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-014-Cladding-Corrosion-Resistant-Pipe-Fitting-ITP

CLADDING-ITP-014 耐蚀堆焊管件晶间腐蚀试验、电化学测试与盐雾试验检验与试验计划

CLADDING-ITP-014 Inspection and Test Plan for Intergranular Corrosion Test, Electrochemical Test and Salt Spray Test of Corrosion-Resistant Clad Pipes

文件编号 Document No.	CLADDING-ITP-014
版本号 Version	A/0
生效日期 Effective Date	2024-01-01
编制 Prepared by	质量部 Quality Department
审核 Reviewed by	技术部 Technical Department
批准 Approved by	管理者代表 Management Representative

1. 目的 Purpose

本检验与试验计划旨在规范科雷丁技术（山西）有限公司在耐蚀堆焊管件产品制造过程中，针对晶间腐蚀试验、电化学测试与盐雾试验的检验与试验活动进行系统化管理，确保堆焊层及母材的耐蚀性能满足技术协议和相关标准要求，为产品质量提供可靠保障。

This Inspection and Test Plan aims to standardize the inspection and test activities for intergranular corrosion test, electrochemical test and salt spray test during the manufacturing process of corrosion-resistant clad pipes at CLADDING-Technology-Shanxi-Co.,-Ltd, ensuring that the corrosion resistance of the cladding layer and base material meets the requirements of technical agreements and relevant standards, providing reliable quality assurance for products.

2. 适用范围 Scope

本计划适用于公司生产的各类耐蚀堆焊管件产品，包括但不限于：

This plan applies to various types of corrosion-resistant clad pipe products manufactured by the company, including but not limited to:

- 法兰堆焊管件 Flanged clad pipes
- 管件堆焊产品 Pipe fitting clad products
- 钢管堆焊产品 Steel pipe clad products
- 轴套管堆焊产品 Shaft sleeve clad products
- 模具堆焊修复产品 Mold cladding repair products

涉及堆焊工艺包括 TIG 堆焊（低稀释率精密成型）、MIG 堆焊（高效熔敷自动化适配）及电弧增材制造工艺。

The cladding processes involved include TIG cladding (low dilution precision forming), MIG cladding (high-efficiency deposition with automation adaptation), and arc additive manufacturing processes.

3. 职责 Responsibilities

部门 Department	职责 Responsibilities
质量部 Quality Department	负责检验与试验计划的编制、执行监督与结果记录；组织晶间腐蚀试验、电化学测试与盐雾试验的实施；对不合格项进行跟踪处理
技术部 Technical Department	负责确定试验参数与工艺要求；提供试验标准依据；参与试验结果分析与技术判定

生产部 Production Department	负责按工艺要求完成堆焊作业；配合取样工作；对不合格品进行返工或返修
设备部 Equipment Department	负责试验设备的维护保养；确保检测设备处于有效校准状态

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

4.1 检验与试验项目 Inspection and Test Items

序号 No.	检验项目 Inspection Item	检验方法 Inspection Method	检验时机 Inspection Timing	检验频次 Inspection Frequency	判定标准 Acceptance Criteria	记录文件 Record Document
1	晶间腐蚀试验 Intergranular Corrosion Test	硫酸-硫酸铜法（GB/T 4334）或硝酸法（GB/T 4334）	堆焊完成后 After cladding	每批次 1 件/每 100 件不少于 1 件	弯曲试验无裂纹；腐蚀速率≤规定值	晶间腐蚀试验报告
2	电化学测试 Electrochemical Test	动电位极化曲线法（GB/T 20627）	堆焊完成后 After cladding	每批次 1 件	腐蚀电位、腐蚀电流密度满足技术要求	电化学测试报告
3	盐雾试验 Salt Spray Test	中性盐雾试验（GB/T 10125）	成品检验阶段 Final inspection stage	每批次 1 件/关键产品必检	试验周期内无红锈、无起泡、无剥落	盐雾试验报告

