

# 摘要撰写说明及模板

摘要应包含以下主要内容：

- 研究目的/问题
- 研究方法
- 主要结果/发现
- 成果意义/对未来研究的启示

摘要格式说明如下表所示。摘要模板详见后面两页。

表一摘要格式说明

文档类型	Word 97/2003/2007/2010				
纸张大小	A4				
页边距	上 21 mm, 下 21 mm, 左21 mm, 右21 mm				
行距	英文行距13 pt, 中文行距17 pt; 题目除外				
	字体		字号 (pt)	对齐方式	备注
	英文	中文			
题目	Times New Roman	宋体	14	居中	<b>粗体</b> , 行距 18 pt
作者	Times New Roman	宋体	11	居中	段前8 pt, 段后8 pt
所属单位	Cambria	楷体GB_2312	8	居中	<i>字体倾斜</i>
E-mail	Cambria	/	8	居中	<i>字体倾斜</i>
摘要	Times New Roman	楷体GB_2312	10	两端对齐	“摘要”二字 <b>粗体</b> ; 段前 8 pt, 段后8 pt
关键词	Times New Roman	宋体	10	两端对齐	“关键词”三字 <b>粗体</b>

# Quantitative Analysis of Surface Flow Behavior of Molten Pool in Laser Welding Based on Particle Image Velocimetry

## 基于 PIV 方法的激光焊接熔池表面流动定量分析

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**Abstract:** Flow behavior is one of the essential characteristics of the laser welding which dominate the formation of welding defects including undercut and porosity. Lack of quantitative evaluation method of such behavior restricts the further improvement of the quality of laser welding. A method for this quantitative analysis was tried by using PIVlab tool which based on particle image velocimetry algorithm, on the molten pool images captured by the high-speed camera image while particles were not used in the experiments which is usually used in PIV measurement. The results showed that the molten metal flows around the keyhole and two convection loops situates the rear of the molten pool. Peak velocity were found at the zone behind the keyhole and relative high velocity can be found at the zones along two sides of keyhole, which may be due to higher temperature and better fluidity at these zones caused by the eruption of plasma inside keyhole. The welding speed perpendicular to welding direction is approximately twice as the speed of along the welding direction which partly offsets by the forward movement of rear molten metal within the molten pool caused by fluid dynamic pressure. Vorticity distributions around the molten pool indicate that there are two large vortices, a vortex around the keyhole is induced by keyhole eruption; another one at the rear of molten pool is the result of confront between plasma eruption and the flow of liquid metal of rear molten pool.

**Keywords:** Laser Welding; Flow Behavior of Molten Pool; Particle Image Velocimetry; Quantitative Analysis

**摘要:** 熔池流动决定着气孔、咬边等缺陷的形成, 是激光焊接的本质特征之一。缺乏熔池流动行为的定量评价方法限制了激光焊接质量的进一步提高。基于粒子图像测速算法思想, 采用 PIVlab 工具, 对未添加粒子试验条件下、高速摄像获得的图像进行了定量分析, 获取了熔池流动速度和涡量等定量评价指标。结果表明, 匙孔周围的液态金属向四周流动, 在熔池的后方存在着顺时针和逆时针两个对流环。速度的峰值区域位于匙孔的后方, 匙孔的两侧的速度值也较高, 这可能也是等离子体的喷发带动作用以及匙孔后方的熔池温度高、流动性好的结果。垂直于焊接方向上的速度值约为沿焊接方向上速度值的两倍, 这可能但是沿焊接方向后侧的熔池在流体动压力的作用下有向前运动的趋势有关。熔池周围的涡量分布结果表明, 在熔池区域存在着两个大的涡流区域, 一个是由于匙孔喷发造成的匙孔周围的涡流区域; 另外一个是由于匙孔喷发与尾部熔池流动相互作用的引起的熔池尾部的涡流区域。

**关键词:** 激光焊接; 熔池流动行为; 粒子图像测速; 定量分析

# Laser Wire Filling Welding of Thick Carbon Steel Plates in Butt Joint with Ultra-narrow-gap

## 碳钢厚板超窄间隙对接接头的激光填丝填充焊接

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**Abstract:** Steel structures with thick-sections are very often met in huge and heavy equipment such as large container ships, power plants and heavy machineries. For its thick plates joining the traditional high efficient welding method is narrow gap arc welding. For further improvement of welding productivity and quality, laser welding methods are being considered worldwide to be applied for such structures with thick sections. Among them the laser wire welding is more suitable for high plate thickness. For laser wire multi-layer welding in form of one pass per layer of thick joints with ultra-narrow gap a stable welding process and a symmetric weld form are very important. In this paper, carbon steel thick butt joints with ultra-narrow-gap were welded in multi-layer by laser filler wire method. The welding process stability in relationship with main welding parameters was investigated through high speed photographing. The influence of the misalignment of laser spot and wire end on weld form was also studied. The experiment results show that the laser-wire distance and laser power have strong influence on process stability, especially the metal transfer; welding speed and wire feeding rate have less influence in comparatively. Based on that, butt weld joints of 35 mm ~ 70 mm thick steel plates without lack of fusion were obtained under optimized laser wire welding parameters.

**Keywords:** laser wire welding; ultra-narrow gap; thick plate; metal transfer; weld form

**摘要:** 在大型集装箱船、发电装备、重型机械等重大装备中厚壁钢结构是十分常见的。其厚板焊接生产目前采用的高效焊接方法是窄间隙电弧焊。为了进一步提高焊接生产效率和质量, 将激光焊接方法用于厚壁结构的焊接正得到世界范围的关注。其中激光填丝焊接相比而言更适合大板厚。对于采用每层单道的超窄间隙厚板接头激光填丝多层焊, 一个稳定的焊接过程和一个对称的焊缝成形是十分重要的。在本论文中, 采用激光填丝多层焊方法对碳钢超窄间隙厚板对接接头进行了焊接。通过高速摄影实验观察, 分析了主要焊接参数对焊接过程稳定性的影响。激光光斑和焊丝端部在坡口中的对中性对焊缝成形的影响也进行了分析。实验结果表明, 光丝间距和激光功率对过程稳定性即熔化金属过渡有明显影响, 而焊接速度和送丝速度的影响相对较小。激光光斑和焊丝端部的对中性对焊缝成形有不同影响。基于上述结果, 采用优化的激光填丝焊接工艺参数, 实现了无未熔合等缺陷的 35 mm ~ 70 mm 厚碳钢对接接头焊接。

**关键词:** 激光填丝焊; 超窄间隙; 大厚板; 金属过渡; 焊缝成形