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A CASE STUDY IN PROJECT BASED LEARNING USING FLOW VISUALISATION

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Abstract

Engineering Design modules, usually introduced in the first and second year's undergraduate Mechanical Engineering courses, present a unique platform to practice the Project Based Learning (PBL). PBL is a widely accepted technique that can be used to achieve two major educational goals; affirming the theoretical principles studied in other modules and developing the professional skill essential for graduates such as team working and effective communication skills.

In this paper we describe the use of PBL to enhance the understanding of turbulence, a classical problem in fluid mechanics. The project is carried out in the "Mechanical Engineering Design & Professional Skills" Module, which requires the students to construct the Prandtl recirculating water channel. The skills and knowledge involved not only fluid mechanics, but design, material selections and engineering mechanics, making it a truly multi-disciplinary project.

Keywords: Project Based Learning, Flow Visualisation, Engineering Education.

1. Introduction

Engineering is a profession that has continuously re-invented itself to respond to the ever changing economical and social needs. This dynamic nature is mirrored in engineering education as well where the latest learning and teaching theories are practiced. One of the most successful approaches to learn engineering is the problem (or project)-based-learning (PBL) whereby the problem is the starting point of the learning process. Problem-based-learning was introduced almost twenty years ago in health sciences as a way to prepare students to handle ill defined, multi-disciplinary problems such as medical diagnosis [1]. Soon, mainly due to students' enthusiasm for this new approach it was introduced in other disciplines and, among others, in undergraduate design courses in engineering [2], [3]. This often resulted in deeper understanding of the explored topics [4]. As during the nineties emphasis shifted from taught to learned in the accreditation criteria, more and more design projects where included in engineering curricula, even in the first year of study [5], [6]. In engineering context, this approach is also known as project-based-learning. The inclusion of a set of different projects, allowing the student to become acquainted with the specifics of different engineering disciplines before having to choose one, is believed to be an original idea.

Although it is preferable for these problems (or projects) to be real life ones, hypothetical problems (projects) may have their own merits. It is crucial that the problem serves as the basis for the learning process, because this determines the direction of the learning process and places emphasis on the formulation of a question rather than on the answer. This also allows the learning content to be related to the context, which promotes student motivation and comprehension. It is essential that the directing force is consistent with the way the assessment drives the educational method [7].

In this paper we present the use of a project that involves the use of flow visualisation with the learning outcome of an understanding of the nature of turbulent flow structures. This is achieved within the "Mechanical Engineering Design & Professional Skills" module offered at the First Year (two semesters) mechanical engineering course.

Flow visualisation projects were widely used as a teaching and learning tool in undergraduate and postgraduate courses, e.g. Hertzberg and Sweetman [8]. They offered a Flow Visualisation Module to the Masters students from the engineering and the art streams. In this module students were required to design their own projects to yield flow visualisation images of good quality. A sample of their students' work is shown in Fig. 1.

2. Module Description

The "Mechanical Engineering Design & Professional Skills" carries 20 credit hours out of the total 120 credit hours required by the students to complete their first year of the course. The learning outcomes of this module are shown in Table 1.

3. Project Selection

In the current context a team of 5 students are given the task to build a replica of Prandtl's circulating water channel shown in Fig. 2 and use this channel to perform flow visualisation studies to understand the flow structures downstream of square cylinders. The project hand-out is shown in Fig. 3.

Fig. 1. Buoyancy through Interface. A Buoyant Jet of Dyed 70% Isopropyl Alcohol Rises through the Interface Formed by Corn Syrup and Water. [9]

Table 1. Learning outcomes of the design module

1. Describe the design process, including the concept of design constraints and the iterative nature of design.
2. Demonstrate awareness of design in other disciplines.
3. Recognise the values of effective team-working.
4. Contribute effectively to team based written project report.
5. Use appropriate visual communication techniques to communicate concepts and ideas.
6. Demonstrate awareness of industrial design.
7. Design a simple mechanical device to meet a specified need involving the understanding of basic mechanical engineering principles.
8. Carry out initial research on a real-world design task and present it effectively.
9. Demonstrate a working knowledge of the patent system and intellectual property rights in general.

