Experimental Observation of Von Karman Vortex Street

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Introduction

When a moving object passes through the fluid, we may find an alternating series of vortices behind the object. This phenomenon is caused by the boundary layer separation. There are examples in life like aircrafts and boats. Since the vortices could be fatal, it's important to study them.

Experimental Method

The method we used is called Particle Image Velocimetry (PIV). The PIV software which is an app in MATLAB is used to analyze the images and calculate the data.

We vary the speed of the moving cylinder and analyze the vorticity at the sampled areas showed in the picture.

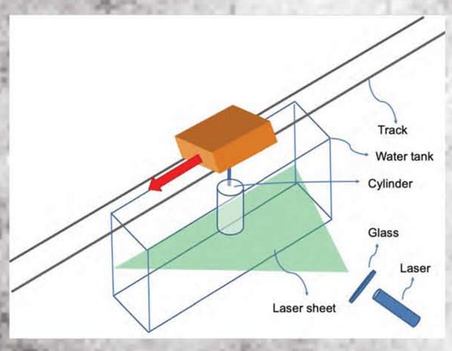

Fig. 1 Experimental Apparatus

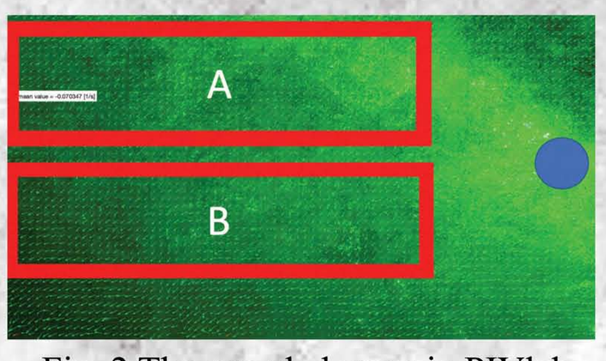

Fig. 2 The sampled areas in PIVlab

Symmetrical Mean Vorticity

In Fig. 3, the black line represents mean vorticity with object moving at speed 0.157 m/s (Slow). The orange line with moving speed 0.404 m/s (Medium). And the purple line with the moving speed 0.455 m/s (Fast). The other characteristic of this picture is that the peak values of the vorticity is slow > medium > fast, which indicates that the rotation speed of induced vortices is slow > medium > fast.

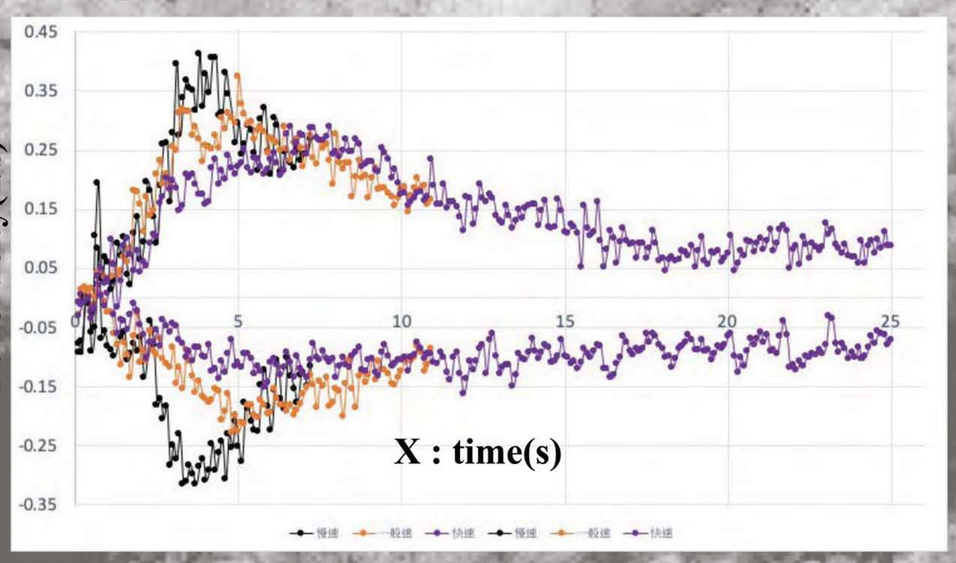

Fig. 3 The symmetrical mean vorticity; purple line correspond to fast, orange correspond to medium speed and black correspond to slow.

