BAOSTEEL

Clad-Rolled Flat Steels

轧制复合钢板/卷

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宝山钢铁股份有限公司
BAOSHAN IRON & STEEL CO., LTD.

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前 言
Foreword

01

轧制复合钢板，是以碳素结构钢、低合金高强度结构钢或高强度调质钢作为基板，利用复合轧制技术，单面或双面与不锈钢、特殊钢等材料的复板进行组织程度的结合后，得到的复合材料钢板。

轧制复合钢板兼具了不同钢种的材料特性，在使用功能上，既有基板作为结构部件材料所必要的强度，以及满足用户的使用性能和加工性能，同时又兼具了复板材料优良的耐蚀性、耐磨性、高强度等功能特性。基板与复板结合后得到的轧制复合板，相比原先完全用复板材料生产的产品，不仅具有优异的可替代性，而且具有更好的性能。因此，轧制复合钢板是一种更加高性价比、高效的复合材料产品。

宝钢轧制复合钢板可在核电、水电、压力容器、船板、结构用钢、管线、装饰等多种行业领域应用。

本公司，基于宝钢高等级厚板的生产技术，利用历年的科研成果，实现了厚板、热轧、冷轧产线全覆盖，可为用户提供多种厚度规格的轧制复合钢板/卷。

感谢您选择宝钢轧制复合钢板 / 卷产品。

Clad-Rolled plates, which are based on carbon structural steels, low alloy high strength structural steels or high strength quenched and tempered steels as the base plate, single or both sides combined with stainless steel, special steel, etc. in a certain degree through the clad rolling technology, to produce the Clad-Rolled plates.

This base material-cladding material combined mode, realizes different kinds of steel material properties blending into one. In the use of functions, both the base plate strength as a structural component meets the requires of customers' machining and processing performance, and the cladding material with excellent corrosion resistance, wear resistance, high strength are obtained. Moreover, Clad-Rolled plates, compared to the original single cladding plate production, have substitution and high cost performance. Therefore, Clad-Rolled plate is a more economical and efficient Cladding product.

Baosteel Clad-Rolled plates are employed in nuclear power, hydropower, pressure vessel, ship, structure steel, pipeline, decoration, such as a variety of industry applications.

Our company, based on high grade heavy plate produce technology, and also using scientific research results over the years, achieves full coverage of heavy plate, hot rolling and cold rolling coil, so as to supply Clad-Rolled plate/sheet with multiple thickness specifications for customers.

Thank you for choosing Baosteel Clad-Rolled productions.

公司概况
Brief Introduction

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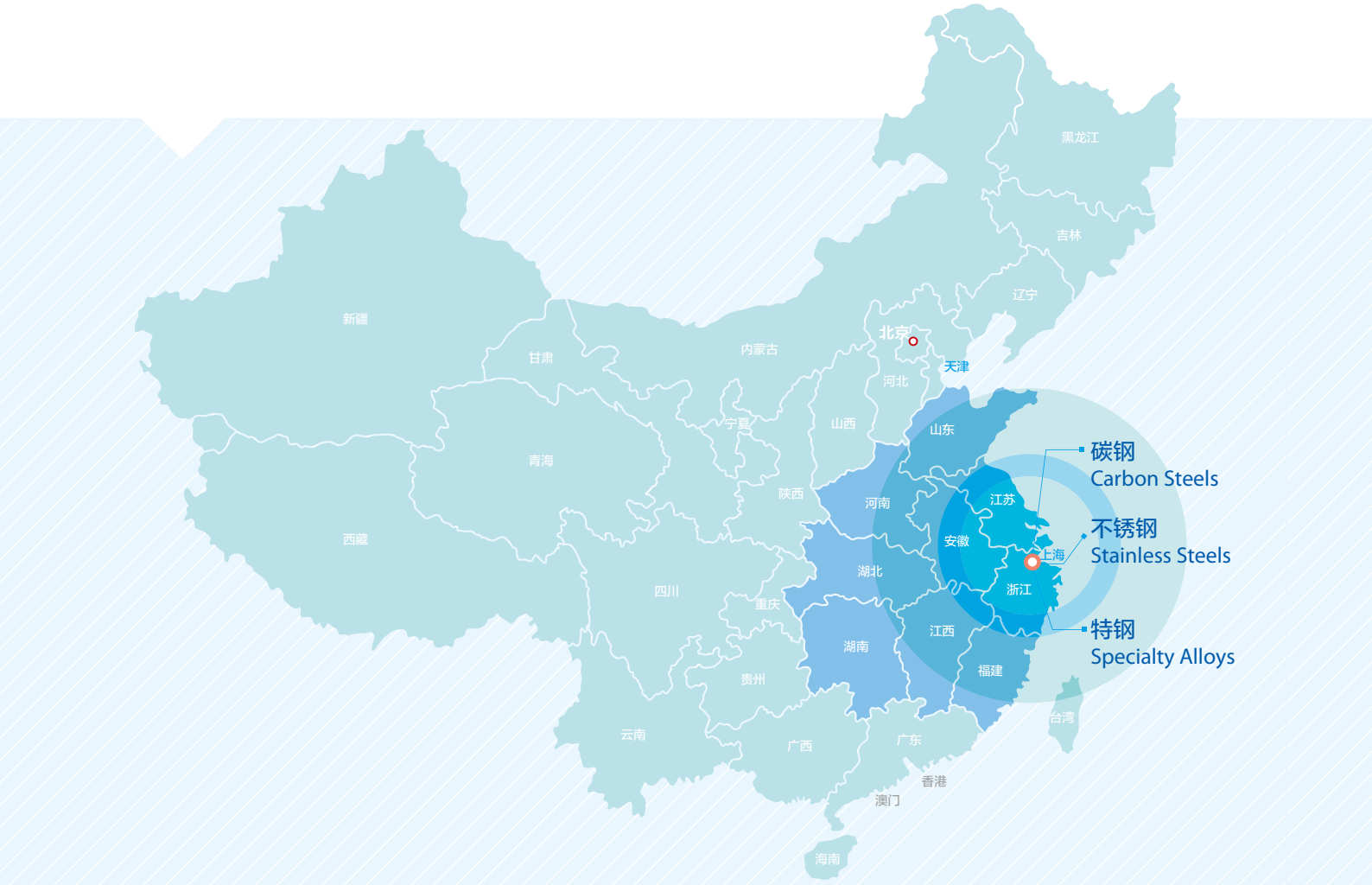
宝钢以钢铁为主业，生产高技术含量、高附加值钢铁精品，已形成普碳钢、不锈钢、特钢三大产品系列。宝钢拥有两条宽厚板产线，多条热轧、冷轧产线，可以满足市场多品种、各种规格的产品需求，钢铁产品通过遍布全球的营销网络，在满足国内市场需求的同时，还出口至日本、韩国、欧美等四十多个国家和地区，广泛应用于汽车、家电、石油化工、机械制造、能源交通、金属制品、航天航空、核电、电子仪表等行业。

Baosteel produces high technology , high value-added steel products, and has formed three major general product series : carbon steel, stainless steel, special steel. Baosteel has two heavy plate mill, several hot rolling and cold rolling production lines. Baosteel steel products can meet the customer's demands at home and abroad, exporting to Japan, South Korea, Europe , the United States and other forty countries and regions. Baosteel products are widely used in automobiles, home appliances, petrochemical industry, machinery manufacturing, energy, transportation, metal products, aerospace, nuclear power, electronic instrumentation and other industries.



轧制复合特点
Characteristics of Clad-Rolled

03

复合生产技术一般有机械复合、爆炸复合和轧制复合三种工艺途径。机械复合技术一般用于直接生产复合钢管，而爆炸复合和轧制复合技术可以直接生产复合钢板，再进一步制管成复合钢管或热轧、冷轧复合钢板/卷。

宝钢复合钢板/卷是利用轧制复合技术生产，通过组坯等准备工作后，复合工序只需在常规轧线上生产，利用加热和轧制技术使复板和基板两层、三层组织结合。而爆炸复合技术是在制备好的复板和基板之上，利用复板上铺设的一层炸药，利用炸药爆炸时产生的瞬时超高压和超高速冲击能实现金属层间的固态冶金结合。

由于复合原理的不同，轧制复合与爆炸复合技术在尺寸精度、结合面状态与组织性能上都有着各自的优缺点。

因此，复合轧制技术在可基本完全替代爆炸复合技术的条件下，有着更加精确的尺寸控制精度、优异的结合面质量与揉合的复合组织性能。因而轧制复合技术生产的钢板就有更加良好的用户使用性能，也更有利于后期进一步的加工应用。

欢迎您使用轧制复合技术生产的宝钢复合钢板/卷!

Clad plate can be divided into three types: mechanical clad, explosion clad and Clad-Rolled plate. Mechanical clad is generally used in production of clad pipe directly, and explosion clad、rolled- clad commonly produce clad steel plate first, and then make into clad pipe or hot rolling、cold rolling clad plate/coil.

The clad steel plate/coil of Baosteel is produced by Clad-Rolled technology. After preparation work such as slab-clad, the clad plate is integrated with base plate by heating and rolling technology. The production processes are basically the same with ordinary steel production. And explosive clad technique is that a layer of explosives is laid on the cladding plate. The technology utilizes ultra-high pressure and ultra-high speed impact energy, to achieve the solid metallurgy association.

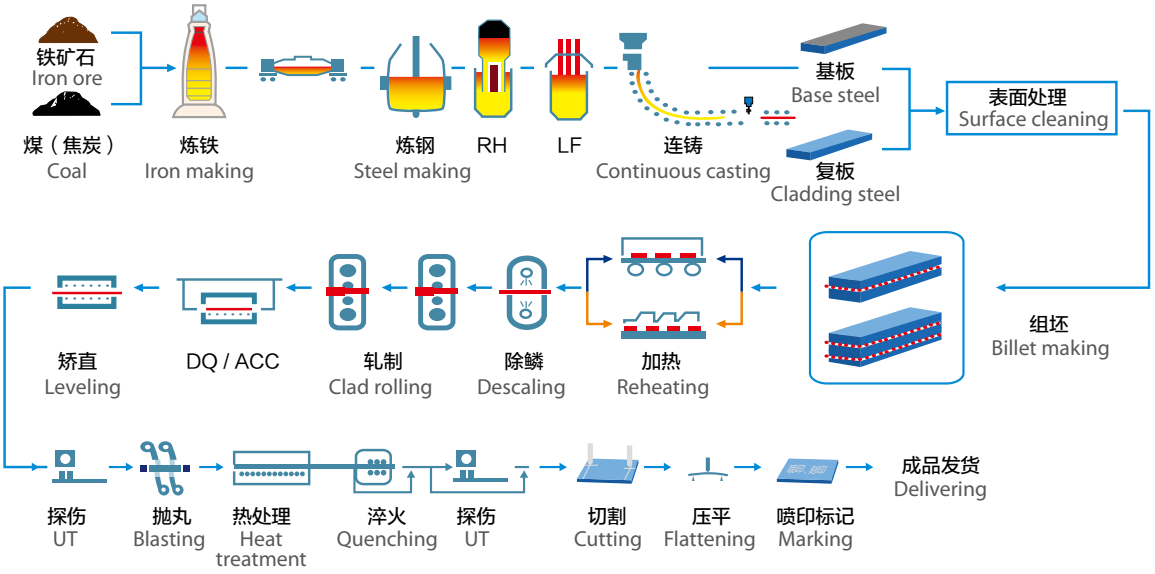
Because of the different clad technology principle, Clad-Rolled combined with explosion clad in dimensional accuracy, surface condition and microstructure performance have their respective advantages and disadvantages.

Therefore, Clad-Rolled technology can entirely replace explosive clad technique, and the more accurate size control, the more excellent surface quality and the better using performance.

Welcome you to choose Clad-Rolled plate/coil of baosteel!