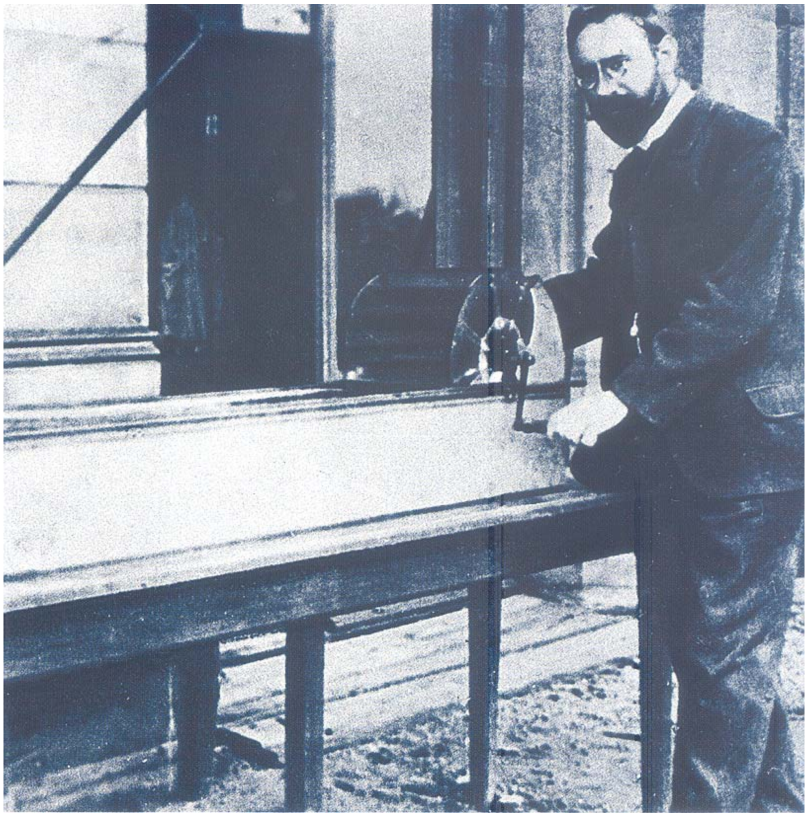

Fig. 2. Prandtl and his Water Channel.

The Prandtl water channel is a recirculating channel in which water is circulated using a wheel that is operated manually. A cross-sectional sketch of the channel is shown in Fig. 4.

This project was selected for various reasons. It can be carried out within the available resources and timeframe, it has a history element attached to it that inspired the authors in the first place and it was hoped to inspire the students as well, and that it leads to a flow visualisation images which are hoped to kindle the interest of students in Fluid Mechanics which is a subject often perceived by students as difficult to imagine as they are unable to visualise it in action.

Mechanical Engineering Design & Professional Skills

Prandtl Channel Project

Prandtl is considered one of the forefathers of modern fluid mechanics. He achieved a number of his discoveries using flow visualisation in a simple water channel. Your task would be to build a replica of that channel and use it to visualise the flow in the wake of square cylinders.

Objectives

1. Assess the design of the original Prandtl channel.
2. Suggest improvement to the design.
3. Construct the (improved) channel.
4. Test and calibrate the channel
5. Build models of square cylinders to be tested in the channel.
6. Use flow visualisation technique(s) to assess the flow structures in the wake of the cylinders.

Time Allocated

Tunnel design, construction and calibration: Semester 1
Flow Visualisation: Semester 2

Assessment

Operational Model:	50% (Group Effort)
Report:	30% (Individual Effort)
Presentation:	10% (Individual Effort)
Logbook:	10% (Individual Effort)

Fig. 3. Handout of the Prandtl Channel Project.

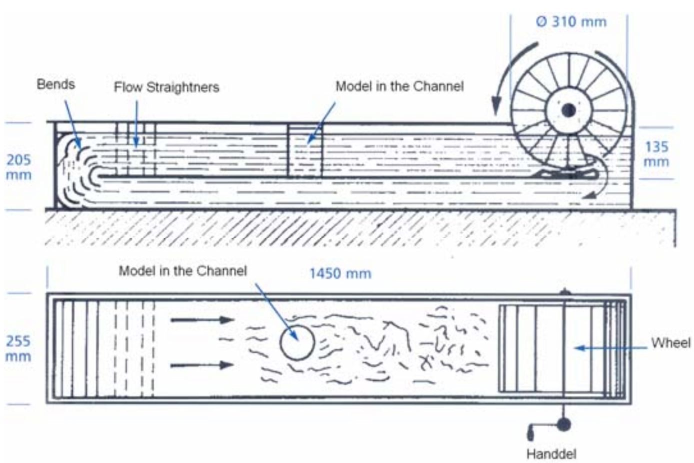

Fig. 4. Schematic View of Prandtl Water Channel.

The Karman vortex street behind a cylinder has been the object of numerous experimental and numerical studies because of the fundamental mechanisms that this flow exhibits and its numerous industrial applications. The classical view of a vortex street in cross section (2D) consists of regions of concentrated vorticity shed into the downstream flow from alternate sides of the body (and with alternate sense of rotation), giving the appearance of an upper row of negative vortices and lower row of positive vortices. This alternate shedding of vortices in the near wake leads to large fluctuating pressure forces in a direction transverse to the flow and may cause structural vibrations, acoustic noise or resonance. The formation of a vortex street is generally considered to be the result of a coupling of Kelvin–Helmholtz instabilities with separated shear layers. In each shear layer, the instabilities lead to vortex-sheet roll-up [10].

