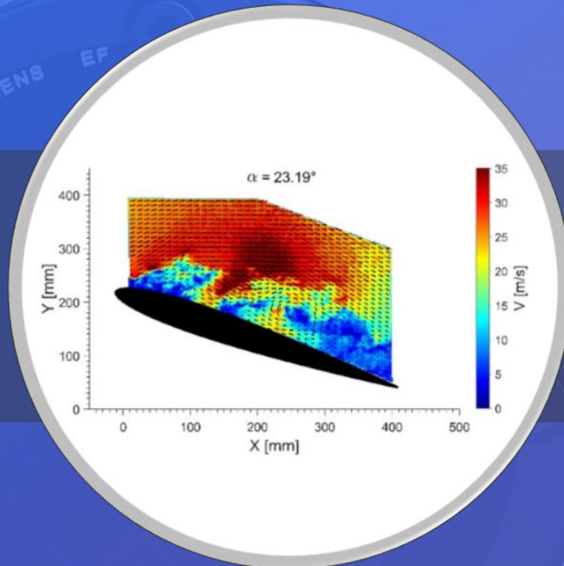
Photron
HIGH-SPEED CAMERAS



UNSTEADY FLOW PHYSICS OF DYNAMIC STALL

BY: PHOTRON USA, Inc. in collaboration with Dr. Phillip Ansell

In aerospace applications high-speed cameras facilitate the detailed analysis of projectile flights, missile launches, combustion processes, engine performance, fuselage durability, material strength, flow/particle movement and more. They do so by providing engineers with super slow-motion video of high-speed events.

Dr. Phillip Ansell is an Assistant Professor and Allen Ormsbee Faculty Fellow in Aerospace Engineering at the University of Illinois at Urbana-Champaign. He is currently the director of subsonic facilities at the Aerodynamics Research Laboratory, where his research group studies complex, unsteady flow interactions about aerodynamic geometries as well as novel aerodynamic solutions for flight vehicle technology.

Recently, in his research on the unsteady flow physics of dynamic stall, Dr. Ansell has utilized Photron's FASTCAM Mini AX200 to capture the rapidly evolving and complex vortex structures across dynamically pitching wing surfaces. However, since aerodynamic flows are not visible and cannot be directly imaged, a measurement technique known as time-resolved particle image velocimetry (PIV) is used. When performing this measurement technique, seed particles are introduced into the free stream, faithfully following the turbulent fluctuations in the flow. The emission of a high-speed laser is shaped into a sheet, which is then directed to cover the region of interest in the aerodynamic flow over the wing surface. The particles in the flow scatter the light produced across the laser sheet, which are imaged in the high-speed camera. By synchronizing the rapid laser pulses with the shutter of the high-speed camera, entire velocity fields can be measured at a high sampling rate.

This high-speed capability was crucial to uncovering a new fundamental understanding about the dynamic stall process across transitional Reynolds number ranges ($Re \approx 1 \times 10^6$). Most notably, this research showed that the dynamic stall vortex was actually produced through a collective interaction of many lumped vortical flow elements, rather than a monolithic structure that had been classically envisioned. Through advanced modal decomposition of the acquired velocity fields, the formation of these small-scale vortex structures was definitively linked to the breakdown of a Kelvin-Helmholtz instability process, alongside flow scales associated with vortex pairing processes and other interactions.

When Dr. Ansell was looking into high-speed camera brands for use in his PIV studies, there were a number of factors that were important for him to consider. These factors are discussed below.

Maximum Frame Rate

The first consideration in the purchase of a high-speed camera is typically frame rate. How many frames per second (fps) are required to capture sufficient video detail to analyze your high-speed event? Most high-speed cameras provide the ability to run at increasingly higher frame rates as pixel resolution is reduced. However, depending upon the camera, there may be restrictions regarding the degree of frame rate improvement that is available as vertical and/or horizontal resolutions are reduced.

Minimum Exposure

Some very fast high-speed events require extremely short exposure times – sometimes even less than 1 microsecond – to stop the motion of those events. A camera's ability to achieve a very short exposure is dependent on two things. First, the camera's sensor must be electronically capable of performing such a short exposure. Second, the camera's sensor must be sensitive enough that when it does utilize a very short exposure it can capture enough photons of light to generate video that is of sufficient quality for analysis.

Image Quality

In certain applications image quality is the single most critical consideration. Cameras that exhibit high levels of random or fixed pattern noise – both of which negatively impact image quality – make accurate PIV-related measurements impossible due to difficulty in distinguishing between noise and seed particles. Light sensitivity also impacts video quality because without sufficient light sensitivity, images will be dark and hard to analyze. As light sensitivity is measured and documented differently by nearly every high-speed camera supplier, it is important to test the camera in the intended application environment to see if it meets the requirements of the application prior to making a purchase.

Synchronization Accuracy

In PIV applications the field of view is often illuminated with a pulsed laser or pulsed LED. The ability to precisely synchronize the start of a high-speed camera's video frame or the start of an individual exposure with an illumination source is critical. Also required of the camera is the ability to accurately adjust (delay) the timing of synchronization signals and trigger signals.

Pixel Resolution and Pixel Size

The resolution and pixel size requirements of PIV can vary widely from one application to the next. The field of view might be small enough and/or seed particles large enough that a one-megapixel (i.e. 1024 x 1024 pixel) resolution and a 20-micron pixel size can capture enough detail within the recorded images. However, if the field of view is large and the seed particles are very small, a 2-megapixel or higher resolution and a 10-micron pixel size might be required.

Summary

Maximum frame rate, minimum exposure time and image quality (including light sensitivity) are typically the most important factors to consider when purchasing high-speed cameras, but as discussed above, there are a number of other things you should think about as well. Aerospace testing environments can be challenging for high-speed camera suppliers. To guarantee the successful implementation of high-speed cameras within such environments it is important to select an experienced supplier who can provide a range of highly reliable cameras and exceptional customer support.