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SAFE AND SOUND?

Non-destructive testing with the help of mathematics

Every day we put our trust in the buildings and vehicles around us, feeling confident that they aren't going to collapse while we use them. One of the main reasons for this confidence is that a small army of engineers is constantly testing our planes, trains and buildings, looking for cracks or defects so that they can be dealt with before they cause a problem.

A major issue which the engineers face is that they can't dismantle a plane or nuclear power station looking for potential cracks – it would destroy the very things which they were trying to save. This is why engineers use what is known as 'non-destructive testing' – using instruments to remotely detect any problems, while not damaging the structures themselves. The UK Research Centre in Non-Destructive Evaluation (RCNDE) has been at the forefront of research in this area, developing many new ultrasonic, electromagnetic or radiographic methods for detecting faults, with each one relying heavily on the use of mathematics.

One technique used to test structures involves transmitting high frequency sound waves (a.k.a. ultrasound) into a material such as metal. If there is a fault inside the metal then it will reflect and scatter the sound wave, just like when water waves hit an obstacle. This reflected wave carries information about the type of flaw and, if it's a crack can be used to measure its size. Exactly the same principles are used by bats to find their prey in the dark and by submarines to navigate deep in the ocean.

Nowadays in a complex structure such as a jet engine, engineers regularly search for very small cracks of a critical size. Where cracks are greater than this critical size, this indicates that the structure is unsafe. To find these critical cracks they need to choose a sound wave with a particular wavelength to find what they are looking for. In order to be sure of detecting cracks of length 1mm, a sound wave with a wavelength of 1mm or less needs to be transmitted. Engineers use the following equation to help them generate a sound wave with the correct wavelength:

Wavelength Equation

$$\lambda = \frac{C}{f}$$

λ = Wavelength

C = Speed of sound in the material (for example in steel it is 6100m/s)

f = Frequency of wave

If an engineer wants to test for cracks of 1mm (0.001m) in a piece of steel, then they need to know which frequency of sound wave to test with. Using the fact that the speed of sound in steel is fixed at 6100 m/s – they can rearrange the Wavelength Equation to calculate: 6100m/s÷0.001m = 6 100 000 Hertz (or 6.1 MegaHertz). This is just one of the many examples of where mathematics is used to keep us safe in the important area of non-destructive testing.

The UK Research Centre in Non-Destructive Evaluation: **www.rcnde.ac.uk**

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SELECTED FOR THE ROYAL SOCIETY SUMMER SCIENCE EXHIBITION 2017
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