



Cladding-Technology-Shanxi-Co.,-Ltd- CLADDING-ITP-002-Cladding-Elbow-ITP

堆焊弯头全流程检验与试验计划

Cladding Elbow Full Process Inspection and Test Plan

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1. 目的 Purpose

本检验与试验计划（ITP）旨在规范科雷丁技术（山西）有限公司堆焊弯头产品从原材料入厂到成品出厂的全过程质量控制活动，确保 TIG/MIG 堆焊工艺参数受控、焊缝质量符合设计要求、热处理工艺有效执行、无损检测覆盖全面，最终交付符合 ASME B16.9、GB/T 12459 及相关客户技术协议的堆焊弯头产品。

This Inspection and Test Plan (ITP) is established to standardize the quality control activities throughout the entire process of cladding elbow products at CLADDING Technology (Shanxi) Co., Ltd., from raw material incoming to finished product delivery. The plan ensures that TIG/MIG



cladding process parameters are controlled, weld quality meets design requirements, heat treatment processes are effectively executed, and non-destructive testing is comprehensively covered, ultimately delivering cladding elbow products that comply with ASME B16.9, GB/T 12459 and relevant customer technical specifications.

2. 适用范围 Scope

本 ITP 适用于公司生产的各类堆焊弯头产品，包括但不限于：

This ITP applies to all types of cladding elbow products manufactured by the company, including but not limited to:

- 碳钢/低合金钢基体堆焊不锈钢弯头 Carbon steel/low alloy steel base material with stainless steel cladding elbows
- 碳钢/低合金钢基体堆焊镍基合金弯头 Carbon steel/low alloy steel base material with nickel-based alloy cladding elbows
- 双金属复合弯头（TIG/MIG 工艺） Bi-metallic composite elbows (TIG/MIG process)
- 大口径厚壁堆焊弯头 Large diameter thick-wall cladding elbows
- 高压管道用堆焊弯头 High-pressure pipeline cladding elbows

适用工艺范围：TIG 堆焊（钨极惰性气体保护焊）、MIG 堆焊（熔化极惰性气体保护焊）、电弧增材制造（WAAM）。

Applicable process scope: TIG cladding (Tungsten Inert Gas welding), MIG cladding (Metal Inert Gas welding), Wire Arc Additive Manufacturing (WAAM).

3. 职责 Responsibilities

3.1 质量部 Quality Department

- 负责本 ITP 的编制、修订与解释
- Responsible for the preparation, revision and interpretation of this ITP
- 负责全过程检验与试验活动的组织实施
- Responsible for the organization and implementation of inspection and test activities throughout the process
- 负责检验记录、试验报告的归档管理
- Responsible for the archiving and management of inspection records and test reports
- 负责不合格品的判定与处置跟踪
- Responsible for the determination and disposal tracking of non-conforming products



3.2 生产部 Production Department

- 负责按工艺规程执行弯头成形、堆焊、热处理作业
- Responsible for executing elbow forming, cladding and heat treatment operations according to process specifications
- 负责设备日常维护与点检
- Responsible for daily equipment maintenance and inspection
- 负责生产过程中的自检与互检
- Responsible for self-inspection and mutual inspection during production

3.3 技术部 Technical Department

- 负责编制焊接工艺规程（WPS）及工艺评定（PQR）
- Responsible for preparing Welding Procedure Specifications (WPS) and Procedure Qualification Records (PQR)
- 负责热处理工艺规程的制定
- Responsible for the development of heat treatment process specifications
- 负责解决生产过程中的技术问题
- Responsible for resolving technical issues during production

3.4 采购部 Procurement Department

- 负责原材料、焊材的采购及供应商资质管理
- Responsible for procurement of raw materials and welding consumables and supplier qualification management
- 负责索取并归档材质证明书
- Responsible for obtaining and archiving material certificates

3.5 设备部 Equipment Department

- 负责堆焊设备、热处理设备的维护保养
- Responsible for maintenance of cladding equipment and heat treatment equipment
- 负责检测设备、量具的校准管理
- Responsible for calibration management of inspection equipment and measuring tools

