



Cladding-Technology-Shanxi-Co.,-Ltd- CLADDING-MPS-018-Hot-Wire- Cladding-Layer-Process-Specification

热丝 TIG/MIG 堆焊工艺参数控制程序

文件编号：CLADDING-MPS-018

文件名称：热丝 TIG/MIG 堆焊加热温度、送丝速度与熔敷速率控制程序

英文标题：Hot Wire TIG/MIG Cladding Process Parameter Control Procedure

1. 目的 Purpose

规范科雷丁技术（山西）有限公司热丝 TIG/MIG 堆焊作业中加热温度、送丝速度与熔敷速率的控制要求，确保法兰堆焊、管件堆焊、钢管堆焊、轴套管堆焊、模具堆焊修复及金属零部件增材制造等业务的工艺参数处于受控状态，保证堆焊层质量稳定可靠，满足客户技术要求与产品性能指标。

To standardize the control requirements of heating temperature, wire feeding speed and deposition rate in hot wire TIG/MIG cladding operations of CLADDING-Technology-Shanxi-Co.,-Ltd, ensure process parameters are under control for flange cladding, pipe fitting cladding, steel pipe cladding, shaft sleeve cladding, mold cladding repair and metal component additive manufacturing, guarantee stable and reliable cladding layer quality, and meet customer technical requirements and product performance specifications.



2. 适用范围 Scope

本程序适用于公司所有采用热丝 TIG 堆焊（Hot Wire TIG）和热丝 MIG 堆焊（Hot Wire MIG）工艺的生产作业，具体包括：

- 法兰密封面堆焊强化
- 管件内壁及外壁堆焊修复
- 钢管防腐耐磨堆焊
- 轴套管表面强化与再制造
- 模具型腔堆焊修复
- 梯度材料增材制造
- 大型零部件表面改性处理

This procedure applies to all production operations using hot wire TIG cladding and hot wire MIG cladding processes, including flange sealing surface cladding strengthening, pipe fitting inner and outer wall cladding repair, steel pipe anti-corrosion and wear-resistant cladding, shaft sleeve surface strengthening and remanufacturing, mold cavity cladding repair, gradient material additive manufacturing, and large component surface modification treatment.

3. 职责 Responsibilities

3.1 生产部 Production Department

负责热丝 TIG/MIG 堆焊设备的日常操作与维护，按照本程序规定的工艺参数执行生产作业，记录实际工艺参数数据，发现异常及时上报。

Responsible for daily operation and maintenance of hot wire TIG/MIG cladding equipment, execute production operations according to process parameters specified in this procedure, record actual process parameter data, and report abnormalities promptly.

3.2 技术部 Technology Department

负责制定和修订热丝 TIG/MIG 堆焊工艺参数标准，编制焊接工艺规程（WPS），对特殊工况下的参数调整提供技术指导，审核工艺参数变更申请。

Responsible for formulating and revising hot wire TIG/MIG cladding process parameter standards, compiling welding procedure specifications (WPS), providing technical guidance for parameter adjustments under special conditions, and reviewing process parameter change applications.



3.3 质量部 Quality Department

负责监督工艺参数执行情况，对堆焊层质量进行检验与评定，审核工艺参数记录，对不符合项提出纠正措施要求。

Responsible for supervising process parameter implementation, inspecting and evaluating cladding layer quality, reviewing process parameter records, and proposing corrective action requirements for non-conformities.

3.4 设备部 Equipment Department

负责热丝 TIG/MIG 堆焊设备的维护保养，确保加热系统、送丝系统、熔敷监测系统运行正常，定期校准温度传感器和流量计。

Responsible for maintenance of hot wire TIG/MIG cladding equipment, ensuring heating , wire feeding , and deposition monitoring operate normally, and regularly calibrating temperature sensors and flow meters.