4. Results and Discussion

4.1 Channel design

Initial assessment of the design of the original channel was undertaken in order to suggest some improvements to the design. The main improvements suggested were to use transparent acrylic sheets (8 mm in thickness) to build the channel rather than the metal sheet used in the original and to use an electric motor to run the channel rather than the manual drive.

These improvements would allow for better visual access to the model and a better control of the lighting conditions and angles to achieve better flow visualisation. Using a DC motor drive instead of the manual drive for the channel wheel would result in a better control for the flow and yield more consistent results. The motor used was an automobile (Proton- Wira) power window motor. The modified channel is shown in Fig. 5.

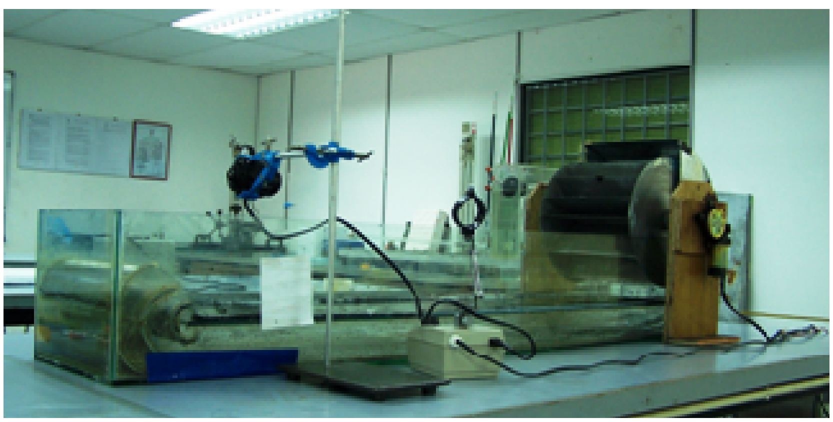

Fig. 5. The Modified Channel.

4.2 Flow visualisation

The flow visualisation was realised by seeding the circulating water with silver glitter dust that is used in cosmetic industry. The glitter dust is selected because it is easily available, floats in water and the fact that it has superior optical qualities that allows for good flow visualisation images when coupled with a right lighting conditions and camera set-up. A sample of the results obtained by the students is shown in Fig. 6.

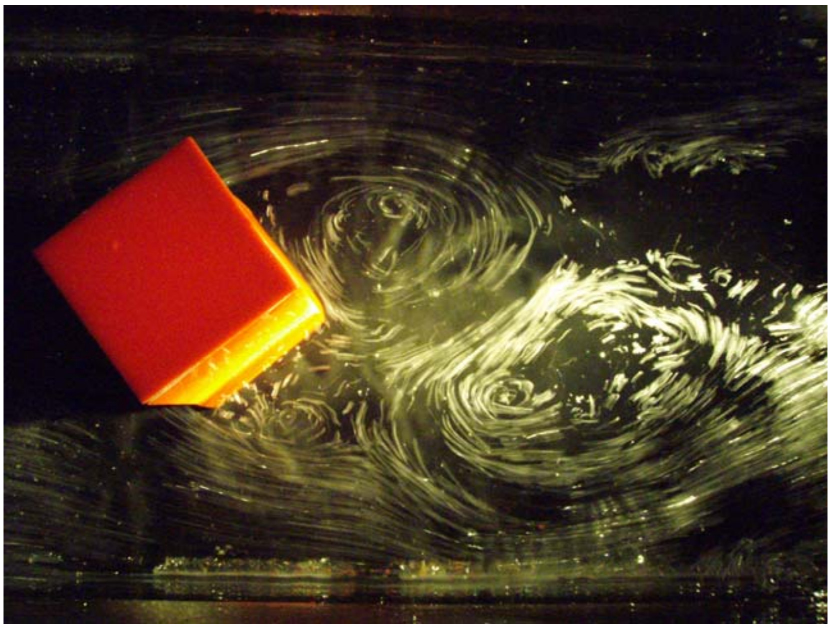

Fig. 6. Flow Visualisation Across A Square Cylinder at Reynolds Number of 6800. The flow is from left to right.

It is clear from Fig. 6 that there is shedding of counter-rotating vortices behind the cylinder.

4.3 Learning outcomes

The learning outcomes of the module were achieved. Although the project is Fluid Mechanics related, the construction of the channel invoked materials and engineering mechanics knowledge as well.

Besides gaining better understanding of fluid mechanics, the students exhibited a great deal of enthusiasm and ownership in the course of constructing and testing the channel. Little was needed from the lecturer to keep them motivated.

5. Conclusions

Building a replica of the Prandtl's recirculating water channel and using it to create classical flow visualisation images was used as a design project offered in the "Mechanical Engineering Design and Professional Skills". Through careful selection of the project and the assessment criteria, the learning outcomes of the module were achieved. Better knowledge and understanding of fluid turbulence, Reynolds number and the characteristics length of a given problem were achieved in the process. Students' enthusiasm and motivation were apparent throughout the course.

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