



# Cladding-Technology-Shanxi-Co.,-Ltd- CLADDING-MPS-019-Dual-Wire- Cladding-Layer-Process-Specification

科雷丁技术（山西）有限公司

Cladding-Technology-Shanxi-Co.,-Ltd

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|----------------|--------------------------------------------------------------------------------------------|
| 文件名称           | 双丝堆焊电流配比、电弧间距与熔深控制管理程序                                                                     |
| Document Title | Dual-Wire Cladding Current Ratio, Arc Spacing and Penetration Control Management Procedure |
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# 双丝堆焊电流配比、电弧间距与熔深控制管理程序

## Dual-Wire Cladding Current Ratio, Arc Spacing and Penetration Control Management Procedure

### 1. 目的 Purpose

本程序旨在规范科雷丁技术（山西）有限公司在双丝堆焊工艺中的电流配比、电弧间距与熔深控制要求，确保法兰堆焊、管件堆焊、钢管堆焊、轴套管堆焊及模具堆焊修复等项目的焊接质量稳定可控，实现低稀释率、精密成型的工艺目标。

This procedure aims to standardize the current ratio, arc spacing and penetration control requirements in dual-wire cladding processes at CLADDING-Technology-Shanxi-Co.,-Ltd, ensuring stable and controllable welding quality for flange cladding, pipe fitting cladding, steel pipe cladding, shaft sleeve cladding and mold cladding repair projects, achieving the process objectives of low dilution rate and precision forming.

### 2. 适用范围 Scope

本程序适用于公司所有采用双丝堆焊工艺的生产项目，包括但不限于：

This procedure applies to all production projects using dual-wire cladding processes in the company, including but not limited to:

- 法兰堆焊（TIG/MIG 双丝） Flange cladding (TIG/MIG dual-wire)
- 管件堆焊 Pipe fitting cladding
- 钢管堆焊 Steel pipe cladding
- 轴套管堆焊 Shaft sleeve cladding
- 模具堆焊修复 Mold cladding repair
- 梯度材料制备 Gradient material preparation
- 金属零部件增材制造 Metal component additive manufacturing

### 3. 职责 Responsibilities

| 部门/岗位 | Department/Position           | 职责                   | Responsibilities                                          |
|-------|-------------------------------|----------------------|-----------------------------------------------------------|
| 工艺技术部 | Process Technology Department | 制定双丝堆焊工艺参数标准；审批特殊工艺参 | Establish dual-wire cladding process parameter standards; |



|       |                       |                    |                                                                             |
|-------|-----------------------|--------------------|-----------------------------------------------------------------------------|
|       |                       | 数变更                | Approve special process parameter changes                                   |
| 生产部   | Production Department | 执行工艺参数设置；记录生产数据    | Execute process parameter settings; Record production data                  |
| 质量部   | Quality Department    | 监督工艺参数执行；检验熔深及焊缝质量 | Supervise process parameter execution; Inspect penetration and weld quality |
| 设备部   | Equipment Department  | 维护双丝堆焊设备；校准电流测量系统  | Maintain dual-wire cladding equipment; Calibrate current measurement        |
| 项目负责人 | Project Leader        | 确认项目工艺参数；协调资源保障    | Confirm project process parameters; Coordinate resource assurance           |

## 4. 管理内容与程序 Management Content and Procedure

### 4.1 双丝堆焊系统概述 Dual-Wire Cladding Overview

双丝堆焊系统由两根焊丝分别通过独立的送丝机构和焊接电源供电，通过精确控制两路电流的配比关系、两电弧之间的空间距离以及焊接热输入，实现对熔深、稀释率和成型质量的精准调控。

The dual-wire cladding consists of two welding wires separately supplied by independent wire feeding mechanisms and welding power sources. Through precise control of the current ratio between the two circuits, the spatial distance between the two arcs, and the welding heat input, precise regulation of penetration, dilution rate and forming quality is achieved.

### 4.2 电流配比控制 Current Ratio Control

#### 4.2.1 基本原则 Basic Principles

双丝堆焊中，前丝（主丝）负责形成主要熔池和熔深，后丝（辅丝）负责填充和成型。两路电流的配比直接影响熔深、稀释率和焊缝成型质量。

In dual-wire cladding, the front wire (main wire) is responsible for forming the main molten pool and penetration, while the rear wire (auxiliary wire) is responsible for filling and forming. The



current ratio between the two circuits directly affects penetration, dilution rate and weld forming quality.