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

4.1 加热温度控制 Heating Temperature Control

4.1.1 预热温度控制 Preheating Temperature Control

根据母材材质、厚度及堆焊材料特性，确定合理的预热温度范围。

母材类型 Base Material	厚度范围 Thickness Range	预热温度 Preheating Temperature	适用工艺 Applicable Process
碳钢 Carbon Steel	≤50mm	100-150℃	TIG/MIG
碳钢 Carbon Steel	50-100mm	150-200℃	TIG/MIG
碳钢 Carbon Steel	>100mm	200-250℃	TIG/MIG
低合金钢 Low Alloy Steel	≤50mm	150-200℃	TIG/MIG
低合金钢 Low Alloy Steel	>50mm	200-250℃	TIG/MIG
不锈钢 Stainless Steel	全部厚度 All Thickness	100-150℃	TIG
镍基合金 Nickel-based Alloy	全部厚度 All Thickness	150-200℃	TIG



预热采用感应加热或火焰加热方式，使用红外测温仪或热电偶测量，确保母材表面温度均匀，温差控制在 $\pm 20^{\circ}\text{C}$ 以内。

Preheating shall be carried out by induction heating or flame heating, measured by infrared thermometer or thermocouple, ensuring uniform base material surface temperature with temperature difference controlled within $\pm 20^{\circ}\text{C}$.

4.1.2 热丝加热温度控制 Hot Wire Heating Temperature Control

热丝 TIG/MIG 堆焊中，填充丝通过独立加热系统预热，加热温度直接影响熔敷质量和稀释率。

热丝加热温度控制要求：

- 不锈钢填充丝：加热温度控制在 $200-350^{\circ}\text{C}$
- 镍基合金填充丝：加热温度控制在 $250-400^{\circ}\text{C}$
- 钴基合金填充丝：加热温度控制在 $300-450^{\circ}\text{C}$
- 硬质合金填充丝：加热温度控制在 $150-300^{\circ}\text{C}$

热丝温度通过热电偶实时监测，温度波动控制在设定值的 $\pm 15^{\circ}\text{C}$ 以内。温度异常时，设备自动报警并暂停送丝。

Hot wire temperature shall be monitored in real time by thermocouple, with temperature fluctuation controlled within $\pm 15^{\circ}\text{C}$ of set value. When temperature is abnormal, equipment shall automatically alarm and pause wire feeding.

4.1.3 层间温度控制 Interpass Temperature Control

多层堆焊作业中，严格控制层间温度，防止过热导致晶粒粗化和性能下降。

堆焊材料 Cladding Material	层间温度上限 Maximum Interpass Temperature	冷却方式 Cooling Method
不锈钢 Stainless Steel	$\leq 250^{\circ}\text{C}$	自然冷却 Natural Cooling
镍基合金 Nickel-based Alloy	$\leq 200^{\circ}\text{C}$	自然冷却 Natural Cooling
硬质合金 Carbide	$\leq 150^{\circ}\text{C}$	强制风冷 Forced Air Cooling
钴基合金 Cobalt-based Alloy	$\leq 200^{\circ}\text{C}$	自然冷却 Natural Cooling

层间温度超过上限时，必须暂停堆焊作业，待温度降至规定范围后方可继续。

When interpass temperature exceeds the upper limit, cladding operation must be suspended until temperature drops to the specified range.



4.2 送丝速度控制 Wire Feeding Speed Control

4.2.1 送丝速度设定原则 Wire Feeding Speed Setting Principles

送丝速度直接影响熔敷速率、堆焊层成形质量及稀释率，应根据以下因素综合确定：

- 填充丝直径 Wire diameter
- 焊接电流 Welding current
- 电弧电压 Arc voltage
- 母材材质 Base material
- 堆焊层厚度要求 Cladding layer thickness requirement
- 稀释率控制要求 Dilution rate control requirement

4.2.2 送丝速度参数表 Wire Feeding Speed Parameter Table

填充丝直径 Wire Diameter	焊接电流 Welding Current	送丝速度范围 Wire Feeding Speed Range	适用场景 Application
Φ2.0mm	120-160A	200-300mm/min	精密堆焊 Precision Cladding
Φ2.4mm	150-200A	250-350mm/min	常规堆焊 Regular Cladding
Φ3.0mm	180-250A	300-450mm/min	高效堆焊 High-efficiency Cladding
Φ3.2mm	200-280A	350-500mm/min	大面积堆焊 Large-area Cladding
Φ4.0mm	250-350A	400-600mm/min	厚层堆焊 Thick-layer Cladding