复合板生产工艺流程
Process Flow

04



钢种
Steel Grade

05

01

复合钢板的适用标准
Standard for Clad Plate

复合板适用的国标标准原则上如下所示：
NB47002.1-2009、GB/T8165-2008
不锈钢复合板

复合板适用国际标准原则上如下所示：
ASTM A263-2012 铬系不锈钢复合板
ASTM A264-2012 铬镍不锈钢复合板
ASTM A265-2012 镍和镍合金复合板

Chinese National Standards for Stainless Steel Clad Plate:

NB47002.1-2009、GB/T8165-2008
Stainless steel-clad plate

International Standards for clad plate:

ASTM A263-2012 Stainless Chromium steel-clad plate
ASTM A264-2012 Stainless Cr-Ni steel-clad plate
ASTM A265-2012 Ni-Ni-Base alloy-clad steel plate

02

基板
Base Plate

基板适用标准原则上如下所示：

GB/T 700-2006 碳素结构钢
GB/T 16270-2009 高强度结构用调质钢板
GB/T 1591-2008 低合金高强度结构钢

Chinese National Standards or International Standards:

GB/T 700-2006 Carbon structural steel

GB/T 16270-2009 High strength quenched and tempered structure steel

GB/T 1591-2008 High strength low alloy structural steel

EN10025 Hot rolled products of structural steels

JIS G 3101 Rolled steels for general structure

JIS G 3106 Rolled steels for welded structure

ASTM A709 Standard specification for structural steel for bridges

ASTM A572 Standard specification for High-strength low-alloy columbium - vanadium structural steel

GB/T 713 Steel plates for boilers and pressure vessels

ASME SA-387/SA-387M Pressure vessel plates, Alloy steel, Chromium-molybdenum

ASME SA-516/SA-516M Standard specification for pressure vessel Plates, Carbon Steel, for Moderate- and Lower - temperature service

ASME SA-533/SA-533M Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Manganese-Molybdenum and Manganese-Molybdenum-Nickel.

API 5L Specification for Line pipe

03

复板
Cladding Plate

复板适用标准原则上如下所示：

GB/T 4237 不锈钢热轧钢板和钢带
GB 24511 承压设备用不锈钢钢板及钢带
GB/T 2054-2013 镍及镍合金板

Chinese National Standards or International Standards:

GB/T 4237 Hot rolled stainless steel plate, sheet and strip

GB 24511 Stainless steel plate, sheet and strip for pressure equipments

GB/T 2054-2013 Nickel and nickel alloy plate

ASTM A240/A240M Standard Specification for Chromium and Chromium- Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

宝钢复合板产品分类
Product Classification

06

01

按产线
According to the Production Line

序号 No.	产线 Production line	厚度范围 Thickness(mm)	宽度范围 Width(mm)
01	厚板 Heavy plate	5-400	900-4500
02	热轧卷 hot rolled coil	1.5-25.4	600-1600
03	冷轧卷 cold rolled coil	0.17-4.5	700-1500

02

按复合层数
According to the cladding layers

序号 No.	复合层数 Cladding layer quantity
01	单面复合 Single side cladded
02	双面复合 Double side cladded

03

按复层钢板类别
According to the Cladding Material

基层材料 Base material		复层材料 Cladding material			
常用牌号 Steel grade	特性与主要用途 Characteristics and main purposes	类别 Classification	GB牌号 GB Steel grade	AISI牌号 AISI Steel grade	特性与主要用途 characteristics and main purposes
Q235A Q235B Q235C Q345A Q345B Q345C SS400 Q245R Q345R	一般强度级别结构用钢以及压力容器用钢，具有较好的综合力学性能。 General strength structural and pressure vessel steel, has good mechanical properties.	奥氏体不锈钢 Austenitic stainless steel	12Cr17Ni7	301	应用最广泛的不锈钢品种，在强氧化性、中性和弱还原性介质中均具有良好的耐蚀性，塑性和韧性优良，焊接性良好，用于石油、化工、核能、纺织印染设备、医疗器械、食品加工、建筑装饰等行业。 Most widely used stainless steel ,has good corrosion resistance plasticity ,toughness,weldability property in strong oxidizing, neutral and weak reducing medium.Used in petroleum, chemical industry, nuclear power, medical equipment, and other industries.
			12Cr18Ni9	302	
			06Cr19Ni10	304	
			022Cr19Ni10	304L	
			10Cr18Ni12	305	
			06Cr20Ni11	308	
			06Cr23Ni13	309S	
			06Cr25Ni20	310S	

基层材料 Base material		复层材料 Cladding material			
常用牌号 Steel grade	特性与主要用途 Characteristics and main purposes	类别 Classification	GB牌号 GB Steel grade	AISI牌号 AISI Steel grade	特性与主要用途 characteristics and main purposes
Q390 Q420 Q460 Q550 Q690 S355M S420M S460M	较高强度级别结构用钢，用于各种工业结构与设施，综合力学性能良好。 High strength structural steel, used in sorts of industrial structure and facilities, good mechanical properties.	奥氏体不锈钢 Austenitic stainless steel	015Cr20Ni18Mo6	312	应用最广泛的不锈钢品种，在强氧化性、中性和弱还原性介质中均具有良好的耐蚀性，塑性和韧性优良，焊接性良好，用于石油、化工、核能、纺织印染设备、医疗器械、食品加工、建筑装饰等行业。 Most widely used stainless steel ,has good corrosion resistance plasticity ,toughness,weldability property in strong oxidizing, neutral and weak reducing medium.Used in petroleum, chemical industry, nuclear power, medical equipment, and other industries.
			06Cr17Ni12Mo2	316	
			022Cr17Ni12Mo2	316L	
			0Cr18Ni12Mo3Ti	316Ti	
			06Cr19Ni13Mo3	317	
X52 X65 X70	石油天然气长输管线用钢，综合性能良好。 Oil and gas pipeline steel, good mechanical properties.		022Cr19Ni13Mo3	317L	
			06Cr18Ni11Ti	321	
			06Cr18Ni11Nb	347	
12CrMo 12CrMoR 14CrMo 14CrMoR 15CrMo 15CrMoR SA516Gr.70 SA387Gr.11 SA387Gr.12 SA387Gr.22 SA533CL1	高温压力容器用钢，具有一定的耐高温性能和良好的综合力学性能。 High temperature pressure vessel steel,with high temperature resistant performance and good mechanical properties.	双相不锈钢 Duplex stainless steel	022Cr23Ni5Mo3N	2205	兼具奥氏体和铁素体不锈钢的优良特性，用于石油、化工容器、海水处理设施等。 Excellent characteristics both austenite and ferrite stainless steel, used in oil, chemical containers, water treatment facilities, etc.
			022Cr23Ni4MoCuN	2304	
			022Cr25Ni6Mo2N	2506	
			022Cr25Ni7Mo4N	2507	
		铁素体不锈钢 Ferritic stainless steel	06Cr13Al	405	良好的耐点蚀、缝隙腐蚀和氯化物应力腐蚀性能，用于耐海水设备、有机酸与制碱设备。 Good resistance to pitting corrosion, crevice corrosion and chloride stress corrosion resistance, used for seawater equipment, organic acid and alkali production equipment.
			10Cr15	429	
			10Cr17	430	
			10Cr17Mo	434	
			019Cr21CuTi	443	
A/B/D/E DH32 DH36 EH36 EH40 FH36 FH40	不同强度级别与使用温度造船用钢，满足各国船级社材料规范要求。 Ship plate, comply with the requirements of classification society	马氏体不锈钢 Martensitic stainless steel	12Cr12	403	主要用于对强度、硬度和耐磨性要求较高，耐腐蚀性要求较低的领域。 Mainly used for high strength, hardness and wear resistance, and do not require corrosion resistance field.
			12Cr13	410	
			06Cr13	410S	
			20Cr13/30Cr13	420	
			14Cr17Ni2	431	
		沉淀硬化型不锈钢 Precipitation-hardening stainless steel	05Cr17Ni4Cu4Nb	630	具有高强度、高韧性与良好的耐蚀性，通常作为耐磨、耐蚀、高强度结构件。 High strength, toughness and good corrosion resistance, usually as wear-resisting, corrosion resistant structure parts .
			07Cr17Ni7Al	631	
			07Cr15Ni7Mo2Al	632	

宝钢复合板的供货能力
Supply Capacity

07

01 具备生产高要求复合钢板的能力，包括单面、多面复合、异质复合钢板等。

02 已商业化供货0.9-400mm厚复合板，并具备生产更宽厚复合板的能力。

03 具有良好的使用性能，应用于对安全性要求非常高的核电站安注箱等场合。

04 具有为用户提供复合板材料设计、使用技术的团队和能力。

05 可以按照用户需求开发个性化的复合板。

The ability to produce Clad-Rolled steels with higher requirements, including single side, multi-layers, and different materials Clad-Rolled steels, etc.

The ability to supply the thickness ranges from 0.9 to 400mm and wider range Clad-Rolled plates.

Good performance, such as the application to the safety injection tank in nuclear power station, with a very high security.

The team has the ability to provide material design, use technology for customers.

The ability to develop a personalized Clad-Rolled plates for customers.

复合板的应用领域
Product Application

08

01 电力工程

水电工业中用于排沙底孔，导流底空的钢衬，以及船闸廊道、闸坂的衬板等，其基本要求是高耐磨性、抗冲击性和适当的耐蚀性。主要用于料仓、料斗、溜槽、脱水器等部位。由于对环保要求的提高，降底空气中的SO_2的烟气脱硫工程的出现，不锈钢复合钢板将成为火电厂的首选材料。

Electrical Engineering

For the steel liners used in sediment bottom holes, diversion bottom outlets, lock culverts and gates in hydropower industry, the basic requirements are high wear resistance, good impact resistance and adequate corrosion resistance. The liners are mainly used for silos, hoppers, chutes, dehydrators and other parts.

Due to the more strictly enviromental protection policies, some air desulfurization projects are applied in order to reduce SO_2 in the air. For those projects, the clad steel plates will become the preferred material of thermal power plants.

02 压力容器、储罐

不锈钢复合板可以减少贵重金属的消耗，大幅度降低工程造价。基板和不锈钢之间可形成牢固的冶金结合，具有良好的机械性能，可以进行热压、冷弯、切割、焊接等各种加工。根据储罐的不同用途，基层材料可以使用Q235B、Q345R等各种普碳钢和容器钢。复层材料可以使用304、316L和双相不锈钢等各种牌号的不锈钢。材质和厚度可以自由组合，能满足不同化工储罐的性能要求。

Pressure Vessels, Storage Tanks

Clad steel plates can reduce the consumption of high price metals or alloys, and reduce project cost significantly. Clad steel has excellent mechanical properties. The base material and cladding layer can form strongly metallurgical combination. Clad steel can be processed with a variety of hot pressing, bending, cutting, welding, etc. According to the applications of storage tanks, the base material can be selected from Q235B, Q345R carbon steels and other vessel steels. The cladding layer can be austenitic stainless steels such as 304, 316L, duplex stainless steel, and so on. The materials and the thicknesses can be freely combined to meet the property requirements of the different chemical storage tanks.

03 石油化工

石化设备中已广泛使用复合板制造容器、塔器、换热器、管道等。高硫、高盐、高酸度值原油的炼制，其主要炼制设备如：减压塔、吸收塔、分馏塔、稳定塔可用不锈钢复合板取代普通容器钢板和不锈钢板来制造，使用复合板能有效的防腐蚀、耐高温，提高了设备的使用年限。随着对石油，天然气的开发和对高H_2S、SO及含氮离子气田的开发，不锈钢复合板优势更加明显。

Petrochemical Industry

Clad steel has been widely used as containers, towers, heat exchangers, pipes in petrochemical equipment. For refining high-sulfur, high-salt and high acidity crude oil, clad steel can replace carbon steel and stainless steel used in the main refining equipment such as vacuum towers, absorption towers, fractionating towers, and the stabilizers, which increases corrosion resistance, heat resistance, as well as the service life of equipment. The advantages of clad steel are more obvious in the development of oil and natural gas fields with high H_2S, SO and nitrogen ions.

04 煤化工领域

我国煤炭资源丰富，庞大的产业规模构成了对新型节能材料的大量需求，不锈钢复合板以其优良的性能在煤化工的气化、液化、焦化及焦油化工、合成设备得到广泛应用。

Coal Chemical Industry

China has plentiful coal resources and the large-scale coal industry is demanding new energy-saving materials for its applications. Stainless steel clad plates have been widely used in the equipment of coal chemical gasification, liquefaction, coking and coal tar chemicals for their excellent performance.