#### 4.2.2 电流配比标准 Current Ratio Standards

| 应用类型  | Application Type      | 前丝电流     | Front Wire Current | 后丝电流         | Rear Wire Current | 电流配比              | Current Ratio | 备注 | Remarks |
|-------|-----------------------|----------|--------------------|--------------|-------------------|-------------------|---------------|----|---------|
| 法兰堆焊  | Flange Cladding       | 220-260A | 180-220A           | 1.2:1-1.4:1  | For TIG/MIG       |                   |               |    |         |
| 管件堆焊  | Pipe Fitting Cladding | 200-240A | 160-200A           | 1.25:1-1.5:1 | For TIG/MIG       |                   |               |    |         |
| 钢管堆焊  | Steel Pipe Cladding   | 240-280A | 200-240A           | 1.2:1-1.4:1  | For MIG/MIG       |                   |               |    |         |
| 轴套管堆焊 | Shaft Sleeve Cladding | 180-220A | 140-180A           | 1.3:1-1.5:1  | For TIG/TIG       |                   |               |    |         |
| 模具修复  | Mold Repair           | 160-200A | 120-160A           | 1.33:1-1.5:1 | For TIG/TIG       |                   |               |    |         |
| 梯度材料  | Gradient Material     | 可调       | Adjustable         | 1.0:1-2.0:1  | 按设计调整             | Adjust per design |               |    |         |

#### 4.2.3 电流配比调整原则 Current Ratio Adjustment Principles

- **增大熔深需求:** 提高前丝电流占比，配比可调整至 1.5:1 以上  
Increase penetration requirement: Increase front wire current proportion, ratio can be adjusted to above 1.5:1
- **降低稀释率需求:** 适当降低前丝电流，提高后丝电流占比，配比可调整至 1.1:1-1.2:1  
Reduce dilution rate requirement: Appropriately reduce front wire current, increase rear wire current proportion, ratio can be adjusted to 1.1:1-1.2:1
- **提高熔敷效率:** 在熔深满足要求前提下，适当提高后丝电流，提升熔敷量  
Improve deposition efficiency: Under the premise that penetration meets requirements, appropriately increase rear wire current to improve deposition volume
- **精密成型需求:** 采用较小电流配比（1.1:1-1.3:1），配合精确的送丝速度控制



Precision forming requirement: Use smaller current ratio (1.1:1-1.3:1), combined with precise wire feeding speed control

### 4.3 电弧间距控制 Arc Spacing Control

#### 4.3.1 电弧间距定义 Arc Spacing Definition

电弧间距指前丝电弧与后丝电弧之间的水平距离，是影响双丝堆焊熔池稳定性和焊缝成型质量的关键参数。

Arc spacing refers to the horizontal distance between the front wire arc and the rear wire arc, which is a key parameter affecting the stability of dual-wire cladding molten pool and weld forming quality.

#### 4.3.2 电弧间距标准 Arc Spacing Standards

| 焊接方法    | Welding Method | 电弧间距范围 | Arc Spacing Range | 推荐值        | Recommended Value                               | 适用场景 | Application |
|---------|----------------|--------|-------------------|------------|-------------------------------------------------|------|-------------|
| TIG/TIG | TIG/TIG        | 2-4mm  | 3mm               | 精密堆焊、模具修复  | Precision cladding, mold repair                 |      |             |
| TIG/MIG | TIG/MIG        | 3-6mm  | 4-5mm             | 法兰堆焊、轴套管堆焊 | Flange cladding, shaft sleeve cladding          |      |             |
| MIG/MIG | MIG/MIG        | 4-8mm  | 5-6mm             | 钢管堆焊、高效熔敷  | Steel pipe cladding, high-efficiency deposition |      |             |

#### 4.3.3 电弧间距调整原则 Arc Spacing Adjustment Principles

- **间距过小（8mm）**：后丝无法有效利用前丝形成的熔池，熔深不足，稀释率升高

Spacing too large (>8mm): The rear wire cannot effectively utilize the molten pool formed by the front wire, insufficient penetration, increased dilution rate

- **最佳间距**：后丝电弧应落在前丝熔池的尾部区域，实现熔池的充分利用和稳定过渡

Optimal spacing: The rear wire arc should fall in the tail area of the front wire molten pool, achieving full utilization and stable transition of the molten pool