4.2.3 送丝速度调节要求 Wire Feeding Speed Adjustment Requirements

- 热丝 TIG 堆焊：送丝速度与加热温度联动控制，温度升高时适当降低送丝速度，防止过热
- 热丝 MIG 堆焊：送丝速度与焊接电流匹配，确保电弧稳定燃烧
- 多层堆焊：首层送丝速度适当降低，后续层根据熔池状态微调
- 薄壁管件堆焊：送丝速度控制在较低范围，防止烧穿
- 大型法兰堆焊：送丝速度可适当提高，保证生产效率

Hot wire TIG cladding: wire feeding speed shall be linked with heating temperature control, appropriately reducing wire feeding speed when temperature increases to prevent overheating. Hot



wire MIG cladding: wire feeding speed shall match welding current to ensure stable arc combustion. Multi-layer cladding: first layer wire feeding speed shall be appropriately reduced, subsequent layers adjusted according to molten pool condition. Thin-walled pipe fitting cladding: wire feeding speed shall be controlled in lower range to prevent burn-through. Large flange cladding: wire feeding speed may be appropriately increased to ensure production efficiency.

4.2.4 送丝系统维护要求 Wire Feeding Maintenance Requirements

- 每日检查送丝轮磨损情况，磨损超过 20%时更换
- 定期清洁送丝管，防止堵塞影响送丝稳定性
- 检查送丝张力，确保送丝顺畅无打滑
- 记录送丝速度实际值与设定值偏差，偏差超过±5%时调整

Check wire feeding wheel wear daily, replace when wear exceeds 20%. Clean wire feeding tube regularly to prevent blockage affecting wire feeding stability. Check wire feeding tension to ensure smooth feeding without slippage. Record deviation between actual and set wire feeding speed, adjust when deviation exceeds ±5%.

4.3 熔敷速率控制 Deposition Rate Control

4.3.1 熔敷速率定义与计算 Deposition Rate Definition and Calculation

熔敷速率是指单位时间内堆焊材料的熔敷量，是衡量堆焊效率和成本控制的重要指标。

熔敷速率计算公式：

熔敷速率 (kg/h) = 送丝速度 (m/h) × 填充丝线密度 (kg/m) × 熔敷效率 (%)

Deposition rate refers to the amount of cladding material deposited per unit time, which is an important indicator for measuring cladding efficiency and cost control.

Deposition rate calculation formula:

Deposition Rate (kg/h) = Wire Feeding Speed (m/h) × Wire Linear Density (kg/m) × Deposition Efficiency (%)

4.3.2 熔敷速率控制目标 Deposition Rate Control Targets

工艺类型 Process Type	目标熔敷速率 Target Deposition Rate	效率范围 Efficiency Range
热丝 TIG 堆焊 Hot Wire TIG	3-8 kg/h	85-95%
热丝 MIG 堆焊 Hot Wire MIG	8-20 kg/h	80-90%
精密堆焊 Precision Cladding	2-5 kg/h	90-95%
高效堆焊 High-efficiency Cladding	10-25 kg/h	75-85%



4.3.3 熔敷速率影响因素及控制 *Factors Affecting Deposition Rate and Control*

焊接电流 *Welding Current*

焊接电流增大，熔敷速率提高，但过大的电流会导致稀释率升高、成形恶化。应根据堆焊材料特性选择合适电流范围。

Increasing welding current increases deposition rate, but excessive current causes higher dilution rate and poor formation. Appropriate current range shall be selected according to cladding material characteristics.

电弧电压 *Arc Voltage*

电弧电压影响熔池宽度和熔深，电压过高导致熔池过宽、成形不良，电压过低导致熔深不足。

Arc voltage affects molten pool width and penetration depth. Excessive voltage causes overly wide molten pool and poor formation, while insufficient voltage causes inadequate penetration.

