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-016-Cladding-Low-Temperature-Pipe-Fitting-ITP

检验与试验计划 ITP

文件编号：CLADDING-ITP-016

文件名称：低温堆焊管件低温冲击试验、韧性与硬度检验计划

页眉信息

左侧	右侧上部分	右侧下部分
D:\Documents\Cladding\logo.png	科雷丁技术（山西）有限公司	Cladding-Technology-Shanxi-Co.,-Ltd

INSPECTION AND TEST PLAN (ITP)

Document No.: CLADDING-ITP-016

Document Title: Low-Temperature Impact Test, Toughness and Hardness Inspection Plan for Low-Temperature Cladded Pipe Fittings

Header Information

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D:\Documents\Cladding\logo.png	科雷丁技术（山西）有限公司	Cladding-Technology-Shanxi-Co.,-Ltd

1. 目的 Purpose

1.1 中文

本检验与试验计划旨在规范科雷丁技术（山西）有限公司低温堆焊管件产品的低温冲击试验、韧性与硬度检验工作，确保堆焊层及母材在低温工况下的力学性能满足设计要求和相关标准规定，为产品质量提供可靠保障。

1.2 English

This Inspection and Test Plan is established to standardize the low-temperature impact testing, toughness and hardness inspection work for low-temperature cladded pipe fittings products of Cladding Technology (Shanxi) Co., Ltd., ensuring that the mechanical properties of the cladding layer and base metal under low-temperature service conditions meet design requirements and relevant standard specifications, providing reliable quality assurance for products.

2. 适用范围 Scope of Application

2.1 中文

本计划适用于公司采用 TIG 堆焊、MIG 堆焊及电弧增材制造工艺生产的低温堆焊管件产品，包括但不限于：

- 低温法兰堆焊管件
- 低温钢管堆焊产品
- 低温轴套管堆焊件
- 低温管件表面强化与再制造修复产品

适用堆焊材料包括但不限于：不锈钢堆焊层、镍基合金堆焊层、双相钢堆焊层及其他适用于低温工况的合金材料。

2.2 English

This plan applies to low-temperature cladded pipe fittings products manufactured by the company using TIG cladding, MIG cladding and arc additive manufacturing processes, including but not limited to:

- Low-temperature flange cladded pipe fittings
- Low-temperature steel pipe cladded products
- Low-temperature shaft sleeve cladded components
- Low-temperature pipe fitting surface strengthening and remanufacturing products

Applicable cladding materials include but are not limited to: stainless steel cladding layer, nickel-based alloy cladding layer, duplex steel cladding layer and other alloy materials suitable for low-temperature service conditions.

3. 职责 Responsibilities

3.1 中文

部门/岗位	职责内容
质量部	负责制定检验计划，组织实施低温冲击试验、韧性与硬度检验，出具检验报告
生产部	负责按工艺要求完成堆焊作业，配合取样工作，提供必要的生产记录
技术部	负责确定检验标准、工艺参数要求，提供技术支持
设备部	负责检验设备的维护保养，确保设备处于良好状态
项目经理	负责协调各部门工作，确保检验工作按计划执行

3.2 English

Department/Position	Responsibilities
Quality Department	Responsible for developing inspection plans, organizing and implementing low-temperature impact tests, toughness and hardness inspections, and issuing inspection reports
Production Department	Responsible for completing cladding operations according to process requirements, cooperating with sampling work, and providing necessary production records
Technical Department	Responsible for determining inspection standards and process parameter requirements, providing technical support
Equipment Department	Responsible for maintenance of inspection equipment, ensuring equipment is in good condition
Project Manager	Responsible for coordinating work among departments, ensuring inspection work is executed according to plan

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

4.1 检验依据 Inspection Basis

4.1.1 中文

序号	标准编号	标准名称
1	GB/T 229	金属材料夏比摆锤冲击试验方法
2	GB/T 230.1	金属洛氏硬度试验方法
3	GB/T 4340.1	金属维氏硬度试验方法
4	GB/T 15817	金属夏比摆锤冲击试验用缺口

		试样
5	NB/T 47014	承压设备焊接工艺评定
6	ASME Section II Part D	材料标准-力学性能
7	ASTM E23	金属材料夏比摆锤冲击试验标准方法
8	产品技术协议	客户特定技术要求

