

Chapter 2

Applications and Physics of Flows over Surface-Mounted Prisms

In this chapter, we present some engineering applications that are related to the flow over surface-mounted prisms. We discuss important fluid flow characteristics encountered in these applications. We also point out flow specifics that are of interest.

2.1 Applications and Relevance of Results

The flow around a surface-mounted prism is a generic flow that represents many flows observed in nature and in technological applications. One application is the wind flow around low-rise structures. By low-rise structures, it is meant one to four-story buildings or hangars. Determining the wind flow around low-rise structures is important for determining peak wind loads on structures. These loads arise from the pressure distribution caused mostly by the inviscid flow field. In relating the application of our work to determine wind loads on low-rise structures, we should note that the incident flow in our modeling is uniform which is totally different from a velocity profile of atmospheric wind. Because it is in the lower part of the atmospheric boundary layer, that profile is not uniform and the turbulence intensities of all velocity components are quite high (over 10%). These characteristics of the velocity profile of the atmospheric wind have been shown to affect the flow field around prismatic structures, and consequently, they affect the pressure distributions and their peak values on prismatic structures

significantly. Thus, any velocity, vorticity or pressure calculations presented here cannot be directly applied to determine wind loads on structures. Another difference is that the simulation considered here is over a two-dimensional prism and the fluid flow is assumed to be two-dimensional as well. This is a stretch of the real wind flow observed over low-rise structures. Having said this, we note that the surface modeling presented here can be enhanced to include the effects of variations in the mean and turbulent characteristics of the incident flow. Moreover, with careful implementation and adequate computer resources, it may be possible to solve for the three-dimensional flow using an extension of the modeling technique presented here.

Another application for the flow considered in this work is the modeling of the airwake behind the superstructure of a ship, which is important for aircraft landing, Buley et al. (1999). The ship superstructure consists of several components that include the hull, upper deck levels, masts, etc. One could model these components which have large rectangular block shapes and smaller parts of various shapes as a single block. While the model geometry is different from the real one, many fundamental inviscid flow features are the same. These include the wake of the block or prism, the generation of vorticity at the sharp corners and the convection of vorticity. It is stressed here that problems discussed in relation to the incident flow as well as the three-dimensionality of the flow around the prism when considering wind flows around low-rise structures apply to the airwake behind ships as well.

Having stressed two applications of the flow around surface-mounted prisms, we stress also the importance of phenomena associated with this flow or other applications. The flow around a surface-mounted prism is intrinsically a complex flow field. It is characterized by separation, vorticity generation and convection, vortex formation and a wake. These characteristics are important to different levels in applications such as vehicle aerodynamics and associated noise, dust and pollution transport and sediment deposition around structures, marine hydrodynamics when examining flow fields around bilge corners, chines and keels. In other applications, they would have a direct effect on heat transfer and drag.

2.2 Motivation for Vorticity Modeling

The next natural question is why vorticity modeling? There is no question that, with the advancements in computer technology, direct solutions of the Navier-Stokes equation have become easier. Yet, and as we explain later, for high Reynolds number flows, obtaining a direct solution of the Navier-Stokes equations in a reasonable time is still not possible. The requirement of reasonable time is needed to have the ability to combine the solution of the fluid flow with other components of a problem. For instance, one would like to have a time-domain solution for the response of a high-rise building or bridge. This solution would be composed of a solution for the fluid flow as well as the structure's response. To date, it is impossible to obtain real-time response, especially if one tries to solve the Navier-Stokes equations. In this work, we examine what vorticity modeling can possibly provide in terms of flow field characteristics and effects on surface pressures as an alternative solution. Such a modeling can enhance our understanding of the relation between the outer flowfield and the surface pressure and possibly enable us to devise control methods for the flow to minimize these peaks. Of course, all such methods would have to be verified experimentally or with direct simulation of the Navier-Stokes equations. We should stress that, with vorticity modeling, several assumptions are made. One should keep these assumptions in mind when applying this technique to determine the flowfield. In chapter 3, we point out aspects of the flowfield that have not been considered by applying vorticity modeling to study flow characteristics over a surface-mounted prism.