The benefits of stress

A unique neutron technique for mapping residual stresses in engineering components can help extend their life

THILO PIRLING <<

Thilo Pirling aligning the neutron strain imaging instrument with a cog as a sample

Every mechanical component is stressed to some extent, even when it is not experiencing a load. This is due to various stages in its manufacture like rolling or machining, heat treatment or welding. These residual stresses remain inside the material, influencing its characteristics, and thus the performance and lifetime of the component.

For ever-more reliable hi-tech products – especially in applications where safety is a priority, it is important to know the distribution and the size of stresses in each component. Tensile stresses can cause cracks to develop, while compressive stresses can prevent them starting. In fact, hardening surfaces by various surface treatments such as 'peening' (shot is fired at a surface so that it is plastically deformed) introduces beneficial compressive stresses.

Neutron strain imaging

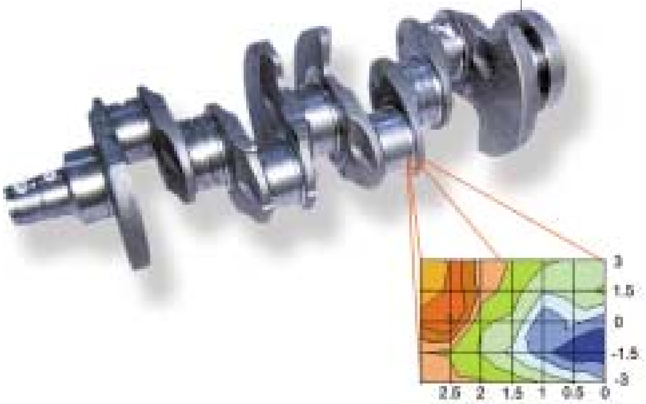
Neutrons provide a unique tool for determining residual stresses deep inside matter. The principle is quite simple: compressive stresses reduce the spacing between atoms in the material while tensile stresses stretch them. Since neutron diffraction can measure atomic distances, it can probe the stresses in an object. This 'neutron strain imaging' technique does not destroy the material and can map stresses with a spatial resolution of a cubic millimetre, or even smaller. The high penetration power of neutrons allows measurements to be carried out to several centimetres deep in steel.

ILL's neutron strain imaging instrument is used in many applications for examining alloys and composites, and various engineering components. The stresses in joints introduced by different welding techniques can also be characterised. We have studied the tungsten-copper brazed components for a fusion reactor, as well as titanium tanks and new composite materials for satellites.

One everyday application, which illustrates how the neutron strain imaging technique helps to develop better products, is in strengthening the crankshafts of car engines. A crankshaft can oscillate when rotating, thus shortening its lifetime. One way of overcoming this problem is to use a process called deep rolling, in which three wheels are turned around the workpiece while applying force in the radial direction. This introduces compressive residual stresses into the material which strengthen the piece and may reduce the amplitude of oscillation by 200 times, provided that the force and number of turns in the process are optimised. Engineers perform calculations to find the optimum parameters, but only experiment can verify their exactness and the efficiency of the deep rolling procedure. The neutron strain imaging technique provides the determination of the stress distribution, which can be directly compared with calculations.

Because the potential of the technique is so high, ILL is constructing a new strain imager with improved characteristics and an extended range of applications. It will enable measurements to be carried out on specimens from 1 centimetre up to 2 metres in length and weighing more than 500 kilograms. ■

The picture below shows the result of a neutron strain-imaging measurement ± 1.5 millimetres around the deep rolled region and down to a depth of 4 millimetres into the material. Compressive stresses are marked in blue and it shows that the deep rolling process modifies the stress field of the workpiece down to a depth of about 2 millimetres



Research team T. Pirling *(ILL)*, Giovanni Bruno *(ILL and University of Manchester, UK)*