真空电弧炉及凝壳炉的控制技术进展 *

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摘 要:综述了真空电弧炉和真空凝壳炉的工作原理和国内外发展现状。介绍了真空电弧重熔(VAR)工艺控制技术发展情况,并指出电弧检测与调控对大型真空凝壳炉安全运行的重要意义。虽然,熔速控制实现了熔池糊状轮廓的稳定。但是,电弧运动改变了熔池的热量分布。基于熔速控制的电弧分布状态优化,是制造高品质铸锭的基础和工艺装备的发展方向。根据电弧运动特性,将电弧分布模型划为四类:集中、扩散、偏心和旋转。其中,扩散电弧分布模型对改善熔池轮廓和提升铸锭品质的作用明显。将 VAR 控制技术分为电弧分布、熔池特性和凝固过程三个组成部分。针对电弧的电磁特性,利用磁场对电弧分布进行检测和调控,将为 VAR 工艺带来新的技术革新。配有霍尔效应磁场传感器阵列和亥姆霍兹线圈的控制系统已应用在工业生产装备中,验证了控制系统对电弧检测与调控的有效性。

关 键 词:真空电弧重熔;真空凝壳炉;熔速控制;熔滴控制;电弧分布;亥姆霍兹线圈
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Progress in the Control Technology of Vacuum Arc Remelting Furnace and Vacuum Arc Skull Casting Furnace

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Abstract: The working principle and development status of vacuum arc remelting furnace and vacuum arc skull casting furnace are described. This paper introduces the development of vacuum arc remelting(VAR) technology control technology, and points out the important significance of arc detection and regulation for the safe operation of large vacuum arc skull furnace. Although the melt rate control realizes the stability of the profile of the melt pool mushy. However, the arc motion changes the heat distribution of the pool. The optimization of arc distribution state based on melt rate control is the development direction of high quality ingots and process equipment. According to the arc motion characteristics, the arc distribution model is divided into four categories: concentrated, diffusive, eccentric and rotating. The distribution model of diffusive arc plays an obvious role in improving the profile of melt pool and the quality of ingots. VAR control technology is divided into three components: arc distribution, melt pool characteristics and solidification process. Aiming at the electromagnetic characteristics of arc, magnetic field is used to detect and regulate the arc distribution, which will bring new technological innovation to VAR process. The control system with Hall effect magnetic field sensor array and Helmholtz coils has been applied in industrial VAR furnace to verify the effectiveness of the control system in arc detection and regulation.

Key words: vacuum arc remelting; vacuum arc skull casting; melt rate control; dripshort control; vacuum arc distribution; Helmholtz coil

1 工作原理及用途

真空电弧重熔炉(简称真空电弧炉)主要用于制造高价值金属和高性能合金。在真空电弧重熔(VAR)工艺过程中,气体放电引燃真空电弧后,自耗电极端部在弧斑作用下熔化;金属熔滴

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