

Analysis of The Venturi Tunnel and Ground Effect

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Abstract. The amendment of Formula One racing rules in 2022 has changed the situation of competitions and championships. In the 2022 season, the FIA will allow teams to use the ground effect again after 1978 to increase the possibility of overtaking and make the race more intense. The amendment is the most noticeable change in these years, and it is very effective. Wind tunnel research and the use of ground effect in the field of racing have special significance and practical value. It has always played an important role in the design and performance improvement of the car. In the design of traditional car styling, the influence of ground effect is not taken into account, so that in the course of the race, accidents often occur when the car body is off the ground. The reason is that the adhesion is reduced. The ground effect is an important method to improve the adhesion and stability of the car. In recent years, with the advancement of wind tunnel experiments, wind tunnels are gradually used in the design of racing cars. This paper will analyze the use of Venturi Wind Tunnel and ground effects in F1 and aircraft, and explain how and why adding ground effects to F1 has such a huge impact.

Keywords: Formula One racing; Wind tunnel research; Racing design; Ground effect.

1. Introduction

The Venturi effect is one of the most common effects in our daily life, the basis of airspeed increases when the area of intersection decreases appears everywhere in daily life. However, the usage of the Venturi Tunnel remains unchanged for a long period of time; people always and only use the Venturi Tunnel as an airspeed tube [1]. The usage and appliance of the Venturi effect vary dramatically until recently, from the original airspeed tube to today's various types of applications. Nowadays, with the pursuit of human beings to be faster and faster, aerodynamics has become an important part of industrial design, so the Venturi tunnel has back on the stage [2]. In the field of Motorsport, things like the Venturi chassis are crucial to the formation of downforce, and enable the car to stick on the ground without the increase of drag force [3].

The Venturi effect is also used in construction ventilation, which can guide the airflow precisely go through the places the designer is willing to. After all, the venturi effect can make air itself form the difference of pressure in spite of other devices or generators, which make the process efficient.

2. Development of fluid mechanics

Founded by Italian scientist Giovanni Battista Venturi, the venturi tunnel can generate low pressure around the area where the flow velocity is fast [4]. Of this effect, people build the Venturi airspeed tube, which is an instrument that can measure the velocity of the flow. Shown in figure 1 below.

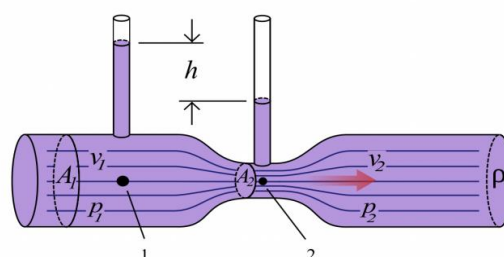


Fig. 1 Venturi tunnel [4]

Fluid mechanics is a subject derived from the traditional mechanics. Fluid represents every matter that will continuously deform after a force is applied, this is mainly liquid and gas. Archimede is the first person who deliberate fluid, he first studies the buoyancy of fluid. He found that the loss of weight when an object is immersed in the liquid is the same as the weight of the water displaced. This concludes one of the most important laws of fluid mechanics, which is also called the law of buoyancy. This law can enable people to conclude the force of buoyancy on fluids, which stimulates the development of the shipbuilding industry [5]. The law of Archimede’s law was used in the construction of hot air balloons and submarines. The reason that a hot air balloon can float in the air is that the total weight that fulfills the balloon is lighter than the weight displaced by the balloon itself. The dive and float of a submarine are also based on Archimedes’ principle. Inside the submarine, there is a separate chamber that can intake and exhaust water, the movement of water causes a change of the density of the submarine, which enables the submarine to dive and float [6].

