FLUID DYNAMICS

Fluid dynamics is the subdiscipline of fluid mechanics that studies fluids in motion. Fluids are specificallyliquids and gases. The solution of a fluid dynamic problem typically involves calculating for various properties of the fluid, such as velocity, pressure, density, and temperature, as functions of space and time. The discipline has a number of subdisciplines, including aerodynamics (the study of gases) and hydrodynamics(the study of liquids). Fluid dynamics has a wide range of applications. For example, it is used in calculatingforces and moments on aircraft, the mass flow rate of petroleum through pipelines, and in prediction ofweather patterns, and even in traffic engineering, where traffic is treated as a continuous fluid. Fluid dynamics offers a mathematical structure that underlies these practical discipines which often also embrace empirical and semi-empirical laws, derived from flow measurement, to solve practical problems.

Equations of fluid dynamics

The foundational axioms of fluid dynamics are the conservation laws, specifically, conservation of mass, conservation of momentum (also known as Newton's first law), and conservation of energy. These are based on classical mechanics and are modified in quantum mechanics and general relativity.

The momentum equations for Newtonian fluids are the Navier-Stokes equations, which are non-lineardifferential equations that describe the flow of a fluid whose stress depends linearly on velocity and on pressure. The unsimplified equations do not have a general closed-form solution, so they are only of use incomputational fluid dynamics or when they can be simplified. The equations can be simplified in a number of ways. All of the simplifications make the equations easier to solve. Some of them allow appropriate fluid dynamics problems to be solved in closed form.

Compressible vs incompressible flow

A fluid problem is called compressible if changes in the density of the fluid have significant effects on the solution. If the density changes have negligible effects on the solution, they are ignored and the problem is called incompressible.

In order to determine whether to use compressible or incompressible fluid dynamics, the Mach number of the problem is evaluated. As a rough guide, compressible effects can be ignored at Mach numbers below approximately 0.3. Nearly all problems involving liquids are in this regime and modeled as incompressible.Acoustic problems require allowing compressibility, since sound waves can only be found from the fluid equations which include compressible effects.

The incompressible Navier-Stokes equations can be used to solve incompressible problems. They are simplifications of the Navier-Stokes equations in which the density has been assumed to be constant.

Viscous vs inviscid flow

Viscous problems are those in which fluid friction have significant effects on the solution. Problems for which friction can be neglected without contributing significant error (as defined by the person solving the problem) are called inviscid.

The Reynolds number can be used to evaluate whether viscous or inviscid equations are appropriate to the problem. High Reynolds numbers indicate that the inertial forces are more significant than the viscous forces. However, even in high Reynolds number regimes certain problems require that viscosity be included. In particular, problems calculating net forces on bodies (such as wings) should use viscous equations. As illustrated by d'Alembert's paradox, a body in an inviscid fluid will experience no force.

The standard equations of inviscid flow are the Euler equations. Another often used model, especially in computational fluid dynamics, is to use the Euler equations far from the body and the boundary layerequations, which incorporate viscosity, close to the body.

The Euler equations can be integrated along a streamline to get Bernoulli's equation. When the flow is everywhere irrotational as well as inviscid, Bernoulli's equation can be used throughout the field.

Steady vs unsteady flow

Another simplification of fluid dynamics equations is to set all changes of fluid properties with time to zero. This is called steady flow, and is applicable to a large class of problems, such as lift and drag on a wing or flow through a pipe. Both the Navier-Stokes equations and the Euler equations become simpler when their steady forms are used.

Whether a problem is steady or unsteady depends on the frame of reference. For instance, the flow around aship in a uniform channel is steady from the point of view of the passengers on the ship, but unsteady to an observer on the shore. Fluid dynamicists often transform problems to frames of reference in which the flow is steady in order to simplify the problem.

If a problem is incompressible, irrotational, inviscid, and steady, it can be solved using potential flow, governed by Laplace's equation. Problems in this class have elegant solutions which are linear combinations of well-studied elementary flows.

Laminar vs turbulent flow

Turbulence is flow dominated by recirculation, eddies, and apparent randomness. Flow in which turbulence is not exhibited is called laminar. Mathematically, turbulent flow is often represented via Reynolds decomposition, in which the flow is broken down into the sum of a steady component and a perturbation component.

It is believed that turbulent flows obey the Navier-Stokes equations. Direct numerical simulation (DNS), based on the Navier-Stokes and incompressibility equations, makes it possible to simulate turbulent flows with moderate Reynolds numbers (restrictions depend on the power of computer). The results of DNS agree with the experimental data.

Newtonian vs non-Newtonian fluids

Sir Isaac Newton showed how stress and the rate of change of strain are very close to linearly related for many familiar fluids, such as water and air. These Newtonian fluids are modeled by a coefficient calledviscosity, which depends on the specific fluid.

However, some other materials, such as milk and blood, and also some plastic solids, have more complicatednon-Newtonian stress-strain behaviours. These are studied in the sub-discipline of rheology.

Other approximations

There are a large number of other possible approximations to fluid dynamic problems. Stokes flow is flow at very low Reynolds numbers, such that inertial forces can be neglected compared to viscous forces. TheBoussinesq approximation neglects variations in density except to calculate buoyancy forces and is appropriate for free convection problems.

Source : http://engineering.wikia.com/wiki/Fluid_dynamics