A Review on Force Implementation over rotating object through Magnus effect

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Abstract - **Magnus effect is the demonstration of Bernoulli's principle. According to this principle, pressure gets decreased with the increase in velocity. Both are inversely proportional to each other. In case of Magnus effect, when a body rotates with an rpm, it swirls the fluid around it generating a force perpendicular to the direction of its motion. This force is called as Magnus force. Due this effect the intended direction of travel of an object changes. The application of Magnus effect is done only when an object spins with some revolutions per minute. It is used in various areas like games, ships, cars, aircrafts, missiles etc. This paper gives the detailed review on generation of Magnus force and its application in various fields.**

INTRODUCTION

In our day-to-day life we come across many designs and engineering elements. There occur many hidden phenomena which are left with unnoticed. One such phenomenon is the Magnus effect. In 1853, a German physicist named Heinrich Magnus is the first person to describe the Magnus effect on a spinning object. If the object moves through the fluid, the pressure above and below is same. Then there is no pressure gradient which makes the ball to move is in same direction. But this not the case when an object spin. When a body rotates in the fluid medium, it drags the fluid around it. At one side, the swirl of the fluid around the object is in same direction with the fluid velocity. Here the velocity gets increased. On the other side, the swirl of the fluid around the object is in direction opposite to the fluid velocity. Here the velocity gets decreased. The velocity at one side is more compared with the other side. From the Bernoulli's principle, the velocity is inversely proportional to the pressure. Therefore, the pressure is more where the velocity is less. There occurs a force perpendicular to the fluid motion and rotation of the object called Magnus force.

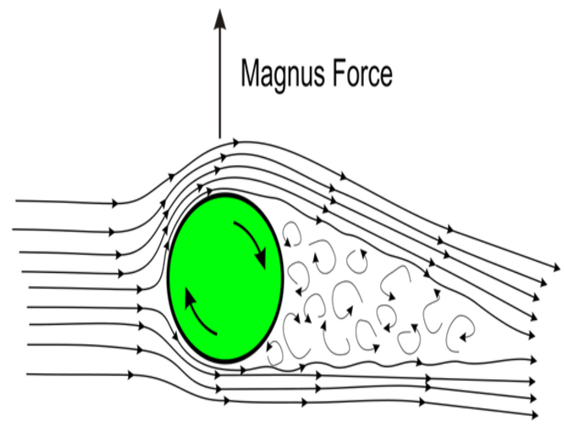

Fig 1: Boundary layer separation

The above figure represents the boundary layer separation on a spun body. When the object is moving through a laminar flow, the flow separation occurs due to the pressure difference. Due to that a low-pressure zone is created which results in increased drag.

According to Kutta-Joukowski theorem, the lift per unit length of the cylinder acts perpendicular to the velocity. The formulae are-

Lift = $C_L q_\infty S$ (1) Drag = $C_D q_\infty S$ (2) Lift rotating vortex = $P_\infty V_\infty \Gamma$ (3)

Γ=vortex/rotational strength

CL=lift coefficient

CD=drag coefficient

S=lift area

$q\infty$ =dynamic pressure

$p\infty$=density of incoming air

$V\infty$=incoming air velocity

There are many areas where the Magnus force is used. Some of the applications are aircrafts, missiles, golf balls, cricket balls, ships, bullets etc. A detailed review of some of the applications is presented in this paper.

EFFECT OF MAGNUS FORCE ON VARIOUS OBJECTS

Ball Games

Many researches where done in use of Magnus effect in all ball games. A ball is similar to the cylinder which spins through the fluid. Based on desired or required direction of moment of ball, the direction is spin should be changed. If the ball is spinning in vertical direction, then the force either acts in downward or upward direction depending on the direction of rotation. If the ball is revolving in horizontal direction, then the ball will deviate laterally.

Aircrafts

Lift can be increased by the introduction of Magnus force in aircrafts. In place of conventional airfoils, simple rotational cylinders can also produce lift. These aircrafts could also take off in less time and requires shorter runway.

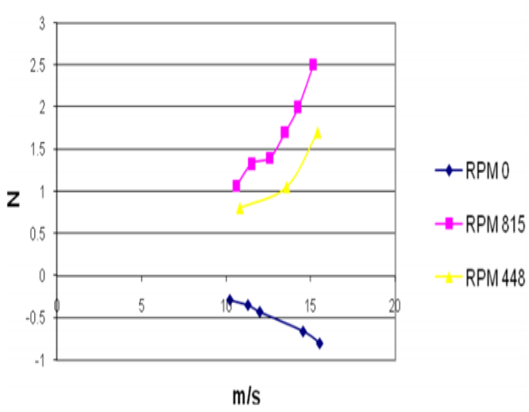

Fig 2: Lift VS Airspeed [8]

The above plot 1 is taken from the journal Rotating cylinder design as a lifting generator.

From the graph, it is clear that the rotating cylinder produce more lift compared with the conventional wings.

Changing the angle of attack (AOA) also affects the lift with the increase or decrease of rpm. The lift value increases with the increase of velocity of upper surface of wing and the rotational speed. The drag value decreases with the increase in rpm and lift. The data obtained from the analysis is plotted in plot 2 and plot 3.