4.1.2 English

No.	Standard No.	Standard Name
1	GB/T 229	Method for Charpy Pendulum Impact Test of Metallic Materials
2	GB/T 230.1	Metallic Rockwell Hardness Test Method
3	GB/T 4340.1	Metallic Vickers Hardness Test Method
4	GB/T 15817	Notched Specimens for Charpy Pendulum Impact Test of Metallic Materials
5	NB/T 47014	Welding Procedure Qualification for Pressure Equipment
6	ASME Section II Part D	Material Standards - Mechanical Properties
7	ASTM E23	Standard Test Methods for Notched Bar Impact Testing of Metallic Materials
8	Product Technical Agreement	Customer-specific Technical Requirements

4.2 检验项目与要求 Inspection Items and Requirements

4.2.1 低温冲击试验 Low-Temperature Impact Test

4.2.1.1 中文

试验目的： 评估低温堆焊管件在低温工况下的冲击韧性，确保堆焊层、熔合区及母材在指定低温下具有足够的抗冲击能力。

取样要求：

取样位置	取样数量	取样方向	备注
堆焊层中心	3 件/组	垂直于堆焊方向	试样长度≥55mm
熔合区	3 件/组	垂直于堆焊方向	缺口位于熔合线
母材	3 件/组	垂直于堆焊方向	距堆焊层≥5mm
堆焊层与母材界面	3 件/组	垂直于堆焊方向	缺口位于界面处

试样制备：

- 试样尺寸：10mm×10mm×55mm（标准试样）或 5mm×10mm×55mm（小尺寸试样）
- 缺口类型：V 型缺口（2mm 深，45°角度）
- 缺口加工：采用线切割或精密切削加工，确保缺口尺寸精度
- 试样表面：除缺口外，表面粗糙度 Ra≤3.2μm

试验条件：

项目	要求
试验温度	按产品技术协议要求，通常为-40℃、-60℃、-70℃、-100℃或-196℃
冲击能量	按设计要求，通常≥27J 或≥41J
试验设备	低温冲击试验机，配备低温介质（液氮或乙醇-干冰混合液）
温度控制精度	±1℃
试样保温时间	在试验温度下保温≥10min

合格标准：

- 每组 3 件试样冲击吸收能量均不低于规定值

- 允许 1 件试样冲击吸收能量低于规定值但不低于规定值的 70%
- 不允许 2 件及以上试样冲击吸收能量低于规定值

4.2.1.2 English

Test Purpose: To evaluate the impact toughness of low-temperature cladded pipe fittings under low-temperature service conditions, ensuring that the cladding layer, fusion zone and base metal have sufficient impact resistance at specified low temperatures.

Sampling Requirements:

Sampling Position	Quantity	Sampling Direction	Remarks
Cladding Layer Center	3 pcs/group	Perpendicular to cladding direction	Specimen length ≥55mm
Fusion Zone	3 pcs/group	Perpendicular to cladding direction	Notch located at fusion line
Base Metal	3 pcs/group	Perpendicular to cladding direction	≥5mm from cladding layer
Cladding-Base Metal Interface	3 pcs/group	Perpendicular to cladding direction	Notch located at interface

Specimen Preparation:

- Specimen dimensions: 10mm×10mm×55mm (standard specimen) or 5mm×10mm×55mm (small specimen)
- Notch type: V-notch (2mm deep, 45° angle)
- Notch machining: Wire EDM or precision machining, ensuring notch dimensional accuracy
- Specimen surface: Except for notch, surface roughness Ra≤3.2μm

Test Conditions:

Item	Requirement
Test Temperature	As per product technical agreement, typically -40°C, -60°C, -70°C, -100°C or -196°C
Impact Energy	As per design requirement, typically ≥27J or ≥41J
Test Equipment	Low-temperature impact testing machine equipped with cryogenic medium (liquid nitrogen or ethanol-dry ice mixture)
Temperature Control Accuracy	±1°C
Specimen Soaking Time	Soak at test temperature for ≥10min

Acceptance Criteria:

- Impact absorbed energy of all 3 specimens in each group shall not be lower than the specified value
- One specimen is allowed to have impact absorbed energy lower than specified value but not lower than 70% of specified value
- Two or more specimens with impact absorbed energy lower than specified value are not allowed