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

4.1 检验与试验流程总览 Inspection and Test Process Overview

序	工序	检验项目	检验方法	检验频次	责任部门	记录文件
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号 No ·	Process	Inspection Item	Inspection Method	Inspection Frequency	Responsible Dept.	Record Document
1	原材料入 厂 Raw Material Incoming	材质证明核 查 Material Certificate Verification	文件审查 Document Review	每批次 Each Batch	采购部/质量部 Procurement/Qualit y	材质证明 Material Certificate
2	原材料入 厂 Raw Material Incoming	化学成分分 析 Chemical Composition Analysis	光谱分析 Spectral Analysis	每批次 Each Batch	质量部 Quality	化学成分报 告 Chemical Analysis Report
3	原材料入 厂 Raw Material Incoming	力学性能试 验 Mechanical Property Test	拉伸/冲击试验 Tensile/Impact Test	每批次 Each Batch	质量部 Quality	力学性能报 告 Mechanical Property Report
4	原材料入 厂 Raw Material Incoming	外观尺寸检 查 Appearance and Dimension Check	目视/量具 Visual/Measurin g Tools	每批次 Each Batch	质量部 Quality	入厂检验记 录 Incoming Inspection Record
5	弯头成形 Elbow Forming	成形后尺寸 检查 Post- forming Dimension Check	量具测量 Measuring Tools	每件 Each Piece	生产部/质量部 Production/Quality	成形检验记 录 Forming Inspection Record
6	弯头成形 Elbow Forming	成形后外观 检查 Post- forming Appearance Check	目视检查 Visual Inspection	每件 Each Piece	生产部 Production	成形检验记 录 Forming Inspection Record
7	焊前准备 Pre-weld Preparatio n	坡口加工检 查 Groove Preparation Check	量具/样板 Measuring Tools/Gauge	每件 Each Piece	生产部 Production	焊前检查记 录 Pre-weld Inspection Record
8	焊前准备	焊材核查	文件审查	每批次 Each	质量部 Quality	焊材检查记



	Pre-weld Preparation	Welding Consumable Verification	Document Review	Batch		录 Consumable Inspection Record
9	焊前准备 Pre-weld Preparation	设备状态确认 Equipment Status Confirmation	点检表 Check Sheet	每班 Each Shift	生产部 Production	设备点检记录 Equipment Check Record
10	堆焊作业 Cladding Operation	焊接工艺参数监控 Welding Parameter Monitoring	设备读数/记录 Equipment Reading/Record	连续监控 Continuous	生产部 Production	焊接参数记录 Welding Parameter Record
11	堆焊作业 Cladding Operation	层间温度控制 Interpass Temperature Control	测温仪 Temperature Measuring Device	每层 Each Layer	生产部 Production	层间温度记录 Interpass Temperature Record
12	堆焊作业 Cladding Operation	堆焊层外观检查 Cladding Layer Appearance Check	目视检查 Visual Inspection	每层 Each Layer	生产部/质量部 Production/Quality	堆焊过程检验记录 Cladding Process Inspection Record
13	堆焊作业 Cladding Operation	堆焊层厚度测量 Cladding Layer Thickness Measurement	超声波测厚仪 Ultrasonic Thickness Gauge	每层 Each Layer	质量部 Quality	堆焊厚度记录 Cladding Thickness Record
14	堆焊作业 Cladding Operation	稀释率控制 Dilution Rate Control	金相分析 Metallographic Analysis	首件/关键件 First Article/Critical	质量部 Quality	稀释率检测报告 Dilution Rate Test Report
15	焊后处理 Post-weld Treatment	焊后外观检查 Post-weld Appearance Check	目视检查 Visual Inspection	每件 Each Piece	质量部 Quality	焊后检验记录 Post-weld Inspection Record