05 建筑模台用

随着建筑产业化的发展，建筑模台用钢板将得到广泛应用。目前市场上以碳钢模台板为主，部分高端产品采用纯铁素体和奥氏体不锈钢。但碳钢板耐蚀性差、光洁度不高，铁素体不锈钢强韧性差，奥氏体不锈钢无磁性等缺陷无法克服。通过碳钢与铁素体不锈钢的复合，可以使模台用复合板得到耐蚀性与强韧性的最佳匹配，因而应用前景广阔。

Constructional Molding Plate

With the development of the construction industry, constructional mold plates will be extensively used. Currently carbon steel is mainly used as constructional mold plates on market. Some pure ferritic and austenitic stainless steel are used in some high-end products. But the disadvantages of the carbon steel, pure ferritic stainless steel or pure austenitic stainless steel limit its use in the field of the constructional mold plates. For carbon steel, it has poor corrosion resistance, and low surface quality. For ferritic stainless steel, it has very poor low temperature toughness, while for austenitic stainless steel, it does not have ferromagnetism which is important for the installation of side mold plates. With the combination of carbon steel and ferritic stainless steel, the clad steel can obtain the best match of the corrosion resistance and toughness, and therefore it may have bright application prospects.

06 移动容器及配套运输设备

乙二醇、橄榄油、化工原料等液体的贮罐和专用槽车的制造。

Mobile Containers and Ancillary Transport Equipment

For manufacturing tanks or dedicated tankers for glycol, olive oil, chemicals and other liquids.

宝钢复合板质量
Supply Quality

09

01 尺寸精度

下面是不锈钢复合钢板厚度精度的实例。

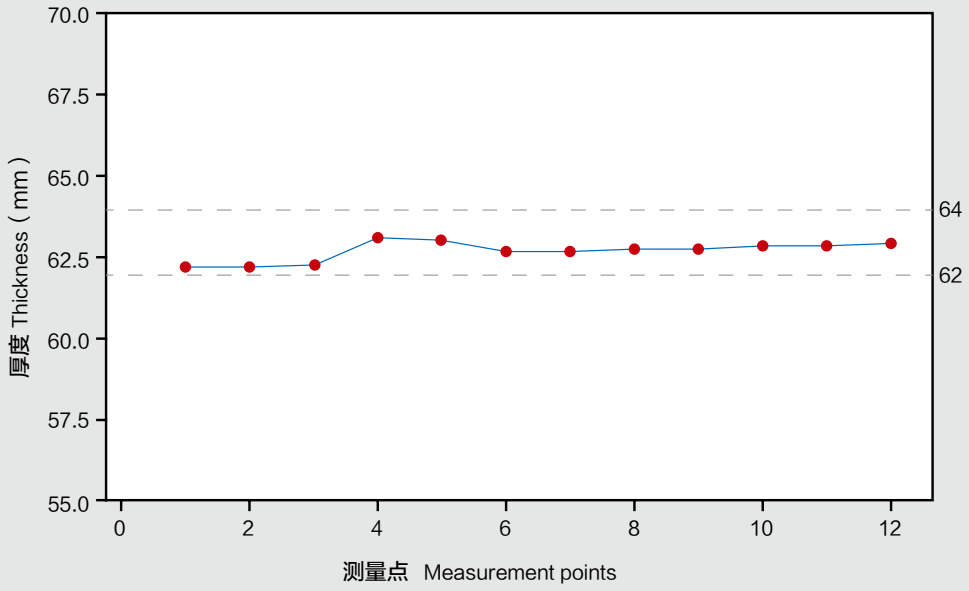
控制目标为基板厚度62mm，复板厚度7mm，厚度公差要求基板和复板均为（0-2mm），已成功生产并供货。

Dimension Precision

An example for the dimension precision of stainless steel Clad-Rolled plates.

The aim is the base plate with thickness 62mm, the cladding plate with thickness 7mm, the tolerance for both layers are (0-2mm), which has been successfully produced and supplying.

基层厚度抽样测量图 Sampling measurement of substrate layer thickness

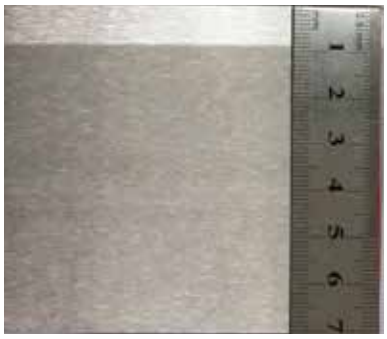


02 结合界面

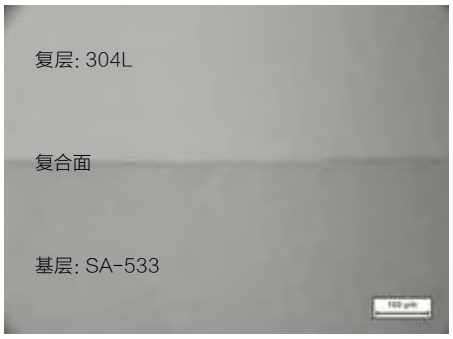
双层复合热轧钢板（上表面不锈钢复板+下面碳钢基板）

Cladding Boundary

Single side cladded hot rolling plate (stainless steel on the upper layer + carbon steel on the bottom layer)

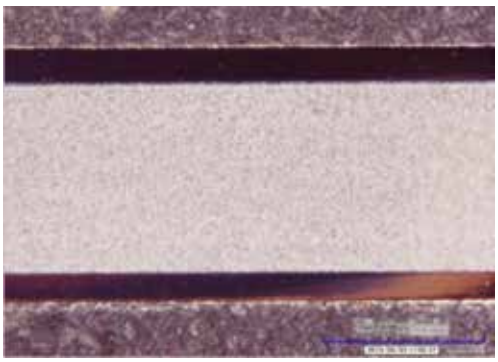


（a）宏观形貌 / Macroscopic morphology

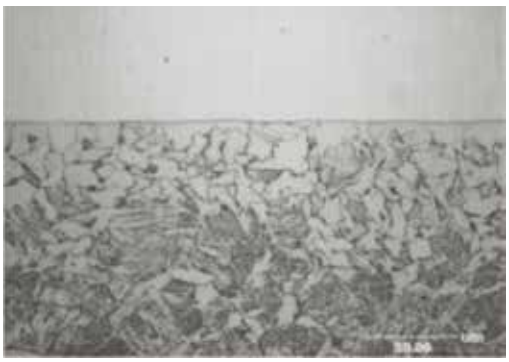


（b）显微组织 / Micro-structure

三层复合热轧钢板（上下表面304L，中间Q235B）
Double sides cladded hot rolling plate (304L on up and bottom sides, Q235B in the middle)

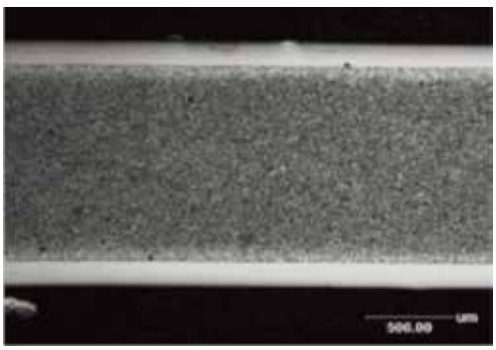


（a）截面宏观形貌 / Macroscopic morphology

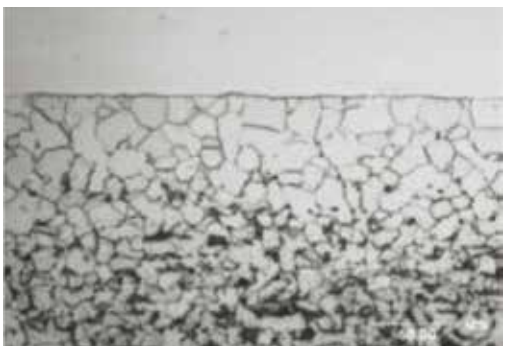


（b）结合界面 / Micro-structure

三层复合冷轧钢板（上下表面304L，中间Q235B）
Double sides cladded cold rolling plate (304L on up and bottom sides, Q235B in the middle)



（a）截面宏观形貌 / Macroscopic morphology



（b）结合界面 / Micro-structure

03 剪切强度

以下是核电不锈钢复合板剪切强度实绩

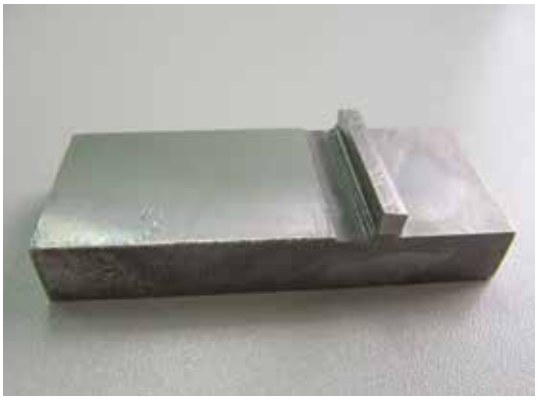
Shearing Strength

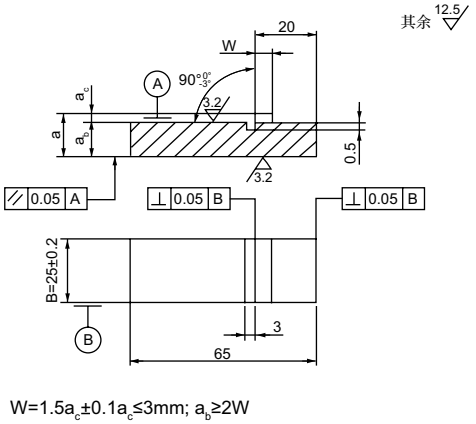
An application example of stainless clad rolled plate to the safety injection tank in nuclear power station as follow: Shear strength results

材质 Steel grade	交货状态 Delivery condition	复合板厚度 Thickness(mm)	钢板位置 Sample location	要求（MPa） Technical requirements	实测值（MPa） Measurement
SA-533TypeB Cl.1+SA-240 Type304L	QT+SPWHT	70	头部 Head	≥310	350~460

宝钢复合板质量
Supply Quality

试样标准　Standard: GB/T 6396-2008





$W=1.5a_c\pm0.1a_c\leq3mm$; $a_b\geq2W$

04 弯曲性能

下面是不锈钢复合板弯曲的例子

外弯标准: GB/T 6396-2008

侧弯标准: GB/T 6396-2008

结合强度标准: ASME SA264

Bend Property

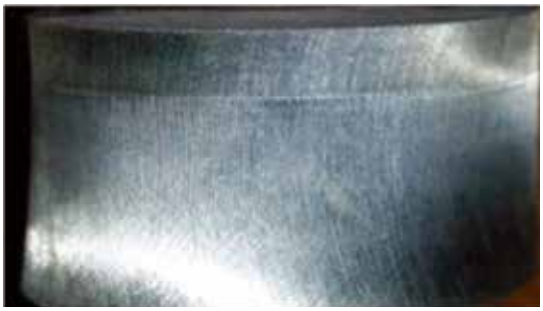
An example for bend property of stainless clad steel as follow

External bend test standard: GB/T 6396-2008

Side bend test standard: GB/T 6396-2008

Bond test standard: ASME SA264

外弯形貌 / External bend test sample



侧弯形貌 / Side bend test sample

三层复合板304L+Q235B+304L弯曲形貌（左，中）金相（右）
Bend test samples of 304L+Q235B+304L

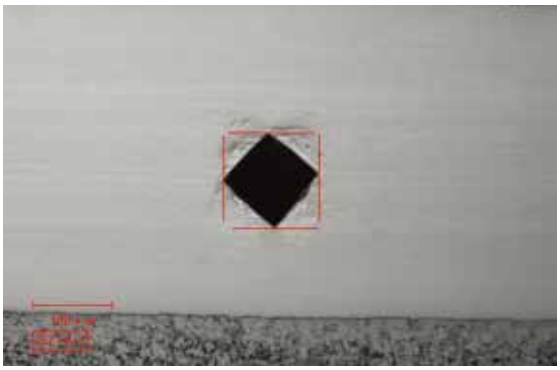


05 硬度性能

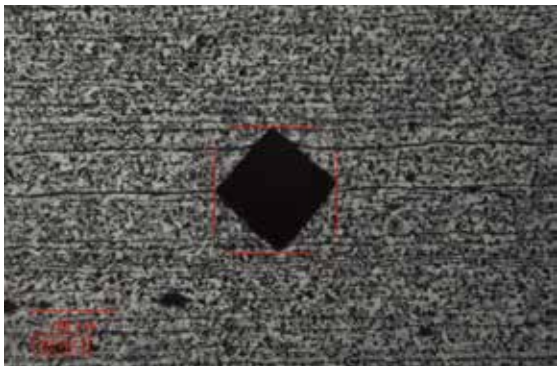
以304L+Q235B+304L热轧卷为例

Hardness Property

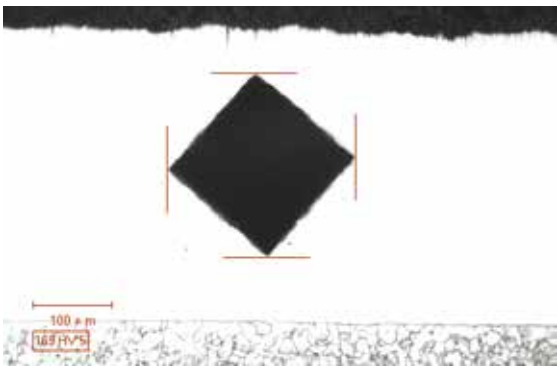
304L+Q235B+304L as an example(hot rolled coil)