#### 4.3.4 电弧间距影响因素及调整 Factors Affecting Arc Spacing and Adjustment

| 影响因素 | Influencing Factor | 调整方向      | Adjustment Direction              | 说明         | Description                                                 |
|------|--------------------|-----------|-----------------------------------|------------|-------------------------------------------------------------|
| 焊接速度 | Welding Speed      | 速度↑, 间距↑  | Speed ↑, Spacing ↑                | 高速焊接需增大间距  | High-speed welding requires larger spacing                  |
| 焊丝直径 | Wire Diameter      | 直径↑, 间距↑  | Diameter ↑, Spacing ↑             | 粗丝需更大间距    | Coarse wire requires larger spacing                         |
| 电流大小 | Current Magnitude  | 电流↑, 间距↑  | Current ↑, Spacing ↑              | 大电流电弧更长    | High current has longer arc                                 |
| 工件材质 | Workpiece Material | 导热性↑, 间距↓ | Thermal conductivity ↑, Spacing ↓ | 高导热材料需缩短间距 | High thermal conductivity materials require shorter spacing |

### 4.4 熔深控制 Penetration Control

#### 4.4.1 熔深控制目标 Penetration Control Objectives

双丝堆焊的熔深控制需满足以下要求：

Dual-wire cladding penetration control must meet the following requirements:

- **熔深均匀性：**单道焊缝熔深波动不超过 $\pm 0.2\text{mm}$

Penetration uniformity: Single pass weld penetration fluctuation shall not exceed  $\pm 0.2\text{mm}$

- **熔深与稀释率匹配：**根据堆焊层设计要求，控制熔深在 0.5-2.0mm 范围内

Penetration and dilution rate matching: Control penetration within 0.5-2.0mm range according to cladding layer design requirements

- **层间熔合良好：**多层堆焊时，层间熔深应达到前层厚度的 30%-50%

Good interlayer fusion: For multi-layer cladding, interlayer penetration shall reach 30%-50% of previous layer thickness

#### 4.4.2 熔深控制参数表 Penetration Control Parameter Table

| 项目 | Project Type | 目标熔深 | Target Penetration | 前丝电流 | Front Wire | 后丝电流 | Rear Wire | 电弧 | Arc | 焊接 | Welding Speed |
|----|--------------|------|--------------------|------|------------|------|-----------|----|-----|----|---------------|
|----|--------------|------|--------------------|------|------------|------|-----------|----|-----|----|---------------|



| 类型    |                       |          | n        |          | Current<br>t |               | Current<br>t | 间距 | g | 速度 |  |
|-------|-----------------------|----------|----------|----------|--------------|---------------|--------------|----|---|----|--|
| 法兰堆焊  | Flange Cladding       | 1.0-1.5m | 220-260A | 180-220A | 4-5mm        | 300-400mm/min |              |    |   |    |  |
| 管件堆焊  | Pipe Fitting Cladding | 0.8-1.2m | 200-240A | 160-200A | 4-5mm        | 350-450mm/min |              |    |   |    |  |
| 钢管堆焊  | Steel Pipe Cladding   | 1.2-1.8m | 240-280A | 200-240A | 5-6mm        | 400-500mm/min |              |    |   |    |  |
| 轴套管堆焊 | Shaft Sleeve Cladding | 0.6-1.0m | 180-220A | 140-180A | 3-4mm        | 250-350mm/min |              |    |   |    |  |
| 模具修复  | Mold Repair           | 0.5-0.8m | 160-200A | 120-160A | 2-3mm        | 200-300mm/min |              |    |   |    |  |

#### 4.4.3 熔深检测方法 Penetration Inspection Methods

- **宏观金相检测：**每批次产品抽检，制作金相试样，测量熔深

Macroscopic metallographic inspection: Sample inspection for each batch, prepare metallographic specimens, measure penetration

- **超声波检测：**对关键部位进行超声波探伤，评估熔深和熔合质量

Ultrasonic testing: Perform ultrasonic testing on critical areas to evaluate penetration and fusion quality

- **焊缝尺寸测量：**使用焊缝量规测量焊缝余高和宽度，间接评估熔深

Weld dimension measurement: Use weld gauge to measure weld reinforcement and width, indirectly evaluate penetration



