



Cladding-Technology-Shanxi-Co.,-Ltd- CLADDING-MPS-009-Cladding-Sleeve- MPS

科雷丁技术（山西）有限公司

Cladding-Technology-Shanxi-Co.,-Ltd

受控文件 / Controlled Document

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堆焊套筒工艺规程

Weld Overlay Sleeve Process Specification

1. 目的 / Purpose

本规程规定了科雷丁技术（山西）有限公司增材制造车间在法兰堆焊、管件堆焊、钢管堆焊及轴套管堆焊修复作业中，针对堆焊套筒类工件的堆焊层厚度控制、结合强度检验与耐压试验的工艺要求与操作规范。旨在确保堆焊套筒产品满足设计图纸、技术标准及客户对耐腐蚀、耐磨损、耐高温等性能指标的要求，保障产品质量的一致性与可靠性。

This specification defines the process requirements and operational standards for weld overlay sleeve components in the additive manufacturing workshop of Cladding-Technology-Shanxi-Co.,-Ltd, covering flange overlay, pipe fitting overlay, steel pipe overlay, and shaft sleeve overlay repair operations. It aims to ensure that weld overlay sleeve products meet the design drawings, technical standards, and customer requirements for corrosion resistance, wear resistance, high temperature resistance and other performance indicators, guaranteeing product quality consistency and reliability.

2. 适用范围 / Scope

本规程适用于公司承接的以下堆焊套筒类产品的生产与检验：

This specification applies to the production and inspection of the following weld overlay sleeve products undertaken by the company:

- 法兰堆焊套筒 / Flange overlay sleeves
- 管件堆焊套筒 / Pipe fitting overlay sleeves
- 钢管堆焊套筒 / Steel pipe overlay sleeves
- 轴套管堆焊套筒 / Shaft sleeve overlay sleeves
- 模具堆焊修复套筒 / Mold repair overlay sleeves

本规程适用于采用 TIG 堆焊（钨极惰性气体保护堆焊）和 MIG 堆焊（熔化极惰性气体保护堆焊）工艺进行金属增材制造与表面强化处理的套筒类产品。

This specification applies to sleeve-type products manufactured using TIG overlay (Tungsten Inert Gas overlay) and MIG overlay (Metal Inert Gas overlay) processes for metal additive manufacturing and surface strengthening treatment.



3. 职责 / Responsibilities

部门/岗位 / Department/Position	职责 / Responsibility
增材制造车间 / Additive Manufacturing Workshop	负责堆焊套筒的生产执行，按本规程进行堆焊层厚度控制、工艺参数设置与记录
焊接工程师 / Welding Engineer	负责制定堆焊工艺方案，审核工艺参数，解决堆焊过程中的技术问题
质量检验部 / Quality Inspection Department	负责堆焊层厚度检测、结合强度检验、耐压试验及检验报告出具
设备管理部 / Equipment Management Department	负责 TIG/MIG 堆焊设备、检测仪器及耐压试验设备的维护保养
生产计划部 / Production Planning Department	负责堆焊套筒生产计划的编制与进度跟踪

4. 管理内容与程序 / Management Content and Procedures

4.1 堆焊前准备 / Pre-overlay Preparation

4.1.1 母材与焊材确认 / Base Material and Filler Material Confirmation

堆焊作业前，操作人员须核对母材材质证明与焊材材质证明，确保匹配性符合设计要求。常用堆焊套筒母材与焊材匹配关系如下：

Before overlay operations, operators shall verify the compatibility between base material certificates and filler material certificates to ensure compliance with design requirements. Common base material and filler material matching relationships for weld overlay sleeves are as follows:

母材 / Base Material	推荐焊材 / Recommended Filler Material	适用场景 / Application
Q345R / 20#	ER309L / ER316L	碳钢基体不锈钢堆焊 / Stainless overlay on carbon steel
16MnR	ERNiCr-3 / ERNiCrMo-3	高温高压工况 / High temperature and pressure conditions
304 / 316L	ER309L / ER347	不锈钢基体强化堆焊 / Stainless steel reinforcement overlay
20# / 45#	ERNiCrMo-3 / ERCoCrMo-A	轴套管耐磨堆焊 / Shaft sleeve wear-resistant overlay



4.1.2 坡口加工 / Groove Preparation

堆焊套筒母材堆焊面须进行坡口加工，坡口形式与尺寸按设计图纸要求执行。无特殊要求时，采用 V 型坡口，坡口角度 $60^{\circ} \pm 5^{\circ}$ ，钝边 1~2mm，间隙 0~2mm。坡口表面须清除氧化皮、油污、锈蚀等杂质，露出金属光泽。

The overlay surface of the sleeve base material shall be prepared with grooves according to design drawing requirements. When no special requirements exist, V-groove shall be used with groove angle of $60^{\circ} \pm 5^{\circ}$, root face of 1~2mm, and gap of 0~2mm. The groove surface shall be cleaned of oxide scale, oil, rust and other contaminants to expose metallic luster.