16	焊后处理 Post-weld Treatment	焊缝尺寸检 查 Weld Dimension Check	量具测量 Measuring Tools	每件 Each Piece	质量部 Quality	焊缝尺寸记 录 Weld Dimension Record
17	焊后处理 Post-weld Treatment	焊缝余高检 查 Weld Reinforcemen t Check	焊缝量规 Weld Gauge	每件 Each Piece	质量部 Quality	焊缝余高记 录 Weld Reinforcemen t Record
18	热处理 Heat Treatment	热处理工艺 参数监控 Heat Treatment Parameter Monitoring	温度记录仪 Temperature Recorder	连续监控 Continuous	生产部 Production	热处理曲线 记录 Heat Treatment Curve Record
19	热处理 Heat Treatment	炉温均匀性 验证 Furnace Temperature Uniformity Verification	热电偶 Thermocouple	每季度/新炉 Each Quarter/New Furnace	质量部 Quality	炉温均匀性 报告 Furnace Uniformity Report
20	热处理 Heat Treatment	热处理后硬 度检测 Post- HT Hardness Test	布氏/洛氏硬度 计 Brinell/Rockwell Hardness Tester	每件 Each Piece	质量部 Quality	硬度检测报 告 Hardness Test Report
21	无损检测 NDT	渗透检测 (PT) Penetrant Testing	PT 检测 PT Inspection	每件 Each Piece	质量部/外委 Quality/Outsource	PT 检测报告 PT Test Report
22	无损检测 NDT	磁粉检测 (MT) Magnetic Particle Testing	MT 检测 MT Inspection	每件 Each Piece	质量部/外委 Quality/Outsource	MT 检测报告 MT Test Report
23	无损检测 NDT	超声波检测 (UT) Ultrasonic Testing	UT 检测 UT Inspection	每件 Each Piece	质量部/外委 Quality/Outsource	UT 检测报告 UT Test Report



24	无损检测 NDT	射线检测 (RT) Radiographic Testing	RT 检测 RT Inspection	按协议要求 Per Agreement	质量部/外委 Quality/Outsource	RT 检测报告 RT Test Report
25	成品检验 Final Inspection	成品尺寸检 查 Final Dimension Check	量具/三坐标 Measuring Tools/CMM	每件 Each Piece	质量部 Quality	成品检验记 录 Final Inspection Record
26	成品检验 Final Inspection	成品外观检 查 Final Appearance Check	目视检查 Visual Inspection	每件 Each Piece	质量部 Quality	成品检验记 录 Final Inspection Record
27	成品检验 Final Inspection	堆焊层厚度 最终确认 Final Cladding Thickness Confirmation	超声波测厚仪 Ultrasonic Thickness Gauge	每件 Each Piece	质量部 Quality	成品检验记 录 Final Inspection Record
28	成品检验 Final Inspection	标识与追溯 性检查 Marking and Traceability Check	目视检查 Visual Inspection	每件 Each Piece	质量部 Quality	成品检验记 录 Final Inspection Record
29	包装发运 Packing and Shipping	包装防护检 查 Packing Protection Check	目视检查 Visual Inspection	每批 Each Batch	生产部/质量部 Production/Quality	发运检查记 录 Shipping Inspection Record

4.2 原材料入厂检验 Incoming Material Inspection

4.2.1 基体材料检验 Base Material Inspection

基体材料（碳钢/低合金钢管材）入厂后，质量部依据采购合同及技术协议进行以下检验：

After incoming of base material (carbon steel/low alloy steel pipe), Quality Department shall conduct the following inspections based on purchase contract and technical agreement:

化学成分检验 Chemical Composition Inspection



采用光谱分析仪对基体材料化学成分进行逐批分析，检验项目包括 C、Si、Mn、P、S、Cr、Mo、Ni 等元素含量，确保符合 GB/T 3077 或 ASTM A335 等相关标准要求。

Chemical composition of base material shall be analyzed batch by batch using spectral analyzer, including elements such as C, Si, Mn, P, S, Cr, Mo, Ni, ensuring compliance with GB/T 3077 or ASTM A335 and other relevant standard requirements.

