

# Importance and Applications of Fluid Dynamics in Civil Engineering and Mechanical Engineering

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**Abstract.** Fluid dynamics is the study of the behavior of liquids and gasses in motion. Scientists across several fields study fluid dynamics. Fluid dynamics cannot only help the development of astronomy, meteorology, oceanography, even provides methods for blood circulation, it can also play an important role in Engineering. In Civil engineering and Mechanical engineering, fluid dynamics has totally different applications. In the future, scientists and engineers must discover more uses of fluid dynamics in many different fields to make people better.

**Keywords:** fluid dynamics; liquids; astronomy.

## 1. Introduction

Around 250 BC, Archimedes invented the law of buoyancy, called Archimedes' Principle in his literary work *On Floating Bodies*. This was the earliest theory about fluid mechanics. In the 15th century, the Italian mechanics scientist, Leonardo da Vinci, developed the principle of fluid volume energy conservation. In 1986, macagno considered the flow characteristics of different liquids, including not only common water, but also the flow phenomena and laws of daily drinks in pipes. This research result directly promoted the development of fluid mechanics [1].

With the rapid development of technology and environment, scientists and engineers begin to pay more attention to how to develop natural resources, like water and gas [2]. Therefore, Fluid Dynamics plays an important role in engineering. In Fluid Dynamics, Speed, pressure, density, and temperature are the main calculation objects [3]. Another number called Reynolds number is used in large numbers when it comes to contact with tubes or heat in fluid dynamics. It usually stands by  $Re$ . The general formula for it is  $Re = \rho uL/\mu$ . Reynolds number is used to estimate the flow in the tube, whether turbulent or stable. Smaller Reynold number usually stands for a larger effect from the viscosity.

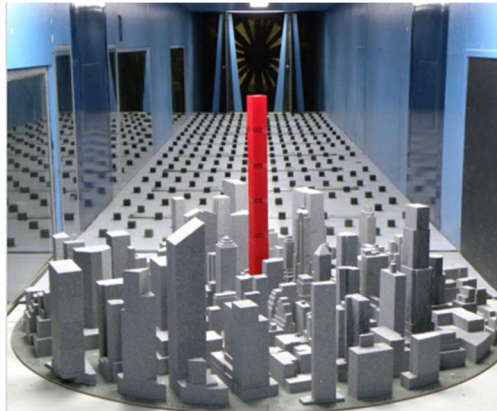
In this paper, it shows the main reasons of the importance and the application of examples of fluid dynamics in Civil Engineering and Mechanical Engineering, and comparison of fluid dynamics in Civil Engineering and Mechanical.

## 2. Fluid Dynamics in Civil Engineering

### 2.1 Wind Tunnel Test

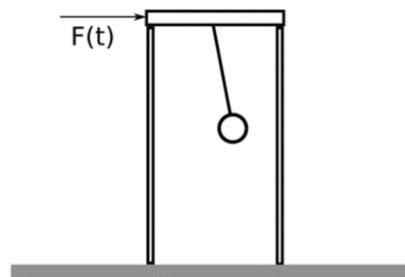
The building code may be used as a starting point for many types of construction' s original design. For the final design, the civil engineers frequently use the wind tunnel test to fine turn. Nonetheless, from a structural design standpoint, taller structures provide greater difficulties since their dynamic response becomes more noticeable [3]. The best way to test the stability of a building is the wind tunnel test. The wind tunnel test uses wind fluid dynamics to ensure the safety of the building in any severe weather.

As the Figure 1 shows, this is the 15:1 Aspect Ratio model of a 96 stories residential tower located at 432 Park Avenue, New York City. During the wind tunnel test, the civil engineers will turn on the wind machine and rotate the model to test wind resistance of each side of the model. After that, the civil engineers would get the data to calculate the stability of the building.

