Experimental Investigation of Rotor Model with Blowing Jets

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Maneuvers of helicopters and tiltrotor aircraft cause rapid variations of angle of attack, flow separations, and dynamic stall on rotor blades. These fluid dynamics phenomena are highly unsteady and three-dimensional. Active flow control methods employ jets in spanwise and chordwise directions of blades to mitigate negative effects but add more complexity into the flow physics. In this experiment, active flow control of a rotor model in a wind tunnel is analyzed.

The rotor assembly used is comprised of two NACA 0012 rotor blades with a channel along the quarter chord, allowing a jet of air to extend through the blade tips in the spanwise direction. The rotor configuration used for this experiment included a 6° angle between the rotor cylinder and mounting rod and a 12° angle between the blades and rotor cylinder.

The rotor model was tested in the Arizona Low Speed Wind Tunnel. Particle Image Velocimetry (PIV) was utilized to capture images of the clockwise-rotating blade at four different angles relative to the freestream. To collect data, an sCMOS camera was used in conjunction with a Class 4 PIV laser. The laser illuminated the blade at the quarter chord on both the top and bottom surface, with the laser sheet being at the same pitch angle as the blade. The camera was oriented to focus on the tip of the blade from the trailing edge, oriented normal to the laser sheet. PIV software was configured to take a set of 100 image pairs, using the time difference between frames to determine a velocity field for the test.

Results were found to be consistent across the range of angles. In the baseline cases, the flow can escape around the tip and flow from the bottom to the top of the blade. This flow continues curling inward along the blade, reducing the spanwise velocity close to the tip. The curling of the flow results in the formation of tip vortices, which propagate backwards in the flow as the blade moves. The activation of the tip jets results in a reversal of this spanwise flow, with velocity increasing drastically just past the tip of the blade. The air on both the top and bottom surfaces of the blade is entrained as the jet is activated, increasing the spanwise velocity. The vortex core is also pushed outward and upward, further diminishing the tip vortex's capacity to affect the flow over the blade.

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