4.2.2 韧性检验 Toughness Inspection

4.2.2.1 中文

检验内容：

低温堆焊管件的韧性检验主要包括低温冲击韧性评估，通过冲击试验结果分析堆焊接头各区域的韧性水平。

检验程序：

1. 根据产品技术协议确定试验温度
2. 按取样要求制备冲击试样
3. 将试样置于低温介质中保温至规定温度
4. 在低温冲击试验机上进行冲击试验
5. 记录冲击吸收能量值
6. 分析断口形貌，评估韧性断裂特征

断口分析要求：

分析项目	要求
断口形貌观察	采用光学显微镜或扫描电镜观察
韧性区比例	按产品要求评估，通常≥85%
脆性断裂特征	不允许出现明显解理断裂
夹杂物影响	评估非金属夹杂物对韧性的影响

4.2.2.2 English

Inspection Content:

Toughness inspection of low-temperature cladded pipe fittings mainly includes low-temperature impact toughness evaluation, analyzing the toughness level of each region of the cladded joint through impact test results.

Inspection Procedure:

7. Determine test temperature according to product technical agreement
8. Prepare impact specimens according to sampling requirements
9. Place specimens in cryogenic medium and soak to specified temperature
10. Perform impact test on low-temperature impact testing machine
11. Record impact absorbed energy values
12. Analyze fracture morphology and evaluate ductile fracture characteristics

Fracture Analysis Requirements:

Analysis Item	Requirement
Fracture Morphology Observation	Use optical microscope or scanning electron microscope
Ductile Fracture Ratio	Evaluate as per product requirement, typically ≥85%
Brittle Fracture Characteristics	Obvious cleavage fracture is not allowed
Inclusion Influence	Evaluate the influence of non-metallic inclusions on toughness

4.2.3 硬度检验 Hardness Inspection

4.2.3.1 中文

检验目的： 评估低温堆焊管件堆焊层、熔合区及母材的硬度分布，确保硬度值满足设计要求，防止因硬度异常导致的性能问题。

取样与布点要求：

检验区域	布点数量	布点间距	备注
堆焊层表面	每 100mm 长度不少于 3 点	≥5mm	沿堆焊方向均匀分布
堆焊层截面	每层不少于 3 点	≥2mm	从表面至熔合线
熔合区	每 100mm 长度不少于 2 点	≥5mm	距熔合线±1mm
母材	每 100mm 长度不少于 2 点	≥5mm	距堆焊层≥5mm

硬度试验方法：

区域	试验方法	试验力	压头类型
堆焊层	洛氏硬度（HRC）	150kgf	金刚石圆锥
堆焊层（薄层）	维氏硬度（HV）	10kgf	金刚石正四棱锥
熔合区	维氏硬度（HV）	10kgf	金刚石正四棱锥
母材	布氏硬度（HB）	3000kgf	硬质合金球

硬度合格标准：

区域	硬度要求	备注
堆焊层	按产品技术协议要求	通常≤250HB 或按材料标准
熔合区	不高于堆焊层和母材较高值的 1.1 倍	防止硬化区脆化
母材	符合母材标准要求	验证母材性能

硬度梯度要求：

- 堆焊层至母材的硬度过渡应平缓
- 硬度梯度变化率≤50HV/mm
- 不允许出现硬度突变区域

4.2.3.2 English

Inspection Purpose: To evaluate the hardness distribution of the cladding layer, fusion zone and base metal of low-temperature cladded pipe fittings, ensuring hardness values meet design requirements and preventing performance issues caused by abnormal hardness.

Sampling and Point Layout Requirements:

Inspection Area	Number of Points	Point Spacing	Remarks
Cladding Layer Surface	≥3 points per 100mm length	≥5mm	Uniformly distributed along cladding direction
Cladding Layer Cross-section	≥3 points per layer	≥2mm	From surface to fusion line
Fusion Zone	≥2 points per 100mm length	≥5mm	±1mm from fusion line
Base Metal	≥2 points per 100mm length	≥5mm	≥5mm from cladding layer

Hardness Test Methods:

