铝合金超声波钎焊过程中液态钎料的填缝及界面润湿行为

Filling and Wetting Behaviors of Liquid Filler Metal in the Process of Ultrasonic Soldering of Aluminum Alloy

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摘要: 研究了超声波振动作用下 6061Al 和 2024Al 合金焊缝中液态钎料的填缝过程, 并分析了加热温度、焊缝预留间隙值对该过程的影响。结果表明, 超声波振动作用下液态钎料的填缝行为与传统毛细填缝行为有很大差别, 该条件下液态钎料在不润湿母材的基础上就迅速发生填缝过程, 钎料初始液-气界面为凸状; 随着填缝进行, 填缝速度有所下降, 填缝前沿钎料/母材界面润湿程度提高, 钎料液-气界面形状转变为凹状。加热温度对超声波作用下液态钎料的填缝过程无明显影响, 焊缝预留间隙值增加, 钎料填缝长度减小, 液-气界面形态发生变化。

关键词: 超声波振动; 润湿; 毛细作用; 氧化膜
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Abstract: Filling of liquid filler metal into the joint clearance of 6061Al and 2024Al alloys under the action of ultrasonic vibration was investigated. The effects of heating temperature and joint clearance value on the filling process were concerned with. The results show that the filling of liquid filler metal under the action of ultrasonic vibration is quite different from that induced by the traditional capillary effect. The non-wetting liquid filler fills rapidly into the joint clearance once the ultrasonic vibration is applied and the morphology of the liquid-gas interface appears convex at the initiate stage. With the development of the filling process, the filling velocity decreases and the wetting between the liquid filler and the base metal at the filling front is improved, giving rise of the transition of the morphology of the liquid-gas interface from convex to concave. Heating temperature shows no obvious influence on the filling process. The filling length decreases and the morphology of liquid-gas interface tend to change with the joint clearance increase.

Key words: ultrasonic vibration; wetting; capillary action; oxide film

超声波在液态钎料中传播时产生的声空化效应能破坏、去除固体表面的氧化膜, 还能冲刷固体表面, 提高表面的清洁度, 从而促进液态钎料与母材基体的润湿结合。因而, 超声波被成功应用于无钎剂、非真空环境下氧化性金属及其合金和难润湿性材料(如铝、铜及其合金、陶瓷等) 的焊接[1,2]。在绿色、环保日益成为当前钎焊主题的形势下, 发展超声波钎焊具有重要的应用前景。

超声波钎焊最早出现于 20 世纪五六十年代。早期的超声波钎焊工艺, 如超声波波峰焊, 为了在液态钎料中产生空化效应, 通常是将在钎料槽的底部将超声波直接导入到钎料池中, 焊接时将待焊部位浸入到钎料池内。这种方式的优点是可实现整体焊接, 生产率高, 因而一直沿用至今。随着研究的不断发展, 超声波钎焊新工艺不断出现, 如超声波电烙铁以及超声频调制激光无钎剂软钎焊等[3,4], 这些方法的特点是将原先的钎料池缩小为钎料液滴, 超声波能量集中施加到其中, 操作方式灵活、节能。最近, 哈尔滨工业大学提出了一种超声波钎焊技术, 获得了中国及美国发明专利[5]。它的特点是将超声波振动施加到母材上, 通过母材将超声能量传导至放置于待焊接头一端的液态钎料中, 钎料即可迅速实现填缝, 实现焊接过程。这种方法与现有的超声波钎焊工艺相比, 操作方式更灵活, 超声波能量从固体母材传导至润湿界面, 损耗更小, 而