科雷丁技术（山西）有限公司
Cladding Technology (Shanxi) Co., Ltd.
增材制造 · TIG 堆焊 · MIG 堆焊 · 精密焊接 · 表面强化 · 再制造修复

# Cladding-Technology-Shanxi-Co.,-Ltd-CLADDING-ITP-008-Cladding-Pipe-Fitting-ITP

## 科雷丁技术（山西）有限公司

## Cladding-Technology-Shanxi-Co.,-Ltd

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# 堆焊管接头焊接、堆焊层无损检测与尺寸检验程序

# Welding, NDT and Dimensional Inspection Procedure for Cladded Pipe Joints

## 1 目的 Purpose

本程序旨在规范科雷丁技术（山西）有限公司堆焊管接头（包括法兰堆焊、管件堆焊、钢管堆焊、轴套管堆焊）的焊接工艺执行、堆焊层无损检测及尺寸检验工作，确保堆焊产品质量符合设计图纸、技术协议及相关标准要求，为增材制造与精密堆焊业务提供质量保障。

This procedure is established to standardize the welding process execution, non-destructive testing and dimensional inspection of cladded pipe joints (including flange cladding, pipe fitting cladding, steel pipe cladding, shaft sleeve cladding) at Cladding-Technology-Shanxi-Co.,-Ltd, ensuring that cladding product quality meets design drawings, technical agreements and relevant standard requirements, providing quality assurance for additive manufacturing and precision cladding services.

## 2 适用范围 Scope

本程序适用于公司以下堆焊产品的焊接、无损检测与尺寸检验：

- 法兰堆焊（Flange Cladding）
- 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）

This procedure applies to the welding, NDT and dimensional inspection of the following cladded products:

- Flange Cladding
- Pipe Fitting Cladding
- Steel Pipe Cladding
- Shaft Sleeve Cladding
- Mold Cladding Repair

# 3 职责 Responsibilities

| 部门/岗位 | 职责 |
| --- | --- |
| 生产部 Production Department | 负责堆焊管接头焊接作业的执行，确保焊接工艺参数符合 WPS 要求 |
| 质量技术部 Quality & Technical Department | 负责制定焊接工艺规程（WPS/PQR），编制检验计划，组织实施无损检测与尺寸检验 |
| 焊接工程师 Welding Engineer | 负责焊接工艺评定、焊工资格管理、焊接过程技术指导 |
| 无损检测人员 NDT Personnel | 负责堆焊层超声波检测（UT）、射线检测（RT）、渗透检测（PT）等无损检测作业 |
| 检验员 Inspector | 负责堆焊层尺寸测量、外观检查、记录检验数据 |
| 设备部 Equipment Department | 负责 TIG/MIG 堆焊设备、无损检测设备的维护保养与校准 |

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

## 4.1 焊接前准备 Pre-welding Preparation

### *4.1.1 母材与焊材管理*

- 母材（基材）应查验材质证明书，确认化学成分与力学性能符合设计要求
- 焊丝、焊条等堆焊材料应查验质量证明文件，核对牌号、规格与 WPS 一致
- 焊材应按牌号、规格分类存放，做好标识，防止混料
- 焊丝使用前应清除表面油污、锈蚀，必要时进行烘干处理
- Base material shall be verified with material certificates, confirming chemical composition and mechanical properties meet design requirements
- Cladding materials (welding wire, electrodes) shall be verified with quality certificates, confirming grade and specification match WPS requirements
- Welding materials shall be stored separately by grade and specification with proper identification to prevent mixing
- Welding wire shall be cleaned of oil, rust before use, and dried when necessary

### *4.1.2 坡口准备与装配*

- 根据 WPS 要求对管接头进行坡口加工，坡口形式、尺寸应符合工艺文件规定

- 装配间隙、错边量应符合标准要求，一般错边量不超过壁厚的 10%且不超过 2mm
- 装配后应进行点固焊，点固焊缝应均匀分布，长度一般为 20-30mm
- 装配完成后进行外观检查，确认合格后进行正式焊接
- Groove preparation shall be performed according to WPS requirements, groove form and dimensions shall comply with process document specifications
- Assembly gap and misalignment shall meet standard requirements, misalignment generally shall not exceed 10% of wall thickness and shall not exceed 2mm
- Tack welding shall be performed after assembly, tack welds shall be evenly distributed with length of 20-30mm
- Visual inspection shall be conducted after assembly, formal welding proceeds after qualification

