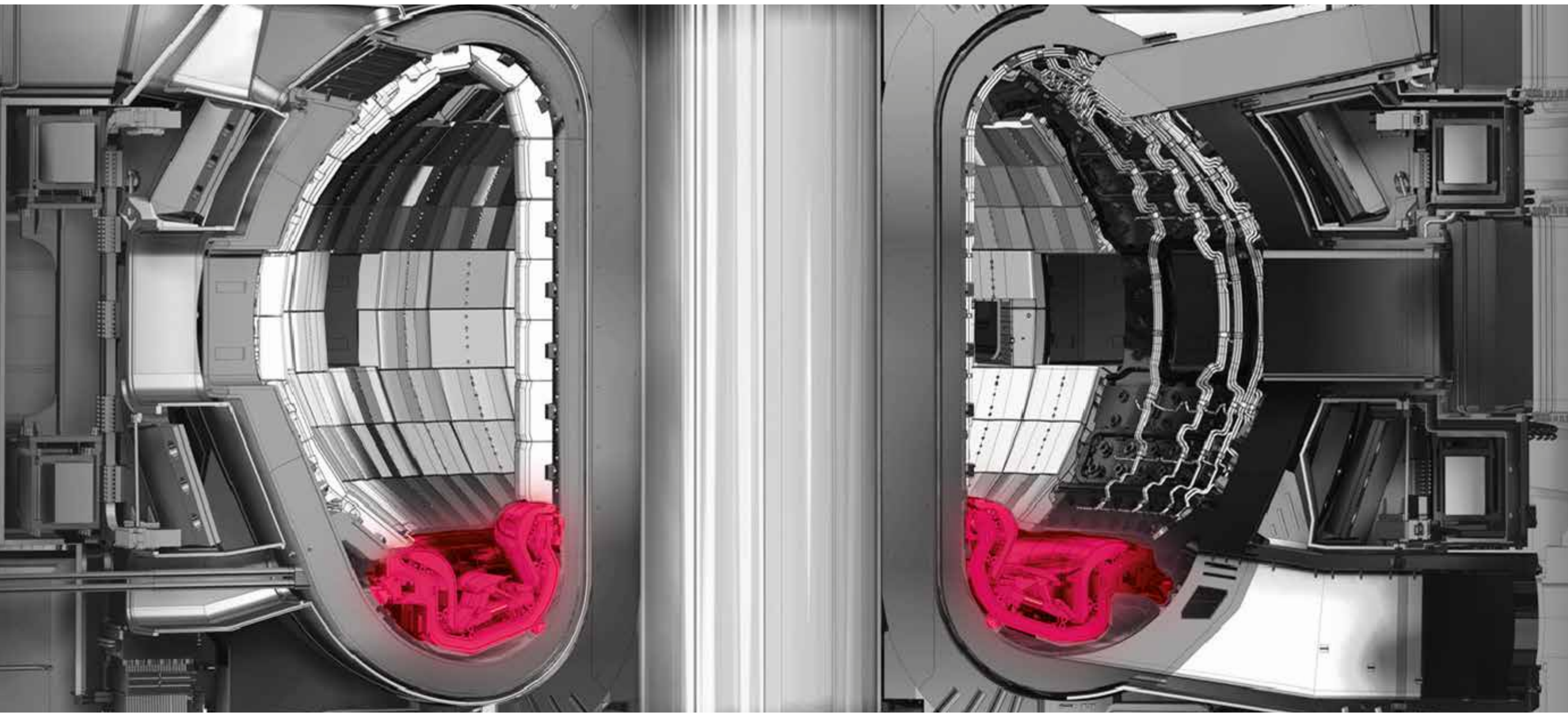
Case study

NUCLEAR AMRC
ADVANCED MANUFACTURING RESEARCH CENTRE



Future decommissioning challenge for robot machining

Nuclear AMRC researchers have shown how a robotic machining tool can be used to reduce the size of irradiated components from a fusion reactor for safe long-term storage.

International fusion project Iter is building the world's largest tokamak reactor to demonstrate the feasibility of hydrogen fusion as a large-scale source of carbon-free energy. Controlling the extreme temperatures and conditions within the experimental reactor chamber presents a host of engineering and material challenges – including the fact that many components will become irradiated and need to be regularly replaced.

These include the 54 divertor cassette assemblies within the vacuum vessel, each measuring several metres across and comprising eight tonnes of various metals including tungsten, stainless steels, and copper and bronze alloys.