4.1.3 设备与工装检查 / Equipment and Fixture Inspection

- TIG/MIG 堆焊设备须处于良好工作状态，气体流量调节正常，送丝机构运转平稳
- Overlay equipment shall be in good working condition with normal gas flow adjustment and smooth wire feeding mechanism
- 堆焊工装夹具须定位准确，确保套筒工件在堆焊过程中不发生位移或变形
- Overlay fixtures shall be accurately positioned to prevent sleeve workpiece displacement or deformation during overlay operations
- 保护气体纯度不低于 99.99%，氩气流量 8~15L/min
- Shielding gas purity shall not be less than 99.99%, argon flow rate 8~15L/min

4.2 堆焊层厚度控制 / Overlay Thickness Control

4.2.1 厚度要求 / Thickness Requirements

堆焊套筒的堆焊层厚度须满足设计图纸要求，无特殊要求时，执行以下标准：

The overlay thickness of weld overlay sleeves shall meet design drawing requirements. When no special requirements exist, the following standards shall be applied:

套筒类型 / Sleeve Type	单层厚度 / Single Layer Thickness	总厚度 / Total Thickness	厚度公差 / Thickness Tolerance
法兰堆焊套筒 / Flange overlay sleeve	2~3mm	6~12mm	$\pm 0.5\text{mm}$
管件堆焊套筒 / Pipe fitting overlay sleeve	2~3mm	4~8mm	$\pm 0.5\text{mm}$
钢管堆焊套筒 / Steel pipe overlay sleeve	2~3mm	6~15mm	$\pm 1.0\text{mm}$
轴套管堆焊套筒 / Shaft	1.5~2.5mm	3~6mm	$\pm 0.3\text{mm}$



sleeve overlay sleeve			
模具堆焊修复套筒 / Mold repair overlay sleeve	1.5~2.5mm	2~5mm	±0.3mm

4.2.2 厚度控制方法 / Thickness Control Methods

TIG 堆焊厚度控制 / TIG Overlay Thickness Control

TIG 堆焊采用低稀释率工艺，单层堆焊厚度控制在 1.5~2.5mm。操作人员通过控制焊接速度、电流大小及摆动幅度来调节单层厚度。焊接电流范围 80~160A，焊接速度 100~250mm/min，焊枪摆动幅度 6~12mm。每层堆焊完成后，使用千分尺或超声波测厚仪测量单层厚度，确保符合工艺要求。

TIG overlay uses low dilution process with single layer thickness controlled at 1.5~2.5mm. Operators control single layer thickness by adjusting welding speed, current magnitude, and oscillation amplitude. Welding current range: 80~160A, welding speed: 100~250mm/min, torch oscillation amplitude: 6~12mm. After each overlay layer is completed, single layer thickness shall be measured using micrometer or ultrasonic thickness gauge to ensure compliance with process requirements.

MIG 堆焊厚度控制 / MIG Overlay Thickness Control

MIG 堆焊采用高效熔敷工艺，单层堆焊厚度控制在 2~3mm。操作人员通过控制送丝速度、电压及焊接速度来调节单层厚度。焊接电流范围 180~320A，电弧电压 22~28V，送丝速度 4~8m/min。每层堆焊完成后，使用千分尺测量单层厚度，偏差超过±0.3mm 时须调整工艺参数。

MIG overlay uses high efficiency deposition process with single layer thickness controlled at 2~3mm. Operators control single layer thickness by adjusting wire feed speed, voltage, and welding speed. Welding current range: 180~320A, arc voltage: 22~28V, wire feed speed: 4~8m/min. After each overlay layer is completed, single layer thickness shall be measured using micrometer. When deviation exceeds ±0.3mm, process parameters shall be adjusted.