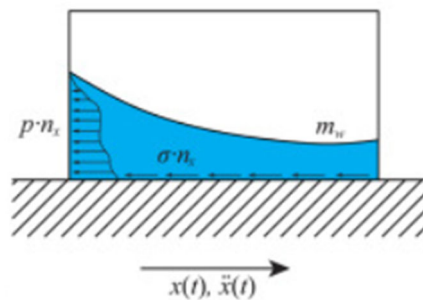


**Fig. 1** The 15:1 Aspect Ratio model of a 96 stories residential tower

After the wind tunnel test, if the building is not stable enough, the civil engineers will use the supplement damping systems to increase the stability. Tuned Mass Damper (Figure 2) and Tuned Sloshing Damper (Figure 3) are the common damping systems [4].



**Fig. 2** Tuned mass damper

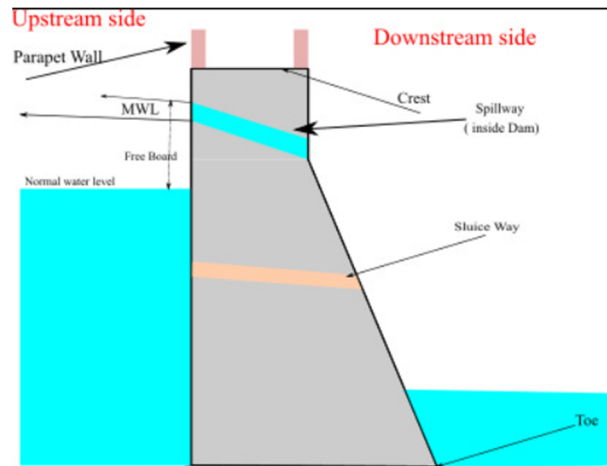


**Fig. 3** Tuned sloshing damper

## 2.2 Designing of Dams

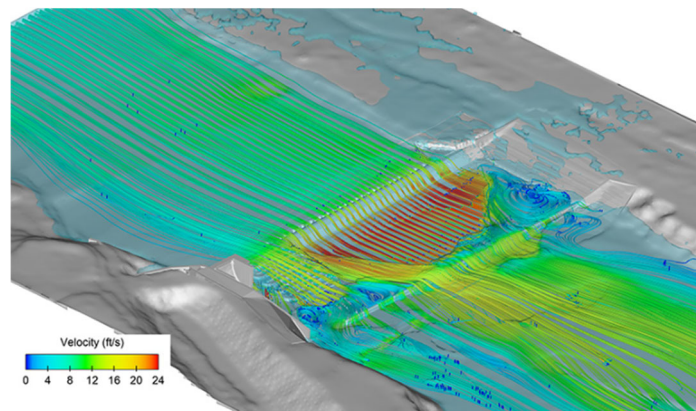
Since the primary engineering challenge is focused on the evaluation of the structure's security and performance, it is generally believed that solid mechanics can solve most of problems. However, Solid mechanics methods may not be sufficient for analyzing the dam's vulnerability to water pressure, though. Fluid mechanics plays an important role in the development of engineering technology and can greatly promote the development and progress of various disciplines. Fluid mechanics no longer exists as an independent branch, but as an auxiliary science can solve many problems in life. Cheng. [5].

The dams are designed to block the water flow (Figure 4), therefore, when the civil engineers design the dam, they need to calculate the actual water pressure along the dam wall from both sides and compare to values from the computer modeling to look for the emergence of concrete fractures.



**Fig. 4** The design of dam

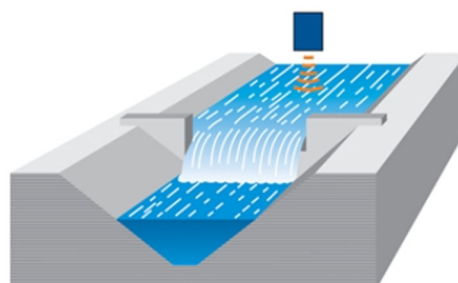
when complicated problems at dams develop due to quick change or unexpected deterioration, the civil engineers will check the hydraulics status and apply the right remedies or repairs. At this time, Civil engineers might resort to computational fluid dynamics (CFD) models [6]. Figure 5 shows the model of CFD. Significant abrasion damage occurs in high-velocity regions, while low-velocity regions show little or no abrasion.