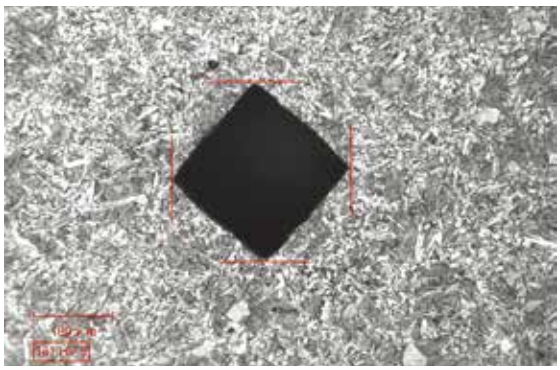
（a）热轧态复层（Hv 259） / Clad layer on hot rolling steel



(b) 热轧态基层（Hv 152） / Base layer on hot rolling steel



（a）冷轧固溶态复层（Hv 169）
Clad layer on cold rolling steel(solid solution)



（d）冷轧固溶态基层（Hv 181）
Base layer on cold rolling steel(solid solution)

宝钢复合板质量
Supply Quality

06 拉伸性能

以304L+Q235B+304L热轧卷板为例，拉伸断口处无分层

Tensile Strength

304L+Q235B+304L as an example (hot rolled coil)

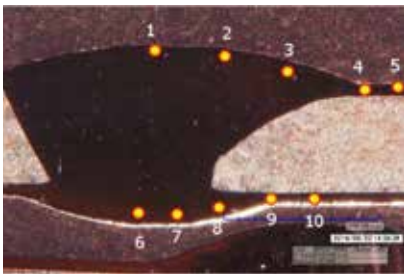
拉伸形貌 / Tensile test sample

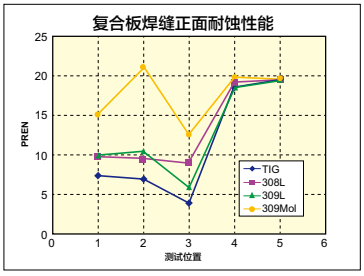
07 焊缝耐蚀性能

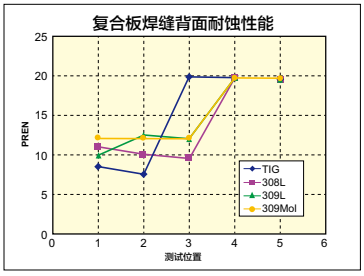
以1.5 mm规格304L+Q235B+304L冷轧不锈钢复合板为例

Corrosion Resistance of Weld

304L+Q235B+304L as an example (cold rolled coil)



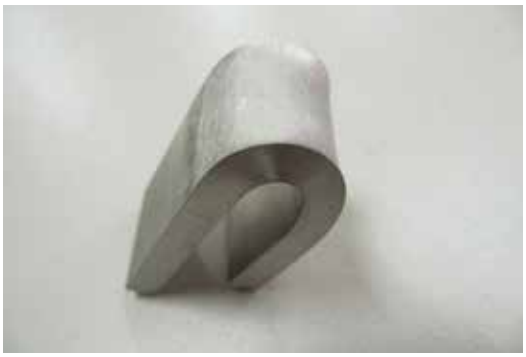




焊缝形貌 / Appearance of welding seam

08 晶间腐蚀 Intergranular Corrosion

检测标准 / Test standard: ASTM A262 E

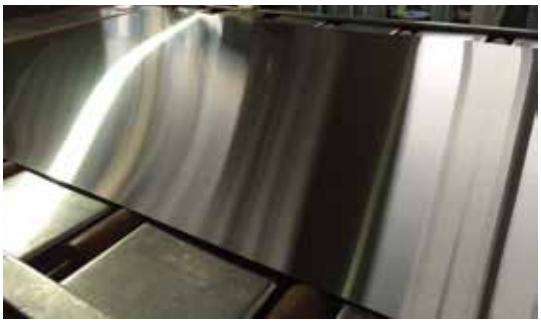


晶间腐蚀形貌 / Intergranular corrosion sample

09 不锈钢表面加工性能
Surface Machinery Performance of Stainless Steel cladded Plate

（a）8K镜面 / 8K Mirror face

（b）No.4表面 / No.4 surface



（c）HL表面 / HL surface

（d）冷轧板纵向剪切面
Longitudinal cutting section of cold rolling plate

复合板试验设备
Test Equipment

10

01 全自动拉伸试验机 Tensile testing equipment

名称 Equipment name	性能指标 Performance
最大负荷 Max. load	1600KN
力值精度 Accuracy	0.5级（I级）
引伸计 Extensometer	标距长度 Gage length:10 mm-205 mm
引伸计精度 Accuracy	I级
速度 Speed	0.001-300mm/min

复合板试验设备
Test Equipment

02 示波冲击试验机 Impact Testing Equipment

名称 Equipment name	性能指标 Performance
最大冲击能量 Max. Impact Energy	750J
试验能量范围 Test range	80%*750J
适用标准 Standards	ASTM/JIS/ISO/GB
冲击速度 Impact speed	5.42 m/s
表盘和光栅数据采集装置 Data acquisition device	分辨率 Resolution : 360/10000 = 0.036°
试样低温箱 Low temperature testing box	室温 Room temp ~ -196℃

03 剪切试验机 Shear Testing Equipment

剪切试验机 / Shear testing machine

剪切试验装置 / Shear testing rig

04 腐蚀试验设备 Corrosion Testing Equipment

→ 多通道恒电位仪 Multichannel potentiostat

名称 Equipment name	性能指标 Performance
恒电位范围 Potential range	±10V
恒电流范围 Current range	10nA~400mA
通道数 Channel num	5
电流精度 Accuracy of current	0.5%

→ 点腐蚀仪 Pitting corrosion instrument

名称 Equipment name	性能指标 Performance
扫描范围 Scanning range	120mm×90mm
灵敏度 Sensitivity	1mV
针步分辨率 Stitch resolution	0.5μm
振动幅度 Amplitude	0~60μm

→ 晶间腐蚀装置 Intercrystalline corrosion test

名称 Equipment name	性能指标 Performance
电炉功率 Power of electric furnace	1000W

复合板试验设备
Test Equipment

→ 循环腐蚀试验箱 Cycle corrosion testing equipment

名称 Equipment name	性能指标 Performance
温度控制 Temperature range	室温 Room temp~60℃
湿度控制 Humidity range	可达到饱和湿度 Saturated humidity : 100%
喷雾能力 Spray capacity	1-2ml/h

复合板的焊接
Welding Technology of Clad Plate

11

11.1

适用场合及要求

以工业结构用不锈钢复合板为主，复合板总厚度不小于4mm。不锈钢复合板基层与复层材料化学成分与性能应满足各自材料标准要求。

Applied Situation and Requirement

The stainless steel clad plates used in most of industrial structure are included with the wall thickness no more than 4mm. The chemical composition and properties of the base plate and cladding plate shall meet the respective standard requirement.

11.2

不锈钢复合板焊接性特点

不锈钢复合板的焊接性包括两方面问题：

(1) 基层碳钢和复层不锈钢本身的焊接性；

(2) 基层焊缝金属与复层焊缝金属之间的相互稀释作用对接头性能的影响。

为了最大程度的降低这种稀释作用，在基层和复层之间需要焊接过渡层，并通过合理选择焊接材料与焊接工艺来保证质量。

Stainless Steel Clad Plate Weldability Characteristics

There are 2 issues in the weldability of stainless steel clad plate:

(1) Respective weldability of carbon steel base plate and stainless steel cladding plate.

(2) Effective of base and cladding weld metal diluting each other to weld joint properties.

To decrease the above dilution, transition layer is needed between base and cladding weld, and welding quality will be guaranteed by consumables optimal section and welding procedure.

11.2.1

基层材料与复层材料焊接性

工业结构用不锈钢复合板基层材料一般为焊接性较好的低碳钢或低合金高强钢。表11-1所示为不同种类不锈钢复合板复层材料焊接性特点。

Base and Cladding Plate Weldability

The base plate of industrial structure stainless steel clad plate is low carbon or low alloy high strength steel with good weldability. Table 11-1 shows cladding plate weldability characteristics of different kinds of stainless steel clad plate.

表11–1 不同种类不锈钢复合板复层材料焊接性特点

Table 11-1 Cladding plate weldability of different kinds of stainless steel clad plate

种类 Kinds	典型钢种 Typical products	焊接性特点 Weldability characteristics
A	022Cr19Ni10(304L) 022Cr17Ni12Mo2(316L) 06Cr18Ni11Ti(321)	1) 热裂纹敏感性较大; 2) 焊接接头晶间腐蚀以及应力腐蚀倾向明显; 3) 焊接接头可能出现δ铁素体或σ相导致的低温脆化; 4) 整体来看，奥氏体不锈钢具有比较良好的焊接性。 1) High hot cracking sensitivity; 2) Obvious intergranular and stress corrosion sensitivity in weld joint; 3) Low temperature brittlement caused by possibly appeared δ-ferrite and σ phase in weld joint; 4) Overall, austenite stainless steel has good weldabillity.
DF	022Cr23Ni5Mo3N(2205) 022Cr25Ni7Mo4N(2507)	1) 具有比较良好的焊接性，只要双相比例控制得当; 2) 焊缝金属可能出现相比例失调并导致性能恶化; 3) 析出σ相和碳氮化物造成接头脆化与耐蚀性下降。 1) Good weldabillity if the rate of double phase is optimal; 2) Possibly phase rate missing will decrease weld metal property; 3) The precipitating σ phase and carbonitride causes weld joint brittlement and decrease the corrosion resistance.
F	10Cr15(429) 10Cr17(430)	1) 某些场合具有较高的焊接冷裂敏感性; 2) 热影响区粗晶区存在粗晶脆化以及σ相脆化倾向; 3) 处于敏化温度区间的焊接热影响区局部会由于碳氮化物的析出引起严重的晶间腐蚀。 1) Fairly high cold cracking sensitivity in certain situation; 2) Coarse grain and σ phase brittlement in coarse grain heat affect zone (CGHAZ); 3) Precipitating of the carbonitride causes serious intergranular corrosion in the local HAZ during sensitization temperature range.
M	12Cr13(410) 20Cr13/30Cr13(420)	1) 淬硬倾向较大，容易产生焊接冷裂纹; 2) 调节碳含量使焊缝金属中获得强韧性较好的低碳马氏体，焊接性能够明显改善; 3) 适当的焊后热处理能够改善接头综合性能。 1) High quench hardening tendency and cold crack often appear; 2) Regulating carbon content to obtain low carbon martensite with fairly good strength and toughness in weld metal and improve its weldability; 3) Proper post-weld heat treatment will improve the integral property of the weld joint.

复合板的焊接
Welding Technology of Clad Plate

种类 Kinds	典型钢种 Typical products	焊接性特点 Weldability characteristics
PH	05Cr17Ni4Cu4Nb(630) 07Cr17Ni7Al(631)	1) 一般均具有良好的焊接性，无需焊前预热和后热； 2) 为了保证接头强度与耐腐蚀性能，焊后一般需要对接头进行与母材相同的析出硬化时效处理过程。 1) Commonly, it has good weldability, preheating and post-heating aren't needed; 2) Precipitation hardening aging treatment with the same procedure as base metal is needed to assure the weld joint strength and corrosion resistance properties.

