

# Chapter 1 Introduction

## 1.1 Preliminary Remark

Flow around cylindrical bodies has been observed, studied, and documented by the humans since ancient time. Ancient Greeks used to play “Harp” (A triangular framed musical instrument supporting series of parallel strings) and knew that strings in the path of wind flow elicit a tone. King David hung a harp over his bed to allow it to sound by arrival of midnight breeze [1]. In 15<sup>th</sup> century famous Italian artist Leonardo-da-Vinci sketched the row of vortices separating from the cylinder in the path of flow. Over the years, the field of fluid flow around cylinders has evolved from early observations and empirical insights to sophisticated theoretical models and advanced computational simulations. The complex interaction between the fluid flow and cylindrical bodies, and the intricate hydrodynamic interaction between bodies in fluid have fascinated researchers and engineers for new innovative solutions and mathematical models.

## 1.2 Background

Fluid flow around single and multiple cylinders is a multifaceted and ubiquitous phenomenon with relevance in numerous fields of engineering and science. Flow around cylinders of different cross-sectional shapes (polygonal shaped cylinders) has profound implications on many applications ranging from the hydrodynamics of submerged cables, pipelines and aerodynamics of flying objects to the design of heat exchangers, suspension bridges, piers of bridges, floating platforms and the behaviour of offshore structures (Figure 1.1). In these applications, cylinders of different shapes behave as a discontinuity in fluid domain and obstruct the flow leading to change in flow parameters like velocity and pressures. Because of changes in flow parameters, the cylinders experience the hydrodynamic loads. The magnitude and nature of these hydrodynamic loads would primarily depend on the flow parameters and geometry of cylinders. In certain conditions, these hydrodynamic loads may cross the threshold limit leading to catastrophic failures of structures or mechanical members. To name some of them, the Tacoma Narrows suspension bridge in Washington collapsed in 1940 due to vibration induced by flow of air, Monju fast breeder reactor in 1995 experienced a Sodium leakage caused by the failure of a thermocouple well that was

inserted into the pipe. Therefore, the exhaustive study of hydrodynamic parameters of flow over cylinders or structural/mechanical members of different cross-sections is essential.



Figure 1.1 Mechanical/structural members of different cross-sectional shapes subjected to fluid flow.

The velocity and pressure distribution, hydrodynamic forces and moments, and hydrodynamic masses are some of the very important hydrodynamic parameters to be investigated for different geometrical and flow conditions. It is important to study the effect of various geometrical parameters of cylinders (e.g. shapes, size, orientation angle, corner radii, center distance between the cylinders, etc.) on the hydrodynamic parameters. Also, the understanding the flow patterns around the members (cylinders) and their impact on the mechanical behaviour of cylinders is crucial.

### 1.3 Motivation

The technical insights gained from studying hydrodynamic parameters for fluid flow around polygonal cylinders can contribute to the optimization of shapes, size, orientation and geometry of structural/mechanical members. This optimization process aims to reduce energy consumption,

improve performance of systems, and enhance efficiency of system, where fluid flows across the cylinders.

In practice, the structural/mechanical members are placed close to each other in fluid flow to attain certain operational requirements. In order to meet these operational requirements against the hydrodynamic interaction effects, the behaviour of the fluid flow in various applications must be understood thoroughly to decide the optimization strategies. The comprehensive study of the interactions between the multiple polygonal cylinders in the fluid flow is very essential from structural design and safety point of view.

#### **1.4 Aim and Scope of Present Study**

The aim of present study is to investigate steady potential flow around single and multiple cylinders of various shapes (e.g. circular and  $N$ -sided polygonal cylinders) using complex variable method. To study the effect of shape, size, corner radius, orientation angle, flow angle and centre-to-center distance on the flow parameters around isolated polygonal cylinder and interaction between two polygonal cylinders falls under the scope of present study. In present study, the fluid flow is considered to be two-dimensional, incompressible, inviscid and irrotational. This study can play vital role in the process of design and optimization of flow around cylinders/members in various applications, and it may also help in deciding passive flow control strategies.

#### **1.5 Objectives of Present Study**

Following are the objectives of present study.

- To provide generalized analytical solution of potential flow around polygonal shaped cylinder with rounded corners and to study the effect of shapes, corner radii, number of sides, and orientation of polygonal cylinder on the hydrodynamic parameters (e.g. velocity and pressure).
- To investigate hydrodynamic interaction between two polygonal cylinders in uniform potential flow and, study the effect of various geometrical parameters and flow parameters on the hydrodynamic interaction between two polygonal cylinders.

## 1.6 Thesis Outline

There are six chapters in thesis. Chapter 1 provides introductory remarks for present problem. It contains motivation for the research, objectives of the problem and, aim and scope of present study. At the end of the chapter, the outline of thesis is presented.

In Chapter 2, the literature survey on the flow around single and multiple cylinders is discussed in detail. The literature review includes fluid flow characteristics around single and multiple circular/polygonal cylinders and, various methods and techniques used by researchers for the study of flow parameters and interaction effects. The use of complex variable method for study of fluid flow around the cylinders of circular and non-circular geometries is discussed in detail. Based on the literature survey, the research gap is identified. Chapter 3 provides the detail mathematical formulation of potential flow around single and multiple cylinders using complex variable method. The complex potentials are derived for uniform and non-uniform flow around single and interacting circular/polygonal cylinders. The hypotrochoidal mapping is presented to obtain polygonal geometries with rounded corners. For the problem of interacting polygonal cylinders, the composite conformal map is developed by combination of hypotrochoidal and bilinear transformation. The equations are derived for the computation of velocity, pressure and hydrodynamic forces between the cylinders for the study flow parameters and interaction effects.

Chapter 4 includes results and discussion of present study. The flow parameters around single and multiple cylinders in potential flow are discussed for various geometrical and flow conditions. The hydrodynamic interaction between two circular cylinders, between polygonal and circular cylinders, and between two polygonal cylinders are discussed for different shapes, corner radii, orientation angle, centre-to-center distance, and flow angles.

In Chapter 5, we summarized the study of potential flow around single and multiple cylinders presented in this thesis. The major conclusions are presented for the uniform and non-uniform potential flow around single isolated polygonal cylinder, and for hydrodynamic interaction between cylinders in potential flow. The limitation of present work and the future directions of present research are also presented.

The list of publication from present work and the cited references are listed at the end of thesis.