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考虑焊接缺陷的厚板高功率激光焊接热-冶金-机械行为研究

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高功率激光焊接技术以其热输入小、变形小、深宽比大等优势，为海洋领域厚壁构件高质高效焊接制造提供了新的技术手段。然而，高功率激光焊接过程极快加热/冷却行为必然加剧多相组织交互作用，形成高梯度焊接残余应力，同时厚壁构件单道焊接接头极易形成塌陷、驼峰等缺陷，应力集中问题突出，加剧了残余应力的不均匀分布，严重影响构件服役性能。为此，本文开展了考虑焊接缺陷（塌陷、驼峰和错边等）的厚板高功率激光焊接热-冶金-机械行为研究（如图1所示）。首先，采用双柱体热源模型进行了焊接过程温度场模拟，考虑和未考虑缺陷时的焊缝截面形貌预测误差分别为9.2%和3.5%。其次，基于固态相变热力学理论，开展了焊接过程微观组织分布模拟，并根据焊缝硬度测试结果进行了验证。最后，对比分析了焊接接头不同厚度位置的残余应力分布规律。结果表明，在所有的厚度位置，纵向/横向残余应力有相同的分布规律：随着与焊缝中心距离的增加，残余应力由压应力变为拉应力。考虑和未考虑缺陷时的纵向/横向残余应力的最大变化均超过150MPa，其原因是缺陷处焊缝金属缺失/增加引起的热循环过程改变和焊缝几何形状急剧变化，前者会影响多相组织间的相互作用力，后者会引起应力集中，两者均加剧了残余应力分布的不均匀。

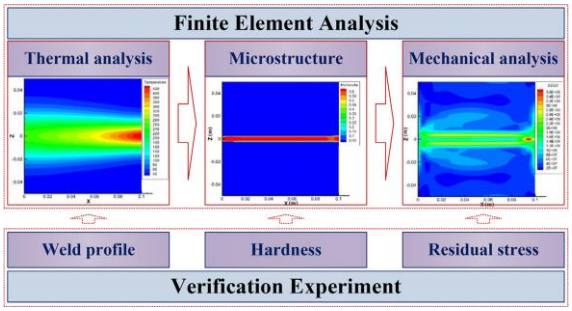

Fig. 1 Simulation and experiment implementation framework of thick plate EH40 welded joint.

关键词： 高功率激光焊接；船用钢；焊接缺陷；残余应力

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