#### 4.4.4 熔深异常处理 Penetration Abnormality Handling

| 异常现象  | Abnormal Phenomenon      | 可能原因                   | Possible Cause                                                                                 | 处理措施                         | Corrective Action                                                                           |
|-------|--------------------------|------------------------|------------------------------------------------------------------------------------------------|------------------------------|---------------------------------------------------------------------------------------------|
| 熔深不足  | Insufficient penetration | 前丝电流过低、焊接速度过快、电弧间距过大   | Front wire current too low, welding speed too fast, arc spacing too large                      | 提高前丝电流 10%-15%，降低焊接速度，减小电弧间距 | Increase front wire current by 10%-15%, reduce welding speed, decrease arc spacing          |
| 熔深过大  | Excessive penetration    | 前丝电流过高、焊接速度过慢、工件预热温度过高 | Front wire current too high, welding speed too slow, workpiece preheating temperature too high | 降低前丝电流 10%-15%，提高焊接速度，降低预热温度 | Reduce front wire current by 10%-15%, increase welding speed, reduce preheating temperature |
| 熔深不均匀 | Non-uniform penetration  | 送丝不稳定、工件表面不平整、保护气体流量波动 | Unstable wire feeding, uneven workpiece surface, shielding gas flow fluctuation                | 检查送丝系统，清理工件表面，稳定保护气体流量       | Check wire feeding, clean workpiece surface, stabilize shielding gas flow                   |

#### 4.5 工艺参数记录与追溯 Process Parameter Recording and Traceability

##### 4.5.1 参数记录要求 Parameter Recording Requirements

每道焊缝的以下参数必须记录并存档：

The following parameters for each weld pass must be recorded and archived:

- 前丝电流、后丝电流及配比 Front wire current, rear wire current and ratio
- 电弧间距 Arc spacing
- 焊接速度 Welding speed
- 熔深检测结果 Penetration inspection results
- 操作人员、操作时间 Operator, operation time
- 设备编号 Equipment number



#### 4.5.2 参数变更管理 Parameter Change Management

- 工艺参数变更需经工艺技术部审批  
Process parameter changes require approval from Process Technology Department
- 变更后的参数需进行工艺验证，确认熔深和焊缝质量符合要求  
Changed parameters require process verification to confirm penetration and weld quality meet requirements
- 参数变更记录纳入项目技术档案  
Parameter change records shall be included in project technical archives

### 5. 监督考核 Supervision and Assessment

#### 5.1 监督检查 Supervision and Inspection

| 检查项目     | Inspection Item                  | 检查频次 | Inspection Frequency | 责任部门 | Responsible Department |
|----------|----------------------------------|------|----------------------|------|------------------------|
| 电流配比执行情况 | Current ratio execution          | 每日   | Daily                | 质量部  | Quality Department     |
| 电弧间距设置   | Arc spacing setting              | 每班次  | Each shift           | 生产部  | Production Department  |
| 熔深检测结果   | Penetration inspection results   | 每批次  | Each batch           | 质量部  | Quality Department     |
| 参数记录完整性  | Parameter recording completeness | 每周   | Weekly               | 质量部  | Quality Department     |

#### 5.2 考核标准 Assessment Criteria

- 工艺参数执行率 $\geq 98\%$  Process parameter execution rate  $\geq 98\%$
- 熔深合格率 $\geq 95\%$  Penetration qualification rate  $\geq 95\%$
- 参数记录完整率 100% Parameter recording completeness 100%
- 工艺参数变更审批率 100% Process parameter change approval rate 100%



## 6. 附则 Supplementary Provisions

### 6.1 相关文件 Related Documents

- CLADDING-WP-001 焊接工艺规程 Welding Procedure Specification
- CLADDING-QC-005 焊缝质量检验规程 Weld Quality Inspection Procedure
- CLADDING-EQ-003 双丝堆焊设备操作规程 Dual-Wire Cladding Equipment Operation Procedure
- CLADDING-TR-002 工艺参数培训管理规定 Process Parameter Training Management Regulation

### 6.2 记录表单 Record Forms

- CLADDING-FRM-019-01 双丝堆焊工艺参数记录表 Dual-Wire Cladding Process Parameter Record Form
- CLADDING-FRM-019-02 熔深检测报告 Penetration Inspection Report
- CLADDING-FRM-019-03 工艺参数变更审批表 Process Parameter Change Approval Form

### 6.3 修订记录 Revision History

| 版本  | Version | 修订日期       | Revision Date | 修订内容            | Revision Content | 修订人                           | Revised By |
|-----|---------|------------|---------------|-----------------|------------------|-------------------------------|------------|
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