Area	Test Method	Test Force	Indenter Type
Cladding Layer	Rockwell Hardness (HRC)	150kgf	Diamond cone
Cladding Layer (thin layer)	Vickers Hardness (HV)	10kgf	Diamond square pyramid
Fusion Zone	Vickers Hardness (HV)	10kgf	Diamond square pyramid
Base Metal	Brinell Hardness (HB)	3000kgf	Hard alloy ball

Hardness Acceptance Criteria:

Area	Hardness Requirement	Remarks
Cladding Layer	As per product technical agreement	Typically ≤250HB or as per material standard
Fusion Zone	Not higher than 1.1 times the higher value of cladding layer and base metal	Prevent embrittlement of hardened zone
Base Metal	Meet base metal standard requirements	Verify base metal properties

Hardness Gradient Requirements:

- Hardness transition from cladding layer to base metal shall be gradual
- Hardness gradient change rate ≤50HV/mm
- Sudden hardness change areas are not allowed

4.3 检验流程 Inspection Procedure

4.3.1 中文

检验流程图：

产品完工 → 外观检查 → 尺寸检验 → 取样 → 试样制备 → 低温冲击试验 → 硬度检验 → 数据记录 → 结果评定 → 出具报告

详细流程：

步骤	工作内容	责任部门	记录文件
1	确认产品完工，具备检验条件	生产部	生产完工记录
2	外观检查，确认堆焊质量	质量部	外观检查记录
3	尺寸检验，确认产品尺寸合格	质量部	尺寸检验记录
4	按取样要求切割取样	生产部/质量部	取样记录
5	制备冲击试样和硬度试样	质量部	试样制备记录
6	进行低温冲击试验	质量部	冲击试验记录
7	进行硬度检验	质量部	硬度检验记录
8	记录检验数据	质量部	检验原始记录
9	评定检验结果	质量部	结果评定记录
10	出具检验报告	质量部	检验报告

4.3.2 English

Inspection Flow Chart:

Product → Visual Inspection → Dimensional Inspection → Sampling → Specimen Preparation → Low-Temperature Impact Test → Hardness Inspection → Data Recording → Result Evaluation → Report Issuance

Detailed Procedure:

Step	Work Content	Responsible Department	Record Document
1	Confirm product and inspection readiness	Production Dept.	Production Record
2	Visual inspection to confirm cladding quality	Quality Dept.	Visual Inspection Record
3	Dimensional inspection to confirm product dimensions	Quality Dept.	Dimensional Inspection Record

4	Cut samples according to sampling requirements	Production/Quality Dept.	Sampling Record
5	Prepare impact and hardness specimens	Quality Dept.	Specimen Preparation Record
6	Perform low-temperature impact test	Quality Dept.	Impact Test Record
7	Perform hardness inspection	Quality Dept.	Hardness Inspection Record
8	Record inspection data	Quality Dept.	Inspection Original Record
9	Evaluate inspection results	Quality Dept.	Result Evaluation Record
10	Issue inspection report	Quality Dept.	Inspection Report

4.4 设备与工装要求 Equipment and Tooling Requirements

4.4.1 中文

设备名称	型号规格	精度要求	校准周期
低温冲击试验机	冲击能量≥300J	能量示值误差≤±1%	每年 1 次
低温恒温槽	温度范围-196℃～室温	温度控制精度±1℃	每年 1 次
洛氏硬度计	试验力 150kgf	示值误差≤±1.5HRC	每年 1 次
维氏硬度计	试验力 1kgf～10kgf	示值误差≤±3%	每年 1 次
布氏硬度计	试验力 3000kgf	示值误差≤±3%	每年 1 次
线切割机床	切割精度±0.02mm	切割精度±0.02mm	每年 1 次
光学显微镜	放大倍数 50×～1000×	分辨率≥0.5μm	每年 1 次

4.4.2 English

Equipment Name	Model Specification	Accuracy Requirement	Calibration Cycle
Low-Temperature	Impact energy ≥300J	Energy indication error	Once per year

Impact Testing Machine		≤±1%	
Cryogenic Constant Temperature Bath	Temperature range -196℃ to room temperature	Temperature control accuracy ±1℃	Once per year
Rockwell Hardness Tester	Test force 150kgf	Indication error ≤±1.5HRC	Once per year
Vickers Hardness Tester	Test force 1kgf～10kgf	Indication error ≤±3%	Once per year
Brinell Hardness Tester	Test force 3000kgf	Indication error ≤±3%	Once per year
Wire EDM Machine	Cutting accuracy ±0.02mm	Cutting accuracy ±0.02mm	Once per year
Optical Microscope	Magnification 50×～1000×	Resolution ≥0.5μm	Once per year