4.2.3 层间温度控制 / Interpass Temperature Control

堆焊过程中，层间温度须控制在 150~250℃范围内，使用红外测温仪进行监测。层间温度超过 250℃时，须暂停堆焊，待自然冷却至规定温度范围后方可继续施焊。层间温度过低（低于 150℃）时，须适当预热后再进行下一层堆焊。

During overlay operations, interpass temperature shall be controlled within 150~250℃ range, monitored using infrared thermometer. When interpass temperature exceeds 250℃, overlay shall be suspended until natural cooling to specified temperature range before continuing welding. When



interpass temperature is too low (below 150°C), appropriate preheating shall be applied before proceeding with the next overlay layer.

4.2.4 厚度检测 / Thickness Inspection

堆焊层厚度检测采用以下方法：

Overlay thickness inspection shall use the following methods:

- **超声波测厚法 / Ultrasonic Thickness Measurement:** 使用超声波测厚仪对堆焊层进行多点测量，每 100mm 长度不少于 3 个测点，取平均值作为该区域堆焊层厚度
- **千分尺测量法 / Micrometer Measurement:** 对堆焊层表面进行多点测量，适用于表面平整度较高的堆焊层
- **金相分析法 / Metallographic Analysis:** 对关键部位堆焊层进行取样分析，精确测定堆焊层厚度及稀释率

4.3 结合强度检验 / Bond Strength Testing

4.3.1 检验目的 / Inspection Purpose

结合强度检验用于评估堆焊层与母材之间的冶金结合质量，确保堆焊套筒在使用过程中不会发生堆焊层剥离、脱落等失效现象。

Bond strength testing is used to evaluate the metallurgical bonding quality between overlay layer and base material, ensuring that weld overlay sleeves will not experience overlay layer delamination or detachment during service.

4.3.2 检验方法 / Inspection Methods

弯曲试验 / Bend Test

弯曲试验是评估堆焊层结合强度的主要方法。从堆焊套筒上截取试样，试样宽度 25mm，长度不小于 100mm。将试样置于弯曲试验机上，以堆焊层朝外进行弯曲，弯曲角度不小于 180°。检验标准：堆焊层与母材结合处无裂纹、无剥离，堆焊层表面无开裂。

Bend test is the primary method for evaluating overlay layer bond strength. Specimens shall be cut from weld overlay sleeves with width of 25mm and length not less than 100mm. Specimens shall be placed on bend testing machine with overlay layer facing outward, bent to angle not less than 180°. Acceptance criteria: no cracks or delamination at overlay-base material interface, no cracking on overlay surface.

拉伸试验 / Tensile Test

拉伸试验用于测定堆焊层与母材的抗拉强度。从堆焊套筒上截取拉伸试样，试样直径 10mm。将试样置于万能材料试验机上进行拉伸试验，记录最大载荷及断裂位置。检验标准：堆焊层与母材结合强度不低于母材抗拉强度的 80%，断裂位置不得发生在结合界面。



Tensile test is used to determine the tensile strength of overlay layer and base material. Tensile specimens shall be cut from weld overlay sleeves with diameter of 10mm. Specimens shall be placed on universal testing machine for tensile testing, recording maximum load and fracture location. Acceptance criteria: overlay-base material bond strength shall not be less than 80% of base material tensile strength, fracture shall not occur at bond interface.

冲击试验 / Impact Test

冲击试验用于评估堆焊层与母材结合区域的韧性。从堆焊套筒上截取 V 型缺口冲击试样，缺口位于堆焊层与母材结合界面。试样在 -20℃ 条件下进行冲击试验，记录冲击吸收能量。检验标准：冲击吸收能量不低于母材标准值的 70%。

Impact test is used to evaluate the toughness of overlay layer and base material bond region. V-notch impact specimens shall be cut from weld overlay sleeves with notch located at overlay-base material interface. Specimens shall be impact tested at -20℃, recording impact absorbed energy. Acceptance criteria: impact absorbed energy shall not be less than 70% of base material standard value.

