pipelines should be used. The root cause for this problem is inadequate education in college. Therefore, it is highly desirable to improve pipeline education at the college level, not only to prepare engineering students more adequately for handling their pipeline related future jobs, but also to train a new generation of engineers who can continue to improve pipeline technologies in order to benefit the public and to improve the environment. It is the purpose of this paper to offer recommendations on how to beef up college education on pipeline engineering to solve these problems.

Survey of universities

The current status of pipeline education at U.S. universities can be seen from the result of a national survey in the United States conducted by the writer in 1997 [2]. It was found that only 12 universities in the United States offer pipeline related undergraduate courses, and only 15 universities offer pipeline-related graduate courses. Only one university, the University of Missouri-Columbia, offers "Pipeline Engineering" or a similar introductory course exclusively on pipelines. The survey concluded that a strong need exists to have more of such courses offered at universities so that civil, chemical, mechanical, mining and other engineers who use pipelines to transport liquids, gases and solids will be better prepared to plan, design, construct and operate various types of pipelines in the future upon graduation from universities.

Pipeline engineering course

The "Pipeline Engineering" course taught at the University of Missouri-Columbia (UMC) is an introductory course that covers the entire field of pipeline [2]. It is an elective course taken mostly by seniors and graduate students in mechanical and civil engineering.

As shown in Table 1, the course number CE/MAE 345 indicates that the course is co-listed by both CEE (Civil and Environmental Engineering Department) and MAE (Mechanical and Aerospace Engineering Department). It is a 3-credit course that requires fluid mechanics as the

prerequisite. The writer has been teaching this course since 1985, once a year. So, the course has been taught 16 times. Since no textbook is available, over the years the writer has developed a rather extensive set of class notes that is handed out to the students in lieu of a textbook. The notes also contain sets of homework problems. Students are required to work on the homework problems as in most other engineering courses. In recent years, the course was taught simultaneously to students on the Columbia Campus and Kansas City Campus, using telecommunication systems such as Instructional Television (ITV), and most recently, Integrated Services Digital Network (ISDN).

Table 1. Course syllabus for "Pipeline Engineering" taught at University of Missouri-Columbia

Course Title	Pipeline Engineering	
Course No.	CE/MAE 345	
Credit Hours	3	
Catalog Description	Theoretical and practical aspects of pipeline engineering including pipeline transport of liquids, gases and various solids such as coal, sand and solid wastes.	
Prerequisites	CE/MAE 251 (Fluid Mechanics)	
Instructor	Dr. Henry Liu, Professor of Civil and Environmental Engineering	
Textbook	None (A set of typed class notes is handed out to students.)	
COURSE CONTENT	Chapter	Title
	1	Introduction
	2	Single-Phase Incompressible Flow of Newtonian Fluid in Pipe
	3	Single-Phase Compressible Flow in Pipe
	4	Non-Newtonian Fluids in Pipe
	5	Flow of Solid/Liquid Mixture in pipe–Slurry Flow
	6	Flow of Solid/Air in Pipe–Pneumotransport
	7	Flow of Capsules in Pipe–Capsule Pipelines
	8	Pipe, Fittings, Valves and Pressure Regulators
	9	Pumps, Blowers, and Compressors
	10	Flow Meters, Sensors, Pigs and Automatic Control Systems
	11	Protection of Pipelines Against Freezing, Abrasion and Corrosion
	12	Planning, Construction and Operation of Pipelines
	13	Structural Design of Pipelines: Load Considerations and Pipe Deformation/Failure
	14	Economics of Pipelines
	15	Legal, Safety and Environmental Issues on Pipelines
	16	Code, Standards and Government Regulations

As listed in the course content in Table 1, the course covers a wide array of topics pertaining to pipeline engineering. Chapter 1, Introduction discusses the history, the widespread use, the various types, the advantages and the special features of pipelines. Chapter 2 through 7 discuss the fluid mechanics of various types of pipe flow including incompressible and compressible flows of Newtonian fluids, non-Newtonian fluids, flow of solid/liquid mixture (slurry), flow of solid/air mixture (pneumotransport), and flow of capsules (capsule pipelines). Chapter 8 discusses the various types of pipes (steel, concrete, PE, PVC, etc.), valves (gate, globe, ball, butterfly, etc.) and pressure regulators in pipelines. Chapter 9 discusses pumps (for liquids and

slurry) and blowers and compressors (for gases). Chapter 10 discusses the various kinds of flowmeters, sensors, pigs (scrapers) and automatic control systems used in pipelines. Chapter 11 discusses various means to protect pipelines against freezing, abrasion and corrosion, such as cathodic protection. Chapter 12 discusses planning, construction and operation of pipelines, including modern use of advanced technologies such as global positioning systems (GPS), directional drillings, automatic control using computers, and pipeline integrity monitoring such as leak detection. Chapter 13 covers structural design of pipelines—load considerations and pipe deformation and failure. Chapter 14 discusses the economics of pipelines including life-cycle cost analysis and comparison of the cost-effectiveness of pipelines with alternative modes of transport such as truck or railroad. Chapter 15 deals with legal, safety and environmental issues about pipelines. Finally, Chapter 16 covers briefly the codes, standards and government regulations on pipelines in the United States.

