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Mechanical characterisation of thin-walled cooling pipes and connections for the CMS tracker upgrade

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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 CO2. In order 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 30 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 range of characterisation techniques have already been employed to investigate previous piping materials, as well as a range of commercially available options. An overview of this work will be presented, including the results from microscopy, energy-dispersive X-ray spectroscopy, profilometry, Computed Tomography (CT) and grain size analysis. This analysis has provided insights into the pinholes observed in CuNi pipes and has revealed that although Ti64 has suitable mechanical properties, the difficulties associated with welding and soldering this material limits its applicability. Stainless steel 316L has emerged as the most likely candidate for use, as it has a good balance between mechanical properties and joinability.

Space limitations within the tracker mean that pipe soldering will be required to connect thin-walled cooling pipes in at least one location. As a result, preliminary testing is being performed to optimise this production technique which will also serve as potential option for use elsewhere within the system. One of the main challenges with this approach is that 'low aggressive'flux must be used order to prevent long-term corrosion. This presents difficulties in soldering conventional materials such as SS316L, and therefore investigations are ongoing into the suitability of thin-film coatings of Ni, Ni+Au and Ni+Cu. The results of mechanical tests, CT, microscopy and focused ion beam residual stress analysis on these samples will be presented.

One of the additional challenges with the design of these thin-walled connections, is that the system will be regularly pressured and depressurised during use. This will lead to cyclic loading of the connections and therefore the fatigue response of these connections needs to be understood. In order to facilitate these tests, a high pressure (200 bar) pressure testing rig has been designed and installed at the University of Bath. An overview of the equipment design and capabilities will be presented, along with initial results.

One of the longer-term goals of this project is to improve understanding of the failure modes of soldered, orbitally welded and laser welded thin-walled pipe connections. A recent synchrotron proposal has been accepted at beamline B16 at Diamond Light Source, UK in order to perform high resolution tomography and microscale strain mapping of these connections during in-situ loading. This experiment has been delayed due to the pandemic, however significant work has been accomplished to design specimens, create an appropriate testing programme and complete preliminary testing and analysis. An overview of this work will be presented in this talk.

The overall aim of this discussion will be to provide a comprehensive summary of the results of our results and improved understanding of thin-walled pipes and connections. It will also serve as an important opportunity to gather feedback from the CMS community in order to guide future research.

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