Fluid Mechanics

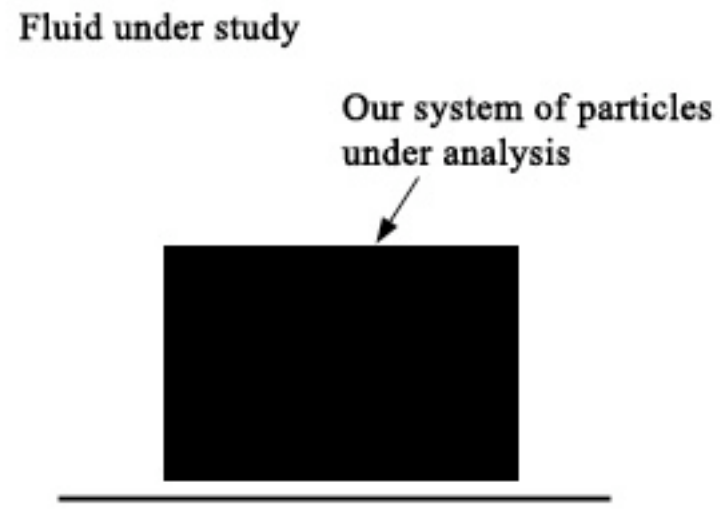
System vs Control Volume Analysis

As we move deeper into our study of fluids, we need to define the type of analysis we are performing. It turns out that in fluid mechanics, we can analyze a fluid in two ways: a system analysis or a control volume analysis. It is advised that the student be clear with the two.

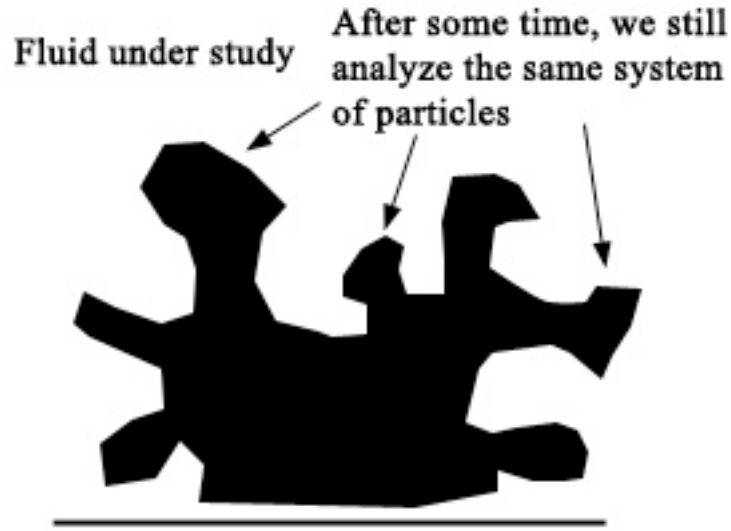
A fluid behavior is governed by a set of fundamental physical laws which are in turn represented by an appropriate set of equations, i.e. law of conservation of momentum, or Newton's laws of motion. In using these equations, we can undertake a *system approach* where our analysis is on a collection of matter of fixed identity which may move, flow and interact with its surroundings or a *control volume approach* where our analysis is in a volume in space through which the fluid may flow.

A system is a specific, identifiable quantity of matter. It may consist of a relatively large amount of mass (such as all of the air in the earth's atmosphere), or it may be an infinitesimal size (such as a single fluid particle). Either case, these molecules are 'tagged' in some way, probably using red dye or simply for imaginative purposes, so that they can be continually identified as they move about. The system will then interact with the rest of the fluid, by which it may change shape or size, but our analysis remains to be on this same mass.

Let as say that we are using a system approach to analyze this system of particles in the fluid. Usually, the fluid would be much bigger than the system. We will pick this cube of particles to be our system.

