2003

Performing Interactively A Thermo-Fluids Laboratory Experiment in the Virtual Domain

Sushil K. Chaturvedi
Old Dominion University

Ali O. Akan
Old Dominion University

Tarek M. Abdel-Salam
Old Dominion University

A. Priyadershini
Old Dominion University

Original Publication Citation

Chaturvedi, S. K., Akan, A. O., Abdel-Salam, T., & Priyadershini, A. (2003). *Performing interactively a thermo-fluids laboratory experiment in the virtual domain.* Paper presented at the 2003 ASEE Annual Conference and Exposition, Nashville, Tennessee.

Performing Interactively a Thermo-Fluids Laboratory Experiment in the Virtual Domain

S. K. Chaturvedi, A. O. Akan, T. Abdel-Salam and A. Priyadershini

College of Engineering and Technology, Old Dominion University
Norfolk, Virginia 23529

Abstract

This paper deals with the development of an experiment in the virtual domain for the undergraduate thermo-fluids laboratory in the mechanical engineering program. A physical experiment titled "Venturimeter as a Flow Measuring Device" is replicated as a computer-based experiment as part of the ongoing effort at Old Dominion University to develop web-based laboratories that would provide students hands-on experience in the virtual domain. A web-based module is developed that allows experimentation and data taking in a virtual setting much like in the physical experiment. This module incorporating the virtual venturimeter has been used by students to take data for several flow rates to determine the coefficient of venturimeter as a function of Reynolds number. The proposed virtual module will provide impetus for development of virtual engineering laboratories which in turn may make it possible offering of web-based undergraduate engineering programs at Old Dominion University.

Introduction

Rapid developments in computer, communication, and internet technologies have opened new pathways to information and knowledge. Virtual classrooms, televised and online courses, video-help sessions, virtual-collaborative learning environments, e-campus, and virtual labs have become the buzzwords of academia. These emerging learning tools have provided a wide array of

opportunities to distance learning students who may have otherwise not pursued higher education [1-5]. From the early seventies to the mid-nineties, synchronous transmission of televised courses was the primary mode of transmission for distance learning courses and programs [6-7]. Easy access to the internet during the nineties has made web-based courses a viable, and increasingly the preferred, mode of distance education [8-9]. Online courses offer "anytime and anywhere" flexibility, and consequently, many distance learning students find them more attractive compared to live televised courses. Also, due to the development of faster computer processors and high-speed fiber optic digital transmission lines in the nineties, multimedia courses and synchronous and asynchronous video streaming of classroom lectures have become feasible [10-11]. The issue of the effectiveness of distance learning courses has also received the attention of researchers in recent years [12-14].

There is a scarcity of undergraduate engineering programs available through distance learning networks. Resistance to the implementation of web-based engineering programs stems from the fact that engineering is perceived, and rightly so, as a hands-on discipline. As a result, there remains considerable skepticism among engineering faculty, and even among students, about offering of undergraduate engineering programs on distance learning networks. There are two notable exceptions, however. In 1998, The University of North Dakota began an undergraduate distance learning engineering program for industry [3], offering undergraduate degrees in chemical, electrical, and mechanical engineering. Courses are delivered to off-campus locations through the asynchronous video-transmission of lectures. The laboratory courses are conducted on-campus in two-week sessions during the summer. Another example is the College of Engineering and Technology at Old Dominion University, which offers mechanical, civil, and

electrical engineering technology programs via Old Dominion's TELECTECHNET distance learning network. Live televised courses are beamed to several receiving sites in Virginia and across the country. Laboratory courses are offered through creation of videotapes and CD-ROMS of all experiments for viewing by distance students [15-16]. However, the videotape and CD-ROM based methods fail to incorporate two critical aspects of laboratory experiments. First, the distance students are passive audience, not actively participating or exercising control generally afforded by a real-life experimental set-up. Second, there is also absence of teamwork and communication among students – critical ingredients of an undergraduate program engineering.

Vision and Scope of the Present Work

The virtual absence of undergraduate engineering programs on distance learning networks can be attributed primarily to a lack of high quality web-based virtual labs capable of capturing the details of lab experiments, including hands-on activities and the collaborative work environment, in the virtual domain. Our vision is to develop web-based virtual engineering laboratories that can be used to recreate the learning environment of physical engineering laboratories. Following the vision, we have designed a virtual venturimeter experiment module as part of the proposed thermo-fluids virtual lab which permits students to perform the experiments interactively by manipulating an e-valve on the computer screen. A special feature of the module is the hands-on experience which is often missing for distance learning students who passively view video or CD-ROM of previously recorded physical experiments. The collaborative work environment, generally encountered in laboratories is not included in the present study but will be reported in a future publication.