Remarks: **A**: Austenite stainless steel; **DF**: Double phase stainless steel; **F**: Ferrite stainless steel; **M**: Martensite stainless steel; **PH**: Precipitation hardening stainless steel

11.2.2

过渡层设计原则与焊接性特点

过渡层的设计原则如下：

- 避免焊缝中化学成分失配而产生马氏体组织以及由此造成的焊缝脆化；
- 弥补基层的稀释作用而造成的合金元素含量降低，保证接头耐腐蚀性能；
- 具有良好的塑性和韧性，避免结构应力开裂与失效。

对于工业结构常用不锈钢复合板，过渡层的焊接一般选择25Cr-13Ni(Mo)和25Cr-20Ni(Mo)型焊接材料，从焊接性角度来讲，具有以下特点：

- 该种奥氏体焊缝具有明显的热裂纹倾向；
- 需要采取适当措施减小过渡层焊缝晶间腐蚀倾向；
- 过渡层在保证基层与复层成分平稳过渡的条件下不宜过厚。

Transition Layer Design Principle and Weldability Characteristics

Transition layer design principles are as follows:

- Avoiding weld metal chemical composition miss matching to bring martensite and weld metal brittlement;
- Compensating alloy content decreasing caused by base plate dilution and assuring weld joint corrosion resistance properties;
- Good ductility and toughness to avoid stress cracking and failure of the structure.

For the industrial structure stainless steel clad plates, 25Cr-13Ni(Mo) and 25Cr-20Ni(Mo) consumables are usually selected for transition layer welding with the following feature:

- Obvious hot cracking sensitivity;
- Intergranular corrosion need to be reduce through proper measures;
- If chemical composition can be transited stably from base plate to cladding plate, transition layer thickness should be as thinner as it can.

11.3

不锈钢复合板焊接材料选择

不锈钢复合板焊接材料选择主要遵循以下原则：

- 基层焊接材料与基层碳钢至少能够实现等强匹配，保证基层焊缝强韧性；
- 过渡层焊接材料能够实现基层与复层化学成分上的平稳过渡；
- 复层焊接材料与同质不锈钢焊接时相同，保证焊缝化学成分与母材一致。

表11-2、11-3分别为常用不锈钢复合板基层、过渡层与复层焊接材料推荐选择方案。

Consumables Selection for Stainless Steel Clad Plate

The main principles for the consumables selection for stainless steel clad plate are as follows:

- Equal strength matching assures the strength and toughness of base plate weld;
- Chemical composition can be transited stably from base plate to cladding plate;
- For cladding plate consumable selection, weld metal chemical composition shall be identical to stainless steel cladding plate.

Table 11-2 and 11-3 show the recommend consumable selection plans for the base plate, transition layer and cladding plate of common stainless steel clad plate.

表11-2 常用不锈钢复合板基层焊材推荐选择方案

Table 11-2 Recommend consumable selection plans for base plate of common stainless steel clad plate

基层材质 Base plate	手工电焊条 Electrode	气体保护焊丝与气体 Gas shielded solid wire and gas		埋弧焊丝与焊剂 Submerged arc welding wire and flux
	AWS(GB)型号 Specification	AWS(GB)型号 Specification	保护气体 Gas	焊剂+焊丝AWS(GB)型号 Flux and wire specification
Q235A~C Q245R	E6013(E4303) E6015(E4315) E6016(E4316)	ER70S-6(ER50-6) ER70S-G(ER50-G)	Ar or CO_2	F7A0-EL8 HJ431/SJ101-H08MnA
Q345A~C Q345R	E7015(E5015) E7016(E5016)	ER70S-6(ER50-6) ER70S-G(ER50-G)		F7A2-EM12 HJ431/SJ101-H10Mn2
Q390 Q420 Q460	E8015(E5515) E8016(E5516) E8018(E5518)	ER80S-G(ER55-G)	Ar、CO_2 or mixed gas	F8A2-EA1 HJ431/SJ101-H08Mn2MoA/H08Mn2SiA
Q550	E9015(E6015) E9016(E6016)	ER90S-G(ER60-G)		F9A4-EA2 HJ431/SJ101-H10Mn2MoA
Q620	E10015(E7015) E10016(E7016)	ER100S-G (ER70-G)		F8A4-EA3 HJ431/SJ101-H10Mn2MoA
Q690	E11015(E7515) E11016(E7516)	ER110S-G (ER75-G)		F11A4-ENi1 HJ431/SJ101-H10MnNiMoA
X52/X60 X65/X70	E6010(E4310) E8010(E5510) E8018(E5518)	ER70S-6(ER50-6) ER70S-G(ER50-G) ER80S-G(ER55-G)	Pure CO_2 or mixed gas	F8A2-EA1 HJ431/SJ101-H08Mn2MoA/H08Mn2SiA

复合板的焊接
Welding Technology of Clad Plate

基层材质 Base plate	手工电焊条 Electrode	气体保护焊丝与气体 Gas shielded solid wire and gas		埋弧焊丝与焊剂 Submerged arc welding wire and flux
	AWS(GB)型号 Specification	AWS(GB)型号 Specification	保护气体 Gas	焊剂+焊丝AWS(GB)型号 Flux and wire specification
12CrMo **12CrMoR**	E8015-B1 (E5515-B1) E8016-B1 (E5516-B1)	ER80S-B2 (ER55-B2)	Ar、CO_2 or mixed gas	F8A2-EB2 (HJ350/SJ101-H13CrMoA)
14CrMo **14CrMoR** **15CrMo** **15CrMoR**	E8015-B2 (E5515-B2) E8016-B2 (E5516-B2)			
A/B/D/E **DH32** **DH36** **EH36**	E7015(E5015) E7016(E5016) E7018(E5018)	ER70S-6(ER50-6) ER70S-G(ER50-G)	Ar or CO_2	F7A2-EM12 (HJ431/SJ101-H10Mn2)
EH40 **FH36** **FH40**	E8015(E5515) E8016(E5516) E8018(E5518)	ER80S-G(ER55-G)	Ar、CO_2 or mixed gas	F8A4-ENi2 (HJ431/SJ101-H10MnNi2A)

表11-3 常用不锈钢复合板过渡层与复层焊材推荐选择方案

Table 11-3 Recommend consumable selection plans for transition layer and cladding plate of common stainless steel clad plate

	过渡层焊接材料推荐选择方案 Consumable selection plans for transition layer		
过渡层材质 Transition layer material	手工电焊条 Electrode	气体保护焊丝与气体 Gas shielded solid wire and gas	
	AWS(GB) Specification	AWS(GB) Specification	保护气体 Gas
304/304L/305/308	E309L (E309L)	ER309L(ER309L)	Ar or mixed gas
309S/310S	E310 (E310)	ER310(ER310)	
312	ENiCrMo-3 (ENiCrMo-3)	ENiCrMo-3(ENiCrMo-3)	
316/316L/317/317L	E309LMo (E309LMo)	ER309LMo(ER309LMo)	
321	E309L (E309L)	ER309(ER309)	
347	E309LNb (E309LNb)	ER309LNb(ER309LNb)	
2205/2304	E309LMo (E309MoL) E2209(E2209)	E309LMo(E309MoL) ER2209(ER2209)	
2506	E309LMo (E309LMo)	ER309LMo(ER309LMo)	
2507	E2594 (E2594)	E2594(E2594)	
405/429/430	E309L (E309L)	ER309L (ER309L)	
434/443	E309LMo (E309LMo)	ER309LMo (ER309LMo)	

过渡层焊接材料推荐选择方案 Consumable selection plans for transition layer

过渡层材质 Transition layer material	手工电焊条 Electrode	气体保护焊丝与气体 Gas shielded solid wire and gas	
	AWS(GB) Specification	AWS(GB) Specification	保护气体 Gas
403/410/420/431	E309L (E309L)	ER309L (ER309L)	Ar or mixed gas
630/631/632	E309L (E309L) E309LMo (E309MoL)	ER309L (ER309L) ER309LMo (ER309MoL)	

复层焊接材料推荐选择方案 Consumable selection plans for cladding plate

复层材质 Cladding plate	手工电焊条 Electrode	气体保护焊丝与气体 Gas shielded solid wire and gas		埋弧焊丝与焊剂 Submerged arc welding wire and flux
	AWS(GB)型号 Specification	AWS(GB)型号 Specification	保护气体 Gas	焊剂+焊丝GB型号 Flux and wire specification
304/304L **305/308**	E308L (E308L)	ER308L (ER308L)		HJ260/SJ601-H0Cr21Ni10
309/310S	E310 (E310)	ER309L (ER309L)		HJ260/SJ601-H0Cr21Ni10
312	ENiCrMo-3 (ENiCrMo-3)	ERNiCrMo-3 (ERNiCrMo-3)		
316/316L	E316L (E316L)	ER316L (ER316L)		SJ601-H0Cr19Ni12Mo2
317/317L	E317L (E317L)	ER317L (ER317L)		
321	E309L (E309L)	ER321 (ER321)		
347	E309LNb (E309LNb)	ER347(ER347)		
2205	E2209(E2209)	ER2209(ER2209)		SJ601-H00Cr22Ni9Mo3
2506	E2593(E2593)	ER2553(ER2553)	Ar or mixed gas	
2507	E2594(E2594)	ER2594(ER2594)		
405 **429** **430**	E430(E430) E308L(E308L)	ER409(ER409) ER430(ER430) ER308L(ER308L)		
434/443	E309LMo (E309MoL)	ER439(ER439)		
		ER446LMo (ER446LMo)		
403/410/ **410S/420/431**	E410(E410) E308L(E308L)	ER410(ER410) ER420(ER420)		
630	E630(E630)	ER630(ER630)		
631	E309L (E309L)	ER309L (ER309L)		
632	E309LMo (E309LMo)	ER309LMo (ER309LMo)		

复合板的焊接
Welding Technology of Clad Plate

11.4

焊接工艺 Welding Procedure

11.4.1

焊接方法选择

针对工业结构用不锈钢复合板，基层和复层材料的焊接可以采用手工焊条电弧焊(SMAW)、钨极氩弧焊(TIG)、熔化极气体保护焊(GMAW)、埋弧焊(SAW)等，过渡层的焊接一般不采用埋弧焊(SAW)。

Welding Process Selection

For industrial structure stainless steel clad plate, shielded metal arc welding (SMAW), Tungsten inert gas arc welding (TIG), Gas metal arc welding (GMAW), Submerged arc welding (SAW) etc. are often applied in base and cladding plate welding, while SAW isn't used in transition layer welding.

11.4.2

下料与焊接坡口型式

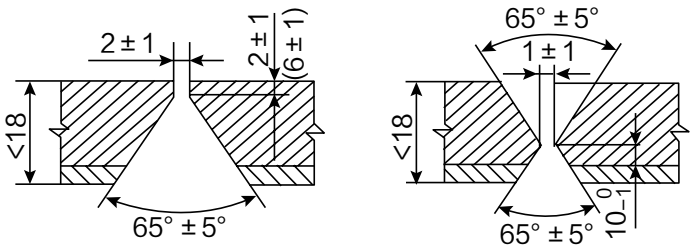
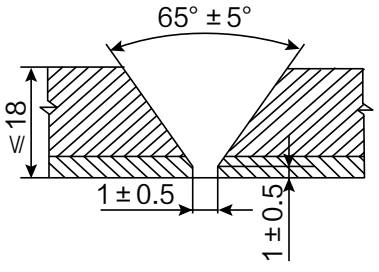
不锈钢复合板优先采用机械切割方法进行下料，切割面应保持平整光滑。主要的焊接坡口型式如表11-4所示，包括对接和角接两种接头型式。