4.2 晶间腐蚀试验程序 Intergranular Corrosion Test Procedure

4.2.1 取样要求 Sampling Requirements

- 取样位置：堆焊层与母材过渡区及堆焊层表面
- Sampling position: transition zone between cladding layer and base material, and cladding layer surface
- 试样尺寸：10mm×10mm×厚度，表面粗糙度 Ra≤3.2μm
- Specimen size: 10mm×10mm×thickness, surface roughness Ra≤3.2μm

- 取样数量：每批次不少于 1 件，关键产品每 100 件不少于 1 件
- Sampling quantity: not less than 1 piece per batch, not less than 1 piece per 100 pieces for critical products

4.2.2 试验方法 Test Method

采用硫酸-硫酸铜法进行晶间腐蚀试验：

Intergranular corrosion test is conducted using the sulfuric acid-copper sulfate method:

- 腐蚀介质：25%硫酸溶液+25g/L 硫酸铜+0.5mL/L 硒粉
- Corrosion medium: 25% sulfuric acid solution + 25g/L copper sulfate + 0.5mL/L selenium powder
- 试验温度：95±2℃
- Test temperature: 95±2℃
- 试验时间：100 小时
- Test duration: 100 hours
- 弯曲试验：180°弯曲，弯心直径 d=3a（a 为试样厚度）
- Bending test: 180° bending, mandrel diameter d=3a (a is specimen thickness)

4.2.3 判定标准 Acceptance Criteria

- 弯曲试验后试样表面无肉眼可见裂纹
- No visible cracks on specimen surface after bending test
- 腐蚀速率不超过技术协议规定值（一般≤0.1mm/a）
- Corrosion rate shall not exceed the value specified in technical agreement (generally ≤0.1mm/a)

4.3 电化学测试程序 Electrochemical Test Procedure

4.3.1 试验设备 Test Equipment

- 电化学工作站（三电极系统）
- Electrochemical workstation (three-electrode)
- 参比电极：饱和甘汞电极（SCE）
- Reference electrode: Saturated calomel electrode (SCE)
- 辅助电极：铂片电极
- Auxiliary electrode: Platinum sheet electrode
- 电解池：耐腐蚀材质
- Electrolytic cell: Corrosion-resistant material

4.3.2 试验条件 Test Conditions

- 电解液：3.5%NaCl 溶液（模拟海水环境）或按技术协议要求

- Electrolyte: 3.5% NaCl solution (simulating seawater environment) or as required by technical agreement
- 试验温度：25±2℃
- Test temperature: 25±2℃
- 扫描速率：0.5mV/s
- Scan rate: 0.5mV/s
- 扫描范围：-250mV 至+500mV（相对于开路电位）
- Scan range: -250mV to +500mV (relative to open circuit potential)

4.3.3 测试参数 Test Parameters

- 开路电位（OCP）稳定时间：30 分钟
- Open circuit potential (OCP) stabilization time: 30 minutes
- 动电位极化曲线扫描
- Potentiodynamic polarization curve scanning
- 电化学阻抗谱（EIS）测试（可选）
- Electrochemical impedance spectroscopy (EIS) test (optional)

4.3.4 结果分析 Result Analysis

- 腐蚀电位（Ecorr）：越正耐蚀性越好
- Corrosion potential (Ecorr): more positive indicates better corrosion resistance
- 腐蚀电流密度（Icorr）：越小耐蚀性越好
- Corrosion current density (Icorr): smaller indicates better corrosion resistance
- 钝化区宽度：越宽耐蚀性越好
- Passivation region width: wider indicates better corrosion resistance

4.4 盐雾试验程序 Salt Spray Test Procedure

4.4.1 试验设备 Test Equipment

- 盐雾试验箱（符合 GB/T 10125 要求）
- Salt spray test chamber (complying with GB/T 10125 requirements)
- 喷雾方式：连续喷雾
- Spray mode: Continuous spray
- 温度控制：35±2℃
- Temperature control: 35±2℃
- 盐溶液浓度：5%NaCl（pH 值 6.5-7.2）
- Salt solution concentration: 5% NaCl (pH value 6.5-7.2)

