**ABSTRACT**

Several plastic deformation techniques find their applications in the production of diverse industrial tools and equipment. Among these, 3-Axis Forging (3AF) stands out as a Severe Plastic Deformation (SPD) method utilized in fabricating the starting material for Superconducting Radio Frequency Cavities (SRFCs). These cavities require a starting microstructure characterized by ultrafine grains (≤ 50µm) with a substantial proportion of High Angle Grain Boundaries (≥60%). Additionally, a high ratio of (111)/(100) texture components aligned parallel to the sheet normal enhances draw-ability and resistance to thinning during spinning and deep drawing.

In this study, an alternative approach involving severe plastic deformation of high purity Niobium (Nb) and oxygen-free high-conductivity (OFHC) copper (Cu) via 3-Axis forging at various temperatures was explored. Previous experimental investigations employing Orientation Imaging Microscopy (OIM) revealed significant reductions in grain size, from 134±12µm to 1.1±0.5µm for high-purity Niobium and from 24±19µm to 2±0.6µm for OFHC Cu. This confirms the occurrence of grain refinement. The resultant microstructures exhibited a high percentage (approximately 61%) of High Angle Grain Boundaries (HAGB%). Accompanying the grain refinement were pronounced degrees of microstructural homogeneity, attributed to shear bands, with non-uniform hardness profiles confirming the presence of inhomogeneities. Additionally, the presence of variations in the grain size and HAGB% also indicates the presence of microstructural inhomogeneities.

To qualitatively assess the degree of microstructural inhomogeneity, a commercial Finite Element Analysis (FEA) software DEFORM 3D was employed. Further analysis using DEFORM 3D revealed the emergence of non-uniform effective strain distributions, corroborating the existence of microstructural inhomogeneities. Analysis of the strain distribution spanned 4 cycles (equivalent to 12 passes), covering processing strains of 0.2, 0.4, 0.65, 0.80, 1.00, 1.33, 1.53, 1.73, 1.98, 2.13, 2.33, 2.66 and temperatures of -196°C, 22oC, 126oC and 227oC for high purity Nb, and 22°C and 200°C for OFHC Cu, under various friction factors of 0.05, 0.25, 0.30, 0.40, 0.50, 0.60, 0.70, and 0.80 respectively.

To quantitatively assess these microstructural inhomogeneities, a mathematical expression termed the Deformation Refinement Index (DRI), which is dependent on the maximum and minimum effective strain, was introduced. Results indicated that high purity Nb exhibited greater microstructural inhomogeneities compared to OFHC Cu, with DRI evaluations under different friction factors further confirming this observation. Notably, the DRI versus processing strain plot revealed two distinct regimes separated by a critical strain value known as the maximum strain , beyond which factors contributing to grain refinement become relaxed or eliminated.

Furthermore, this study highlighted the significant influence of temperature on the DRI of both high purity Nb and OFHC Cu. Additionally, investigations into the effects of grain rotation and saturation on grain refinement were conducted, providing valuable insights into the overall grain refinement process.

This study highlights the feasibility of quantitatively assessing microstructural inhomogeneity using a mathematical expression, thereby contributing to a deeper understanding of grain refinement processes.