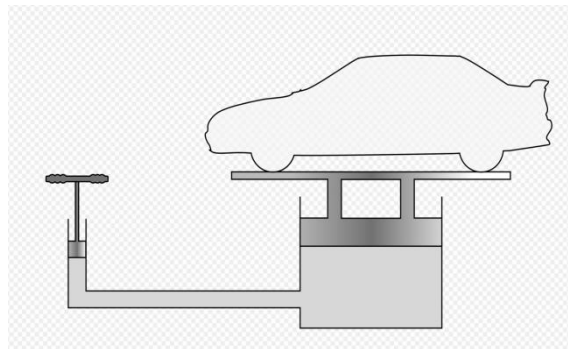


Fig. 2 Pascal effect [3]

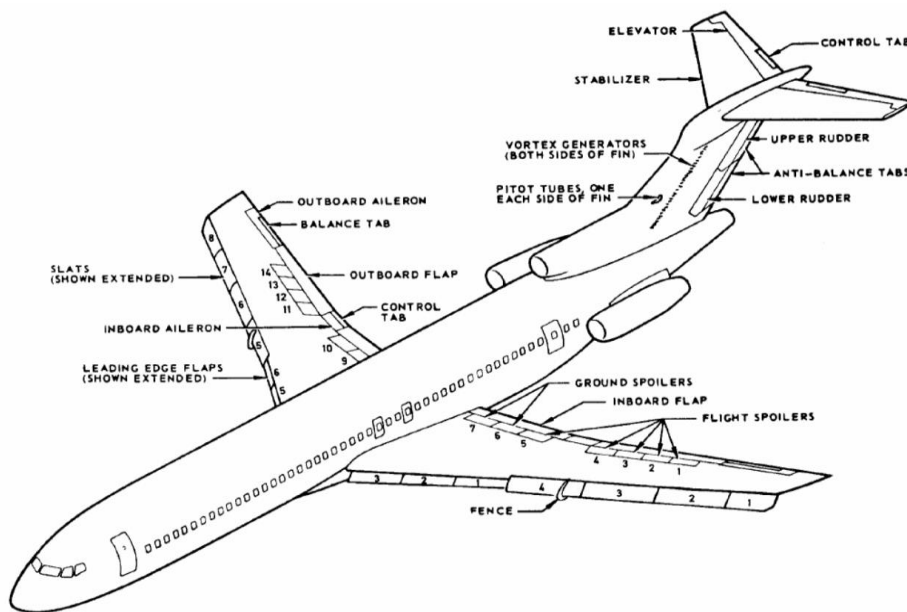


Fig. 3 Hydraulic system [8]

The second person who contributed to fluid mechanics is French mathematician Blaire Pascal. The Pascal principle states that the pressure change at any point in a closed container will be the same at every point it occurred [1]. The most widely used application of the pascal principle is the hydraulic system because the pressure change in a closed system is constant, according to the equation $P=F/S$, if we increase the surface of a platform or piston immerses in the liquid, the force it needs to be applied will be decreased [7]. Shown in figure 2 below. The invent of the hydraulic system actually boost human beings into a new generation, before the principle was established, the only way for people to move or transport an object with enormous mass is either by lever or pulley. Both methods are not only distance-consuming but also hard to put into practice. The hydraulic system, however,

can lift or displace an object at a faster rate and is easy to apply in real life. For example, the hydraulic jack makes people possible to lift the car to change tires or check the chassis. Surprisingly, this powerful machine is very small and can be stored in cars for people easier to change tires when they have a puncture [8]. If people use a lever or pulley to lift the car it will consume a lot of space and nearly impossible for people to carry them in cars. The hydraulic system has also been used in other applications, for example, aircraft such as Boeing 727 and DC 10. Both of them have three hydraulic systems powered by an engine-generated pump. Shown in figure 3. The system enables pilots to control the pitch and dive, yaw, and roll of an aircraft by controlling the aileron and rudder [9].

