eMAP

A new diffractometer for diffraction studies of real-world engineering industrial components which, together with complementary facilities on ENGIN-X and IMAT, will provide a suite of world-leading instrumentation at ISIS.

Summary of physical changes

This project aims to design, build and commission a new diffractometer, eMAP, to perform neutron diffraction studies of engineering components, with a performance complementary to the diffraction capabilities offered by ENGIN-X and IMAT. The high diffraction resolution of ENGIN-X is difficult to match (and a separate project to increase its count rate whilst maintaining its high resolution has been prepared). As a consequence, eMAP will be optimised as a medium resolution instrument offering a higher flux than available on ENGIN-X. The increased number of neutrons that can be collected will improve count times and thus reduce the time needed for each experiment. It is important to emphasise that the diffraction resolution of the instrument indicates when peak overlap may occur, while efficient strain analysis relies on the accurate location of the Bragg peaks. Elastic strains in materials are typically of the order of 10^{-3} to 10^{-4}, requiring strain measurement uncertainties (strain resolution) of the order of 10^{-4} to 10^{-5}. Such accuracy in Bragg peak shift determination can be achieved by good Bragg peak definition. Thus, instruments of different diffraction resolutions and neutron fluxes achieve the same strain resolution by counting for different times. For example, to achieve the same strain resolution of 50 microstrain, the original ENGIN instrument at ISIS had to count >10 times longer than the current ENGIN-X.

Science justification

eMAP is a new instrument providing greater depth penetration capability to enable measurements on real size engineering components, and represents a step change in our ability to study real world engineering components. The flux and resolution characteristics will allow: 3D residual stress mapping; high spatial resolution; large, thick, heavy and complex shaped components; near-to-surface measurements; process measurement (e.g. in-situ welding); in-situ loading and special environments; long-term tests (e.g. creep). The flux will be sufficient to allow in-situ and in-operando experiments at industrially-relevant time scales and under complex stress conditions.

The key drivers for the design of eMAP are a flux at sample position that surpasses that of ENGIN-X by a factor 10 over the instrument wavelength range ~0.5 – 6 Å; diffraction resolution at a scattering angle of 2θ=90° of 0.4-0.5%; a neutron beam profile at the sample position as homogeneous as possible within a 4 mm (wide) × 14 mm (high) area defined at the sample position; an accurately defined instrumental gauge volume (GV) defined at the sample position using a set of retractable slits; small horizontal divergence of the incident beam (up 0.24° FWHM) to maintain good diffraction resolution and GV size accuracy (the count rates can be maximised by utilising the fact that the primary measuring position of eMAP is at a scattering angle of 2θ=±90°, where the Bragg peak widths (and hence resolution) are less sensitive to the changes in the vertical divergence of the incident beam); a maximum instrument primary flight path length of 64 m and a secondary flight path length of 2 m to accommodate large engineering specimens and complex sample environments.

The specification for the new instrument has been chosen to lie between that of ENGIN-X and IMAT, with increased flux compared to ENGIN-X and better Δd/d resolution than IMAT. As a consequence, e-MAP will provide enhanced and tuneable capabilities to measure thicker samples, improved 2D/3D mapping, and enhanced time resolution for in-situ experiments (e.g. in-situ welding would become routine). In a longer-term development, eMAP will benefit from very large detector coverage enabling simultaneous texture analysis during, for example, thermomechanical processing. The instrument will also have large laboratory space to store special sample environments and carry out offline long term tests, e.g. creep experiments where intermittent measurements are desirable.

Business case

ENGIN-X is currently the only instrument at ISIS dedicated to neutron diffraction studies of engineering components. As a consequence, there is consistently high demand for beamtime from both academic and industrial researchers (the latter includes proposals submitted via the ISIS Collaborative Research and Development (ICRD) scheme). Strain scanning at more modest resolution will also be available on IMAT once the current project to install 2θ=90° detectors and collimators is completed, though beamtime will be shared with the imaging programme on the instrument. In view of the current high demand in this strategically important area, and its likely increase in the future, there is a very strong case to construct a new high flux engineering diffractometer, eMAP.

Taken together, ENGIN-X, eMAP and IMAT will provide a world-leading suite of instrumentation to address key technological problems. Their highly complementary performance will be beneficial to the existing user base and allow new types of research to be performed. This combined strategy has been presented to the user community (including at an Engineering User Meeting held at Milton Hill House in August 2019) and strongly endorsed.

Finally, a major opportunity could be provided by the creation of a National Stress Engineering Centre, NSEC based at ISIS. NSEC would provide a unique centre offering a combined non-destructive and destructive residual stress measurement service, with access to ENGIN-X, IMAT and eMAP. As a key part of NSEC, the construction of a new eMAP diffractometer will further bring together ISIS neutron instrumentation and diverse residual stress measurement capabilities, providing access to a complementary suite of characterisation techniques for academic and industrial research. It will help drive the UK economy by partnering with industry to develop high performance structural materials and promote competitive high value manufacturing in a global market.

Summary of current status

A first draft of all of the major project documents is complete and the project team has been assembled. There is a complete basic layout of the beamline and this is being used to develop the technical specification.

Summary from engineering side on status of design, costing and schedule

eMAP is a new instrument to be constructed on the vacant TS2 Port-W4. The design of the main instrument is very similar to IMAT, and some complications exist due to the close proximity of IMAT and eMAP choppers. The project is a 3.5 year project, comprised of 3 main over-lapping project phases, each of approximately 1.5 years duration: design; manufacture; installation. IDD Instrument Section has confidence in designing and constructing eMAP, due to the similarities with IMAT.