Essay 1

Case Studies in Thermal Engineering/Advanced Thermal Science

There are several goals that serve to motivate this course. One of these goals is to connect the real world of engineering with the skill-sets that are taught in academic courses. To accomplish this, a broad spectrum of real-world problems are brought into the classroom, and the necessary solution skills are taught. In general, the needed solution skills are not taught in typical undergraduate courses. In the present course, the solution skills are based on numerical simulation. The software that is used in implementing the numerical simulations is state-of-the-art commercial programs that are used broadly in industrial practice as well as in research.

The numerical solutions will not only be used to solve cutting-edge industrial problems, but it will also be employed to reveal the fundamentals in a way which is more revealing than that which is taught in basic undergraduate courses. For example, boundary-layer theory is taught in all undergraduate courses in fluid flow. Here, the glossy veneer that has coated boundary-layer theory is stripped away and, by this, major weaknesses are revealed. As a second example, the standard undergraduate model for pipe flow is based on a fluid that enters a pipe with a uniform velocity profile. In reality, such a uniform inlet profile is an impossibility. Here, the inlet flow will be modeled to take account of the physical processes that occur upstream of the inlet.

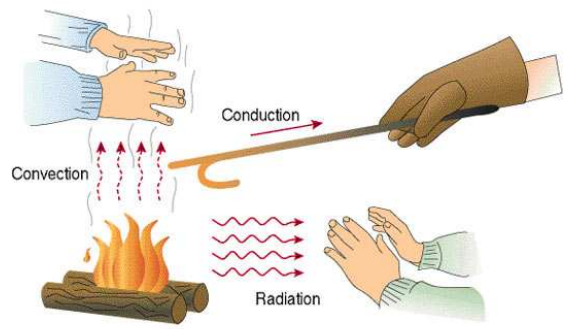

Fig. 1. 1 The three modes of heat transfer

In fact, we will teach solution methods that even eclipse the mathematical methods that are taught in graduate courses. For example, graduate courses in heat conduction teach solution methods that are so restricted as to severely limit their capability to solve the overwhelming majority of practical heat conduction problems. Here, in a period of two to three weeks, solution methods will be taught that are capable of solving virtually every possible problem that will occur in heat conduction. The same situation is also true with regard to graduate-level fluid flow and convective heat transfer.

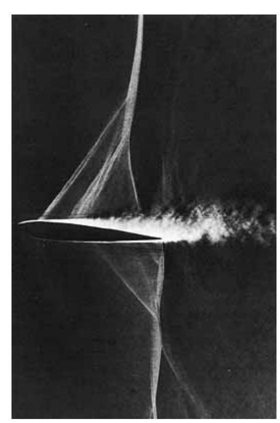

Fig. 1. 2 Flow over an airfoil showing shockwaves and separated regions

Quantities such as the friction factor and the heat transfer coefficient have served for well over hundred years as crutches for determining pressure drop and heat transfer rates for simple problems. However, these quantities are generally not available when more difficult practical problems must be solved. Here, it will be shown that these venerated and marginally useful quantities are not needed. Instead, we will be able to solve for the pressure drop and for the heat transfer rate directly.

Overall, the subject matter of this course will include: heat conduction, thermal stresses, some structural analysis, fluid flow, and convective heat transfer. The numerical simulation software will be taught from scratch, and no prior knowledge is needed or desired. There will be no textbook used in this course. Instead, essays will be delivered electronically and will also be posted on the website of the course.

As an illustration of the type of result provided by numerical simulation, a vector diagram showing the pattern of fluid flow about a plate of finite thickness is displayed in Fig. 1.3.

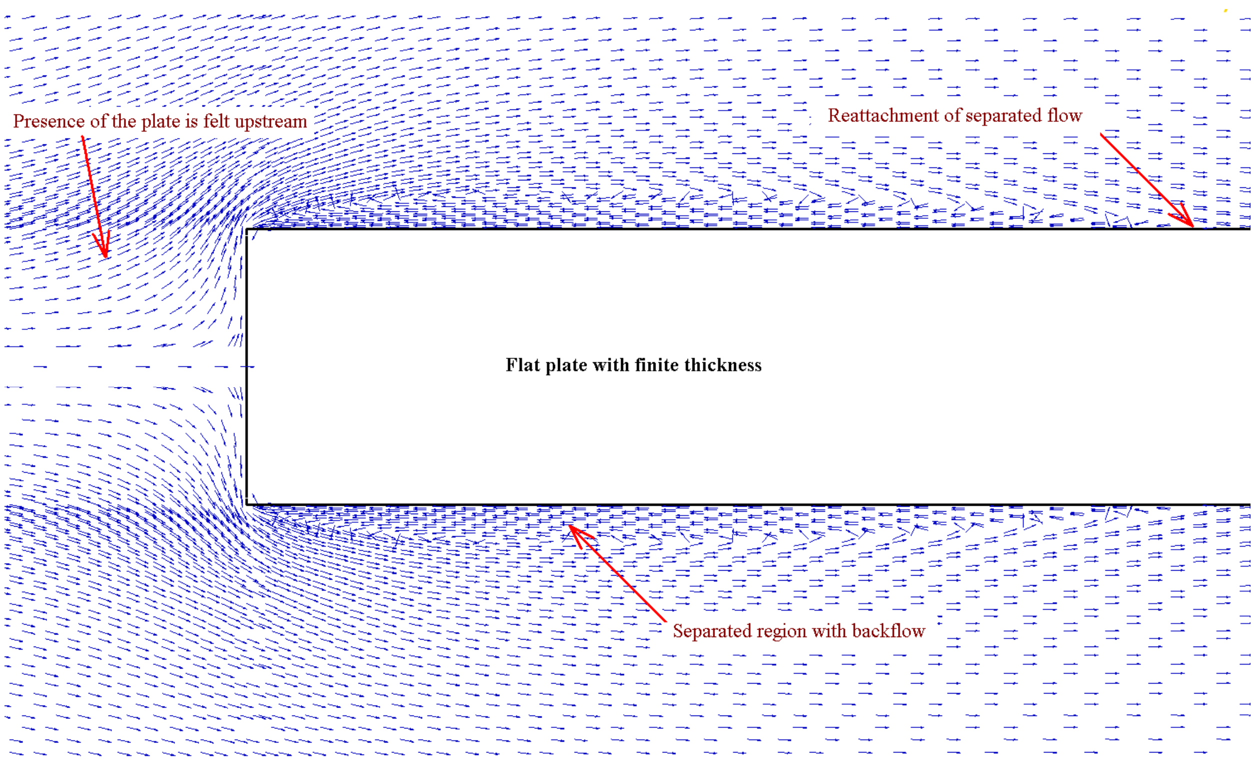

Fig. 1. 3 Pattern of fluid flow around a plate of finite thickness

The noteworthy feature that is seen in this vector diagram is the recirculating flow that occurs in the separated region situated adjacent to the plate surface just downstream of its forward-facing edge. The presence of the plate is felt upstream of it. The flow is unable to follow the sharp corner at the upper edge of the front-facing surface. Instead, the flow follows a lofty trajectory that ignores the plate for a considerable distance downstream of the front face. Eventually, as pointed out in the diagram, the flow reattaches to the surface, and the development of the boundary layer begins. Although it might be expected that if heat transfer is involved, its magnitude would be small in the recirculation zone. However, the contrary occurs in practice.