Artist concept of an X-43-A hypersonic vehicle in flight, source: NASA.

Thermal imaging camera helps improve hypersonic aerodynamic designs

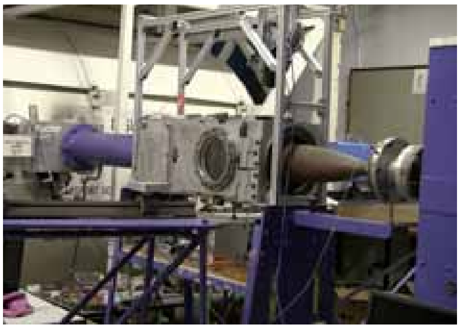
The FLIR SC655 thermal imaging camera combines high image quality and thermal sensitivity with external triggering options and high speed thermal video capturing capabilities, making it the perfect tool for hypersonic wind tunnel tests.

For the purpose of space exploration and aircraft technologies, researchers have explored travelling at hypersonic speeds, which entails attaining speeds over Mach 5, more than five times the speed of sound. This puts a huge strain on the aerodynamic and thermal designs of vessels and components. To test components and their capability to withstand airflows at such velocities, the University of Manchester in the United Kingdom combines their hypersonic wind tunnel with a thermal imaging camera from FLIR Systems.

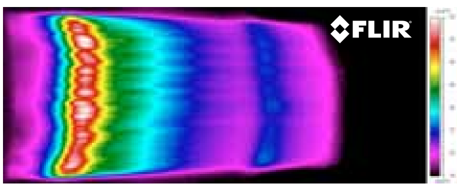
Future space exploration will lead to a rise in demand for re-entry space vessels that are capable of bringing payloads to orbit and re-entering the atmosphere to land safely on the Earth's surface. The desire for faster planes, both for transportation and for military purposes, will also lead to a demand for aircraft designs that are capable of withstanding high speed airflows. The wind tunnel at the University of Manchester is one of the few experimental facilities in Europe that can reach Mach numbers higher than 5.

Travelling at Mach 6, which roughly translates to a speed of over 4000 kilometer per hour, massive airflows would rush past the vessel's surface, causing friction, which in turn causes a rise in temperature, explains Prof. Konstantinos Kontis, head of the Aerospace Research Group at the University of Manchester. "The prolonged exposure to friction induced heat can be detrimental to the structural integrity of the used material. It is therefore very important to test components and designs extensively before they are employed in the field."

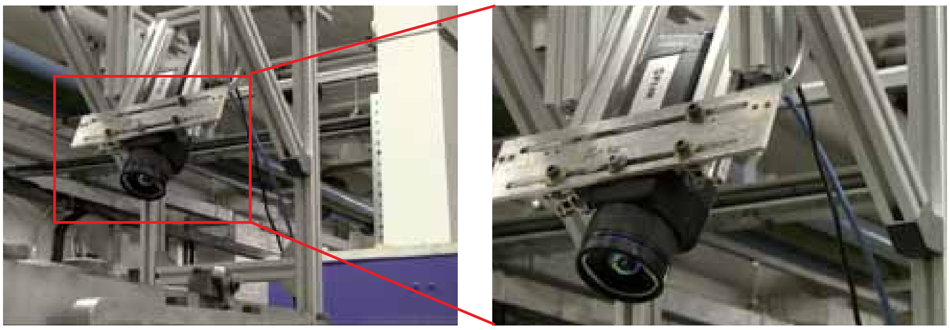
According to Kontis the hypersonic flow wind tunnel at the Manchester University is the perfect place for such tests. "We can subject models and components to airflows similar to what they will be subjected to in the field. This rush of air will cause hot spots on the surface of the test object which can be mapped with a thermal imaging camera. This information allows us to make recommendations to our clients for design improvements."



The air flows from the pressure chamber (to the right) through the test chamber (middle) and into the vacuum tanks (left), reaching air speeds of over 4000 kilometer per hour.