**Fig. 5** The CFD model results

### 2.3 Channel Flow

In fluid dynamics, the channel flow (Figure 6) is a kind of water flow. Channel flow has a free surface.



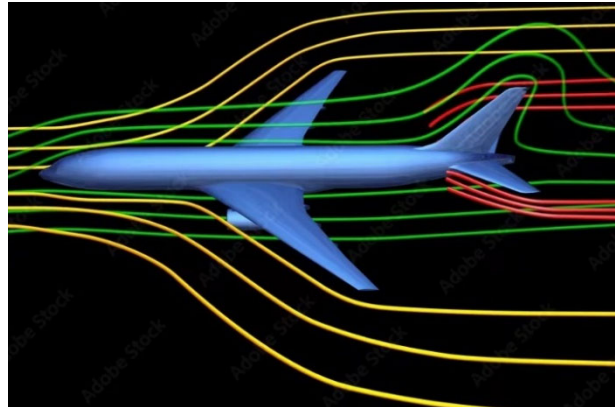
**Fig. 6** Open-Channel Flow

In the channel flow, the laminar channel flow is linearly stable at Reynolds number  $rel = 5772$ . However, this is not the case in some cases, and it needs to be determined according to the actual conditions. Therefore, the conditions of numerical simulation must be improved according to the actual situation [7].

### 3. Fluid Dynamics in Mechanical Engineering

#### 3.1 Wind Tunnel Test

For aero and mechanical engineers, determining the air flowing through the aircraft is quite important. For different Reynolds numbers, different results will be shown by the cabin. When the Reynold number is low, this means the surrounding air is stable and steady flow, at this time, the aircraft will fly in a smooth line. In contrast, if the Reynold number is too large, the aircraft will be unstable and meet a turbulent. The passengers in the cabin will obviously feel the difference. At this time, the inertia will take the lead in turbulence.



**Fig. 7** Wind flows around plane

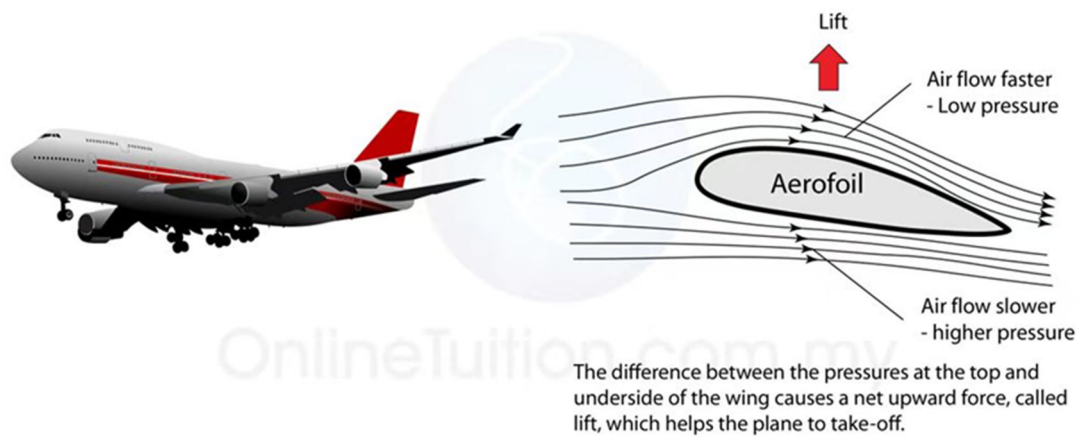
Such conditions require engineers to test the structure of the aircraft. The mechanical and aero engineers will design a model and put it into the wind tunnel. The real conditions can be simulated in the wind tunnel by adjusting the wind flow and angles, the computer models can be uploaded and show us how the force and momentum perform on the aircraft model. Car models will also be tested in wind tunnels, especially the racing cars. Figure 8 is a plane model in the wind tunnel.