焊接速度 *Welding Travel Speed*

焊接速度与熔敷速率呈反比关系，速度过快导致熔敷量不足、层间结合不良，速度过慢导致过热、稀释率升高。

Welding travel speed is inversely proportional to deposition rate. Excessive speed causes insufficient deposition and poor interlayer bonding, while insufficient speed causes overheating and higher dilution rate.

热丝温度 *Hot Wire Temperature*

热丝温度升高，预热效果增强，熔敷速率提高，同时稀释率降低。但温度过高可能导致填充丝过热、合金元素烧损。

Increasing hot wire temperature enhances preheating effect and improves deposition rate while reducing dilution rate. However, excessive temperature may cause wire overheating and alloy element burn-off.

4.3.4 熔敷速率监测与记录 *Deposition Rate Monitoring and Recording*

- 每班次记录实际熔敷速率，与目标值对比分析
- 熔敷速率偏差超过 $\pm 10\%$ 时，分析原因并调整工艺参数
- 建立熔敷速率数据库，为工艺优化提供数据支持
- 定期统计材料利用率，评估成本控制效果

Record actual deposition rate per shift and compare with target value for analysis. When deposition rate deviation exceeds $\pm 10\%$, analyze causes and adjust process parameters. Establish



deposition rate database to provide data support for process optimization. Regularly calculate material utilization rate to evaluate cost control effectiveness.

4.4 工艺参数联动控制 Process Parameter Linkage Control

4.4.1 参数匹配原则 Parameter Matching Principles

加热温度、送丝速度与熔敷速率三者相互关联，必须综合考虑，实现最佳匹配。
Heating temperature, wire feeding speed, and deposition rate are interrelated and must be comprehensively considered to achieve optimal matching.

4.4.2 典型工况参数组合 Typical Working Condition Parameter Combinations

工况一：法兰密封面精密堆焊 Flange Sealing Surface Precision Cladding

参数 Parameter	设定值 Set Value
填充丝直径 Wire Diameter	Φ2.0mm
焊接电流 Welding Current	140A
电弧电压 Arc Voltage	14V
热丝温度 Hot Wire Temperature	280℃
送丝速度 Wire Feeding Speed	250mm/min
焊接速度 Travel Speed	80mm/min
目标熔敷速率 Target Deposition Rate	4 kg/h

工况二：钢管大面积高效堆焊 Steel Pipe Large-area High-efficiency Cladding

参数 Parameter	设定值 Set Value
填充丝直径 Wire Diameter	Φ3.2mm
焊接电流 Welding Current	240A
电弧电压 Arc Voltage	22V
热丝温度 Hot Wire Temperature	320℃
送丝速度 Wire Feeding Speed	450mm/min
焊接速度 Travel Speed	200mm/min
目标熔敷速率 Target Deposition Rate	15 kg/h



工况三：轴套管再制造修复 Shaft Sleeve Remanufacturing Repair

参数 Parameter	设定值 Set Value
填充丝直径 Wire Diameter	Φ2.4mm
焊接电流 Welding Current	170A
电弧电压 Arc Voltage	16V
热丝温度 Hot Wire Temperature	300°C
送丝速度 Wire Feeding Speed	300mm/min
焊接速度 Travel Speed	120mm/min
目标熔敷速率 Target Deposition Rate	8 kg/h

4.5 异常处理 Abnormal Handling

4.5.1 温度异常处理 Temperature Abnormal Handling

- 热丝温度过高：降低加热功率，检查热电偶是否正常，必要时更换
- 热丝温度过低：检查加热电源，清理加热元件，调整温度设定值
- 层间温度超标：暂停作业，加强冷却，待温度降至规定范围后继续

Hot wire temperature too high: reduce heating power, check thermocouple condition, replace if necessary. Hot wire temperature too low: check heating power supply, clean heating element, adjust temperature set value. Interpass temperature exceeds limit: suspend operation, enhance cooling, continue after temperature drops to specified range.