4.3.3 取样要求 / Sampling Requirements

套筒类型 / Sleeve Type	弯曲试验 / Bend Test	拉伸试验 / Tensile Test	冲击试验 / Impact Test
法兰堆焊套筒 / Flange overlay sleeve	每批次 2 件 / 2 pcs per batch	每批次 1 件 / 1 pc per batch	每批次 1 件 / 1 pc per batch
管件堆焊套筒 / Pipe fitting overlay sleeve	每批次 2 件 / 2 pcs per batch	每批次 1 件 / 1 pc per batch	每批次 1 件 / 1 pc per batch
钢管堆焊套筒 / Steel pipe overlay sleeve	每批次 3 件 / 3 pcs per batch	每批次 2 件 / 2 pcs per batch	每批次 2 件 / 2 pcs per batch
轴套管堆焊套筒 / Shaft sleeve overlay sleeve	每批次 2 件 / 2 pcs per batch	每批次 1 件 / 1 pc per batch	每批次 1 件 / 1 pc per batch

4.3.4 不合格处理 / Non-conformance Handling

结合强度检验不合格时，按以下程序处理：

When bond strength inspection fails, handle according to the following procedure:

1. 隔离不合格品，标识并记录不合格情况

Isolate non-conforming products, label and record non-conformance details

2. 分析不合格原因，确定是工艺参数不当、焊材问题还是母材问题

Analyze non-conformance causes to determine whether due to improper process parameters, filler material issues, or base material issues



3. 制定返工方案，经焊接工程师审核批准后实施

Develop rework plan, implement after welding engineer review and approval

4. 返工后重新进行结合强度检验，合格后方可放行

Re-perform bond strength inspection after rework, release only after passing

4.4 耐压试验工艺 / Pressure Test Process

4.4.1 试验目的 / Test Purpose

耐压试验用于验证堆焊套筒的结构完整性和密封性能，确保产品在额定工作压力下安全可靠运行。

Pressure test is used to verify the structural integrity and sealing performance of weld overlay sleeves, ensuring safe and reliable operation under rated working pressure.

4.4.2 试验条件 / Test Conditions

套筒类型 / Sleeve Type	试验介质 / Test Medium	试验压力 / Test Pressure	保压时间 / Holding Time
法兰堆焊套筒 / Flange overlay sleeve	水 / Water	1.5 倍设计压力 / 1.5× design pressure	30min
管件堆焊套筒 / Pipe fitting overlay sleeve	水 / Water	1.5 倍设计压力 / 1.5× design pressure	30min
钢管堆焊套筒 / Steel pipe overlay sleeve	水 / Water	1.5 倍设计压力 / 1.5× design pressure	60min
轴套管堆焊套筒 / Shaft sleeve overlay sleeve	水 / Water	1.2 倍设计压力 / 1.2× design pressure	30min
模具堆焊修复套筒 / Mold repair overlay sleeve	水 / Water	1.2 倍设计压力 / 1.2× design pressure	30min

4.4.3 试验程序 / Test Procedure

试验前准备 / Pre-test Preparation

- 堆焊套筒须经外观检验、尺寸检验、无损检测合格后方可进行耐压试验
- Weld overlay sleeves shall pass visual inspection, dimensional inspection, and non-destructive testing before pressure testing
- 试验用水须清洁，不含腐蚀性物质，水温不低于 5℃
- Test water shall be clean, free of corrosive substances, with temperature not less than 5℃



- 试验设备须经计量检定合格，压力表精度不低于 1.5 级
- Test equipment shall pass metrological verification, pressure gauge accuracy not less than Class 1.5

试验步骤 / Test Steps

5. 将堆焊套筒安装于耐压试验装置上，确保密封可靠
Install weld overlay sleeve on pressure test apparatus, ensuring reliable sealing
6. 缓慢充水排气，排除套筒内部空气
Slowly fill with water and exhaust air, removing air from inside sleeve
7. 缓慢升压至试验压力的 50%，稳压 5min，检查有无渗漏
Slowly increase pressure to 50% of test pressure, hold for 5min, check for leakage
8. 继续升压至试验压力，稳压至规定保压时间
Continue increasing pressure to test pressure, hold for specified duration
9. 保压期间，观察压力表读数变化，检查堆焊层表面及母材表面有无渗漏、变形
During holding period, observe pressure gauge reading changes, check overlay surface and base material surface for leakage or deformation
10. 保压时间结束后，缓慢降压至常压，排空试验用水
After holding period ends, slowly reduce pressure to atmospheric pressure, drain test water

4.4.4 合格标准 / Acceptance Criteria

耐压试验合格标准如下：

Pressure test acceptance criteria are as follows:

- 保压期间，压力表读数下降不超过试验压力的 1%
- During holding period, pressure gauge reading drop shall not exceed 1% of test pressure
- 堆焊层表面及母材表面无渗漏、无裂纹
- No leakage or cracks on overlay surface and base material surface
- 套筒无可见变形
- No visible deformation of sleeve
- 试验后外观检查无异常
- No abnormalities in post-test visual inspection