4.4.2 试样要求 Specimen Requirements

- 试样尺寸：按产品实际尺寸或标准试样
- Specimen size: actual product size or standard specimen
- 试样数量：每批次不少于 1 件
- Specimen quantity: not less than 1 piece per batch
- 试样状态：堆焊完成后，表面清洁处理
- Specimen condition: after cladding , surface cleaned

4.4.3 试验周期 Test Duration

产品类别 Product Category	试验周期 Test Duration	判定标准 Acceptance Criteria
一般耐蚀堆焊管件 General corrosion-resistant clad pipes	500 小时	无红锈、无起泡、无剥落
高耐蚀堆焊管件 High corrosion-resistant clad pipes	1000 小时	无红锈、无起泡、无剥落
特殊要求产品 Special requirement products	按技术协议	按技术协议规定

4.4.4 试验后检查 Post-Test Inspection

- 目视检查：表面是否有红锈、白锈、起泡、剥落
- Visual inspection: red rust, white rust, blistering, peeling on surface
- 腐蚀面积评估：按 GB/T 10125 规定评级
- Corrosion area assessment: rating according to GB/T 10125
- 堆焊层完整性检查：是否有裂纹、剥离
- Cladding layer integrity inspection: cracks, delamination

4.5 不合格品处理 Non-Conforming Product Handling

4.5.1 不合格判定 Non-Conformance Determination

出现以下情况之一判定为不合格：

Non-conformance is determined when any of the following situations occurs:

- 晶间腐蚀试验弯曲后出现裂纹
- Cracks appear after bending in intergranular corrosion test
- 电化学测试腐蚀电流密度超过规定值
- Corrosion current density exceeds specified value in electrochemical test
- 盐雾试验出现红锈、起泡或剥落

- Red rust, blistering or peeling appears in salt spray test

4.5.2 处理措施 Handling Measures

- 分析原因：工艺参数、材料质量、设备状态等
- Analyze causes: process parameters, material quality, equipment status, etc.
- 制定纠正措施：调整堆焊工艺参数、更换焊材等
- Develop corrective actions: adjust cladding process parameters, change welding materials, etc.
- 返工或返修：按技术部批准的方案执行
- Rework or repair: execute according to the plan approved by Technical Department
- 重新检验：返工后重新进行相关试验
- Re-inspection: re-test after rework

5. 监督考核 Supervision and Assessment

5.1 监督内容 Supervision Content

- 检验与试验计划的执行情况
- Execution status of inspection and test plan
- 试验数据的真实性与准确性
- Authenticity and accuracy of test data
- 不合格品处理的及时性
- Timeliness of non-conforming product handling
- 试验设备的维护保养状况
- Maintenance status of test equipment

5.2 考核指标 Assessment Indicators

考核项目 Assessment Item	目标值 Target Value	考核周期 Assessment Period
试验计划执行率 Plan execution rate	100%	月度 Monthly
试验数据准确率 Data accuracy rate	≥99%	月度 Monthly
不合格品处理及时率 Non-conformance handling timeliness	≥95%	月度 Monthly
设备完好率 Equipment availability rate	≥98%	月度 Monthly

6. 附则 Supplementary Provisions

6.1 相关文件 Related Documents

- CLADDING-QP-001 质量手册 Quality Manual
- CLADDING-WI-012 堆焊工艺控制程序 Cladding Process Control Procedure
- CLADDING-WI-018 不合格品控制程序 Non-Conforming Product Control Procedure
- CLADDING-ITP-001 堆焊管件检验与试验计划 Clad Pipe Inspection and Test Plan

6.2 记录表格 Record Forms

- CLADDING-FM-ITP-014-01 晶间腐蚀试验记录表 Intergranular Corrosion Test Record Form
- CLADDING-FM-ITP-014-02 电化学测试记录表 Electrochemical Test Record Form
- CLADDING-FM-ITP-014-03 盐雾试验记录表 Salt Spray Test Record Form
- CLADDING-FM-ITP-014-04 不合格品处理记录表 Non-Conforming Product Handling Record Form

6.3 修订记录 Revision History

版本号 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	质量部 Quality Department

文件结束 End of Document