Pressure swirl atomizers are commonly used in IC, aero engines, and liquid propellant rocket combustion. Understanding the atomization process is important in order to enhance vaporization, mitigate soot formation, design of combustion chambers, and improve overall combustion efficiency. This work utilizes non-invasive techniques such as ultra-speed imaging, and Phase Doppler Particle Anemometry (PDPA) in order to investigate the atomization process of pressure-swirl atomizers by examining swirling liquid film dynamics and the localized droplet characteristics of the resulting hollow cone spray. Specifically, experiments were conducted to examine these effects for three different nozzles with orifice diameters .3mm, .5mm, and .97mm.

The ultra-speed imaging allowed for both visualization and interface tracking of the swirling conical film which emanated from each nozzle. Moreover, this allowed for the measurement of the radial fluctuations, film length, cone angle and maximum wavelength. Radial fluctuations are found to be maximum near the breakup or rupture of a swirling film. Film length decreases as Reynolds number increases. Cone angle increases until a critical Reynolds number is reached, beyond which it remains constant.

A new approach to analyze the temporally unstable waves was developed and compared with the measured maximum wavelengths. The new approach incorporates the attenuation of a film thickness, as the radius of a conical film expands, with the classical dispersion relationship for an inviscid moving liquid film. This approach produces a new long wave solution which accurately matches the measured maximum wavelength swirling conical films generated from nozzles with the smallest orifice diameter. For the nozzle with the largest orifice diameter, the new long wave solution provides the upper bound limit, while the long wave solution for a constant film thickness provides the lower bound limit. These results indicate that temporal instability is the dominating mechanism which generates long Kelvin Helmholtz waves on the surface of a swirling liquid film.

The PDPA was used to measure droplet size and velocity in both the near field and far field of the spray. For a constant Reynolds number, an increase in orifice diameter is shown to increase the overall diameter distribution of the spray. In addition, it was found that the probability of breakup, near the axis, decreases for the largest orifice diameter. This is in agreement with the cascading nature of atomization.