Chapter 7.20
Computational Fluid Dynamics and Neural Network for Modeling and Simulations of Medical Devices

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ABSTRACT

This chapter describes the utilization of computational fluid dynamics (CFD) with neural network (NN) for analysis of medical devices. First, the concept of mathematical modeling and its use for solving engineering problems is presented followed by an introduction to CFD with a brief summary of the numerical techniques currently available. A brief introduction to the standard optimization strategies for NN and the various methodologies in use are also presented. A case study of the design and optimization of scaffolds for tissue engineering heart valve using the combined CFD and NN approach is presented and discussed. This chapter concludes with a discussion of the advantages and disadvantages of the combined NN and CFD techniques and their future potential prospective.

MATHEMATICAL MODELING

Introduction

Many engineering systems are of a complex nature and require techniques that relate the relevant variables in the system under consideration. Equations that express physical phenomena between quantities require absolute numerical and dimensional equality. Historically, the use of dimensional analysis of the physics observed experimentally has been very successful in adding to our understanding of the complexity of the problem in hand. Generally speaking, all physical relationships can be expressed in terms of quantities such as mass M, Length L, and time T or other related quantities such as force F, pressure P, stress τ, and so on. The application of such a

system may include converting one system of units to another, developing relations or equations, reducing the number of variables required for an experimental program and, in some cases, determining the principles of model design. It should be noted that for a physical system, dimensional analysis can only indicate variables or groups of variables that are functionally related, and it does not give insight of the nature of the correlation and its complexity. One of the most common uses of dimensional analysis is in experimental planning of examining a particular phenomena or system. Moreover, the dimensional analysis does not estimate the actual behavior of the system. This requires the development of a more comprehensive mathematical model which often requires a solution to the governing equations, either ordinary differential equations or partial differential equations (ODEs/PDEs).

The Governing Equations

In recent years, the utilization of mathematical modeling to solve engineering problems has been advanced greatly by the availability of fast and user-friendly software packages. However, these models, even today, still require experimental or physical modeling results to validate and verify the numerical results. However, in general, the process of mathematical modeling may require a continuing four-stage cycle, as illustrated in Figure 1 to have a solution.

The mathematical model is constructed based on fundamental laws of physics, often by making quite a number of assumptions. Some are justified quite rigorously on scientific grounds, while others render the problem tractable or solvable within an economically acceptable time frame. In any case, the mathematical assumptions formulate a mathematical model, and the next two stages of the cycle are intended to test this model and modify it if need be (Figure 1). To test a model, one needs to draw certain conclusions about the real problem at hand. Such terminations are often of two types, those related to previously observed situations (*explanatory in nature*) or those related to new, not previously observed situations (*predictive in nature*). Both types are important for validating a mathematical model, though for purposes of discussion, it is reasonable

Figure 1. The typical loop of mathematical modeling
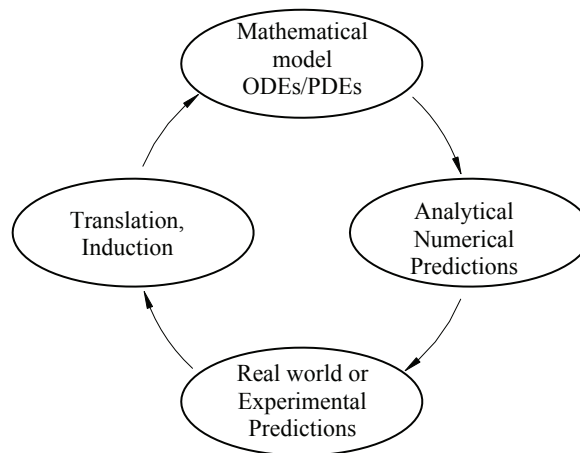
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