力学性能检验 Mechanical Property Inspection

每批次基体材料应进行拉伸试验和冲击试验，检验项目包括抗拉强度、屈服强度、延伸率、冲击功等，确保符合设计要求。

Each batch of base material shall undergo tensile test and impact test, including tensile strength, yield strength, elongation, impact energy, etc., ensuring compliance with design requirements.

外观及尺寸检查 Appearance and Dimension Inspection

- 表面质量：无裂纹、折叠、结疤、夹杂等缺陷 Surface quality: no cracks, laps, scabs, inclusions and other defects
- 外径及壁厚：符合 GB/T 12459 或客户图纸要求 OD and wall thickness: comply with GB/T 12459 or customer drawing requirements
- 直度：每米不超过 1.5mm Straightness: not exceeding 1.5mm per meter

4.2.2 堆焊焊材检验 Cladding Consumable Inspection

堆焊焊丝（ER309L、ER347、ERNiCrMo-3 等）入厂后应核查以下项目：

After incoming of cladding welding wire (ER309L, ER347, ERNiCrMo-3, etc.), the following items shall be verified:

- 焊丝牌号及规格 Welding wire grade and specification
- 化学成分证明 Chemical composition certificate
- 焊丝表面质量（无锈蚀、油污、机械损伤）Wire surface quality (no rust, oil stain, mechanical damage)
- 焊丝直径偏差 Wire diameter deviation
- 保护气体纯度（Ar≥99.99%）Shielding gas purity (Ar≥99.99%)

4.3 弯头成形检验 Elbow Forming Inspection

4.3.1 成形工艺参数记录 Forming Process Parameter Record

弯头成形（推弯/压弯工艺）过程中，生产部应记录以下参数：

During elbow forming (push bending/press bending process), Production Department shall record the following parameters:

参数 Parameter	控制要求 Control Requirement	记录频次 Record Frequency
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成形温度 Forming Temperature	按工艺规程要求 Per process specification	每次 Each time
成形速度 Forming Speed	按工艺规程要求 Per process specification	每次 Each time
弯制角度 Bending Angle	按图纸要求 Per drawing requirement	每件 Each piece
减薄率 Thinning Rate	≤15%（按标准） ≤15% (per standard)	每件 Each piece

4.3.2 成形后检验项目 Post-forming Inspection Items

尺寸检验 Dimension Inspection

- 弯曲半径：符合图纸要求，偏差±1% Bending radius: comply with drawing requirement, deviation ±1%
- 端部椭圆度：不超过公称外径的 1% End ovality: not exceeding 1% of nominal OD
- 壁厚减薄：最大减薄率不超过 15% Wall thinning: maximum thinning rate not exceeding 15%
- 直边长度：符合图纸要求 Straight length: comply with drawing requirement

外观检验 Appearance Inspection

- 表面无裂纹、褶皱、起皱 Surface without cracks, wrinkles, corrugation
- 内外表面光滑，无机械损伤 Inner and outer surface smooth, no mechanical damage
- 无过烧、氧化皮脱落现象 No overheating, scale peeling

4.4 焊前准备检验 Pre-weld Preparation Inspection

4.4.1 坡口加工检查 Groove Preparation Inspection

堆焊前，基体表面应进行坡口加工或预处理，检验要求如下：

Before cladding, base material surface shall be grooved or pre-treated, inspection requirements as follows:

- 坡口角度：30°±5°（TIG 堆焊）/ 不开坡口（MIG 堆焊） Groove angle: 30°±5° (TIG cladding) / No groove (MIG cladding)
- 坡口表面粗糙度：Ra≤6.3μm Groove surface roughness: Ra≤6.3μm
- 坡口边缘无毛刺、裂纹 Groove edge without burrs, cracks
- 待焊区域清洁度：无油污、锈蚀、氧化皮 Welding area cleanliness: no oil, rust, oxide scale