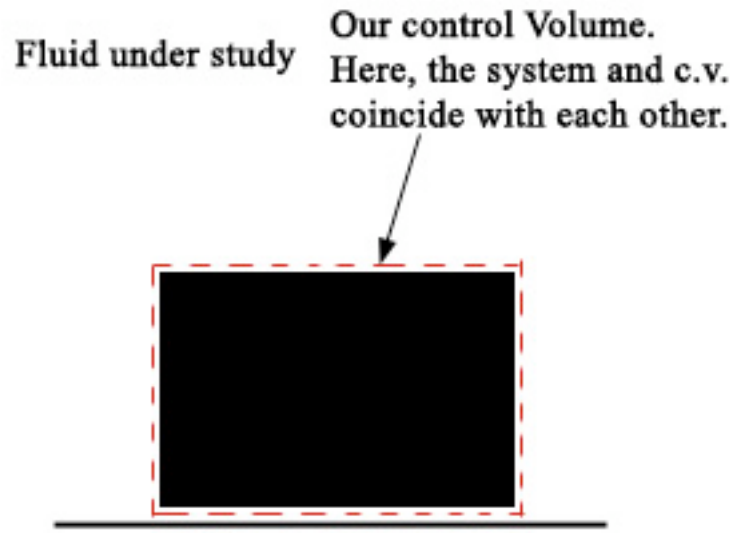


Some time later, this system would have interact with the rest of the fluid but our analysis still continues with the *same* particles that we have picked from the start.

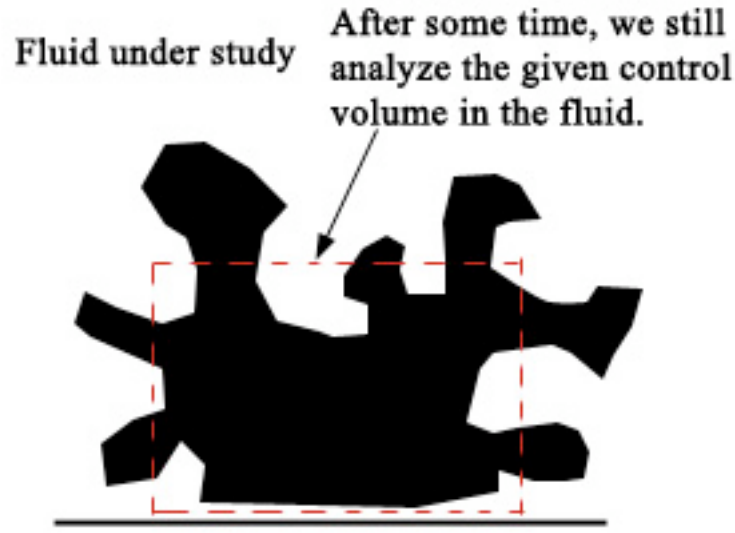


When using this approach, we are then able to borrow concepts from the study of statics and dynamics. See, once we have identified our system of particles, it allows us to apply Newton's laws of motion where the free-body diagram otherwise used in mechanics is our system. This in fact is the method is used to derive the equivalent laws in fluid mechanics.

A control volume approach is used when we are more interested in determining the forces put on a fan, airplane, or automobile by air flowing past the object and not the information obtained by a given portion of the air, a system, as the fluid moves along. This approach involves identifying a specific volume in space and the analyzing the fluid flow within, through, or around that volume. In general, the control volume can be a moving volume, although for most situations considered, it is a fixed nondeformable control volume.



In the fluid, we identify a volume we wish to analyze, as shown here by the dotted red line. If we were to choose our system as we did before, we say here that the system of particles and the control volume coincides at a certain time *t*.



As expected, after some time *t*, the system will mix with its surroundings and be displaced in all sorts of way. However, our analysis *remains* in the control volume that we have initially set. We are still analyzing what goes on inside the box formed by the dotted red lines.

The term *control surface* is used to call the surfaces which make up the control volume. If you were to imagine a fluid flowing through a pipe, the fixed control surfaces consist of inside surface to the pipe, the outlet end of the section and a section across the pipe.

For those who know more about mechanics, the relationship between a system and a control volume is similar to the relationship between the

Lagrangian and Eulerian flow. A system parallels a Lagrangian description as we follow the fluid and observe its behavior as it moves about. The control volume parallels the Eulerian description as we remain stationary and observe the fluids' behavior at a fixed locations.

At any rate, most laws in fluid mechanics can be derived from a system approach or from a control volume approach. Problems also can usually be answered from either approach as the equations used to solve them require the reader to set certain conditions on the fluid. Having said that, it goes without saying that the distinction between both approaches must be made clear. Failure to do so will usually result in equations, though may be correctly applied, are conceptually wrong.