AEngD Research Writer of the Year - Potential Impact Category

Robert Hughes
Research Engineer
University of Warwick
Rolls-Royce plc.

Title: Pushing the Limits of Materials Testing

Everything degrades. Everything breaks. It is a sad truth that there is not a man-made construction on the planet that Mother Nature cannot render useless, given time. All we can do to safeguard our creations is to fend her off as best we can with whatever technology we have. Alas, for the aerospace industry, it is an expensive business.

Have you ever considered that every time you fly there are literally thousands of moving parts, some superheated to thousands of degrees, rotating at tremendous speeds just meters from you as you sit in your pressurized, fuel filled, canister? The structural failure of one of these failure-critical components, as they are known, would cause the total immobilization of the engine and potentially endanger the aircraft. The severe loss of life, not to mention the significant financial toll, would be crippling to the industry. As a result, enormous sums of money are spent every year on over-engineering, precautionary overhauling and replacement of these parts to prevent this.

Phew! What a weight off your mind. However, this Safety First attitude inevitably leads to perfectly functional components being scrapped. So what if there was some clever way to spot a damaged component before a catastrophe could occur?

Let me introduce you to an area of materials testing known as non-destructive evaluation, or NDE to its friends. The field of NDE uses a wide range of techniques, some of which you will already have come across if you have been to a hospital. X-ray and ultrasound are two very prominent techniques in industrial NDE, each capable of detecting damage only a few millimeters in size, within the bulk of the material. Critical components are designed with the assumption that the smallest flaw that is detectable using NDE techniques is present within the part from the outset. This is why the most sensitive approaches must be used for failure-critical component inspections.

My challenge as an EngD student has been to develop a method of improving the sensitivity of a technique known as eddy-current testing, or ECT. ECT is cheap, repeatable and is one of the most sensitive inspections available. However, research and development in the technology over the past decade has waned, and the current use of superalloy materials has made inspection of these failure-critical components more complicated and begun to test the limits of this technology.

Although still in its infancy, my work breaks away from conventional approaches used by most commercial developers, and revisits the principles of some of the earliest commercial ECT systems. An eddy-current system will experience the greatest changes in its electrical properties at excitation frequencies close to electrical resonance. When the probe encounters any damage, the resonant frequency of the system shifts slightly giving rise to very great changes in the measurements.

My research has identified a range of defect-signal boosting excitation frequencies within a carefully tuned system. By intelligently selecting a frequency within this range, it will be possible to boost the signals of smaller defects above the background ‘electrical noise’, thus allowing them to be reliably detected. Achieving this would increase confidence in the structural integrity of these failure-critical components, leading to longer service lives, and less regular inspections. Alternatively, the parts could be re-designed. They could be made using less material, so that they are lighter and more fuel efficient, yet still as strong and long-lasting. Or they could be designed to take higher stresses and strains in order to improve work efficiency.

What is more, this simple approach to enhancing the sensitivity of an ECT technique can be developed into a technique for using eddy-current arrays. Arrays improve the coverage of standard ECT techniques so that larger areas can be inspected faster. One of the key problems with arrays is that element-to-element interference can increase background noise, making them less reliable particularly for smaller defects. However, implementing the signal boosting effect being developed could rectify this issue, leading to arrays achieving the necessary sensitivity and reliability to become more accepted and wide spread within the aerospace industry, and beyond.

All to keep Mother Nature at bay and you safer in the air. That’s the main thing.