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Grinding Sludge Waste from High-Alloy Tool Steel through a Smelting-Metallurgical Process

This study explores the upcycling of grinding swarf, a by-product of subtractive machining, into semi-finished cast products by recovering silicon carbide (SiC) and aluminum oxide (Al_2O_3) abrasives and using them as alloying additions. Two cold-work tool steels, X153CrMoV12 (1.2379) and 80CrV2 (1.2235), were modified, with emphasis on X153CrMoV12 due to its higher content of critical alloying elements. The recycling route comprised the thermal removal of coolant residues, particle separation by sieving and magnetic purification, and direct alloying of the residual abrasives during casting. Al_2O_3 floated into the slag while SiC fully dissolved, raising the melt's carbon content from 1.53 mass% to 1.78–2.51 mass% and its silicon content from 0.35 mass% to 0.94–1.73 mass%. Using up to 31.0 mass% recyclates met the X153CrMoV12-1 standard; relaxing the silicon target to ~1.0, mass% allowed the incorporation of up to 68.0 mass% recyclates. Thermodynamic simulations predicted a similar solidification sequence and microstructure in recycled and reference alloys. Microstructural investigations of the cast samples by SEM and the methods adapted to it (EBSD) revealed an austenitic as-cast matrix with blocky M_7C_3, MC, and $M_{23}C_6$ carbides. After quenching, comparable hardness levels were achieved between the three steel grades (800 HV1 vs. 806 HV1 vs. 800 HV10). Upon tempering at 500 °C, hardness differences became apparent (618 HV1 vs. 664 HV1 vs. 726 HV10). Microscopically, all materials exhibited a microstructure consisting of a metal matrix of tempered martensite with a high-volume fraction of carbides.

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