Methodology

The present work has developed the virtual venturimeter experiment module that allows distance learners to access it through the internet and enables them to conduct the experiment much in the way an on-campus student experiences it in a real laboratory. The undergraduate thermo-fluids lab course (ME 305) has been identified as the course for transformation to the virtual domain. In addition to receiving an introduction to thermodynamics and fluid mechanics experimentation and measurement techniques, students in this course are also exposed to digital data acquisition using software, such as LabView, and statistical treatment of data and error.

The experiment chosen for validation of the proposed methodology involves measurement of the venturimeter coefficient which in turn allows it to be used as a flow-measuring device. The physical experiment, shown in Fig. 1, involves measuring the pressure drop between the inlet and throat sections of the venturimeter for a number of flowrates. The flow through the system is regulated by opening or closing a valve. The pressure reading in the piezometer tubes connected to the inlet and the throat sections of venturimeter are recorded for the selected flowrate, and the coefficient of venturimeter (c_v) is calculated using the following equation.

$$\dot{Q}_{Actual} = c_v A_2 \sqrt{\frac{\frac{2(P_1 - P_2)}{\rho}}{1-\left(\frac{A_2}{A_1}\right)^2}} \qquad (1)$$

where $\dot{Q}_{Actual}$ is the measured flowrate, A_1 and A_2 are inlet and throat areas respectively, ρ is water density, and $(P_1 - P_2)$ is the pressure drop from the inlet to throat section.

Figure 2 shows the web-based virtual experiment module (www.mem.odu.edu/ simulations) that has been designed to replicate the physical experiment. The virtual experiment procedure is described on the left side of the window in Fig. 2. The flowrate is measured from an e-flowmeter while the flowrate is controlled through an e-valve through clicking action of the mouse. The experiment is commenced by clicking the valve to the half open position, and clicking the pump on. This creates a sound of rising water, and eventual stabilization of water level in the piezometer tubes (Fig. 3). The flowrate indicated on flowmeter dial can be noted directly while the water level heights in the first and fourth tubes can also be noted directly. Since in real experiment, the tube water level generally fluctuates around a mean value, a fluctuating motion of the water meniscus around the mean height was also incorporated to achieve more realistic simulation.

Using the flowrate and pressure drop data, and the Eq. (1), students can determine the values of c_v and Reynolds number, Re, for a graphical representation on a c_v-Re diagram. After completing one set of experiment, the higher flowrate case (Fig. 4) can be implemented by following the virtual experiment procedure. It should be noted here that to enable the virtual module to yield data, two approaches can be used. First, experimental data from the physical experiment can be used in the computer program as the virtual data for the computer simulated experiment. Alternatively, computational fluid dynamics techniques can be used to predict pressure drop and venturimeter coefficient for the chosen venturimeter geometry for a number of flowrates (Reynolds number). Although we have used both techniques to generate database for the virtual experiment, only data from the physical experiment was used in the present study to power the virtual experiment module. The results (c_v versus Re) from the virtual experiment are

shown in Table 1.

Concluding Remarks

The virtual venturimeter module has been developed, and successfully tested in a laboratory class setting. Students used both the physical experiment as well as the virtual experiment module to acquire data and determine venturimeter coefficient. An important characteristic of lab experiments, namely hands-on experience through interactive data taking has been demonstrated in the virtual experimentation domain. The proposed methodology offers three distinct advantages that are likely to enhance quality of engineering education. First, it will provide impetus for development of virtual engineering laboratories which in turn will enable engineering departments at Old Dominion University to offer web-based distance undergraduate engineering programs in the near future. The second, but equally important, benefit will be that an instructor will be able to perform virtual experiments in lecture classes for clarification of concepts and reinforcement of physical principles. Instead of taking students for a lab demonstration, the instructor using the web-based modules can bring (virtual) laboratory experiments to lecture classes. Last but not least, virtual experiments can be combined with physical experiments in on-campus laboratories that will improve the quality of students by providing them with hands-on experiences in both physical and virtual domains.