4.5 不合格品处理 Nonconforming Product Handling

4.5.1 中文

不合格判定：

检验项目	不合格判定标准
低温冲击试验	冲击吸收能量低于规定值，或断口出现明显脆性断裂特征
韧性检验	韧性区比例低于规定值，或出现解理断裂
硬度检验	硬度值超出规定范围，或硬度梯度异常

处理程序：

13. 发现不合格项，立即标识并隔离
14. 质量部组织分析不合格原因
15. 技术部制定返工或返修方案
16. 生产部执行返工或返修
17. 返工后重新进行相关检验
18. 检验合格后解除隔离，恢复正常流程
19. 检验仍不合格，按报废或让步接收程序处理

让步接收条件：

- 经客户书面同意
- 不影响产品安全性能
- 有明确的使用限制说明
- 记录完整的让步接收审批记录

4.5.2 English

Nonconformance Determination:

Inspection Item	Nonconformance Criteria
Low-Temperature Impact Test	Impact absorbed energy below specified value, or obvious brittle fracture characteristics on fracture surface
Toughness Inspection	Ductile fracture ratio below specified value, or cleavage fracture observed
Hardness Inspection	Hardness value outside specified range, or abnormal hardness gradient

Handling Procedure:

20. Upon discovery of nonconformance, immediately identify and isolate
21. Quality Department organizes analysis of nonconformance cause
22. Technical Department develops rework or repair plan
23. Production Department executes rework or repair
24. Re-inspect relevant items after rework
25. After passing inspection, release isolation and resume normal process
26. If inspection still fails, handle according to scrap or concession acceptance procedure

Concession Acceptance Conditions:

- Written approval from customer
- Does not affect product safety performance
- Clear usage limitations specified
- Complete concession acceptance approval records maintained

5. 监督考核 Supervision and Assessment

5.1 中文

监督内容	监督方式	考核标准	考核周期
检验计划执行情况	定期检查	按计划完成率≥95%	每月
检验记录完整性	记录抽查	记录完整率≥98%	每月
设备校准状态	校准记录核查	设备在校准有效期内	每季度
不合格品处理及时性	处理记录核查	处理及时率≥90%	每月
检验人员资质	资质档案核查	持证上岗率 100%	每年

5.2 English

Supervision Content	Supervision Method	Assessment Criteria	Assessment Cycle
Inspection Plan Execution	Regular inspection	Plan rate ≥95%	Monthly
Inspection Record Completeness	Record sampling check	Record completeness rate ≥98%	Monthly
Equipment Calibration Status	Calibration record verification	Equipment within calibration validity period	Quarterly
Nonconforming Product Handling Timeliness	Handling record verification	Handling timeliness rate ≥90%	Monthly
Inspector Qualification	Qualification file verification	Certified personnel rate 100%	Annually

6. 附则 Supplementary Provisions

6.1 中文

27. 本检验与试验计划由质量部负责解释和修订。

28. 本计划自发布之日起实施，原有相关规定同时废止。
29. 当相关标准更新或产品技术要求变更时，应及时修订本计划。
30. 本计划一式多份，分发至质量部、生产部、技术部、设备部及相关项目部。
31. 检验过程中如发现本标准未涵盖的特殊情况，应及时上报技术部，由技术部确定处理方案。

6.2 English

32. This Inspection and Test Plan shall be interpreted and revised by the Quality Department.
33. This plan shall be implemented from the date of release, and previous relevant regulations shall be simultaneously abolished.
34. When relevant standards are updated or product technical requirements are changed, this plan shall be revised in a timely manner.
35. This plan shall be issued in multiple copies and distributed to Quality Department, Production Department, Technical Department, Equipment Department and relevant project departments.
36. If special circumstances not covered by this standard are found during inspection, they shall be reported to the Technical Department in a timely manner, and the Technical Department shall determine the handling plan.

文件控制信息 Document Control Information

项目	内容
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审核部门 Reviewed By	技术部 Technical Department
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A/0	首次发布	-	-	-	-
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