Agitation of Snow Via Helicopter Propeller

Image Assignment #4

MCEN 5151

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https://youtu.be/N1meq2-XlaA

Introduction:

For the fourth image/video assignment, I captured the flow of small snow particles agitated by the large, high-speed propeller of a helicopter. I was skiing at Eldora Mountain Resort when mountain safety needed to conduct an evacuation drill. The bottom of the mountain was shut down and a large fence was erected to give the helicopter a space to land. I initially captured this video because I thought it would be fun to have a close-up shot of a helicopter landing. When I was reviewing the footage later, I noticed the extreme vortices and turbulent flow surrounding the propeller blades and decided to use this video as my fourth video assignment.

As the helicopter approaches the ground, snow begins to be picked up by the heavy current generated by the helicopter blades. What makes this flow so interesting, in my opinion, is that the low density of the snow particles allows them to act similarly to air, so the flow shows the overall movement of the air. It is very interesting to see how the flow interacts with the ground, rebounding and then rising back up to the top of the propellers. Overall, this video successfully captures the fluid flow of air and snow around the moving blades of a helicopter.

Science of the Flow:

The main flow visualized in the video is due to the rotor tip vortices caused by the spinning rotor. At the edge of each blade, a vortex forms due to the differences in pressure between the blade region and the surrounding air [1]. This creates the following flow pattern:

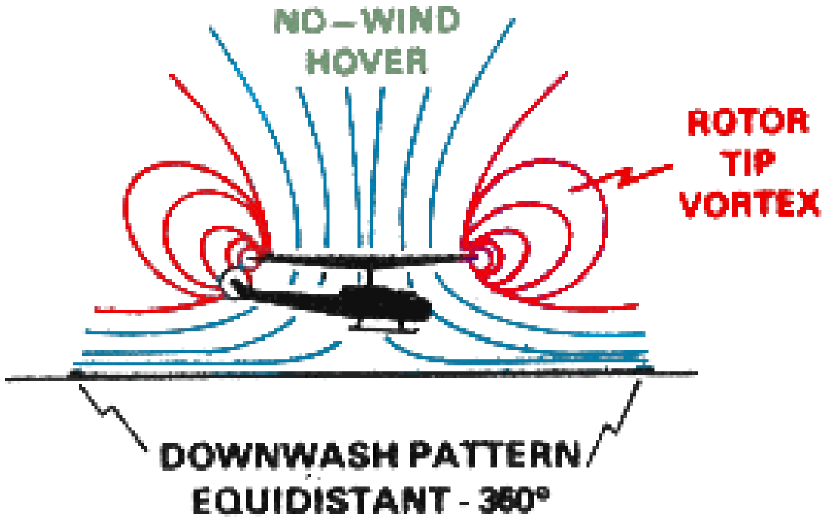

Figure 1 - Expected vortices resulting from a helicopter rotor

It is especially interesting to note the compression of the flow below the helicopter. As the helicopter flies, the tip vortices extend far below the helicopter itself. But as the helicopter lands, these vortices get compressed with the rigid ground and begin to pick up snow off of the ground. The flow of air through a helicopter propeller is nearly laminar in the above the rotor, except on the edges where these vortices exist. Mathematically, the vortices can be described by the following equation, which is derived from the curl of the Navier-Stokes equations:

$$\frac{D\vec{\omega}}{Dt} = (\vec{\omega} \cdot \nabla)\,\vec{v} + \nu \nabla^2 \vec{\omega} \qquad [2]$$

Experimental Setup:

This media was captured spontaneously, so I was unable to create studio lighting or an artificial setup. Nevertheless, the video turned out quite nicely, with clear focus and contrast between the flow and the background. Since the video was taken outside, here is a Google Earth screenshot of the estimated experimental setup:

[3]

The video was captured on an iPhone 12 Pro Max, using the telephoto lens that has a 2.5x optical zoom and a f/2.2 aperture. This lens was selected to flatten the view, making the background seem a bit closer than it actually is, emphasizing the contrast between the flow and the background.

Conclusion:

For this assignment, I captured a video of snow flow agitated by a helicopter rotor. The video pretty clearly shows the flow by having high foreground to background contrast. The flow itself is turbulent and includes some extreme vertices at the edges of the rotor, as discussed above. Overall, I was extremely happy with how the video turned out. I was very lucky to be in the right place at the right time to capture this flow, as it would be very hard to film a helicopter land under normal circumstances.

References

[1] P. Cantrell, "Hovering, Copters.com," [Online]. [Accessed 13 12 2021].

[2] M. I. o. Technology, "MIT Marine Hydrodynamics," 2005. [Online]. Available: https://ocw.mit.edu/courses/mechanical-engineering/2-20-marine-hydrodynamics-13-021-spring-2005/lecture-notes/lecture9.pdf. [Accessed 13 12 2021].

[3] Google LLC, "Google Earth," 11 06 2001. [Online]. Available: https://earth.google.com/web/. [Accessed 13 12 2021].