MATERIALS ENGINEERING

Neutrons get the job done when other analysis techniques can't

Oak Ridge National Laboratory (ORNL) is the US epicenter of neutron scattering, a powerful technique for studying the nature of engineered materials in helping develop products such as jet engine turbine blades, landing gear, welded airframes and other mission critical components.

Both scientists and non-scientists can access ORNL's research facilities via the US Dept. of Energy's User Program. ORNL's two world-leading, complementary neutron research user facilities — the **High Flux Isotope Reactor (HFIR)** and the **Spallation Neutron Source (SNS)** — are open to researchers to facilitate their studies in science and technology. Together, HFIR and SNS offer users 31 advanced instruments and their supporting laboratories to use for a wide range of materials research experiments.

"Neutron diffraction is excellent for measuring a wide range of bulk materials. Because neutrons can penetrate much farther into metals than x-rays, we are able to make accurate measurements of thick samples non-destructively. That's why we chose to use the HIDRA high intensity diffractometer at ORNL's High Flux Isotope Reactor to study welded materials for US Navy applications."

Lesley D. Frame
University of Connecticut
Photo credit: Carson Stifel

No neutron science experience is necessary

Oak Ridge National Laboratory's neutron science User Program invites you to collaborate with us, onsite or remotely, to achieve greater success. No neutron science experience is necessary, as our experts work closely with users to ensure the success and safety of their experiments. We can help you find the neutron techniques, instruments and sample environments best suited for your research.

Neutron users can access neutron facilities — at little or no cost

Beam time is granted through a proposal system managed by the User Program and is free of charge (with the exception of travel costs, if necessary) as long as researchers intend to publish their results to the scientific community. A fee is charged only for proprietary research that will not be made public.

Contact the Neutron Users Office

Web: neutrons.ornl.gov/users
Email: NeutronUsers@ornl.gov
Phone: 865-574-4600 or 865-341-4451

MATERIALS ENGINEERING

Neutrons can help study and optimize materials

Each year, ORNL neutrons help scientists gain a better understanding of the processes and properties of materials engineering. From penetrating dense materials and probing light elements, to their neutral charge and magnetic moment, neutrons facilitate studies that are difficult or impossible for other research techniques. Neutron diffraction can be used under operating conditions on large samples under applied mechanical loads or thermal, magnetic or electric fields to better understand the structure-property relationships in engineered materials that have a direct impact on our daily lives. Neutron scattering can also evaluate manufacturing processes, thermal treatments and the performance of real-world engineered components.

Neutron diffraction on engineered materials takes advantage of increased penetration depth to go through centimeters of alloyed samples. Users have many sample environments to support their experiments, including resistive heating furnaces, in situ mechanical loading stages, battery cyclers, controlled-atmosphere furnaces, an electrostatic levitator and more.

Additive Manufacturing

- Neutron diffraction (ND) can map hidden residual stress in 3D-printed metals like Inconel, titanium and stainless steel to facilitate adopting additive manufacturing (AM) in critical sectors such as aerospace, energy and medical devices.
- Neutron-based techniques help validate computational stress models and optimize post-processing, heat treatments, and scanning strategies.

Nuclear Energy Materials

- ND is helping develop new reactor materials by providing non-destructive, volumetric stress analysis of fuel claddings and pressure vessels.
- Neutrons can help optimize accident-tolerant fuels by reducing residual stress in FeCrAl alloys, ODS steels, and SiC composites to boost radiation resistance and thermal stability.
- ND also aids in validating stress-relief treatments and assessing hydrogen embrittlement in zirconium alloys to extend fuel lifetimes, improve reactor safety and accelerate developing next-generation nuclear materials.

Aerospace Materials

- ND is helping advance aerospace materials research by enabling deep, non-destructive residual stress mapping in jet engine turbine blades, landing gear, welded airframes and other mission critical components.
- Unlike traditional techniques, neutrons can penetrate deeply into metals to reveal stress profiles that impact fatigue life and failure risk to support improved AM techniques, optimize heat treatments and enhance welding.
- Applications include extending the life of superalloy turbine blades, refining friction stir welding in fuselages and strengthening landing gear.
- These improvements lead to safer, more durable and more fuel-efficient aircraft, while supporting the development of next-generation composites and superalloys for extreme environments.

Automotive and Heavy Industry

- ND helps improve safety and performance in both the automotive and industrial sectors by enabling precision internal stress analysis of welded and formed parts.
- ND helps optimize joining and forming processes for lightweight materials like aluminum and high-strength steel to reduce fatigue risk.
- In heavy industry, ND has improved weld integrity for bridges, railways and equipment in the power and mining sectors, including rail stress mapping that led to improved heat treatments to prevent fractures. These findings strengthen infrastructure, enhance vehicle safety and reduce maintenance costs.

Oil and Gas

- ND improves pipeline reliability by providing non-destructive, deep residual stress measurements, even where traditional methods fall short.
- ND enables internal stress mapping of thick-walled welded joints, leading to better welding techniques, improved post-weld heat treatment and validated stress models. It also aids in mitigating hydrogen embrittlement and cracking mechanisms like stress corrosion cracking and hydrogen-induced cracking.
- ND also supports fitness-for-service assessments, enabling operators to make informed repair and replacement decisions, making it a vital tool for safe, long-term pipeline operation.