#### *4.1.3 设备与工装检查*

- TIG/MIG 堆焊设备应处于良好状态，电流、电压、送丝速度等参数可正常调节
- 焊枪、导电嘴、喷嘴等易损件应检查更换，确保焊接过程稳定
- 保护气体（Ar 气或 Ar+$CO_2$混合气）纯度应≥99.99%，流量按 WPS 设定
- 工件定位工装应稳固可靠，确保焊接过程中工件不发生位移
- TIG/MIG cladding equipment shall be in good condition, current, voltage, wire feed speed shall be adjustable normally
- Consumables (torch, contact tip, nozzle) shall be inspected and replaced to ensure stable welding process
- Shielding gas (Ar or Ar+$CO_2$ mixture) purity shall be ≥99.99%, flow rate set per WPS
- Workpiece positioning fixtures shall be secure and reliable to prevent displacement during welding

### 4.2 焊接工艺执行 Welding Process Execution

#### *4.2.1 焊接工艺参数*

| 工艺参数 | TIG 堆焊 | MIG 堆焊 |
|---|---|---|
| 焊接电流 Welding Current | 80-160A | 150-300A |
| 焊接电压 Welding Voltage | 12-18V | 22-30V |
| 焊接速度 Welding Speed | 50-150mm/min | 200-500mm/min |
| 送丝速度 Wire Feed Speed | - | 3-8m/min |
| 保护气流量 Gas Flow Rate | 10-15L/min | 15-25L/min |
| 层间温度 Interpass Temperature | ≤150℃ | ≤200℃ |

#### *4.2.2 焊接操作要求*

- 焊工应持有相应项目的有效资格证书，按 WPS 要求进行焊接作业
- 堆焊前应对基材表面进行预热，预热温度按 WPS 规定执行，一般碳钢预热至 100-150℃
- 堆焊层数应根据堆焊厚度确定，单层堆焊厚度一般不超过 4mm
- 每层焊接完成后应清除焊渣、飞溅，进行层间检查
- 严格控制层间温度，防止过热导致稀释率升高或晶粒粗化
- TIG 堆焊应采用低稀释率工艺，确保堆焊层与基材界面清晰
- MIG 堆焊应控制熔深，避免过度熔入基材
- Welders shall hold valid qualification certificates for corresponding items and perform welding per WPS requirements
- Preheating shall be applied to base material surface before cladding, preheating temperature per WPS, generally carbon steel preheated to 100-150℃
- Number of cladding layers shall be determined based on cladding thickness, single layer thickness generally shall not exceed 4mm
- After each layer, slag and spatter shall be removed, interpass inspection shall be conducted
- Interpass temperature shall be strictly controlled to prevent overheating causing increased dilution rate or grain coarsening
- TIG cladding shall adopt low dilution rate process to ensure clear interface between cladding layer and base material
- MIG cladding shall control penetration depth to avoid excessive melting into base material

#### *4.2.3 焊接顺序*

- 管接头环焊缝应采用分段退焊法，减少焊接变形
- 堆焊层应采用螺旋式或环形堆焊，每层错开 1/3-1/2 圈
- 多层堆焊时，相邻层焊缝应错开，避免热输入集中
- 焊接方向应保持一致，确保堆焊层组织均匀
- Circumferential welds of pipe joints shall adopt segmented back-step welding to reduce welding distortion
- Cladding layers shall adopt spiral or circumferential cladding, each layer offset by 1/3-1/2 turn
- For multi-layer cladding, adjacent layer welds shall be staggered to avoid concentrated heat input
- Welding direction shall remain consistent to ensure uniform cladding layer structure

### 4.3 堆焊层无损检测 NDT of Cladding Layer

#### *4.3.1 检测时机*

- 外观检查：每层焊接完成后立即进行
- 渗透检测（PT）：堆焊完成后，热处理前进行

- 超声波检测（UT）：堆焊完成后，热处理后进行
- 射线检测（RT）：根据技术协议要求，必要时进行
- Visual inspection: Immediately after each layer welding
- Penetrant testing (PT): After cladding , before heat treatment
- Ultrasonic testing (UT): After cladding , after heat treatment
- Radiographic testing (RT): According to technical agreement requirements, when necessary