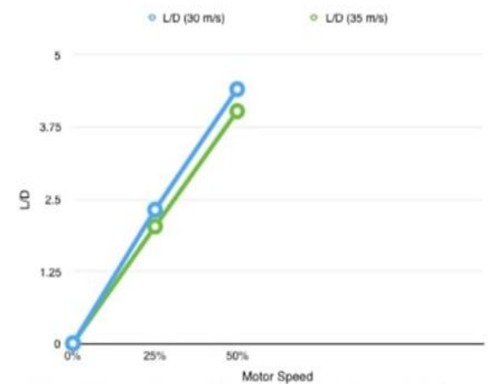

Fig 3: Motor speed VS L/D at 0^0 AOA [6]

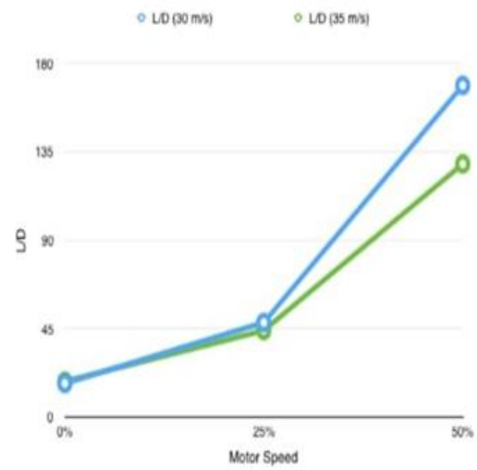

Fig 4: Motor speed VS L/D at 5^0 AOA [6]

The above plot 2 and plot 3 is taken from the journal Experimental study of Magnus effect over an aircraft wing.

Eternal Ballistics

When a bullet is fired from the gun, the motion of the bullet gets affected. It is due to the side force which acts on it. The bullet also spins during its motion to the target which generates the force perpendicular to both side force and motion of the bullet. This Magnus force effects the stability of the bullet and it tends to twist towards the flight path or away from the flight path.

Missiles

Magnus effect can be used in the missile manoeuvring. Other than the conventional methods like thrust vectoring, canard control, mid wing control, tail control, Magnus effect can also be used for missile manoeuvres. This can also be used as a backup method for manoeuvers when control surfaces or thrust vectoring fails.

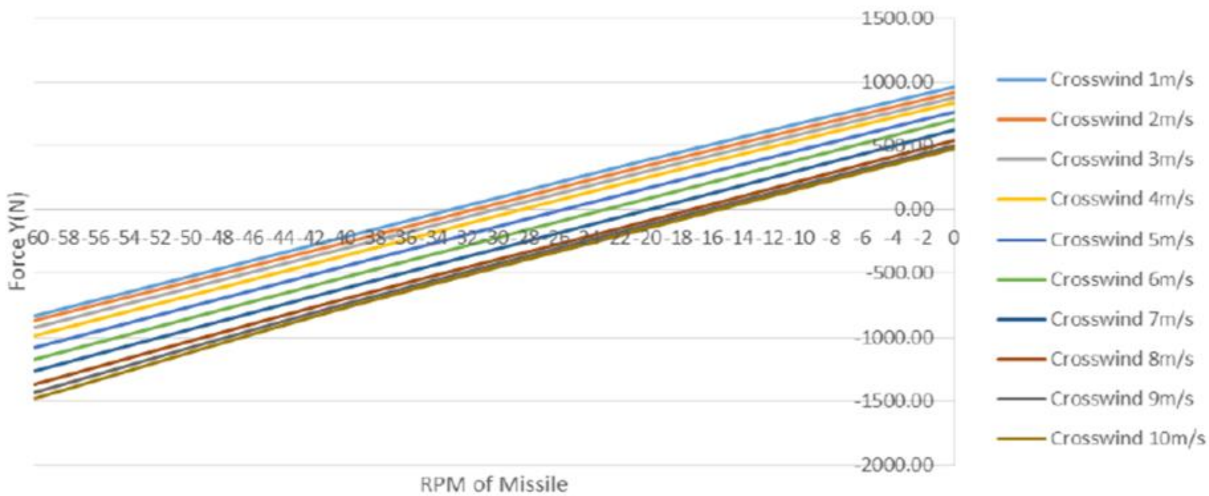

Fig 5: Magnus force VS RPM of Missile at different crosswinds [3]

The above plot 4 is taken from the journal Effect of Magnus force on spin stabilized missile in normal cross wind conditions.

The plot 4 describes the variation of Magnus force with the rpm of a missile at each crosswind condition. At one location, the force becomes zero which means the Magnus effect on missile is absent. So that force can be used for missile manoeuvring. The velocity chosen here is the subsonic range.

CONCLUSION

The Magnus effect phenomena are seen in various areas which includes ball games like cricket, football, golf, soccer etc. Apart from this, Magnus effect is widely used in aviation industry and in vehicles like cars and ships. Magnus effect in regular day to day existence will give you an appreciation for the designing and plan that normally goes unseen. More research would occur on exploiting the Magnus effect on varies fields and application.

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