Conclusion

1. Symmetry of mean vorticity along the axis behind the cylinder.

2. The faster a vortex rotates, the shorter it can live.

3. When a cylinder moves fast through the water surface, the wave fronts induced brakes the vortices formed behind the cylinder, causing an incomplete pattern.

Lifetime of Induced Vortices

In the following picture, we rescale the vorticity by dividing each value with the maximum. We do so for the reason that we tend to define 1 as the birth of the vortices and the minimum as the death of the vortices. We can see that the faster the object passes by, the longer the induced vortices can live due to the fact that the rotation speed of induced vortices is slower when the object passes by faster. According to the equation $lifetime = \eta/u$, in which η is the viscosity and u is the speed of flow, the faster is the flow, the larger is the rotation speed.

We can see that the lifetime and its rotation speed is inversely proportional. This is due to the fact that $\tau = \frac{\partial u}{\partial y}$, in which τ is the shear stress of the flow, which is like the friction of the flow. The faster a vortex rotates, the larger shear stress it will feel, causing the fact that it can't live long.

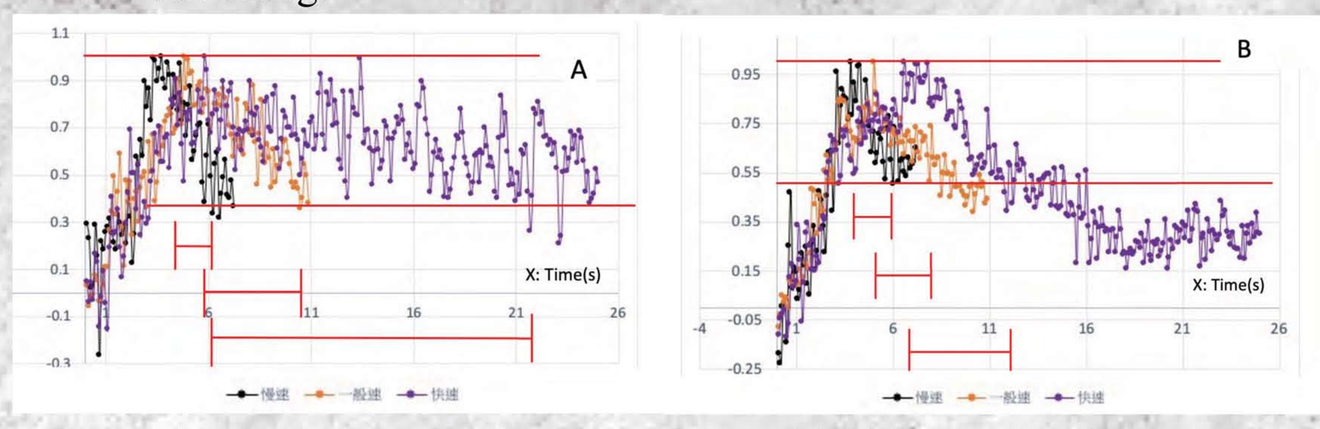

Fig. 5 & 6 The rescaled mean vorticity and the lifetime of vortices

Simulation & Patterns of Vortex Street

Through experiments, we discover that if we move the obstacle fast, we can't see clear vortex street behind the cylinder. The result is shown in Fig. 7. Instead, we can only see vortices far away from the cylinder.

Through simulation, we can explain such phenomenon with the fact that the faster the obstacle moves, the smaller is the angle of the wave front it induces. (See Fig. 8) When the angle of wave fronts is narrow, the vortices behind the cylinder would be broken by the wave front, causing the fact that we can't see clear vortices in the last picture of Fig. 7.