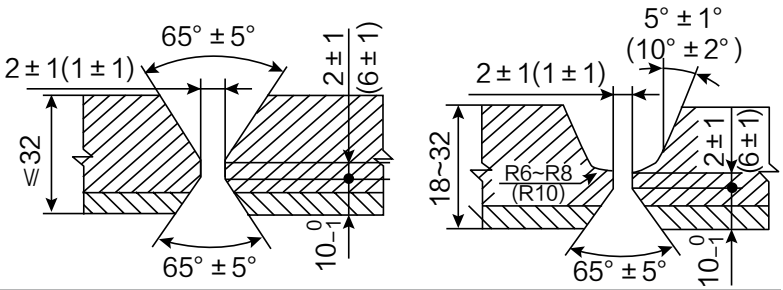
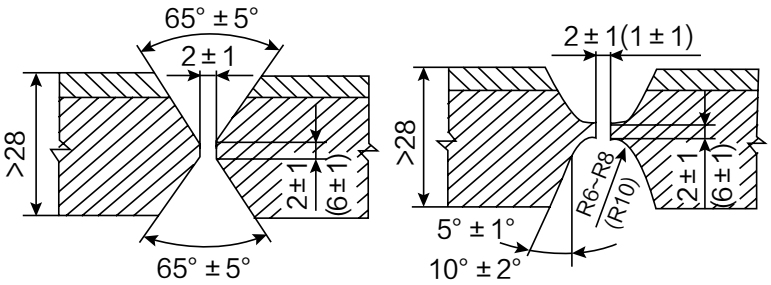
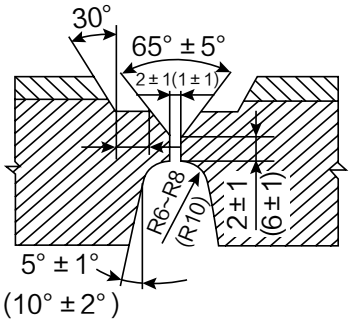
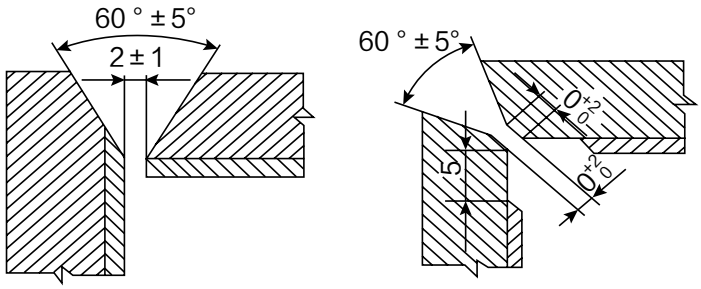
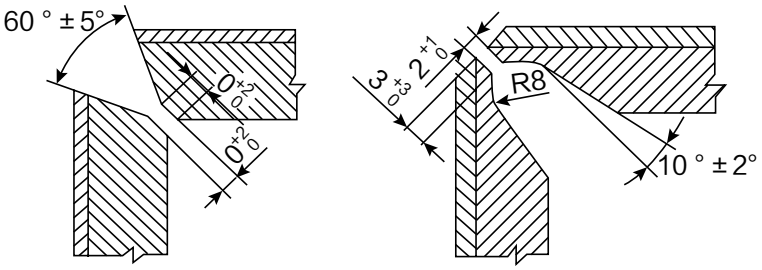
Blanking and Welding Bevel Type

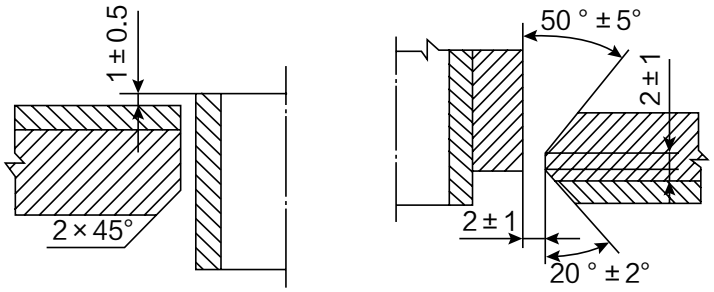
Mechanical cutting is prior to be used in stainless steel clad plate blanking with smooth and glossy surface. Table 11-4 shows the main welding bevel type, including butt and fillet.

表11-4 不锈钢复合板主要焊接坡口型式

Table 11-4 The main welding bevel type

应用条件 Applied condition	焊接坡口形式与尺寸 Welding bevel type and dimension
复合板厚度 Clad plate thickness<18mm	
复合板厚度 Clad plate thickness <18mm 并且只能单面施焊 And only be single side welded	

应用条件 Applied condition	焊接坡口形式与尺寸 Welding bevel type and dimension
复合板厚度 Clad plate thickness 18~32mm	
复合板厚度 Clad plate thickness >28mm	
要求基层焊缝对复层焊缝低稀释率的场合 For situation of low dilution of base weld to cladding weld	
不锈钢复层在内侧的角接头 Stainless steel cladding plate is inside of the fillet	
不锈钢复层在外侧的角接头 Stainless steel cladding plate is outside of the fillet	

应用条件 Applied condition	焊接坡口形式与尺寸 Welding bevel type and dimension
不锈钢复合板与复合管对接 Butt welding of stainless steel clad plate and tube	

11.4.3

焊前准备工作与装配

不锈钢复合板施焊前，需要进行相关准备工作，主要包括焊接设备、焊接材料以及焊接操作人员资质审核、焊件清理、组装与定位等。为了保证焊接质量，需要应用机械方法或有机溶剂将焊接坡口及其两侧20mm范围内的水分、锈蚀、油污等清理干净。厚度相同的焊件组装时，应以复层表面为基准，其错边量不应大于复层厚度的1/2，且不应大于2mm。厚度不同的不锈钢复合板装配应按照用户设计要求执行。定位焊必须在基层坡口面上进行。

Preparation and Assembling Before Welding

Before welding of stainless steel clad plate, some related preparations are needed, in which welding equipment, consumables, operators certifications, weldment cleaning and assembling, etc. The water, corrosion and greasy shall be removed with mechanical machining or organic solvent 20mm all around the bevel to guarantee the welding quality. When assembling the weldment with the same wall thickness, the misalignment shall be no more than 1/2 of the wall thickness of cladding plate, and not exceed 2mm. While for the stainless steel clad plate with different wall thickness, the company's design requirement shall be observed. Tack-weld shall be carried out in the base plate bevel.

11.4.4

焊接工艺要求

不锈钢复合板对接接头的焊接顺序是：首先焊接基层碳钢，然后焊接过渡层，最后焊接复层不锈钢。如果无法按照这种顺序执行，则需要遵循用户设计要求。

- 基层焊道焊接时不能熔化复层不锈钢材料；
- 过渡层焊接前，碳钢焊缝距离复合界面1.5~2.5mm；
- 过渡层焊缝厚度2~4mm，应覆盖基层焊缝和母材，并采用较小热输入；
- 在过渡层焊缝上进行复层的焊接，尽可能采用较小的焊接热输入；
- 实际的不锈钢复合板产品施焊时，需要进行焊接工艺评定，依据评定合格的焊接工艺，编制焊接工艺规程，并在焊接施工时严格遵守。

Welding Procedure Requirement

The welding sequence of stainless steel clad plate is as follows: firstly, base carbon steel plate is welded, then the transition layer, finally the stainless steel cladding plate. If it is impossible, the design requirement shall be observed.

- The cladding stainless steel shall not be fused during the base plate welding;
- Before transition layer welding, the distance between carbon weld and composite interface will be 1.5~2.5mm;
- Fairly lower heat input is recommended for transition layer welding with thickness 2~4mm, which shall cover base weld and base metal;
- Fairly lower heat input is recommended for cladding plate welding on transition layer;
- Welding procedure qualification is necessary before the stainless steel clad plate product. According to qualified welding procedure, welding procedure specification(WPS) will be constituted and observed in the field construction.

11.4.5

焊后清理与热处理

不锈钢复合板焊接完成后，需要清除焊缝及其两侧的焊渣、焊瘤、飞溅物等，保证焊缝美观。对于大厚度不锈钢复合板结构件，进行适当的焊后热处理能够消除焊接残余应力，对焊接接头抗应力腐蚀能力的提高有利。

Post-weld Cleaning and Heat Treatment

After welding, the slag, overlap and spatters shall be cleaned in the weld and all around it to assure good weld appearance. For the thick stainless steel clad plate product, proper post-weld heat treatment can eliminate welding residual stress, which is benefit to improve the stress corrosion cracking resistance of the weld joint.

11.5

焊接质量检验

不锈钢复合板焊接接头质量检验应由经过专业技能培训并持有相关资质证书的人员进行。焊接质量检验包括工序检验和成品检验。焊接工序经过现场质检人员认可后，方可转入下一道工序。成品检验包括外观检验、无损检验、压力试验和密封性试验、焊接接头力学性能试验、焊接接头耐腐蚀性能试验等。

Welding Quality Inspection

Stainless steel clad plate weld joint quality inspection shall be done by special training and certificated person. Welding quality inspection includes process inspection and product inspection. Welding working procedure can be shifted to the next one when it is approved by the site inspector. Product inspection includes visual inspection, non-destructive testing, pressure testing, leakage testing, mechanical and corrosion resistance testing of the weld joint.

11.6

典型不锈钢复合板焊接与接头性能评估

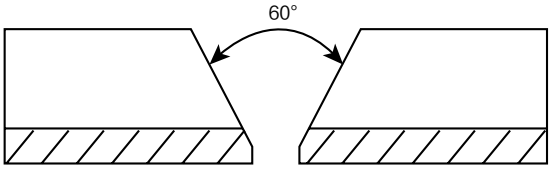
针对壁厚为6+2mm的Q345+304L不锈钢复合板进行了制管焊接工艺技术探索与接头性能评估。图11-1所示为不锈钢复合板焊接坡口型式。整个焊缝包括复层、过渡层和基层，所有焊道均采用手工TIG焊接方法。图11-2(a)~(c)所示分别为不锈钢复合板焊缝不同焊道金相组织。接头横向抗拉强度为557MPa，试样断在母材位置。在D=4a条件下进行焊接接头正弯和背弯试验，受拉面均没有出现开裂。如图11-3(a)，(b)所示，不锈钢复合板复层焊缝焊态下具有较明显的晶间腐蚀倾向，经过1050℃/30min固溶处理，基本消除了焊缝金属的晶间腐蚀。

Representative Stainless Steel Clad Plate Welding and Weld Joint Evaluation

Q345+304L stainless steel clad plate with wall thickness of 6+2mm has been conducted welding test and evaluation to develop pipe making welding procedure. Figure 11-1 shows the stainless steel clad plate bevel type. The integral weld includes cladding weld, transition layer weld and base weld, which have been welded by manual TIG. Figure 11-2 (a)~(c) show different weld bead microstructure of stainless steel clad plate, respectively. In transverse tensile test, the tensile strength is 557MPa and the specimen fractured at base metal. The face and root bending test of weld joint has been conducted at D=4a condition, and there isn't any cracks in the tension surface. Figure 11-3 (a) and (b) show obvious intergranular corrosion in as-weld state in the stainless steel cladding weld, while after solution treatment at 1050℃/30min, the intergranular corrosion almost disappear.

图11-1 不锈钢复合板焊接坡口型式

Figure 11-1 The stainless steel clad plate bevel type



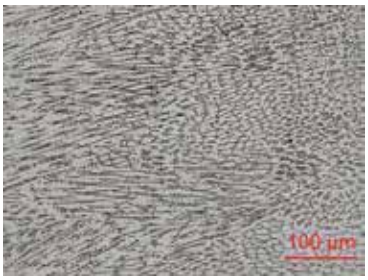
坡口钝边为0.5mm，间隙为1mm

Root face is 0.5mm, assembling gap is 1mm

复合板的焊接
Welding Technology of Clad Plate

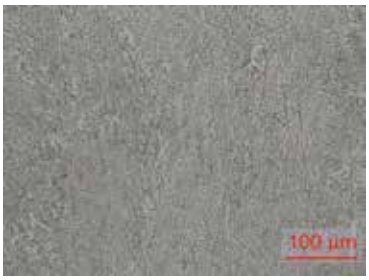
图11-2 不锈钢复合板焊缝不同焊道金相组织

Figure 11-2 Different weld bead microstructure of stainless steel clad plate



（a）复层焊缝 / Cladding weld

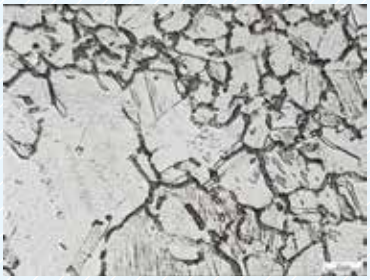
（b）过渡层焊缝 / Transition layer weld



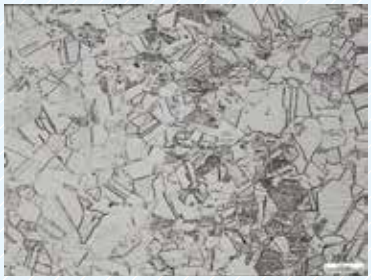
（c）基层焊缝 / Base plate weld

图11-3 焊态和固溶处理态不锈钢复合板复层焊缝晶间腐蚀试验后组织形貌

Figure 11-3 Stainless steel cladding weld metal microstructure after intergranular corrosion testing in as-weld state and solution treatment state



（a）焊态 / As-weld state



（b）固溶处理态 / Solution treatment state

复合板的运输、存储、切割
Transportation, Storage, Cutting

12

复合板的运输、存储

运输时为了避免表面划伤，利用橡胶或枕木，尽可能采用不锈钢保护专用材，为避免指纹产生的表面污染，操作时应带手套。

吊装的时候建议使用专门的吊具。仅仅使用钢丝绳时容易滑动造成危险，同时也容易压伤、划伤不锈钢复层表面，造成缺陷。

推荐存在在室内，如果室外存放时应当覆盖雨布。在室内存放时，应当注意监控室内的温度与湿度，避免因为气温与湿度的急剧变化造成“结露”现象。

应避免与水分、灰尘、油、润滑油等直接接触，以免表面生锈，或者焊接不良耐蚀性下降。

贴膜和钢板基体之间侵入水分时，腐蚀速度反而比没贴膜时情况还要快。

仓库保管时应放在干净、干燥易通风处，保持原来的包装状态，贴膜的不锈钢应避免阳光直射光线，贴膜应周期性做检查，要是贴膜变质（贴膜寿命6个月）应立即替换，加垫纸时包装材料若浸湿，为防止表面腐蚀应立即除掉垫低。

Transportation and Storage

Avoid surface scratches in transportation, rubber or sleeper can be adopted, special tools will be better. Working with gloves to prevent contamination with fingerprint.