### *4.3.2 外观检查 Visual Inspection*

| 检查项目 | 合格标准 |
|---|---|
| 焊缝外观 | 表面平整，无裂纹、气孔、夹渣、未熔合等缺陷 |
| 焊缝尺寸 | 宽度、余高符合图纸要求，偏差±1mm |
| 咬边 | 深度≤0.5mm，连续长度≤100mm |
| 飞溅 | 清除干净，不得残留 |
| 堆焊层过渡 | 与基材过渡圆滑，无突变 |

| Inspection Item | Acceptance Criteria |
|---|---|
| Weld Appearance | Surface smooth, no cracks, porosity, slag inclusion, lack of fusion |
| Weld Dimensions | Width, reinforcement meet drawing requirements, deviation ±1mm |
| Undercut | Depth ≤0.5mm, continuous length ≤100mm |
| Spatter | Cleaned thoroughly, no residue |
| Cladding Transition | Smooth transition to base material, no abrupt change |

### *4.3.3 渗透检测（PT）*

- 检测标准：NB/T 47013.5 或 GB/T 15825
- 检测范围：堆焊层表面及与基材过渡区
- 灵敏度等级：荧光法采用 A 级，着色法采用 B 级
- 合格标准：
- 不允许存在线性显示（裂纹、未熔合）
- 圆形显示直径≤1.5mm，且间距≥3mm
- 不允许存在密集气孔

- Testing standard: NB/T 47013.5 or GB/T 15825
- Testing scope: Cladding layer surface and transition zone with base material
- Sensitivity level: Fluorescent method Grade A, Dye penetrant method Grade B
- Acceptance criteria:
- No linear indications (cracks, lack of fusion) allowed
- Circular indications diameter ≤1.5mm, spacing ≥3mm
- No dense porosity allowed

#### *4.3.4 超声波检测（UT）*

- 检测标准：NB/T 47013.3 或 JB/T 4730.3
- 检测范围：堆焊层与基材界面、堆焊层内部
- 探头频率：2.5MHz-5MHz
- 检测灵敏度：Φ2 平底孔当量
- 合格标准：
- 堆焊层与基材界面不允许存在未熔合
- 堆焊层内部不允许存在大于Φ1.5mm 当量的缺陷
- 不允许存在延伸性缺陷
- Testing standard: NB/T 47013.3 or JB/T 4730.3
- Testing scope: Interface between cladding layer and base material, inside cladding layer
- Probe frequency: 2.5MHz-5MHz
- Testing sensitivity: Φ2 flat-bottom hole equivalent
- Acceptance criteria:
- No lack of fusion allowed at interface between cladding layer and base material
- No defects greater than Φ1.5mm equivalent allowed inside cladding layer
- No extended defects allowed

#### *4.3.5 射线检测（RT）*

- 检测标准：NB/T 47013.2
- 检测范围：根据技术协议确定
- 射线等级：AB 级
- 合格标准：
- 不允许存在裂纹、未熔合、未焊透
- 点状缺陷按标准评定
- 条状缺陷按标准评定
- Testing standard: NB/T 47013.2
- Testing scope: Determined according to technical agreement
- Radiography grade: Grade AB

- Acceptance criteria:
- No cracks, lack of fusion, incomplete penetration allowed
- Point defects evaluated per standard
- Linear defects evaluated per standard

## 4.4 尺寸检验 Dimensional Inspection

### *4.4.1 检验项目*

| 序号 | 检验项目 | 检验工具 | 合格标准 |
|---|---|---|---|
| 1 | 堆焊层厚度 | 超声波测厚仪/千分尺 | 符合图纸要求，偏差±0.5mm |
| 2 | 堆焊层宽度 | 游标卡尺/钢尺 | 符合图纸要求，偏差±1mm |
| 3 | 内径/外径 | 内径千分尺/外径千分尺 | 符合图纸要求，按公差等级评定 |
| 4 | 长度 | 钢尺/卷尺 | 符合图纸要求，偏差±2mm |
| 5 | 圆度 | 圆度仪/三坐标 | 符合图纸要求 |
| 6 | 直线度 | 平尺/拉线法 | 符合图纸要求 |
| 7 | 同轴度 | 三坐标测量仪 | 符合图纸要求 |

| No. | Inspection Item | Inspection Tool | Acceptance Criteria |
|---|---|---|---|
| 1 | Cladding Layer Thickness | Ultrasonic Thickness Gauge/Micrometer | Per drawing requirements, deviation ±0.5mm |
| 2 | Cladding Layer Width | Vernier Caliper/Steel Ruler | Per drawing requirements, deviation ±1mm |
| 3 | ID/OD | Internal Micrometer/External Micrometer | Per drawing requirements, evaluated per tolerance grade |
| 4 | Length | Steel Ruler/Tape Measure | Per drawing requirements, deviation ±2mm |

| | | | |
|---|---|---|---|
| 5 | Roundness | Roundness Tester/CMM | Per drawing requirements |
| 6 | Straightness | Straightedge/String Line Method | Per drawing requirements |
| 7 | Coaxiality | CMM | Per drawing requirements |

