ABSTRACT

Friction stir welding (FSW) is facing the challenge of tool wear while expanding its horizon in welding relatively high melting point materials such as Cu, steel, Ti, and their alloys. This has necessitated developing tool materials with high-temperature strength, toughness, and wear resistance. The present thesis investigates the application of direct metal laser deposition (DMLD), a powder-blown method of laser additive manufacturing (LAM), in developing tools for butt-FSW of CuCrZr and friction stir lap welding (FSLW) of CuCrZr-SS304. FSW tool made by depositing crack-free Stellite 6 on H13 steel performed the best in butt welding of CuCrZr in terms of wear resistance compared to the tools made of as-received, heat-treated, and laser remelted H13 steel. Tools made by DMLD, with shoulders of Stellite 6 and pins of Stellite 6, Stellite 6-30%WC and Stellite 6-60%WC were evaluated in FSLW of CuCrZr-SS304. Stellite 6-WC metal matrix composites (MMC) were deposited on Stellite 6 cladding with substrate preheating to mitigate cracks. Cooling rate and melt pool lifetime calculated from the thermal history monitored during the process were correlated with the crack occurrence, microstructure and hardness of the MMC. The pins of the above tools underwent wear and plastic deformation with 17%, 16% and 6.5% length reduction, respectively. In comparison, a sintered WC pin suffered negligible wear. With an increasing percentage of WC, the better performance of the DMLD pin is attributed to the enhanced resistance to abrasive wear and plastic deformation. Optimization of FSW of CuCrZr and FSLW of CuCrZr-SS304 were performed by varying tool rotational and traverse speed, and the microstructural and mechanical properties of the weld were correlated with the parametric combinations used. Laser shock peening (LSP) as a post-weld treatment applied on the friction stir welded CuCrZr induced significant compressive residual stress at the surface and sub-surface region, resulting in an appreciable enhancement in tensile strength (~35%) and fatigue life (~70%).

Keywords: Friction stir welding, Laser additive manufacturing, Laser shock peening, FSW tool, CuCrZr, SS304, Stellite 6-WC MMC, H13 steel.