Appropriative hanger is recommended.

Stored inside as you can as possible, it should be covered when stored outside. Be careful range of temperature and moisture in storehouse which may leads to condensation phenomena.

Avoid contact with aggressive medium like water, dust, all kinds of acid and so on to prevent rust.

Be careful water invasion into metal surface and plastic film.

Keep storehouse clean, dry and ventilative. Clad plate covered with plastic film should be stored away from direct sunlight, and plastic film should be checked periodically.

复合板的切割

复合板可以采用等离子切割、也可以采用机械式剪力切割。

Cutting

Cutting methods like plasma cutting and mechanical shearing are viable.

典型产品介绍
Typical Products

13

1. 核电安注箱复合板SA-240 Type304L+SA-533TypeB Cl.1
Clad-rolled steel plate for safety injection tank of nuclear plants

背景

国核压水堆示范工程CAP1400核电站安注箱用复合板，结合面剪切强度及探伤等技术要求高，生产难度大。

Background

Clad plates for safety injection tank of the nuclear plant CAP1400, which is a demonstration project of pressurized water reactor designed by State Nuclear Power Technology Corporation (SNPTC), require high shear strength of bonding interface. Additionally, there are strict standards of defect inspection for these clad plates, which makes these plates rarely produced by Chinese before.

工作条件

安注箱是核电站安全注入系统中重要的应急安全设备，在反应堆压力降到中压时，安注箱能快速将硼酸液注入堆芯防止燃料棒熔化，保证核电站安全，其质保要求非常严格。

Service condition

Safety injection tank is an significant emergency facility of safety injection system of nuclear plants. When the pressure in the nuclear reactor decreases to medium level, boric acid will be injected into the core of the reactor unit to prevent the nuclear fuel rods from melting to ensure the security of the nuclear plants, which leads to the enhanced quality assurance of the secure injection tank.

复合板要求

- 力学性能：拉伸、冲击、落锤、剪切、外弯、内弯、侧弯、晶间腐蚀、显微硬度。
- 无损检测：超声、磁粉、渗透、结合率。
- 厚度精度：碳钢基材和不锈钢覆材的厚度精度要求高。

Requirements of Clad Steel

- Mechanical examination including tensile test, impact test, drop-weight test, bend test, inter-granular corrosion and hardness test.
- Non-destructive examination including ultrasonic examination, magnetic examination, permeation test and bonding area fraction test.
- Accuracy of thickness: strict requirement on thickness control of carbon steel as base material and stainless steel as clad material.

宝钢与用户签订商务合同后，在厚板5m产线生产了核电安注箱用复合板SA-240 Type304L+SA-533TypeB Cl.1，钢板的各项性能指标均达到用户要求，并通过用户现场见证，该产品将用于CAP1400核电站的安注箱，标志着中国钢铁在高等级厚钢板的生产上又前进了一大步。

After the business contract between baosteel and customers was signed, the clad-rolled steel plates SA-240 Type 304L+SA-533 Type B Cl for safety injection tank of nuclear plants was produced on the heavy-plate product line (maximum width of 5 m) in Baosteel. The properties of the steel plates fulfilled the requirement of the customers, and were supervised by customers. This product will be used for safety injection tank of the nuclear plants CAP1400,indicating a big step of steels produced by Chinese steelworks towards high-quality heavy-plate steels.

典型产品介绍
Typical Products

性能实绩 Properties

牌号 Steel grade	厚度 Thickness (mm)	拉伸试验（横向） Tensile test (transverse)			冲击试验（纵向） Impact test (longitudinal)		剪切强度 Shear strength /MPa	弯曲试验(横向) Bending test (transverse)	
		下屈服强度 ReL, MPa	抗拉强度 Rm, MPa	伸长率 Elongation A, %	温度 Temperature ℃	冲击值 Impact value J	标准要求 Required strength≥210	弯曲角度 Bending angle	弯曲直径 Bending diameter
SA533CL1 +304L	62+7	555	661	25	10	230	393	180°	3.5a

供货日期 Supply date: 2015.3

供货规格及数量 Supply dimensions and quantity

钢种牌号 Steel grade	厚度 Thickness (mm)	宽度 Width (mm)	长度 Length (mm)	数量（张） Quantity (piece)	总重 Total weight / (t)
SA533+304L	62+7	2000-2600	4000-7000	21	149.6

2. 高酸性环境烟气管道
Pipeline for Strongly acidic gas S31254+Q345B

背景

S31254属超级奥氏体不锈钢，其合金元素Cr、Ni、Mo含量均很高，耐蚀性极佳。采用S31254作为复层的S31254+Q345B复合板之前为进口或国内爆炸复合生产。

Background

S31254 belongs to super austenitic stainless steel, excellent corrosion resistance due to its high content of Cr, Ni, Mo alloy elements. Currently, S31254 + Q345B clad plate is mainly imported or domestic Exploding Clad Plate.

工作条件

具有较高温度（>50℃）和强酸性（PH=2-3）的严苛的腐蚀环境服役。

Service condition

Gas with high temperature (> 50℃) 、strong acidic (PH :2~3) and corrosive.

复合板要求

- 力学性能：拉伸、冲击、剪切、面弯、背弯、侧弯、点腐蚀、晶间腐蚀、焊接性能及焊缝耐蚀性能。
- 探伤要求：超声、复合率
- 高厚度精度要求：碳钢基层和不锈钢的厚度精度要求均较高

Requirements of Clad Steel

- Mechanical examination including tensile test, impact test, shearing test, bend test, pitting corrosion, inter-granular corrosion and welding performance.
- Non-destructive examination including ultrasonic examination, bonding area fraction test.
- Accuracy of thickness: strict requirement on thickness control of carbon steel as base material and stainless steel as clad material.

性能实绩 Properties

牌号 Steel grade	厚度 Thickness (mm)	拉伸试验（横向） Tensile test (transverse)			冲击试验（纵向） Impact test (longitudinal)		剪切强度 Shear strength /MPa	弯曲试验(横向) Bending test (transverse)	
		下屈服强度 ReL, MPa	抗拉强度 Rm, MPa	伸长率 Elongation A, %	温度 Temperature ℃	冲击值 Impact value J	标准要求 Required strength≥210	弯曲角度 Bending angle	弯曲直径 Bending diameter
S31254+ Q345B	8-20	450	650	30	0	300	460	180°	2a

典型产品介绍
Typical Products

3. 镍基合金复合板
Nickel Based Alloy Clad Steel

背景

油气田常含有硫化氢，氯离子、硫酸根等离子而带有较强的酸性。825镍基合金复合管线钢兼具碳钢与镍基合金各自的优点，可以保证复合管足够的强度与韧性以及内衬复层优良的耐蚀性。

Background

Crude oil and natural gas exploited from fields often contain corrosive substance such as hydrogen sulfide, chloride, sulfate and other ions. UNS08825 nickel-based alloy clad steel has the advantages of both base material and cladding material. Thus, it can ensure sufficient strength and toughness of backing steel as well as the excellent corrosion resistance of the cladding material.

工作条件

适用于石油化工等较强的酸性介质的环境下使用。如原油气田的油气的运输管道及储罐等，可以确保在高硫、高酸值的油气田中的管道工作的安全性与较长的使用寿命。

Service condition

The applications of nickel based alloy clad steel can be used in high corrosive enviroment, such as transimission pipelines or storage tanks of crude oil and natual gas. It can ensure safety and long service life of pipes or storage tanks in high-sulfur, strong acid oil and gas fields.

复合板要求

- 力学性能要求：室温拉伸、高温拉伸、低温冲击、落锤、剪切、弯曲、显微硬度、断裂韧性试验。
- 腐蚀试验：内复层点腐蚀、晶间腐蚀、模拟环境应力腐蚀等；基材的HIC、SSC腐蚀试验。
- 结合要求：需要满足ASTM A265 Class1的规定要求。
- 高厚度精度与表面质量要求。

Requirements of Clad Steel

- Mechanical properties: Strength, toughness, DWTT, shear strength, bending, hardness, CTOD, etc.
- Corrosion properties: Pitting corrosion, intergranular corrosion, SCC, HIC, etc.
- Bonding requirement: Fulfill ASTM A265 Class1.
- High surface quality and high thickness accuracy.

性能实绩 Properties

牌号 Steel grade	厚度 Thickness (mm)	拉伸试验（横向） Tensile test (transverse)			冲击试验（纵向） Impact test (longitudinal)		剪切强度 Shear strength /MPa	DWTT	
		下屈服强度 ReL, MPa	抗拉强度 Rm, MPa	伸长率 Elongation A, %	温度 Temperature ℃	冲击值 Impact value J	标准要求 Required strength≥250	Temperature ℃	剪切面积分数 SA%
825+X65	3+22	500	594	46	-20	339	397	-10	100%

供货

与中石油下属公司对复合板制管进行了联合评定，已成功试制Φ610mm直径复合管，各项性能满足要求。

Supplies

A joint assessment of 825+X65 clad pipe manufacturing has been conducted by China National Petroleum Corporation(CNPC) and Baosteel. A clad pipe has been successfully manufactured and the pipe properties meet all the requirements of a certain CNPC project.

4. 电梯轿厢装饰用冷轧复合板
Cold-Rolled Steel Sheet for Elevator

背景

304L+BDT01+304L电梯轿厢装饰用冷轧复合板是一种以碳钢为基体、双面整体连续地包覆一定厚度不锈钢的双金属高效节能材料。它充分发挥两种材料特性优势，既具有不锈钢的耐蚀性，又具有碳钢良好的力学性能，同时它可节约镍铬等贵金属，降低成本，可广泛应用于装饰面板等领域。

Background

304L+BDT01+304L cold-rolled steel sheet is a kind of energy-efficient bimetallic material which is combined with carbon steel as base metal and 304L stainless steel as clad metal on double surface. It owns both excellent corrosion resistance of stainless steel and good mechanical property of carbon steel, also noble metal is saved compared with stainless steel 304L, the cost of this material is obviously reduced, the application prospect of cold-rolled clad material can be predicted.

工作条件

适用于大气腐蚀环境条件下的各种装饰领域，尤其轿厢电梯装饰板。要求材料具有良好的表面装饰性、一定的成形性及304不锈钢同等级的表面耐蚀性。

Service condition

Suitable used in atmospheric environment, such as decorative panel in elevator. Excellent surface appearance, good formability and corrosion resistance are required.

