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耐强酸冲蚀的高熵合金涂层成分设计、激光制备及应用

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摘要：为了延长搅拌桨叶片在极端条件下的服役寿命，运用团簇加连接原子模型，设计了耐强酸冲蚀的$[Cr\text{-}Fe_4Co_4Ni_4]Cr_{2.6-x}Al_xMo_{0.4}$ (x=0, 0.2, 0.4, 0.6, 0.8, 1.0 at.%)高熵合金成分，并利用激光熔覆技术在 904L 不锈钢表面制备高熵合金涂层。利用 XRD、SEM/EDS、TEM、显微硬度计、摩擦磨损试验机、电化学工作站、冲刷腐蚀试验机等表征高熵合金涂层的组织结构与性能。结果表明，当激光功率 P=5 kW，扫描速度 v=5 mm/s 时，涂层表面质量良好，无裂纹孔洞。涂层主要由单一 FCC 固溶体组成。涂层显微组织主要为典型的胞状枝晶。随着 Al 含量增加，涂层晶粒逐渐细化，涂层的硬度和耐磨性逐渐升高，涂层主要发生粘着磨损和氧化磨损。涂层的电化学性能先增加后降低，当 x=0.8 时涂层具有最好的耐蚀性。在固体颗粒冲蚀(30wt.%SiO_2+50wt.% H_2SO_4)条件下，随着 Al 含量增加，涂层失重量先减少后增加，当 x=0.8 时涂层失重量最小，耐冲蚀性能最好，涂层的冲蚀机理以微切削+犁削为主。

关键词：高熵合金涂层；团簇加连接原子模型；激光熔覆；耐磨性；冲刷腐蚀

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Composition Design, Laser Preparation and Application of High Entropy Alloy Coating with Strong Acid Erosion Resistance

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Abstrate: To prolong the service life of the blade, a series of $[Cr\text{-}Fe_4Co_4Ni_4]Cr_{2.6-x}Al_xMo_{0.4}$ (x=0, 0.2, 0.4, 0.6, 0.8, 1.0 at.%) high entropy alloy (HEA) coatings were designed by a cluster-plus-glue-atom model and fabricated by laser cladding technology on the 904L stainless steel. The microstructure and properties of the HEA coatings were characterized using XRD, SEM/EDS, TEM, hardness tester, friction-wear testing machine, electrochemical workstation and erosion tester. The experimental results show that, the HEA coatings possess good surface quality and free of pores in the laser parameters of P = 2.5 kW, v=5 mm/s. A single face-centered-cubic (FCC) solid solution is mainly detected in the HEA coatings. The addition of Al element can effectively refine the cellular dendrites, improve microhardness and wear resistance. The wear mechanism of the HEA coatings is a mixture of adhesive and oxidation wear. The electrochemical performance of the coating first increases and then decreases, and the coating has the best corrosion resistance when x = 0.8. Under the condition of solid particle erosion (30wt.%SiO_2+50wt.% H_2SO_4), the weight loss of the coating decreases first and then increases with the increase of Al content. When x=0.8, the weight loss of the coating is the minimum and the erosion resistance is the best. The erosion mechanism of the HEA coating is mainly micro-cutting + plough-cutting.

Keywords: High entropy alloy coating; Cluster-plus-glue-atom model; Laser cladding; Wear resistance; Erosion resistance