From aircraft aerodynamics to improved heart implants

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At first glance airplane wings and human hearts have little in common, but, say a team of European researchers, a technology used to measure airflow over wings can now be used to help keep hearts in working order.

The researchers optimised a Particle Image Velocimetry (PIV) system traditionally used to improve the aerodynamics of aircraft wings to make it capable of accurately measuring the effects of medical implants on blood flow. Their work will allow medical device manufacturers to improve the design of devices such as heart valves and pumps, and provide doctors with a way to detect – and ultimately correct - the side-effects that commonly afflict patients who receive implants.

“This system could revolutionise heart treatments,” says Fabrizio Lagasco, coordinator of the SMART-PIV project.

The SMART-PIV system - which combines the optimised PIV hardware with advanced image processing and numerical analysis software over a parallel computing subsystem - fills a gap in the heart device sector that has limited the efficiency of implants.

Though ultrasound scans allow doctors to view potential problems with the natural heart, as well as locally in the circulatory system, they fall short of providing a detailed analysis of the causes of problems related to blood flow when modified by artificial implanted devices. In the field of biomedical device design, experiments involving the implantation of

medical devices into animals can prove that a device functions, but such in vivo trials are lengthy and costly as well as not always being indicative of the effects the implant will have in humans.

Complications, ranging from the minor to the potentially fatal, are widespread among patients who receive implants either as a long-term solution to a failing heart or as a temporary 'bridge' while they await a transplant. Though such implants play a vital role in prolonging the lives of people with cardiovascular disease, reducing their side-effects through improved in vitro design would undoubtedly increase patients' quality of life and their chances of long-term survival. That is particularly true in the case of ventricular-assist devices (VADs), battery-operated pumps that support a failing left ventricle and help supply blood to the rest of the body. VADs are primarily used to buy patients time until a heart donor can be found, but even in a best case scenario they can currently only extend a patient's life by up to two years and frequently just a few months.

By applying PIV technology in their development Lagasco expects it would be possible to greatly enhance their performance and grant patients more time to obtain a transplant.

"With so few donors available compared to the people who need new hearts the number of people with implants is only going to continue increasing," notes Lagasco.

Indeed, cardiovascular disease is the principal cause of death in Europe, claiming around four million lives a year. "That is why we saw the need for this technology to be applied in the medical sector," Lagasco says.

At the core of the project's PIV system is miniaturised optical sensor technology using ultra-thin laser light sheets to capture images of the fluid dynamics of blood flowing through implanted devices. Numerical

analysis is carried out on the images in a parallel computing subsystem allowing device designers or doctors to detect problems with the blood flow, such as high velocity gradients that can cause blood cell damage, or low velocity that could lead to thrombosis or coagulation.

Based on the results of trials, by employing parallel computing the analysis can be performed in under a day in 80 per cent of cases and in less than two days in all cases.

“As computer processing power increases we estimate that within two years the analysis could probably be performed in two to three hours,” Lagasco says. “That compares with the weeks or months it can take to obtain results from using traditional PIV systems.”

Having tested the system in vitro during the project, the partners are planning to develop and evaluate it further in trials involving a medical device manufacturer.

“We’re currently in talks with Sorin, a multinational producer of heart valves, and with an Italian SME that is looking to use SMART-PIV to optimise the design of their VADs,” Lagasco says. “The commercial possibilities for the system are therefore extensive and a product based on the project results will probably be in use within the next few years.”

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