4.4.2 焊前预热检查 Preheating Inspection

根据 WPS 要求，对需要进行预热的工件进行预热温度检查：



According to WPS requirements, preheating temperature inspection shall be conducted for workpieces requiring preheating:

母材类型 Base Material Type	预热温度 Preheating Temperature	测温位置 Temperature Measurement Position
碳钢 Carbon Steel	100-150°C	距坡口 50mm 处 50mm from groove
低合金钢 Low Alloy Steel	150-200°C	距坡口 50mm 处 50mm from groove
高合金钢 High Alloy Steel	按 WPS 要求 Per WPS	距坡口 50mm 处 50mm from groove

4.5 堆焊过程检验 Cladding Process Inspection

4.5.1 TIG 堆焊工艺参数监控 TIG Cladding Parameter Monitoring

TIG 堆焊过程中，生产部应实时监控并记录以下工艺参数：

During TIG cladding process, Production Department shall monitor and record the following process parameters in real time:

参数 Parameter	控制范围 Control Range	监控方式 Monitoring Method
焊接电流 Welding Current	80-160A（按 WPS）	设备显示 Equipment Display
电弧电压 Arc Voltage	12-18V（按 WPS）	设备显示 Equipment Display
焊接速度 Welding Speed	50-150mm/min（按 WPS）	设备显示/计时 Equipment Display/Timing
钨极直径 Tungsten Electrode Diameter	φ2.4-φ4.0mm（按 WPS）	目视确认 Visual Confirmation
保护气体流量 Gas Flow Rate	10-15L/min	流量计 Flow Meter
摆动参数 Oscillation Parameters	按 WPS 要求	设备显示 Equipment Display

4.5.2 MIG 堆焊工艺参数监控 MIG Cladding Parameter Monitoring

MIG 堆焊过程中，生产部应实时监控并记录以下工艺参数：

During MIG cladding process, Production Department shall monitor and record the following process parameters in real time:



参数 Parameter	控制范围 Control Range	监控方式 Monitoring Method
焊接电流 Welding Current	180-300A（按 WPS）	设备显示 Equipment Display
电弧电压 Arc Voltage	24-32V（按 WPS）	设备显示 Equipment Display
送丝速度 Wire Feed Speed	4-8m/min（按 WPS）	设备显示 Equipment Display
焊接速度 Welding Speed	200-500mm/min（按 WPS）	设备显示/计时 Equipment Display/Timing
保护气体流量 Gas Flow Rate	15-25L/min	流量计 Flow Meter
干伸长 Dry Extension	10-15mm	目视确认 Visual Confirmation

4.5.3 层间温度控制 Interpass Temperature Control

堆焊过程中，层间温度应严格控制，防止过热导致稀释率过高或组织劣化：

During cladding process, interpass temperature shall be strictly controlled to prevent excessive dilution rate or microstructure deterioration caused by overheating:

堆焊材料 Cladding Material	层间温度上限 Maximum Interpass Temperature	测温方法 Temperature Measurement Method
ER309L	$\leq 200^{\circ}\text{C}$	红外测温仪/测温笔 Infrared Thermometer/Temperature Pen
ER347	$\leq 200^{\circ}\text{C}$	红外测温仪/测温笔 Infrared Thermometer/Temperature Pen
ERNiCrMo-3	$\leq 150^{\circ}\text{C}$	红外测温仪/测温笔 Infrared Thermometer/Temperature Pen

4.5.4 堆焊层外观检查 Cladding Layer Appearance Inspection

每层堆焊完成后，应进行外观检查，检查项目包括：

After of each cladding layer, appearance inspection shall be conducted, including:

- 焊缝成形：均匀、平整，无咬边、未熔合 Weld bead formation: uniform, flat, no undercut, lack of fusion
- 表面缺陷：无气孔、裂纹、夹渣 Surface defects: no porosity, cracks, slag inclusion
- 焊缝宽度：符合 WPS 要求 Weld width: comply with WPS requirement
- 焊缝余高：0-2mm Weld reinforcement: 0-2mm
- 层间清渣：彻底清除，无残留 Slag removal between layers: thoroughly cleaned, no residue