#### *4.4.2 检验方法*

- 堆焊层厚度测量：沿堆焊层圆周方向均匀选取不少于 4 个测点，取平均值
- 内径/外径测量：在堆焊区域两端及中间位置各测量一次，取最大值与最小值
- 长度测量：使用钢尺或卷尺测量堆焊区域总长度
- 圆度测量：使用三坐标测量仪或圆度仪进行测量
- 同轴度测量：使用三坐标测量仪测量堆焊层内外表面的同轴度
- Cladding layer thickness measurement: Select no less than 4 measurement points evenly along the circumference, take average value
- ID/OD measurement: Measure at both ends and middle of cladding area, take maximum and minimum values
- Length measurement: Use steel ruler or tape measure to measure total length of cladding area
- Roundness measurement: Use CMM or roundness tester
- Coaxiality measurement: Use CMM to measure coaxiality of inner and outer surfaces of cladding layer

#### *4.4.3 检验记录*

- 所有尺寸检验数据应记录在《堆焊产品尺寸检验记录表》中
- 检验记录应包含：产品名称、规格、图号、检验日期、检验人员、检验数据
- 检验记录应保存至产品交付后至少 5 年
- All dimensional inspection data shall be recorded in "Cladding Product Dimensional Inspection Record"
- Inspection records shall include: product name, specification, drawing number, inspection date, inspector, inspection data
- Inspection records shall be retained for at least 5 years after product delivery

### 4.5 不合格品处理 Non-conforming Product Disposition

- 发现不合格项时，应立即标识并隔离
- 质量技术部组织评审，确定处置方案（返工、返修、让步接收、报废）
- 返工/返修后应重新进行相关检验

- 不合格品处置记录应完整保存
- When non-conformity is found, it shall be immediately identified and isolated
- Quality & Technical Department shall organize review to determine disposition (rework, repair, concession acceptance, scrap)
- Re-inspection shall be conducted after rework/repair
- Non-conforming product disposition records shall be fully retained

## 5 监督考核 Supervision and Assessment

- 质量技术部每月对堆焊产品质量进行统计分析，计算一次合格率
- 对连续出现质量问题的工序或人员，应组织专项培训
- 年度质量目标：堆焊产品一次合格率≥98%，客户投诉率≤1%
- 对违反本程序规定的行为，按公司质量奖惩制度执行
- Quality & Technical Department shall conduct monthly statistical analysis of cladding product quality, calculate first-pass yield rate
- For processes or personnel with continuous quality issues, special training shall be organized
- Annual quality targets: Cladding product first-pass yield rate ≥98%, customer complaint rate ≤1%
- For violations of this procedure, company quality reward and punishment shall be enforced

## 6 相关文件 Related Documents

| 文件编号 | 文件名称 |
|---|---|
| CLADDING-WPS-001 | TIG 堆焊焊接工艺规程 |
| CLADDING-WPS-002 | MIG 堆焊焊接工艺规程 |
| CLADDING-QP-001 | 焊接工艺评定程序 |
| CLADDING-QP-002 | 焊工资格管理程序 |
| CLADDING-QP-003 | 无损检测管理程序 |
| CLADDING-QP-004 | 不合格品控制程序 |

## 7 记录表格 Records

| 记录编号 | 记录名称 |
|---|---|

| | |
|---|---|
| CLADDING-REC-001 | 堆焊产品焊接记录表 |
| CLADDING-REC-002 | 堆焊产品外观检查记录表 |
| CLADDING-REC-003 | 堆焊产品渗透检测记录表 |
| CLADDING-REC-004 | 堆焊产品超声波检测记录表 |
| CLADDING-REC-005 | 堆焊产品尺寸检验记录表 |
| CLADDING-REC-006 | 不合格品处置记录表 |

## 8 附则 Supplementary Provisions

- 本程序由质量技术部负责解释和修订
- 本程序自发布之日起生效，原有相关程序同时废止
- 本程序每年评审一次，必要时进行修订
- 本程序修订时，应更新文件版本号和生效日期
- This procedure shall be interpreted and revised by Quality & Technical Department
- This procedure shall take effect from the date of release, previous related procedures shall be simultaneously abolished
- This procedure shall be reviewed annually, revised when necessary
- When this procedure is revised, document version number and effective date shall be updated

**科雷丁技术（山西）有限公司**

**Cladding-Technology-Shanxi-Co.,-Ltd**

**质量技术部**

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