4.5.2 送丝异常处理 Wire Feeding Abnormal Handling

- 送丝不畅：检查送丝轮压力，清理送丝管，检查填充丝质量
- 送丝速度波动：检查送丝电机，调整编码器参数，更换磨损部件
- 断丝：停止作业，清理熔池，重新引弧，分析断丝原因

Wire feeding 不畅: check wire feeding wheel pressure, clean wire feeding tube, check wire quality. Wire feeding speed fluctuation: check wire feeding motor, adjust encoder parameters, replace worn parts. Wire breakage: stop operation, clean molten pool, re-strike arc, analyze breakage cause.

4.5.3 熔敷异常处理 Deposition Abnormal Handling

- 熔敷速率过低：检查送丝速度、焊接电流、热丝温度，综合调整
- 熔敷速率过高：降低送丝速度或焊接电流，防止稀释率超标



- 成形不良：调整电弧电压、焊接速度，优化参数组合

Deposition rate too low: check wire feeding speed, welding current, hot wire temperature, adjust comprehensively. Deposition rate too high: reduce wire feeding speed or welding current to prevent excessive dilution rate. Poor formation: adjust arc voltage, welding travel speed, optimize parameter combination.

5. 监督考核 Supervision and Assessment

5.1 监督检查内容 Supervision and Inspection Content

质量部每月对热丝 TIG/MIG 堆焊工艺参数执行情况进行监督检查，重点检查以下内容：

Quality Department shall conduct monthly supervision and inspection of hot wire TIG/MIG cladding process parameter implementation, focusing on the following content:

- 加热温度控制记录是否完整、准确
- 送丝速度设定是否符合工艺要求
- 熔敷速率是否达到控制目标
- 工艺参数异常处理是否及时、有效
- 设备维护保养记录是否规范

Whether heating temperature control records are complete and accurate. Whether wire feeding speed settings meet process requirements. Whether deposition rate achieves control targets. Whether process parameter abnormal handling is timely and effective. Whether equipment maintenance records are standardized.

5.2 考核标准 Assessment Criteria

考核项目 Assessment Item	合格标准 Qualified Standard	扣分标准 Deduction Standard
温度记录完整率 Temperature Record Completeness	$\geq 98\%$	每降低 1%扣 2 分
参数执行符合率 Parameter Implementation Compliance	$\geq 95\%$	每降低 1%扣 3 分
异常处理及时率 Abnormal Handling Timeliness	$\geq 90\%$	每降低 1%扣 2 分
设备完好率 Equipment Availability	$\geq 95\%$	每降低 1%扣 2 分
熔敷速率达标率 Deposition Rate Target Achievement	$\geq 90\%$	每降低 1%扣 3 分



5.3 考核结果应用 Assessment Result Application

- 月度考核得分 ≥ 90 分：评为优秀，给予适当奖励
- 月度考核得分 80-89 分：评为合格，保持现状
- 月度考核得分 70-79 分：评为待改进，限期整改
- 月度考核得分 < 70 分：评为不合格，追究责任

Monthly assessment score ≥ 90 : rated as excellent, appropriate reward given. Monthly assessment score 80-89: rated as qualified, maintain current status. Monthly assessment score 70-79: rated as needing improvement, rectification within deadline. Monthly assessment score < 70 : rated as unqualified, accountability pursued.

6. 附则 Supplementary Provisions

6.1 相关文件 Related Documents

- CLADDING-WPS-001 热丝 TIG 堆焊焊接工艺规程
- CLADDING-WPS-002 热丝 MIG 堆焊焊接工艺规程
- CLADDING-QC-015 堆焊层质量检验规程
- CLADDING-EQP-008 堆焊设备维护保养规程

6.2 记录表格 Record Forms

- CLADDING-REC-018-01 热丝堆焊工艺参数记录表
- CLADDING-REC-018-02 熔敷速率统计报表
- CLADDING-REC-018-03 工艺参数异常处理记录表

6.3 修订记录 Revision History

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