References

1. Strong, R. W. and E. G. Harmon, "Online Graduate Degrees. A Review of Three Internet-Based Master's Degree Offerings," American J. of Distance Education, Vol. 11, No. 2, 1997, pp. 58-70.

2. Whittington, C. D., Niall Schacter, "Building and Testing a Virtual University," Computers Education, Vol. 30, Nos. 1, 2, 1998, pp. 41-47.

3. Bengiamin, N. N., et al., "The Development of an Undergraduate Distance Learning Degree

for Industry – A University/Industry Collaboration," Journal of Engineering Education, Vol. 87, No. 3, 1991, pp. 277-82.

4. Goodson, C. E. and S. L. Miertschin, "Development and Implement of Web Based Courses for Engineering Technology," Proceedings 1998 ASEE Annual Conference, ASEE 1998, Session 1547.

5. Rutz, E., "Use of Distance Learning for Continuing Education of Engineers: Results of an Educational Needs Assessment," Journal of Engineering Education, Vol. 89, No. 3, 2000, pp. 261-264.

6. Verma, A., Stanley, W. and Crossman, G., "Televised Instruction in Engineering Technology: The 2+2 Program at Old Dominion University," Proceedings of the ASEE Annual Conference at University of Illinois at Urbana-Champaign, June 20-23, 1993.

7. Verma, A. and Richards, L., "Televised Instruction in Engineering Technology," Proceedings of the ASEE Annual Conference at University of Illinois at Urbana Champaign, June 20-23, 1993.

8. Williamson, C., Bernhard, J. T. and Chamberlin, K., "Perspectives on an Internet-Based Synchronous Distance Learning Experience," Journal of Engineering Education, Vol. 89, No. 1, 2000, pp. 53-61.

9. Rojas, E. M., "Use of Web-Based Tools to Enhance Collaborative Learning," Journal of Engineering Education, Vol. 19, No. 1, 2002, pp. 89-95.

10. Bourne, J. R. et. Al., "A Model for On-Line Learning Networks in Engineering Education," Journal of Engineering Education, Vol. 85, No. 3, 1996, pp. 256-260.

11. Latchman, H. A. and Latchman, S. M., "Bringing the Classroom to Students Everywhere," Journal of Engineering Education, Vol. 89, No. 4, 2001, pp. 429-433.

12. Wallace, D. R. and Mutooni, P., "A Comparative Evaluation of World Wide Web-Based and Classroom Teaching," Journal of Engineering Education, Vol. 86, No. 3, 1997, pp. 211-219.

13. Thiagrajan, G., and Jacobs, C., "Teaching Undergraduate Mechanics via Distance Learning: A New Experience," Journal of Engineering Education, Vol. 90, No. 1, 2001, pp. 151-155.

14. Smith, L. P., and Dillian, L. C., "Comparing Distance Learning and Classroom Learning: Conceptual Considerations," The American Journal of Distance Education, Vol. 13, No. 2, 1999, pp. 6-23.

15. Considine, C. L. and Lewis, Jr., V. W., "Assessment Methods for Virtual Technologies in Civil Engineering Technology," Proceedings of the 2001 American Society of Engineering Education Annual Conference and Exposition, Session 2647.

16. Crossman, G. R., "A CD-ROM Based Laboratory in Fluid Mechanics," Proceedings of the

2001 American Society of Engineering Education Annual Conference and Exposition Session 2247.

Table 1 Venturimeter Discharge Coefficient (c_v)

Case	Flowrate Liter/s	Pressure Drop (Δh) mm	Reynolds Number	C_v
1	0.3	241	19,493	.94
2	0.45	112	12965	.928