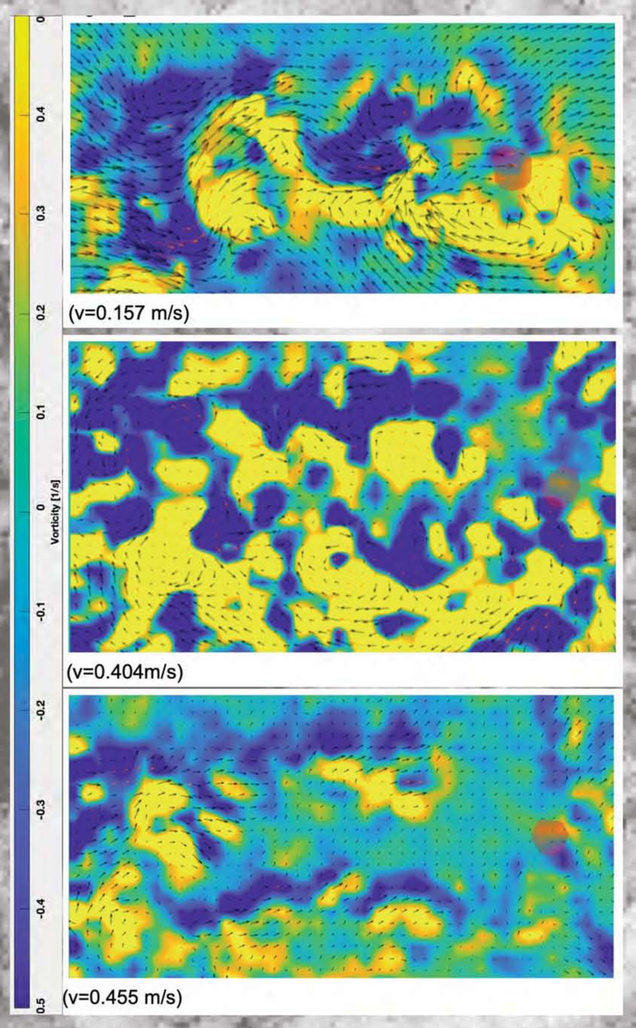

Fig.7 Vorticity of three different speed of cylinder

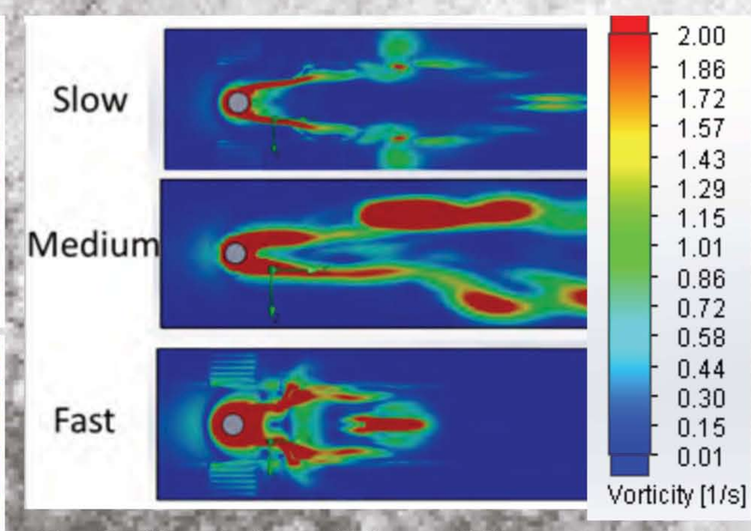

Fig 8. Simulation of three different speed of cylinder

Reference

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[3] PIVlab - particle image velocimetry (PIV) tool. Retrieved June 5, 2019, from https://www.mathworks.com/matlabcentral/fileexchange/27659-pivlab-particle-image-velocimetry-piv-tool
[4] Background picture, from https://de.wikipedia.org/wiki/Datei:Vortex-street-1-90deg.jpg