4.5.5 堆焊层厚度控制 *Cladding Layer Thickness Control*

堆焊层厚度是堆焊弯头的关键质量指标，应采用超声波测厚仪逐层测量：

Cladding layer thickness is a critical quality indicator for cladding elbows, and ultrasonic thickness gauge shall be used for layer-by-layer measurement:

- 测量位置：弯头内外表面均匀分布不少于 6 个测点 Measurement position: at least 6 measuring points evenly distributed on inner and outer surfaces of elbow
- 测量频次：每层堆焊完成后测量 Measurement frequency: after of each cladding layer
- 厚度公差：符合图纸要求，一般 $\pm 0.5\text{mm}$ Thickness tolerance: comply with drawing requirement, generally $\pm 0.5\text{mm}$
- 记录要求：每个测点数据应记录在《堆焊厚度记录表》中 Record requirement: data of each measuring point shall be recorded in Cladding Thickness Record

4.5.6 稀释率控制 *Dilution Rate Control*

稀释率是评价堆焊质量的重要指标，直接影响堆焊层的化学成分和性能：

Dilution rate is an important indicator for evaluating cladding quality, directly affecting the chemical composition and properties of cladding layer:

- 检测方法：金相分析（截取堆焊试样，制备金相试样，测量稀释率） Test method: Metallographic analysis (cut cladding sample, prepare metallographic specimen, measure dilution rate)
- 控制要求：TIG 堆焊稀释率 $\leq 10\%$ ，MIG 堆焊稀释率 $\leq 15\%$ Control requirement: TIG cladding dilution rate $\leq 10\%$, MIG cladding dilution rate $\leq 15\%$
- 检验频次：首件必检，批量生产时按每批次抽检 Inspection frequency: mandatory for first article, sampling inspection per batch during mass production

4.6 焊后处理检验 *Post-weld Treatment Inspection*

4.6.1 焊后外观检查 *Post-weld Appearance Inspection*

堆焊完成后，质量部应对堆焊层进行 100%外观检查：

After of cladding, Quality Department shall conduct 100% appearance inspection of cladding layer:

检查项目 *Inspection Items*

- 堆焊层表面质量：无裂纹、气孔、夹渣、未熔合 Cladding layer surface quality: no cracks, porosity, slag inclusion, lack of fusion
- 堆焊层与母材过渡：平滑过渡，无咬边 Smooth transition between cladding layer and base material, no undercut



- 堆焊层表面粗糙度: $Ra \leq 12.5\mu m$ (粗堆焊) / $Ra \leq 6.3\mu m$ (精堆焊) Cladding layer surface roughness: $Ra \leq 12.5\mu m$ (rough cladding) / $Ra \leq 6.3\mu m$ (fine cladding)
- 堆焊层颜色: 均匀, 无严重氧化变色 Uniform color, no severe oxidation discoloration

缺陷处理 Defect Disposition

发现表面缺陷时, 应按以下程序处理:

When surface defects are found, they shall be disposed according to the following procedure:

- 缺陷标记与记录 Mark and record the defect
- 缺陷评估 (深度、长度、数量) Defect assessment (depth, length, quantity)
- 缺陷清除 (打磨/挖补) Defect removal (grinding/patching)
- 缺陷修补 (重新堆焊) Defect repair (re-cladding)
- 修补后复检 Re-inspection after repair

4.7 热处理检验 Heat Treatment Inspection

4.7.1 热处理工艺参数 Heat Treatment Process Parameters

堆焊弯头热处理 (消除应力热处理) 工艺参数如下:

Heat treatment (stress relief heat treatment) process parameters for cladding elbows are as follows:

参数 Parameter	控制要求 Control Requirement
加热速率 Heating Rate	$\leq 200^\circ C/h$ (壁厚 $\leq 25mm$) / $\leq 100^\circ C/h$ (壁厚 $> 25mm$)
保温温度 Holding Temperature	$620-680^\circ C$ (碳钢/低合金钢) / 按 WPS 要求 (不锈钢)
保温时间 Holding Time	按壁厚计算, 一般 $1h/25mm$
冷却速率 Cooling Rate	$\leq 200^\circ C/h$ (至 $300^\circ C$ 以下)
炉内气氛 Furnace Atmosphere	保护气氛或真空 (不锈钢)

4.7.2 热处理过程监控 Heat Treatment Process Monitoring

热处理过程中, 应使用温度记录仪连续监控并记录以下参数:

During heat treatment process, temperature recorder shall be used to continuously monitor and record the following parameters:

- 炉温曲线: 升温、保温、降温全过程 Furnace temperature curve: entire process of heating, holding, cooling



- 工件温度：使用热电偶监测工件实际温度 Workpiece temperature: monitor actual workpiece temperature using thermocouple
- 炉温均匀性：每季度进行一次炉温均匀性试验 Furnace temperature uniformity: conduct furnace uniformity test quarterly

4.7.3 热处理后硬度检测 Post-HT Hardness Test

热处理完成后，应对堆焊层和母材进行硬度检测：

After of heat treatment, hardness test shall be conducted on cladding layer and base material:

检测位置 Test Position	硬度要求 Hardness Requirement	检测方法 Test Method
堆焊层 Cladding Layer	按技术协议要求 Per technical agreement	布氏硬度 HBW
母材 Base Material	符合材料标准要求 Comply with material standard	布氏硬度 HBW
熔合线附近 Near Fusion Line	符合技术协议要求 Per technical agreement	维氏硬度 HV

4.8 无损检测 Non-destructive Testing

4.8.1 渗透检测 (PT) Penetrant Testing

堆焊层表面应进行 100%渗透检测，检查表面开口缺陷：

Cladding layer surface shall undergo 100% penetrant testing to inspect surface-breaking defects:

- 检测标准：NB/T 47013.5 或 ASME V Article 6 Test standard: NB/T 47013.5 or ASME V Article 6
- 检测比例：100%检测 Inspection ratio: 100%
- 验收标准：无线性显示，圆形显示按技术协议 Acceptance criteria: no linear indications, circular indications per technical agreement
- 检测时机：堆焊完成后、热处理前（或按技术协议） Test timing: after cladding, before heat treatment (or per technical agreement)

4.8.2 磁粉检测 (MT) Magnetic Particle Testing

对铁磁性堆焊层进行磁粉检测，检查表面及近表面缺陷：

Magnetic particle testing shall be conducted on ferromagnetic cladding layers to inspect surface and near-surface defects:



- 检测标准：NB/T 47013.4 或 ASME V Article 7 Test standard: NB/T 47013.4 or ASME V Article 7
- 检测比例：100%检测 Inspection ratio: 100%
- 验收标准：无裂纹显示，其他显示按技术协议 Acceptance criteria: no crack indications, other indications per technical agreement

4.8.3 超声波检测 (UT) Ultrasonic Testing

堆焊层与母材结合面应进行超声波检测，检查未熔合、裂纹等缺陷：

Ultrasonic testing shall be conducted on the interface between cladding layer and base material to inspect defects such as lack of fusion, cracks:

- 检测标准：NB/T 47013.3 或 ASME V Article 4 Test standard: NB/T 47013.3 or ASME V Article 4
- 检测比例：100%检测（关键件）/ 抽检（一般件） Inspection ratio: 100% (critical parts) / sampling (general parts)
- 验收标准：无未熔合、裂纹显示，其他显示按技术协议 Acceptance criteria: no lack of fusion, crack indications, other indications per technical agreement
- 检测时机：热处理后 Test timing: after heat treatment

4.8.4 射线检测 (RT) Radiographic Testing

根据技术协议要求，对堆焊层进行射线检测：

According to technical agreement requirements, radiographic testing shall be conducted on cladding layer:

- 检测标准：NB/T 47013.2 或 ASME V Article 2 Test standard: NB/T 47013.2 or ASME V Article 2
- 检测比例：按技术协议要求 Per technical agreement
- 验收标准：按技术协议或相关标准要求 Acceptance criteria: per technical agreement or relevant standard

4.9 成品检验 Final Inspection

4.9.1 成品尺寸检验 Final Dimension Inspection

成品弯头应进行以下尺寸检验：

Finished elbows shall undergo the following dimension inspections:

检验项目 Inspection Item	检验方法 Inspection Method	验收标准 Acceptance Criteria
外径 Outer Diameter	卡尺/千分尺 Caliper/Micrometer	符合图纸要求 Comply with drawing



壁厚 Wall Thickness	超声波测厚仪 Ultrasonic Thickness Gauge	符合图纸要求 Comply with drawing
弯曲半径 Bending Radius	样板/量具 Gauge/Measuring Tools	符合图纸要求 Comply with drawing
端部椭圆度 End Ovality	卡尺 Caliper	≤1% OD
直边长度 Straight Length	钢尺 Steel Ruler	符合图纸要求 Comply with drawing
堆焊层厚度 Cladding Layer Thickness	超声波测厚仪 Ultrasonic Thickness Gauge	符合图纸要求 Comply with drawing

4.9.2 成品外观检验 Final Appearance Inspection

成品弯头外观应满足以下要求：

Finished elbow appearance shall meet the following requirements:

- 堆焊层表面：光滑、均匀，无可见缺陷 Cladding layer surface: smooth, uniform, no visible defects
- 标识：产品标识清晰、完整 Marking: product marking clear and complete
- 包装：防护到位，无磕碰损伤 Packing: properly protected, no impact damage

4.9.3 标识与追溯性 Marking and Traceability

每件成品弯头应具有以下标识：

Each finished elbow shall have the following markings:

- 产品编号 Product Number
- 规格型号 Specification
- 堆焊材料牌号 Cladding Material Grade
- 生产日期 Production Date
- 检验状态标识 Inspection Status Marking
- 炉批号（追溯用） Heat Number (for traceability)

5. 监督考核 Supervision and Assessment

5.1 检验记录管理 Inspection Record Management

所有检验与试验记录应真实、完整、可追溯，保存期限不少于产品寿命周期或 10 年（取较长者）。



All inspection and test records shall be authentic, complete, and traceable, with retention period not less than product life cycle or 10 years (whichever is longer).

5.2 不合格品控制 Non-conforming Product Control

检验过程中发现的不合格品，应按《不合格品控制程序》执行，包括：

Non-conforming products found during inspection shall be handled according to Non-conforming Product Control Procedure, including:

- 标识与隔离 Identification and segregation
- 评审与处置 Review and disposition
- 纠正措施 Corrective action
- 验证确认 Verification and confirmation

5.3 检验人员资质 Inspection Personnel Qualification

从事无损检测的人员应持有相应级别的资格证书（RT/UT/MT/PT II 级及以上）。

Personnel engaged in non-destructive testing shall hold corresponding level qualification certificates (RT/UT/MT/PT Level II or above).

6. 附则 Supplementary Provisions

6.1 相关文件 Related Documents

- CLADDING-WPS-001 焊接工艺规程 Welding Procedure Specification
- CLADDING-WI-001 堆焊作业指导书 Cladding Work Instruction
- CLADDING-QP-001 不合格品控制程序 Non-conforming Product Control Procedure
- CLADDING-QP-002 检验与试验控制程序 Inspection and Test Control Procedure

6.2 相关记录 Related Records

- CLADDING-FM-001 入厂检验记录 Incoming Inspection Record
- CLADDING-FM-002 堆焊过程检验记录 Cladding Process Inspection Record
- CLADDING-FM-003 堆焊厚度记录 Cladding Thickness Record
- CLADDING-FM-004 热处理曲线记录 Heat Treatment Curve Record
- CLADDING-FM-005 成品检验记录 Final Inspection Record

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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A/0	2024-01-01	首次发布 First Issue	质量部 Quality Dept.
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