Vortex-Induced Vibrations and Impact Displacement Response

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1 Introduction

Vortex-induced vibration (VIV) of a cylinder has been thoroughly studied and documented over the course of the past fifty years. VIV was known as a destructive phenomenon and researchers attempted to decrease the harmful energy that could cause failures in engineering assemblies.

A common occurrence of the harmful effects of VIV include the Tacoma Narrows Bridge collapse in 1940 where wind-induced vortex shedding caused large oscillation and led to failure. Another example are subsea marine risers and drilling pipes that are subject to ocean currents which induces vortex shedding and vibrations, which is a concern for offshore oil and gas platforms. What is most pertinent to this experiment is the example of tall structures like a wind turbine that experiences crosswind VIV which can lead to swaying and affects structural integrity.

2 Objective

This study investigates the effects of vortex induced vibrations (VIV) under varying reduced velocities and the separate influence of solid-body impact from fluid-structure interactions. Understanding these effects is necessary for mitigating structural damage caused by VIV and impact events.

3 Methodology

Experiments were conducted at three reduced velocities (Vr = 5.75, 6.10, 7.45) using a 35 mm diameter cylinder with a low mass ratio of 45 in a 1.50 m's fluid flow, facilitated by University College Dublin's wind tunnel. Cylinder displacement and velocity were analyzed using the Phantom High-Speed camera.

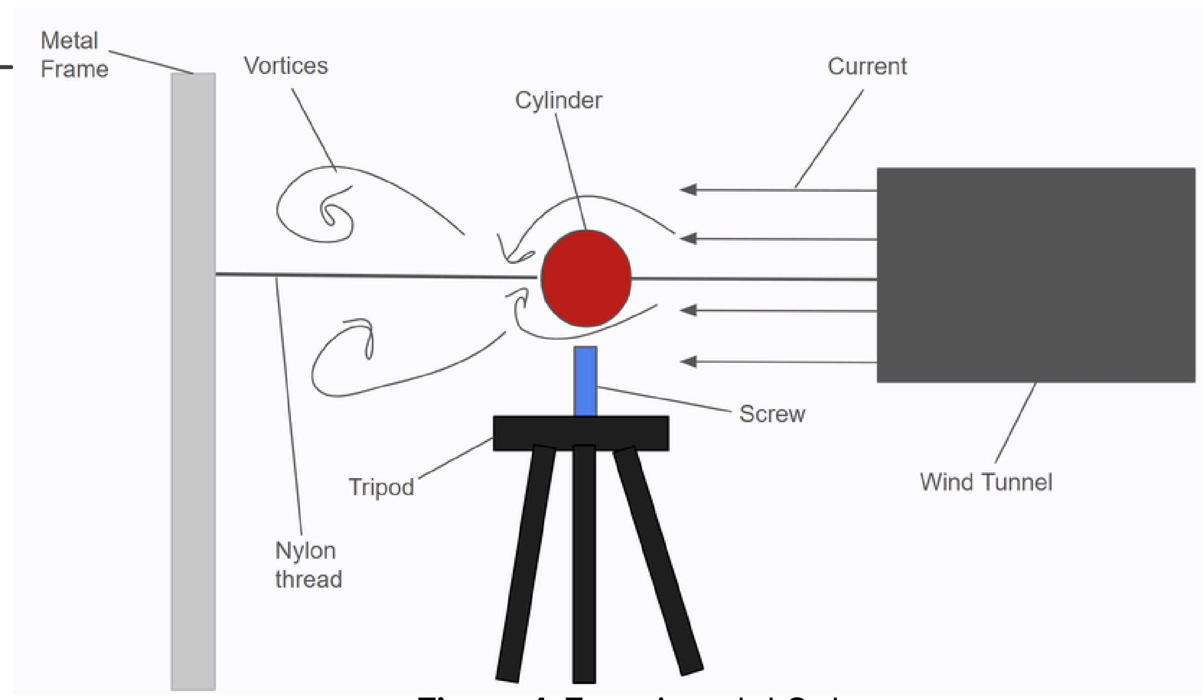

Figure 1: Experimental Set-up

4 Results

Table 1: Maximum and mean amplitudes for reduced velocities.