**Fig. 8** Plane model in Wind tunnel

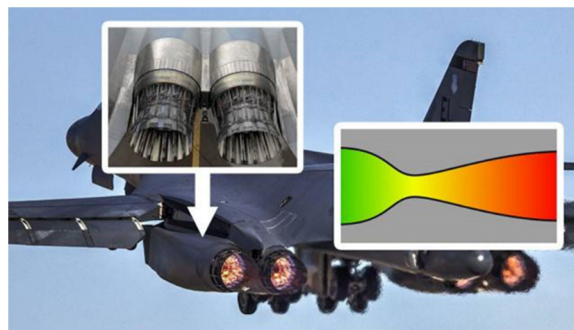
#### 3.2 Aircraft

Aircraft, as a typical successful case in the development of fluid mechanics, integrates the application of all aspects of fluid mechanics. In the flight process, how to reduce the wind resistance is the primary problem to be considered.



**Fig. 9** Flows pass wing [8]

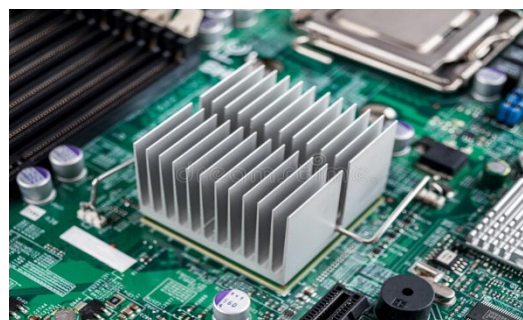
The turbine also asks the designer to learn the knowledge about nozzle flow. For the turbine on the business airplane, the Mach number of flows generated is usually less than 1. While for the military aircraft, the Mach number of flows generated is usually larger than 1. There are huge differences between them. In addition, there are different nozzle types which can lead to different results on the jet engine.



**Fig. 10** Jet engine and nozzle

### 3.3 Cooling

The cooling is another application for heat transfer. for example, the cooling fans for the electronic chips in the computer or other device. When engineers want to cool the chip, they need to design a longer time to achieve a better cooling effect. When the wind passed through the small electronic board, the heat in the gaps was taken away. The cooling performance was also required between the tubes. Mostly see in the power plant, which heat transfer happens between the cold tubes and hot tubes. Usually the Reynolds number was calculated to help get a most economical structure.



**Fig. 11** Chips with gaps

### 3.4 Discussion

Although Fluid dynamics uses the same principles of water or gas, the application in Civil engineering is completely different than that in Mechanical engineering. In fact, Civil engineers use fluid dynamics to make sure the buildings they designed are safe and stable, for example, how to make sure skyscrapers can sustain large winds, how to make sure rivers will not destroy the dam, or how to use the open-channel flow [9]. While mechanical engineers care more about how they can use fluid dynamics to move or carry objects, for instance: how to make wind flows become the power of aircraft, how water or wind flows can take away heat efficiently. Therefore, Fluid dynamics already helps engineers a lot, and the engineers can use Fluid dynamics in many different fields [10].

### 4. Conclusion

From the above content, Fluid dynamics is quite important to modern society, it is more than civil and mechanical engineering. Without it, people will not see the tall buildings, because they will be destroyed by winds; people will not get water from the tap since water flows can damage the tubes; people will never take planes to travel a large distance because planes need to use airflow. Thus, fluid dynamics is a large area, only if you study a specific field deeply, you can hold the specific work. In the future, scientists and engineers will discover more uses of fluid mechanics to make people's lives more convenient.

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