From the perspective of the thermal imaging camera the air flows from left to right. The red area indicates the shock impingement area, where air friction causes an increase in heat.



The FLIR SC655 thermal imaging camera is positioned above the test chamber, looking in through a Germanium window. This allows the camera to accurately map the thermal hot spots caused by the air friction, without being subjected to the force of high velocity airflows.

Prof. Konstantinos Kontis, head of the Aerospace Research Group at the University of Manchester.

Perfect tool

The thermal imaging camera used in this setup is the FLIR SC655 thermal imaging camera. "We chose this camera model because it is capable of recording thermal maps of the entire surface of the test object" says Kontis. "It has an excellent thermal sensitivity, so it allows us to record tiny temperature differences. With the external triggering options and high speed video capturing capabilities it is the perfect tool for this type of test."

The FLIR SC655 thermal imaging camera contains an uncooled microbolometer detector that produces thermal images at a resolution of 640 × 480 pixels and a thermal sensitivity of 50 mK (0.05 °C). The full resolution can be captured at a frame rate of 50 frames per second (fps), but it also provides high-speed windowing modes that allow the operator to increase the frame rate to 200 fps with a resolution of 640×120 pixels. Fully compliant with both GenICam and GigE Vision protocols, the SC655 is relatively easy to integrate with a variety of third-party analysis software packages.

Choice for FLIR was obvious

"Our choice for a camera of FLIR Systems was an obvious one", adds Kontis. "FLIR has an excellent track record when it comes to high quality thermal imaging cameras and software solutions. The deal FLIR offers really is a good one, especially with the option to upgrade to a better thermal imaging camera model if our research needs might require that in the future."

To capture the thermal footage and perform the initial analysis of the temperature data Kontis and research associate Dr. Erinc Erdem use FLIR ResearchIR software. "This software package is very easy to use and provides a lot of options for the researcher", says Erdem. "We use it to capture the data, define special regions of interest and export the temperature measurement strings to third party software for an in-depth analysis of the data. The versatile software and the possibility to use embedded macros make it very easy to export data to other software programs. All in all I would say that the software and its features are very convenient for the user."

Wind tunnel airflow

The wind tunnel consists of three global components. On one end of the wind tunnel there is a pressure chamber capable of pressurizing air up to a pressure of 15 bar, 15 times the regular atmospheric air pressure. At the other end is a vacuum tank which is brought to 1 mbar, one thousandth of regular atmospheric air pressure. In between the two is the test chamber where the test object is placed. At the push of a button the pressurized air travels from the pressure chamber into the vacuum chamber, passing the test object en route with a speed of about 4000 kilometer per hour, similar to travelling at Mach 6. The FLIR SC655 thermal imaging camera is located on top of the test chamber, looking in through a Germanium window. This allows the camera to accurately map the thermal hot spots caused by the air friction, without being subjected to the force of high velocity airflows.

Thermal pattern

"In the thermal sequence the red part is where the air friction is causing the strongest rise in temperature, also called shock impingement" explains Erdem. "Beyond that point you see streaks in the thermal image that indicate the transition from laminar airflow to turbulent airflow. Especially in the area of the shock impingement it is wise to strengthen the component with an extra band of insulation material of with an extra plastic coating. By taking these measures the regions of high heat flux will be better able to withstand the heat which will help prolong the lifetime of the component."

The knowledge gained by these wind tunnel tests will help enhance designs for high speed aircrafts and re-entry space vessels that need to be capable of bringing payloads to orbit and returning to the Earth's surface more or less intact. "The thermal imaging camera is a crucial tool for these developments, which will lead to better version of crafts like the Boeing X-5 and the NASA X-43", concludes Kontis.

Kontis' research associate Dr. Erinc Erdem uses FLIR ResearchIR software to analyze the thermal data.

For more information about thermal imaging cameras or about this application, please contact:

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