Reduced Velocity (Vr)	Maximum Amplitude (mm)	Mean Amplitude (mm)
5.75	1.42	0.87
6.10	22.51	17.76
7.45	16.95	8.48

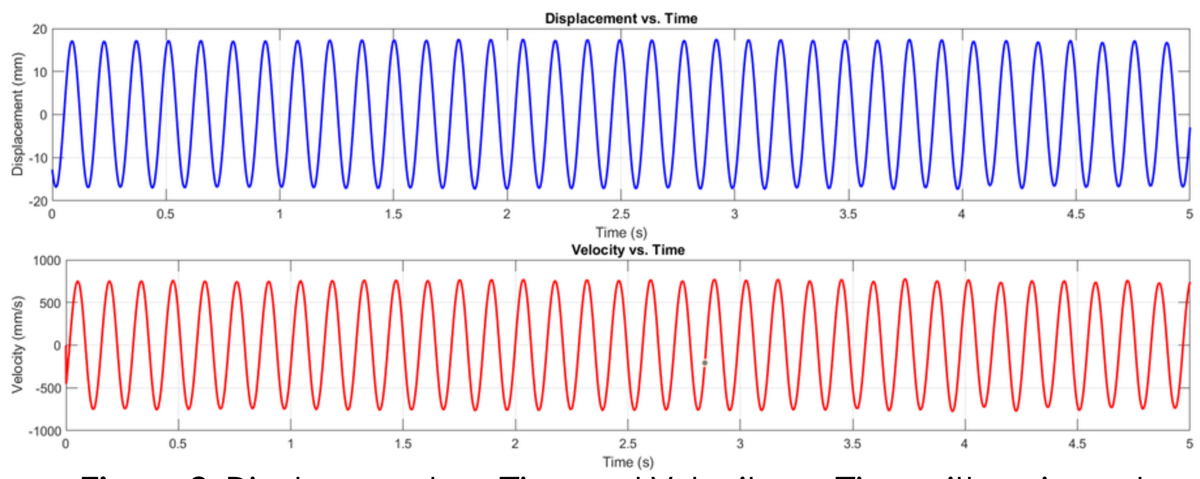

Figure 2: Displacement vs. Time and Velocity vs. Time with no impact

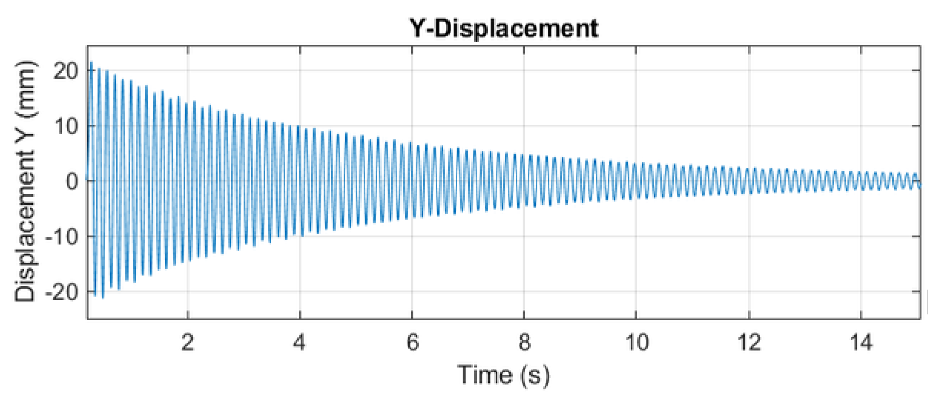

Figure 6: Displacement vs. Time in free decay

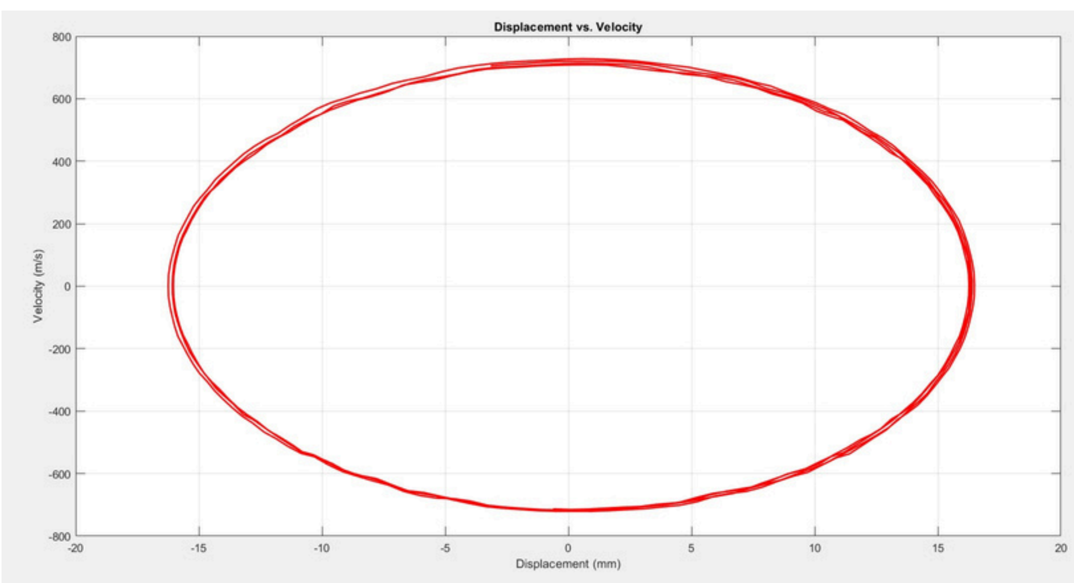

Figure 3: Velocity vs Displacement under no impact

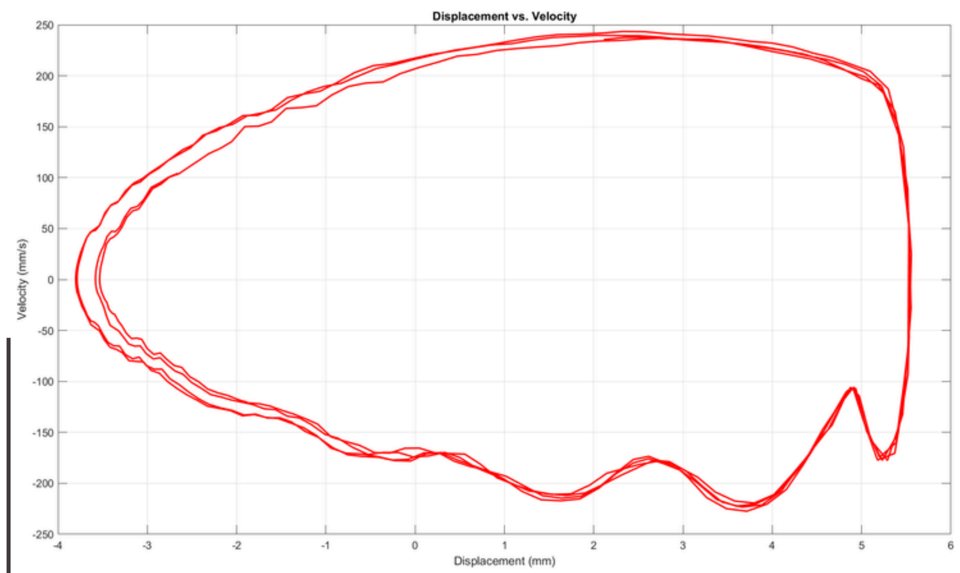

Figure 4: Velocity vs Displacement under impact at impact distance of 3.17 mm

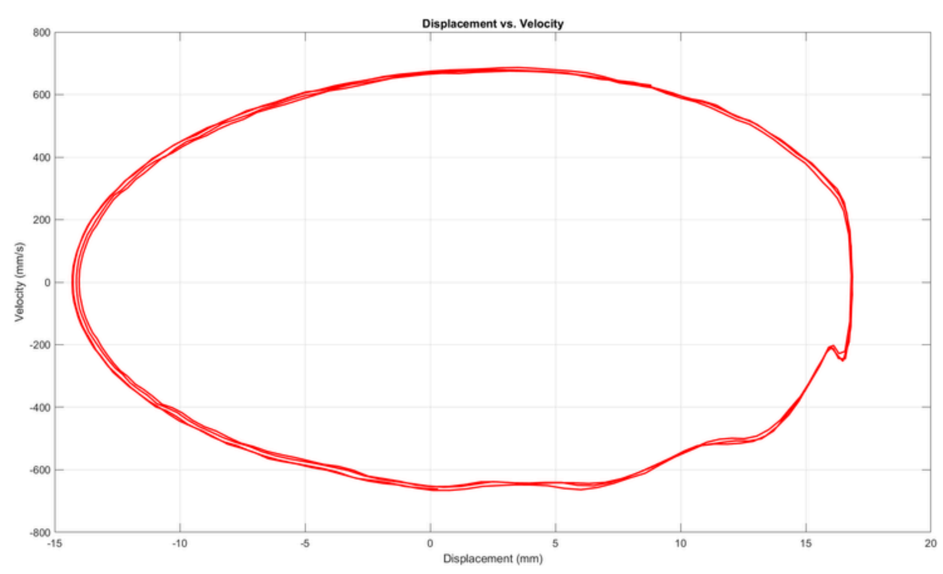

Figure 5: Velocity vs Displacement under impact at impact distance of 12.8 mm

5 Discussion

According to Raghavan and Bernitsas (2011) the amplitude ratio of A/D, amplitude over diameter, increases until the reduced velocity is about 9 and then there is a sharp drop off thereafter. However, it is not fundamental that increasing the reduced velocity leads to the increasing