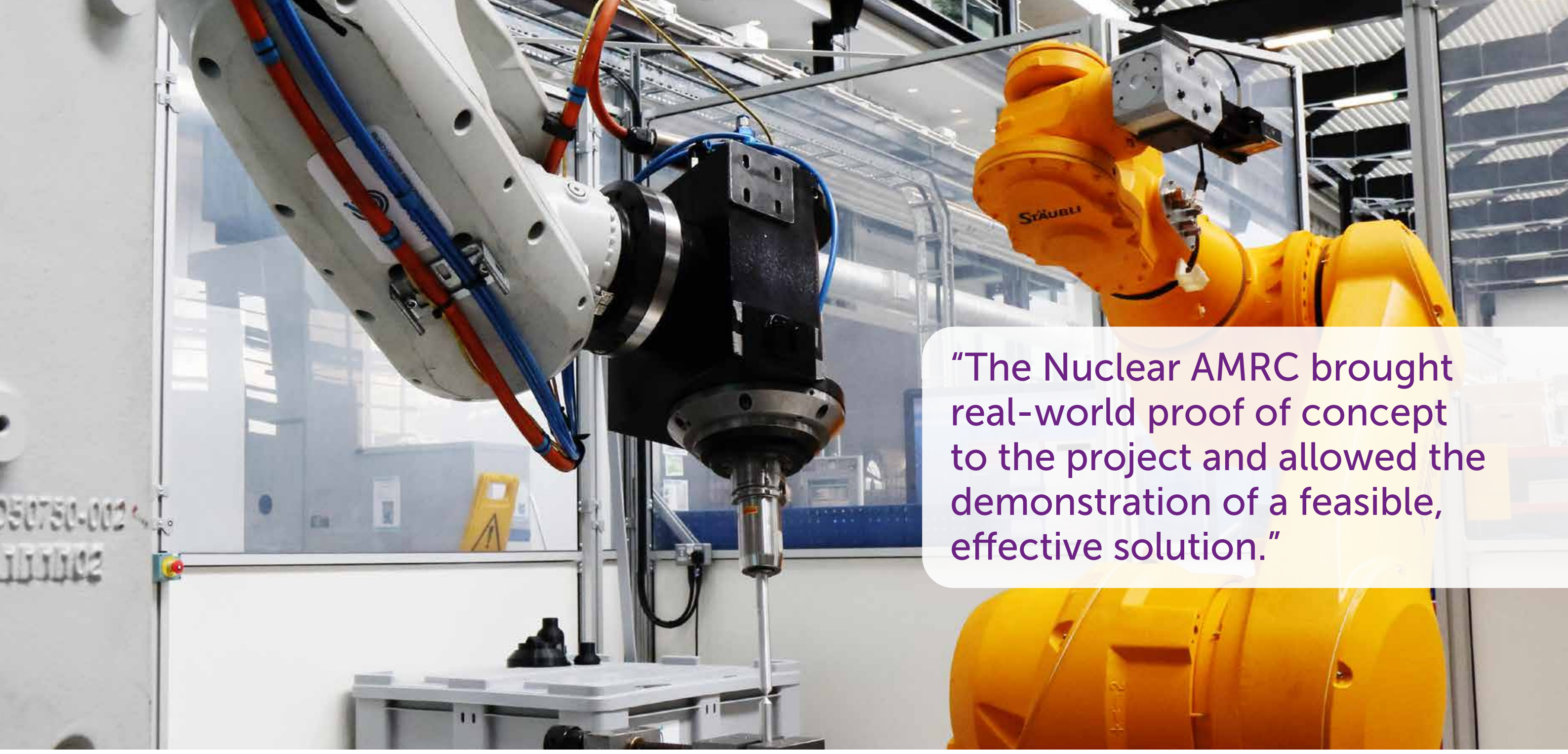
After removal, these will need to be treated as medium-level long-lived waste, which must be safely stored in a suitable nuclear repository. Reducing the size of the waste will significantly reduce the cost of this long-term storage, and also optimise recovery of tritium, the hydrogen isotope used as fuel for Iter.

"The scale of everything at Iter is extra-large, from the main reactor itself to the many sub-component assemblies and modules that make up the sum of its parts," says Vincent Micheneau, hot cell engineer at Iter. "Eventually, these sub-components will succumb to wear and tear, so it is important that they can be handled and disposed of at the end of their viable life in a safe and cost-effective manner."

The Iter team asked the Nuclear AMRC to investigate a robotic machining method for reducing the volume of damaged components and preparing them for storage.

The proposed method uses a cutting tool mounted on a remotely-programmed industrial robot arm to break these complex assemblies into small fragments within a secure waste management complex known as the Hot Cell Facility.

Technical challenges include managing the lack of rigidity in the robot arm, and controlling the risk of harmful vibrations caused by the cyclical cutting forces.



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To meet regulations, the machining process has to be dry, with no liquid or gas coolant used.

"The main challenge is that robots aren't built to do this," says Benjamin Rae, technical lead at the Nuclear AMRC. "There are a lot of advantages to working with robots, but they really struggle to deal with the forces and damaging vibrations caused by machining. We know that they can cut metal, but the challenge is how can we achieve the required level of productivity."

To resolve these challenges, Rae worked with colleagues to complete extensive cutting trials on a variety of metals, testing a range of cutting tools and machining strategies.

The trials used the centre's ABB 6700 robot arm with an electric spindle. The combination provides an accuracy of around 1mm, Rae notes, which is too large for many machining operations but fine for this kind of destructive cutting.

The team collected data from a cutting force dynamometer, with a thermal camera to help predict tool wear. The robot was also equipped with a piezoelectric accelerometer and microphone to monitor vibrations, linked to a custom algorithm to alert the operator and suggest a new spindle speed in case of chatter or high dynamic forces.

The researchers then used the data to identify safe and stable cutting conditions, allowing the spindle speed and feed speed to be optimised for each specific geometry and material.

The trials established a set of optimised material removal rates for different materials – for example, almost 25cm^3 per minute for 316L stainless steel – which met or exceeded the client's target rates. Tool life was measured at between 10 and 30 minutes, depending on the material and cutting parameters.

"The Nuclear AMRC brought real-world proof of concept to the project and allowed the demonstration of a feasible, effective solution to the volume reduction of large, very heavy reactor vessel internal components," says Micheneau. "The team at Nuclear AMRC are highly skilled, highly knowledgeable and highly efficient. They were intuitive to our needs and became real partners in this project, working alongside us and providing true value to the tasks, with suggestions and ideas for improvements all along the scope of the trials."

To better understand the effects of the divertor assembly's complex geometry on machining performance, the team constructed a small replica of part of the component. Cutting trials successfully demonstrated milling of a variety of representative features, although at a lower rate of material removal than with a solid block.

The team are now working with industrial suppliers to develop tool-changing techniques for use in hot cells, and are looking to engage with other fusion technology developers on robotic techniques for size reduction and decommissioning.

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