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Lattice strain mapping and tomography of thin-walled cooling pipe connections studied using synchrotron radiation

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In order to meet the increased thermal load associated with the enhanced detector chip designs, the CMS tracker upgrade will be cooled using two-phase CO_2. To minimise radiation shadowing, 2 mm diameter thin walled (100 µm) cooling pipes will be used within the detector. This system operates at low temperatures (-35℃) and high pressures (typical operating pressures of 8 bar to 70 bar, max test pressure 163 bar). Previous designs for these pipes have been based on CuNi alloys which do not possess the mechanical strength or reliability required for this new system. For this reason, investigations are currently ongoing into the suitability of new piping materials, and pipe joining mechanisms.

A number of characterisation techniques have been employed in the analysis of the pipes and their associated joining methods, however, this study has utilised synchrotron radiation to provide unique insight into the loading behaviour and failure modes of such connections. In this work, laser and orbitally welded connections of thin-walled stainless-steel pipes were subjected to in-situ tensile loading at the UK's synchrotron facility, Diamond Light Source in Oxfordshire.

X-ray diffraction (XRD) patterns were taken at various loading increments, alongside high-quality tomographic images around the central joint area, and above and below the joint, to determine the effect of heat affected zones (HAZ) on stress evolution. From preliminary testing at the University of Bath, it was determined that even without complete failure of the joint itself, there were significant changes to the pipes and joint, which would ultimately affect performance of the cooling system

Trends in axial and radial strain distribution within thin-walled cooling pipe connections under increasing load increments will be presented. Comparing between load states will then give information on how such samples carry load, the high strain regions, and the effects of any defect present from the manufacturing process. The insights gained will ultimately be used to refine finite element simulations of the joints and optimisation of joining parameters and methods.

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