Design of a wind tunnel to study the Magnus effect

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1. Introduction

The costs of acquiring a wind tunnel are very high, however a wind tunnel would be very useful when teaching about aerodynamics in physics lessons. For this reason, we aim to design a wind tunnel, with a price-performance ratio fit for schools. Our goal was to provide a wind tunnel in which it should be possible to measure the Magnus effect, which will be explained in the following text.

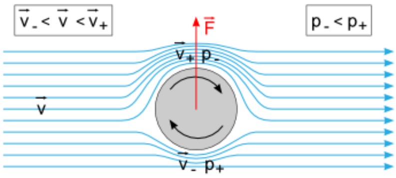

Fig.1: Magnus effect explanation

Due to the rotation of the cylinder the air flow gets accelerated above the cylinder and decelerated below. Because of that the pressure over the cylinder is lower than below, which leads to an ascending force.

2. Experimental setup

We decided in favour of an open wind tunnel. The measuring section is made from an acrylic glass tube and the skeletal structure is built from aluminium profiles. To create a laminary airflow we build a flow straightener out of drinking straws on either end of the measuring section.

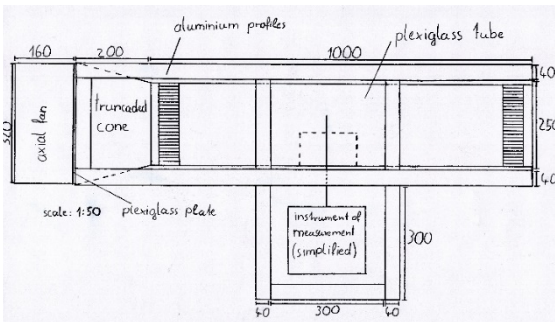

Fig.2: top view of the wind tunnel

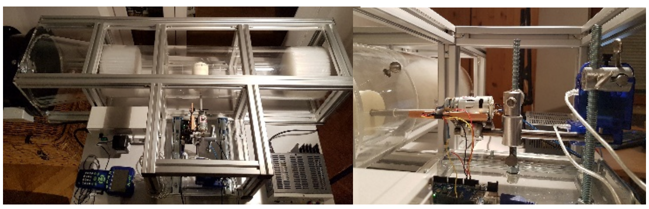

Fig.3: photo of the wind tunnel

The instrument of measurement is made of two force sensors in vertical and horizontal position, which detect the ascending and descending forces. The sensors are attached to a bar, which goes through two hinges to transmit the forces, On the other end of the bar is a motor to rotate the objects so they can be investigated in every position. Using, an anemometer, the wind speed can be determined. In order of investigating the Magnus-effect we optimised our wind tunnel even further. For one did we need a motor with a higher rotational frequency and an impeller set in a light barrier to determine the angular velocity. A major problem was the imbalance of the measuring cylinder, which could be solved with an exactly manufactured shaft from Bosch. We could already run several tests with different wind speeds, angular velocities and surfaces using our installation.

3. Results

To get reliable results, we did an average of five measurements. In Fig.4 you can see F_a (force ascending) as a function of F_W (air resistance) for a measuring cylinder of 105 mm length and 35 mm radius with a wind speed of 6 m/s and different angular velocities (0-100 rad/s).

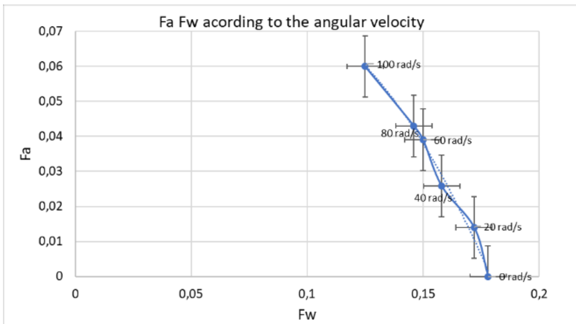

Fig.4: Magnus-effect according to the angular velocity

The graph clearly states, how with a bigger angular velocity the ascending forces increases while the air resistance decreases. On this basis we concluded $F_a \sim \omega$ Moreover, the Magnus-effect is dependent on the wind speed and the measurements of the cylinder. Following experiments showed how the surface is influencing the Magnus-effect too. A rougher surface increases the Magnus-effect

Conclusion

We managed to design a low-cost wind tunnel for our physics lessons and showed its functionality. We got reproducible results, which were as good as those from the professional wind tunnel from the Kepler-Seminar. To perform many different experiments on the Magnus-effect, we had to improve the instrument of measurement to get reproducible results. In further experiments we will examine the Magnus-effect on other objects and try to improve the wind tunnel even more.

References

[1] http://people.physik.hu-berlin.de/~mitdank/dist/scriptenm/magnus-versuch.htm