3. Venturi tunnel and ground effect

Cars are like exaggerated airfoils, the chassis of cars is relatively flat, and the upper area is arched upward. This caused the upper airflow to be faster than the lower chassis' airflow and create a huge lift force. It is acceptable when people are driving in the city at a lower speed. But when cars are on the highway or on track, the lift force will slightly lift the car upward and decrease the area of tire contact with the ground [10]. The loss of contact area will consequently decrease the friction of the tire which makes cars undrivable and loss control. For racing cars, it's more important to eliminate the effect of lift force, because they are at high speed and frequently facing corners. There are two ways to manage to do it, they are to increase the car's weight and decrease the lift force or in another words, to increase the downforce. The increase in the car's weight will of course cause the speed loss of racing cars which is unacceptable, so this proposal was eliminated when it was first proposed. As a result, the only way to improve performance during corners is to increase the downforce. The first instrument introduced to racing cars is the diffuser, it's a gadget with vertical fences mounted on the rear chassis of racing cars. They can produce strong vortices on the rear of cars, and the vortices will diffuse to the air along the rear wing and beam wing. Shown in figure 4.

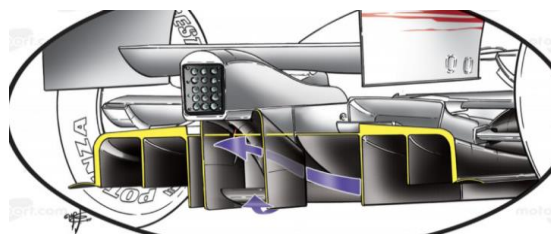


Fig. 4 F1 diffuser [1]

Although the vortices will increase the drag force of racing cars, the high-energy spinning flow can create a low-pressure zone as well. The difference between the atmospheric pressure and the pressure near the diffuser can create a strong downforce that can stick the car on the ground. The drawback of diffusers is quite obvious as well, the vortices will form a dirty air zone behind the racing cars and make others hard to get close to the car in front. Also, the diffuser will only increase the downforce at the rear, which will cause a huge difference in downforce differentiation that makes the car hard to drive and easy to spin. In order to fix these two problems, the FIA regulates that Formula 1 in the 2022 season is able to use the ground effect and Venturi tunnel. ground effect is a phenomenon discovered in aircraft and Formula 1. When the chassis of Formula 1 car forms a shape resembling venturi tunnel which is a spoon shape, the ground effect will appear. Because the air velocity will increase when the intersection area decreased, the air pressure due to the Bernoulli principle will decrease. These cause the atmospheric pressure to apply force on the car and keep it stuck on the ground. The venturi tunnel is effective because it reduces the defects of vortices, and it increased the downforce on the whole car instead of one specific section. However, nothing is perfect the venturi chassis also has some problems. First, because the downforce of the car highly relies on the chassis, any small damage or bumps of the curb will dramatically alter the downforce of the car. The difference will make the car lose all of the downforce during the corner, if the driver didn't notice these changes, they will be in great danger. Figure 5 is shown below.

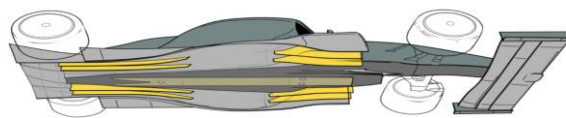


Fig. 5 Ground effect [5]

4. Ground effect on aircrafts

The reason for the ground effect on aircraft is still uncertain, there is a hypothesis that the ground effect was caused by vortices on the wing tip, and the spinning high-energy vortices will produce a reaction force on the ground, which makes the aircraft gain more lift force when they are close to the ground. The ground effect was highly used in the construction of helicopters because the helicopter is mostly used in low altitudes, so this phenomenon will happen frequently when it's flying. Shown in figure 6. The ground effect can also be dangerous for aircraft, when they are landing at a low speed, the ground effect will lift the aircraft upward when it's close to the ground. Account the aircraft is already at a low speed, the upward lift can easily make the aircraft lose energy and enter the stage of stall. It's terrifying for aircraft because it's nearly impossible for them to recover stall from this low altitude [8].

5. Conclusion

The fluid has brought enormous changes to human life. Archimede's law help people to calculate the buoyancy in fluids and furthermore the shipbuilding industry. Bernoulli's principle builds the basis of fluid mechanics and makes people possible to quantize fluid velocity, pressure, and flow rate. Pascal's principle enables people to move objects with enormous mass. Venturi tunnel and ground effect's appliance on Formula 1 and aircraft can contribute a lot to the vehicle's efficiency.

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