of the amplitude. When examining figure 6 the logarithmic decline in the free decay oscillations is apparent. This is expected and a sign that the experimental setup is built correctly and provides the expected and anticipated results. Figure 2 showing a typical Displacement vs. Time graph with no impact shows the vortex induced vibrations are periodic and large, and is the anticipated outcome of free oscillation. Figure 4 and 5 displays the Displacement vs. Velocity graphs and seen in Figure 3 the normally smooth oval generated from the VIV without impact displays a flat side on the right with some irregularities afterwards, all of which are repetitive as seen by the multiple lines overlapping in the same pattern. The flat side is a result of the impact and was hypothesized and proved in the work of Chawla (2024) in the electrical experiments.

6 Conclusion

Results show that it is not fundamental that increasing the reduced velocity leads to the increasing of the amplitude. In separate impact tests, repeated flattening was observed on the velocity-displacement curves on the impacted side, with the degree of flattening decreasing as the impact distance increased, resulting in higher displacement amplitudes.

References

1. Chawla, R., Rounak, A., Bose, C., & Pakrashi, V. (2024). Wake-induced response of vibro-impacting systems. *Physics of Fluids*, 36(12), 127148.
2. Raghavan, K., & Bernitsas, M.M. (2011). Experimental investigation of Reynolds number effect on vortex induced vibration of rigid circular cylinder on elastic supports. Ocean Engineering, 38(5–6), 719–731. https://doi.org/10.1016/j.oceaneng.2010.09.003
3. Sarpkaya, T. (2004). A critical review of the intrinsic nature of vortex-induced vibrations. *Journal of Fluids and Structures*, 19(4), 389–447. https://doi.org/10.1016/j.jfluidstructs.2004.02.005

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