The aforementioned course provides students with a broad knowledge and background in pipeline engineering so that upon graduation they can easily undertake pipeline-related jobs and assignments, whether they work for a pipeline company, pipeline design firm, petroleum company, natural gas company, water utility, mining firm, electric utility, sewer authority, irrigation company, or any other firm or job that uses pipelines. It is an interdisciplinary course that serves the need of students in various fields.

Judging from course evaluation by students, most students feel that the course is highly relevant and practical. They appear to be well motivated. The only problem with the course is it is difficult to cover all the 16 chapters adequately in one semester with only 3 hours of lectures per week. A 4-hour-per-week course will be more adequate.

Pipeline curriculum

Universities that wish to become leaders in pipeline education and research in any nation may want to have a curriculum (more than one course) in pipeline engineering. This can be done in different forms under different existing departments such as civil engineering and mechanical engineering. It is not advisable to have a separate educational degree program (department) devoted solely to pipeline. That would certainly be too narrow in scope, as it would be too narrow for having a degree program solely on highway and railroad. Due to the importance of fluid mechanics or hydraulics to pipeline engineering, a logical base for launching a pipeline engineering curriculum is programs of "hydraulics" or "fluid mechanics" that exist in many civil engineering or mechanical engineering departments. The pipeline curriculum can also be placed under chemical, petroleum, or hydraulic engineering departments.

Courses in the pipeline engineering curriculum may cover any of the subjects (chapters) listed in Table 1—either individually or in some combination, depending on the related research program offered at the school. For instance, at the University of Missouri-Columbia (UMC), a graduate course entitled "Capsule Pipelines" is taught, providing in-depth treatment of various types of capsule pipelines including hydraulic capsule pipeline (HCP), pneumatic capsule pipeline (PCP) and coal log pipeline (CLP). This course is taught to provide the training of the graduate students who work for the Capsule Pipeline Research Center (CPRC), a unique interdisciplinary research center of UMC, and to maintain UMC's leadership position in this field. Another graduate course taught at UMC deals heavily with unsteady flow and water hammer in pipelines. Other possible courses that can be offered in a pipeline engineering curriculum includes "compressible pipe flow," "non-Newtonian fluids," "multi-phase flow," "pipeline

design," "advanced pipeline engineering," etc. they can be tailored to the needs of individual schools and programs.

Conclusions

Pipeline engineering is important to many fields of engineering including civil, environmental, chemical, hydraulic, mining, nuclear and petroleum. It is a subject grossly neglected in current engineering education at universities in the U.S. and around the world.

To remove this deficiency in current college education, it is recommended that all engineering colleges should start teaching an elective course "Pipeline Engineering" for both undergraduates and graduate students. In addition, special schools that have strong pipeline-related research programs, or schools which wish to become a leader in pipeline education and/or research, should develop additional pipeline-related courses for a curriculum in pipeline engineering. Graduate students, both at the M.S. and Ph.D. levels, should be able to focus their training in pipeline engineering, or have a heavy dose of courses in pipeline engineering, in order to prepare them to be the future leaders in the pipeline field.

References

[1]. H. Liu, R. L. Gandhi, M. R. Carstens and G. Klinzing, "Freight pipelines: current status and anticipated use,"(Report of American Society of Civil Engineers (ASCE) Task Committee on freight Pipelines), ASCE J. of Transportation Engr., **vol. 124**, no. 4, pp.300-310, Jul/Aug 1998.

[2]. H. Liu and T. Marrero, "Pipeline engineering research and education at universities in the United States," C.D. Proc. of Intl. Conf. on Engr. Education (ICEE-98), Rio de Janeiro Brazil, 15 pages, August 17-20, 1998.

Acknowledgment

The writer wishes to thank the National Science Foundation (NSF) for nine years of funding of Capsule Pipeline Research Center (CPRC) under NSF's State/Industry University Cooperative Research Center (S/IUCRC) program. The NSF funding contributed greatly to the advancement of the science, knowledge and technology of capsule pipelines, and to the development of a Pipeline Engineering curriculum at UMC.