Photron
HIGH-SPEED CAMERAS

THERMO-ACOUSTIC OSCILLATIONS IN GAS TUBINE ENGINES

BY: PHOTRON USA, Inc. in collaboration with Dr. Sina Kheirkhah

Thermo-acoustic oscillations often arise in combustion equipment such as gas turbine engines and power generation devices. In-phase heat release and pressure oscillations result in positive net energy transfer to these devices which causes resonance that can potentially lead to thermal and mechanical fatigue that, in extreme cases, can destroy the devices. By studying the dynamics of the pressure oscillations, scientists can develop technology to mitigate the damage caused by those oscillations.

Dr. Sina Kheirkhah is an Assistant Professor of Mechanical Engineering at the University of British Columbia – Okanagan. At the university's Combustion for Propulsion and Power Laboratory, he conducts thermo-acoustic investigations that contribute to the knowledge of combustion instabilities and the improvement of new combustion devices.

Dr. Kheirkhah currently utilizes a monochrome Photron FASTCAM Nova S12 high-speed camera coupled with an ultraviolet image intensifier to visualize the thermo-acoustics and kinematics of flame propagation. He runs the Nova S12 at between 1,000 and 5,000 fps with a 25-microsecond exposure to capture high quality, blur-free videos of the extremely fast combustion events. The ultraviolet intensifier is electronically synchronized to the Nova S12 allowing the camera to collect chemiluminescence around 310nm, which has significant contribution from OH*, as related to the heat release rate for premixed flames.

For his thermo-acoustic tests, Dr. Kheirkhah also pairs the Nova S12 with pressure transducers so that pressure changes taking place within the combustion event can be measured in synchronization with high-speed image sequences. The high-speed camera and intensifier provide the ability to see how the heat release rate changes over time and space. The data from the pressure transducers provides insight

into the regions within the combustor that might lead to the generation of thermo-acoustic oscillations.

When looking for a high-speed camera to perform combustion analysis, there are many important factors to consider. Three of the most important factors are described below.

Light Sensitivity. For combustion applications, light sensitivity is probably the single most critical consideration when it comes to purchasing a high-speed camera, especially when that camera is to be used with an image intensifier. Because of the way they work (i.e. multiplying photons), image intensifiers are inherently noisy. The higher the sensitivity of the camera, the less gain that is required by the intensifier and the less noise that is introduced into the images. Less noise results in better image quality.

Light sensitivity is measured in many ways by high-speed camera suppliers. Therefore, ISO values indicated on data sheets might not provide an entirely accurate description of a camera's sensitivity. An onsite, real world evaluation of the camera is essential to determine if image quality and light sensitivity are appropriate for a given application.

Frame Rate. Perhaps the most obvious consideration in the purchase of a high-speed camera is frame rate. How many video frames per second are required to capture a sufficient number of images to allow you to analyze your high-speed event? Depending upon the specific event, combustion applications can require frame rates between 1,000 and 50,000 fps. It is important to not only achieve the frame rate requirement, but also to make certain that the frame rate can be attained with sufficient pixel resolution to capture the necessary detail within the camera's field of view.

Synchronization with External Devices. It is often necessary, when researching combustion events, to synchronize high-speed cameras with other equipment such as image intensifiers and data acquisition devices. Therefore, it is important that the camera provides user-adjustable signal delays and similar controls to ensure highly accurate synchronization of the high-speed video with information captured by the other equipment.