4.4.5 试验记录 / Test Records

耐压试验完成后，须填写《堆焊套筒耐压试验记录表》，记录内容包括：

After pressure test, fill in Weld Overlay Sleeve Pressure Test Record Form, recording the following content:

- 套筒编号、规格、材质



- Sleeve number, specification, material
- 试验日期、试验人员
- Test date, test personnel
- 试验压力、保压时间、压力变化
- Test pressure, holding time, pressure changes
- 试验结果、结论
- Test results, conclusion

4.5 堆焊工艺参数记录 / Overlay Process Parameter Records

堆焊作业过程中，操作人员须实时记录以下工艺参数：

During overlay operations, operators shall record the following process parameters in real time:

参数项目 / Parameter Item	TIG 堆焊 / TIG Overlay	MIG 堆焊 / MIG Overlay
焊接电流 / Welding Current	80~160A	180~320A
电弧电压 / Arc Voltage	12~18V	22~28V
焊接速度 / Welding Speed	100~250mm/min	150~350mm/min
送丝速度 / Wire Feed Speed	-	4~8m/min
保护气体流量 / Gas Flow Rate	8~15L/min	15~25L/min
层间温度 / Interpass Temperature	150~250°C	150~250°C
预热温度 / Preheating Temperature	100~150°C	100~150°C

5. 监督考核 / Supervision and Assessment

5.1 监督检查 / Supervision and Inspection

质量检验部每月对堆焊套筒生产过程进行监督检查，检查内容包括：

Quality Inspection Department shall conduct monthly supervision and inspection of weld overlay sleeve production process, including:

- 堆焊层厚度控制是否符合工艺要求
- Whether overlay thickness control complies with process requirements
- 工艺参数记录是否完整、准确
- Whether process parameter records are complete and accurate
- 结合强度检验及耐压试验是否按规定执行



- Whether bond strength testing and pressure testing are performed as required
- 不合格品处理是否规范
- Whether non-conformance handling is standardized

5.2 考核指标 / Assessment Indicators

考核项目 / Assessment Item	目标值 / Target Value	权重 / Weight
堆焊层厚度合格率 / Overlay thickness pass rate	≥98%	30%
结合强度检验合格率 / Bond strength test pass rate	100%	30%
耐压试验合格率 / Pressure test pass rate	100%	25%
工艺记录完整率 / Process record completeness	≥95%	15%

5.3 奖惩措施 / Rewards and Penalties

- 月度考核达标，给予增材制造车间及质量检验部相关责任人奖励
- Monthly assessment targets met, reward relevant responsible persons in additive manufacturing workshop and quality inspection department
- 月度考核未达标，分析原因，制定改进措施，限期整改
- Monthly assessment targets not met, analyze causes, develop improvement measures, rectify within deadline
- 连续三个月考核未达标，对相关责任人进行岗位调整或培训
- Three consecutive months of assessment failure, adjust positions or provide training for relevant responsible persons

6. 附则 / Supplementary Provisions

6.1 相关文件 / Related Documents

- 《TIG 堆焊作业指导书》 / TIG Overlay Work Instruction
- 《MIG 堆焊作业指导书》 / MIG Overlay Work Instruction
- 《堆焊层无损检测规程》 / Overlay Layer Non-destructive Testing Procedure
- 《堆焊套筒检验规程》 / Weld Overlay Sleeve Inspection Procedure
- 《不合格品控制程序》 / Non-conformance Control Procedure



6.2 记录表格 / Record Forms

- 《堆焊工艺参数记录表》 / Overlay Process Parameter Record Form
- 《堆焊层厚度检测报告》 / Overlay Thickness Inspection Report
- 《结合强度检验报告》 / Bond Strength Test Report
- 《堆焊套筒耐压试验记录表》 / Weld Overlay Sleeve Pressure Test Record Form
- 《堆焊套筒出厂检验报告》 / Weld Overlay Sleeve Final Inspection Report

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
A/0	2024-01-01	首次发布 / Initial release	焊接工程师 / Welding Engineer

编制 / Prepared by: 焊接工程师 / Welding Engineer

审核 / Reviewed by: 质量经理 / Quality Manager

批准 / Approved by: 总经理 / General Manager

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