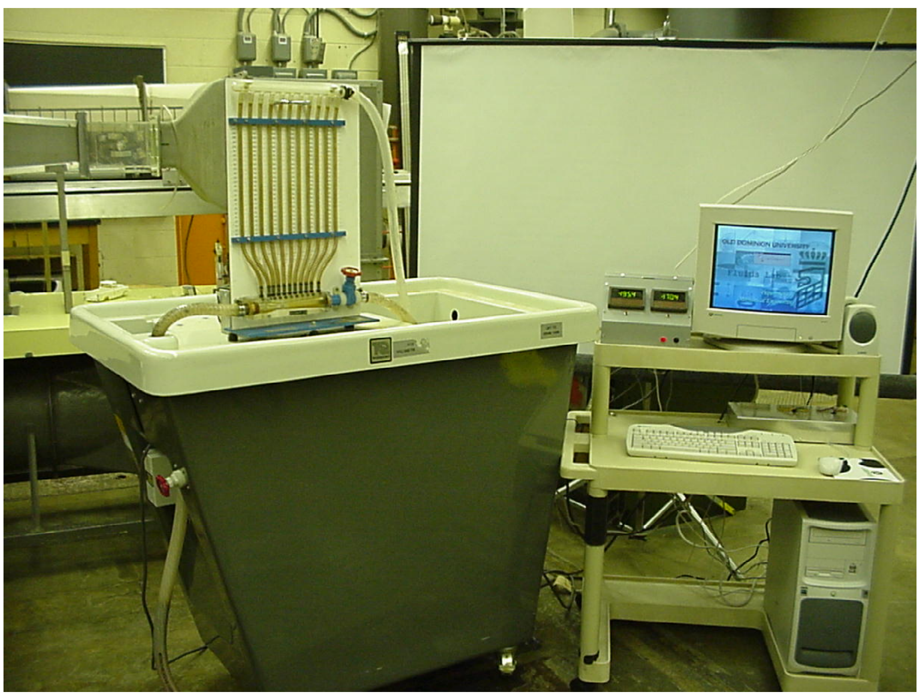

Fig. 1 Physical configuration for the venturimeter experiment

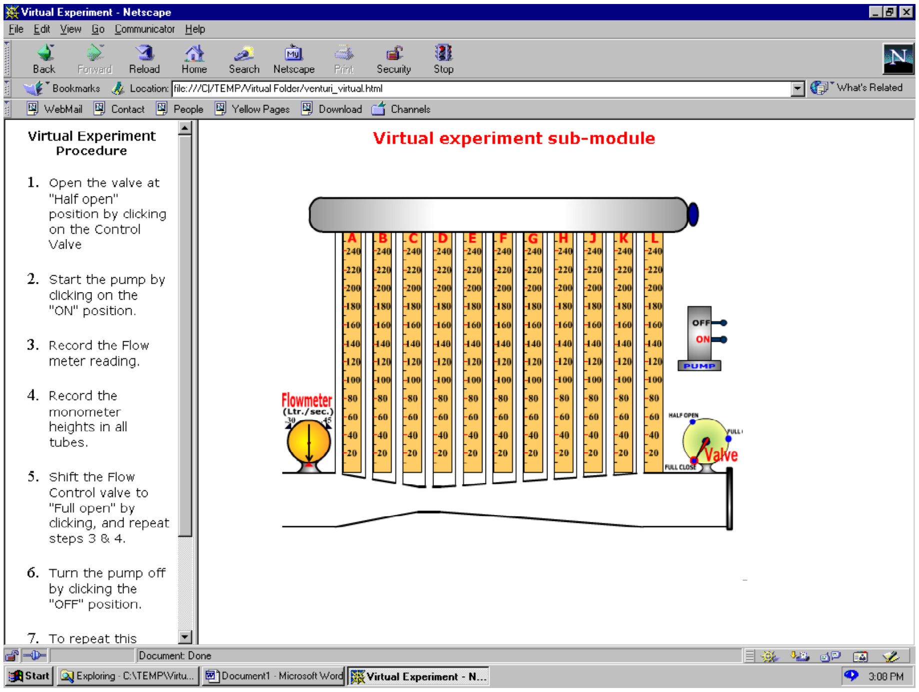

Fig. 2 Virtual venturimeter module

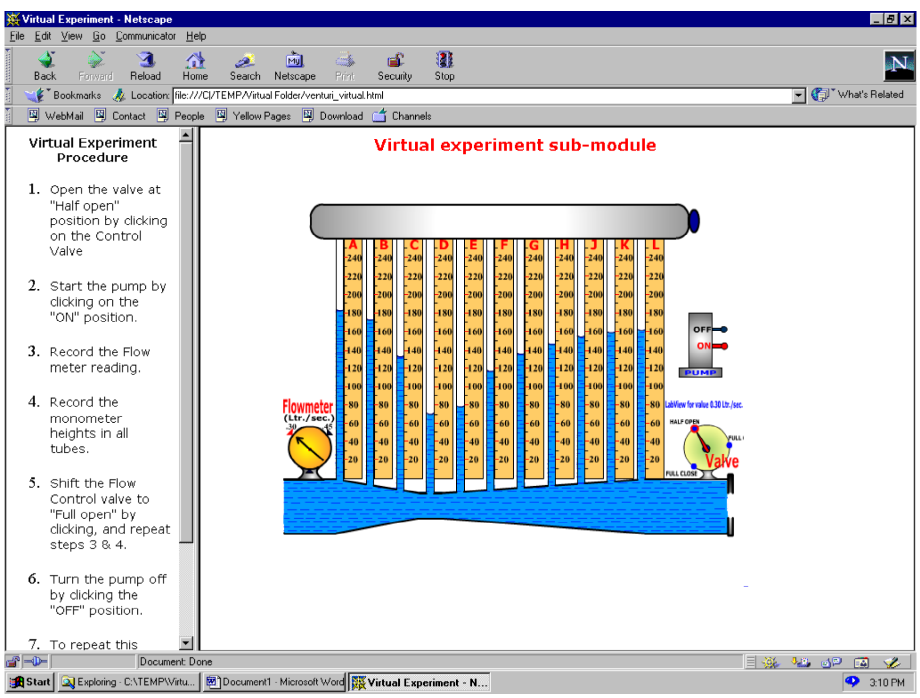

Fig. 3 Virtual experiment for low flowrate case

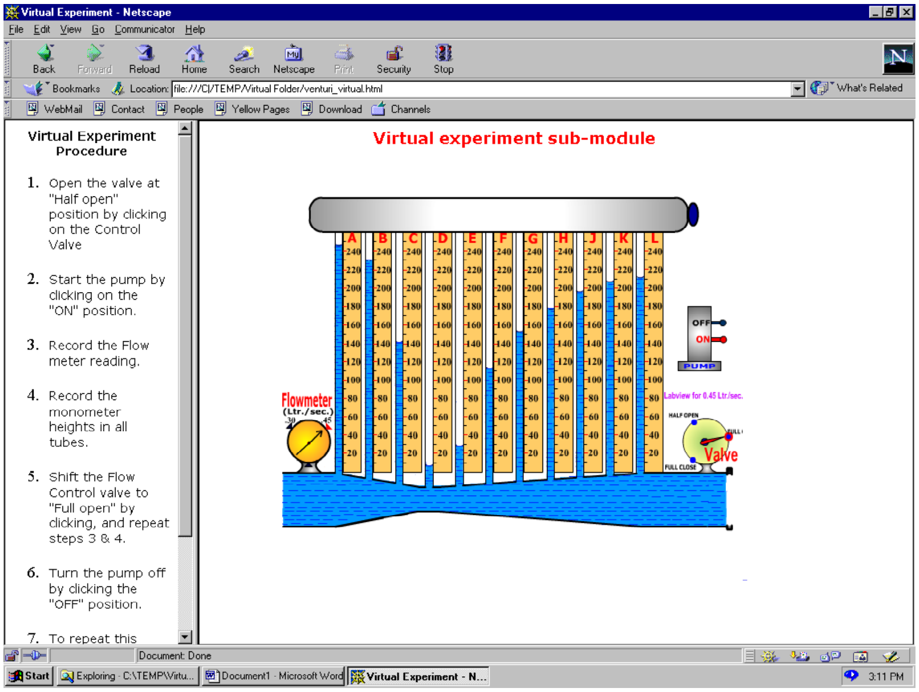

Fig. 4 Virtual experiment for high flowrate case

Sushil K. Chaturvedi is the Chair of the Mechanical Engineering Department at Old Dominion University. He received his Ph. D. in Mechanical Engineering from Case Western Reserve University in 1975, and has been with Old Dominion since 1978.

Ali Osman Akhan is the Chair of the Civil and Environmental Engineering Department at Old Dominion University. He received his Ph. D. in Civil Engineering from the University of Illinois in 1980, and has been with Old Dominion since 1983.

Tarek M. Abdel-Salam is a graduate teaching assistant in the Department of Mechanical Engineering at Old Dominion University. He received his Bachelor degree in Mechanical Engineering from Cairo University in 1988, and he is expected to receive his Ph. D. from Old Dominion University in May 2003.

A. Priyadershini is a graduate student in the College of Business and Public Administration. She is also a graduate assistant in the Department of Mechanical Engineering.