复合板要求

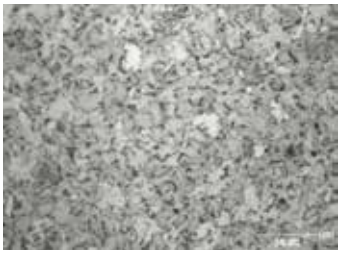
- 表面要求：装饰领域客户对产品表面质量要求非常高，如划伤、麻点、折痕、污染等缺陷一般都不允许出现，尤其麻点缺陷在抛光表面中很难抛掉。我们通过原材料内在质量及生产过程表面质量控制来确保冷轧成品表面。
- 成型要求：一些面板使用领域，涉及折边、打孔、焊接等加工方式，要求材料具有良好的界面结合力、抗折弯性能及焊接性能。
- 腐蚀性能：同常规不锈钢一样，要求表面具有较好的耐腐蚀性，该性能通常通过复层不锈钢化学成分及冷轧生产工艺过程控制来保证。
- 其它要求：力学性能、尺寸精度及板形控制等。

Requirements of Clad Steel

- Surface: High quality is necessary, defections such as scratches, pits, creases, dirts are not permitted.
- Processing: Good formability and weldability are needed.
- Corrosion resistance: The same with conventional 304, it is guaranteed by chemical composition and microstructure of clad layer.
- Other requirements: Mechanical property, dimensional precision and shape control etc.,

性能实绩 Properties

(a) 截面宏观形貌 / Cross sectionstate



(b) 基材 / Base metal

(b) 覆材 / Clad metal

冷轧不锈钢复合板典型微观组织

Typical microstructure of 304L+BDT01+304L cold-rolled sheet

典型产品介绍
Typical Products

钢种牌号 Steel grade	屈服强度 Yield Strength Rp0.2,MPa	抗拉强度 Tensile Strength Rm,MPa	延伸率 Elongation A50,%	基层硬度 Hardness of Base metal Hv	杯突值 Erichsen value IE,mm	深拉延 Deep drawing Value LDR	冷弯 Cold bend 180°(4d)
304L+BDT01+304L	395	540	32	158	11.5	2.2	合格 Good

供货日期 Date: 2015.1-2015.8

供货规格 Supply dimensions:

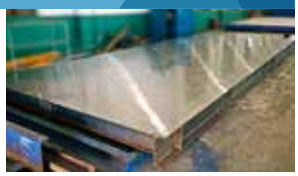
钢种牌号 Steel grade	规格 Specification	用途 Application
304L+BDT01+304L	0.89、1.2、1.4、1.8*1219*C	容器包覆面板 Outter panel
304L+BDT01+304L	1.2*1219*C	电梯面板 Elevator
304L+BDT01+304L	1.2*1219*C	金属门板 Door

室内电梯 / Elevator

金属门板 / Door

5. 模台专用铁素体不锈钢复合板

Special Ferritic Stainless Steel Clad Plate for the Application of Precast Concrete Mold



背景

工厂化生产混凝土预制件所需要的优质模台板则是建筑产业现代化的关键基础材料。纯碳钢或不锈钢作为模台板使用都存在自身难以克服的问题。碳钢表面易锈蚀，造成预制件表面的污染。纯铁素体不锈钢表面质量好，但是其强度、韧性差，使用过程中可能出现弯曲或开裂现象。模台专用铁素体不锈钢复合板充分考虑了碳钢与不锈钢两种材料的优缺点，挑选优质铁素体不锈钢与碳钢配比通过轧制而成。

Background

High quality precast concrete mold plate is the key point to the production of precast concrete components in the modernization of construction industry. As the material of mold plates, pure carbon steel or pure stainless steel has its own insurmountable issues. Carbon steel has poor corrosion resistance, and rust can contaminate the surface of concrete products easily. While for ferritic stainless steel, the strength and toughness are relatively low, which may result in bending or cracking of mold plates in use. Special ferritic stainless steel clad plate is designed and hot rolled by a selection of high quality ferritic stainless steel and carbon steel with a complete consideration of the advantages and disadvantages of both materials.

工作条件

适用于高表面质量的混凝土预制件生产，具有良好的表面光洁度与耐蚀性，并且具有优良的磁性，确保侧模板的安装。

Service condition

It is applicable for the production of high surface quality of precast concrete components due to its good surface finishing quality and corrosion resistance. Also, the installation of side mold plates can be ensured with its excellent ferromagnetic properties.

复合板要求

- 表面要求：表面质量要求非常高，一般不允许出现麻点、折痕、污染等缺陷。
- 平整度要求：复合板用于制造混凝土预制件，钢板需要很高的平直度。
- 腐蚀性能：复合板复层需要具有较高的耐腐蚀性。
- 力学性能：具有较高的强度与韧性，以及优异的结合性能。

Requirements of Clad Steel

- Surface quality: Very strict and high requirement of surface quality. Generally, pitting, crease, contamination are not allowed.
- Flatness: High flatness of clad plates is required for the manufacture of precast concrete.
- Corrosion resistance: The cladding material shall have high corrosion resistance.
- Mechanical Properties: High strength and toughness, as well as excellent bonding properties.

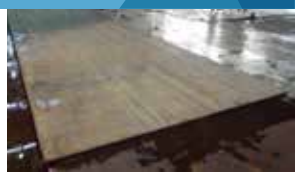
性能实绩 Properties

规格 Specifications of supply: 10*3000~4000mm*12000mm

牌号 Steel grade	厚度 Thickness (mm)	拉伸试验（横向） Tensile test (TD)			冲击试验（纵向） Impact test (longitudinal)		面弯 Bending(2d)	点蚀电位 Pitting potential(mv)	盐雾腐蚀试验 Salt mist test
		屈服强度 YS Rp0.2, MPa	抗拉强度 UTS Rm, MPa	伸长率 EL A, %,	温度 Temperature ℃	冲击值 Absorbed energy J	180°		240h
专用铁素体不锈钢 Special ferritic stainless stee+Q345	10	400	540	36	0	131	合格 Good	220-350	合格 Good

典型产品介绍
Typical Products

6. 双相不锈钢复合板
Duplex Stainless Steel Clad Plate



背景

双相不锈钢复合钢板由于其双相不锈钢层耐磨性能好、耐蚀性强等优点，能显著降低含沙水流对过流面的磨损及水中氯离子的腐蚀，同时，复合基材采用碳钢材料，可以使复合板具有较高的低温韧性，以及优良的可焊性与可加工性。该复合板近年来逐渐运用在水电工程中与石油化工等领域。

Background

The duplex stainless steel cladding layer in duplex stainless clad steel has very good wear resistance and corrosion resistance, especially the corrosion caused by chlorine ions. Furthermore, the clad steel has excellent strength and low temperature toughness, as well as excellent weldability. Duplex stainless clad steels have been extensively used in hydropower engineering and petrochemical fields in recent years.

工作条件

适用于对耐磨、耐蚀性有较高的使用环境，尤其是含氯离子的腐蚀环境。如水电站含沙高速水流用涵洞等，也常用于石油化工等对强度与耐腐蚀性有较高要求的管道与设备。

Service condition

The clad steel is suitable in wear and corrosive enviroment, especially in corrosive environment containing chlorine ions, such as sediment culverts in hydropower station and petrochemical pipes and equipment with requirements of high strength and high corrosion resistance.

复合板要求

- 力学性能要求：拉伸、冲击、剪切、粘结、外弯、内弯、显微硬度。
- 探伤要求：超声波探伤，结合率一级。
- 高板形及厚度精度要求：复合板不平整度以及碳钢基层和不锈钢的厚度精度要求均较高。

Requirements of Clad Steel

- Mechanical properties: Tensile strength、toughness、shear strength、bonding strength、bending、hardness.
- Bonding rate: Fulfill ASTM A265 Class1.
- Good plate flatness and high accuracy of thickness of clad steel.

性能实绩 Properties

规格 Specifications of supply: 4+20*12000mm*3000mm

牌号 Steel grade	厚度 Thickness (mm)	拉伸试验（横向） Tensile test (TD)			冲击试验（纵向） CVN (RD)		剪切强度 Shear Strength MPa	弯曲试验(横向) Bending		粘结强度 Bonding strength MPa
		屈服强度 YS Rp0.2, MPa	抗拉强度 UTS Rm, MPa	伸长率 EL A, %,	温度 Temperature ℃	冲击值 Absorbed energy J	标准要求 Requirement≥210	弯曲角度 Angle 180°	弯曲直径 Diameter 3a	
S32205 +Q345C	4+20	545	638	22	0	296	400	合格 Good		414

7. 耐磨管道复合钢板
Clad Plate for Wear-Resisting Pipe 30Cr13+Q235B

背景

30Cr13属马氏体不锈钢，其合金元素C、Cr含量较高，兼具极强的耐磨性和一定的耐蚀性。

Background

30Cr13 belongs to martensite stainless steel, with extremely strong wear resistance and corrosion resistance due to its high content of C, Cr alloy elements.

工作条件

具有一定温度（≤150℃）和强耐磨、弱腐蚀环境服役。

Service condition

Higher temperature (150 ℃) 、wear-resisting and corrosion environment.

复合板要求

- 力学性能要求：碳钢基层冲击、复合面剪切、不锈钢层硬度及耐磨性。
- 探伤要求：超声、复合率。
- 高厚度精度要求：碳钢基层和不锈钢的厚度精度要求均较高。

Requirements of Clad Steel

- Mechanical properties: Toughness、shear strength、hardness、Wear resistance.
- Non-destructive examination including ultrasonic examination, bonding area fraction test.
- Accuracy of thickness: Strict requirement on thickness control of carbon steel as base material and stainless steel as clad material.

性能实绩 Properties

牌号 Steel grade	厚度 Thickness (mm)	硬度 hardness		冲击试验（纵向） CVN(RD)		剪切强度 Shear strength /MPa	弯曲试验(横向) Bending	
		复层 Base plate	基层 Cladding plate	温度 Temperature ℃	冲击值 Absorbed energy J	标准要求 Requirement≥210	弯曲角度 Angle 180°	弯曲直径 Diameter 3a
30Cr13 +Q235B	10-50	57HRC	115HB	0	50	350	25	≥6a

供货日期 Supply date: 2015.9

供货规格及数量 supply dimensions and quantity

钢种牌号 Steel grade	厚度 Thickness (mm)	宽度 Width(mm)	长度 Length (mm)	数量（张） Quantity(piece)	总重 Total weight/(t)
30Cr13+Q235B	6+8	2500-3000	12000	89	300

典型产品介绍
Typical Products

8. 耐蚀管道复合钢板
Clad plate for corrosion resistant pipeline 316L+Q345B

背景

316L属奥氏体不锈钢，其合金元素Cr、Ni含量较高，且含有一定量的Mo元素，耐蚀性较佳。

Background

316L belongs to austenitic stainless steel, with good corrosion resistance performance due to its high content of Cr, Ni and Mo element .

工作条件

具有一定温度（≤50℃）和弱酸性（PH=5-6）、氯离子浓度在100-1000 ppm波动范围内的腐蚀环境服役。

Service condition

At a certain temperature (≤50℃) 、weakly acidic (PH =5-6) and Corrosive environment (chloride concentration :100~1000 ppm).

复合板要求

- 力学性能要求：拉伸、冲击、剪切、面弯、背弯、侧弯、点腐蚀、晶间腐蚀、焊接性能及焊缝耐蚀性能。
- 探伤要求：超声、复合率。
- 高厚度精度要求：碳钢基层和不锈钢的厚度精度要求均较高。

Requirements

- Mechanical examination including tensile test, impact test, shearing test, bend test, Pitting corrosion ,inter-granular corrosion and Welding performance.
- Non-destructive examination including ultrasonic examination, bonding area fraction test.
- Accuracy of thickness: strict requirement on thickness control of carbon steel as base material and stainless steel as clad material.

性能实绩 Properties

牌号 Steel grade	厚度 Thickness (mm)	拉伸试验（横向） Tensile test (TD)			冲击试验（纵向） CVN(RD)		剪切强度 Shear Strength MPa	弯曲试验(横向) Bending	
		屈服强度 YS Rp0.2, MPa	抗拉强度 UTS Rm, MPa	伸长率 EL A, %,	温度 Temperature ℃	冲击值 Absorbed energy J	标准要求 Requirement≥210	弯曲角度 Angle 180°	弯曲直径 Diameter 2a
316L +Q345B	8-20	430	580	30	0	300	450	合格 Good	

供货日期 Supply date: 2015.9

供货规格及数量 supply dimensions and quantity

钢种牌号 Steel grade	厚度 Thickness (mm)	宽度 Width(mm)	长度 Length (mm)	数量（张） Quantity(piece)	总重 Total weight/(t)
316L+Q345B	3+10	2500-3000	12000	51	160

宝山钢铁股份有限公司
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BAOSHAN IRON & STEEL CO., LTD.
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