DONGBEI SPECIAL STEEL GROUP CO.,LTD.
FUSHUN SPECIAL STEEL CO.,LTD.

Ultra-high Strength Steel

Advancement in Solution Plan for Metallic Materials

CHINA · FUSHUN

Introduction

The first heat of ultra–high strength steel 30CrMnSiNi2A was produced for airplane landing gear by Fushun Special Steel in PRC in March 1956.

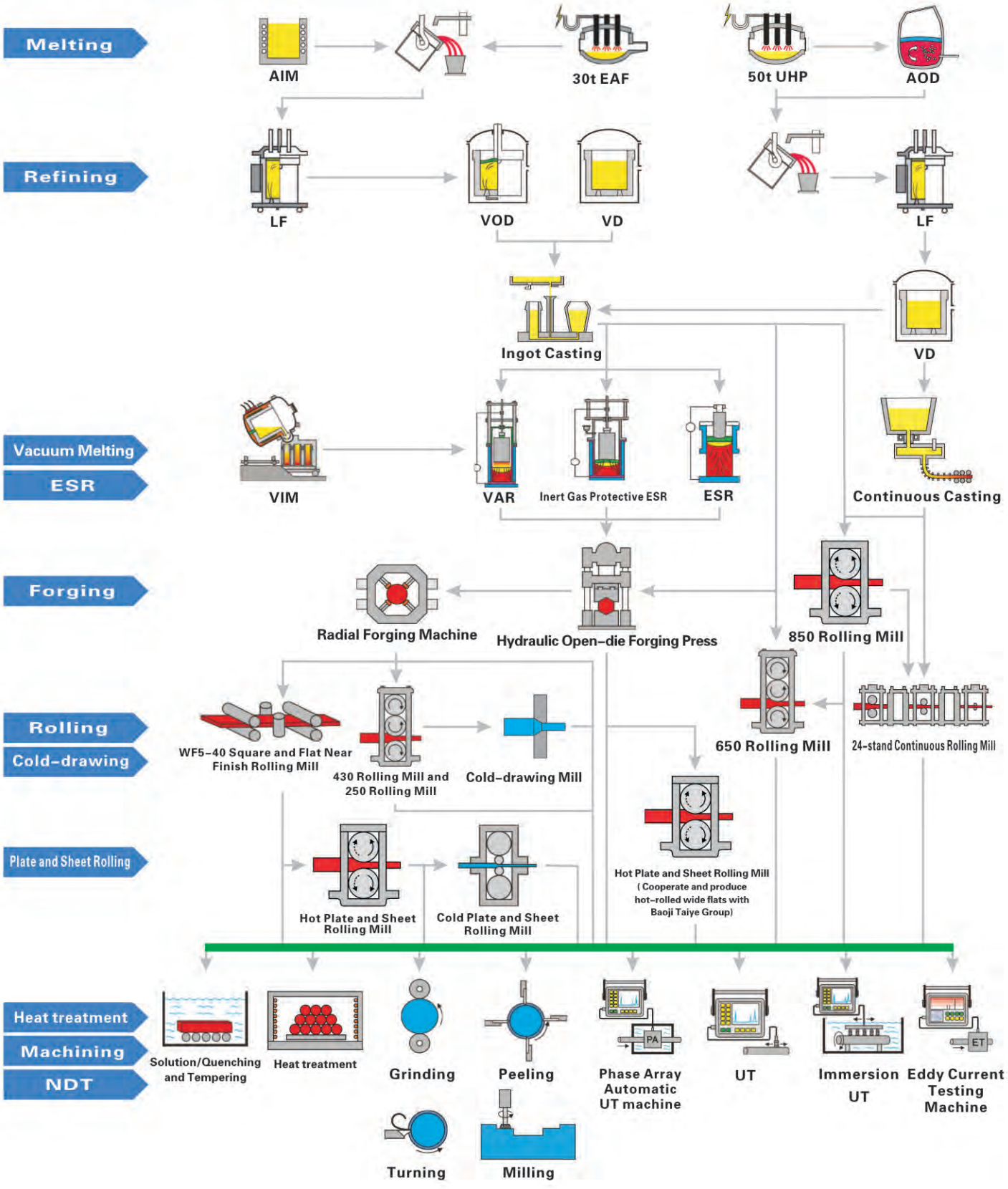
Fushun Special Steel Co.,Ltd.(hereinafter referred to as FSSS for short)was set up in 1937, the former Fushun Steel Plant, which is the scientific research and production base of wrought superalloys for aerospace and aviation in China. FSSS, Dalian Iron and Steel Plant and Beiman Special Steel Plant were reorganized to form Dongbei Special Steel Group Co., Ltd. in Sep., 2004. FSSS has the total assets of 10 billion RMB with the manufacturing capacity of 1 million tons of steel and 0.9 million tons of finished products. FSSS has employees of over 8,600, of which special technicians are over 1,100. FSSS has one technical center, which was promoted to one of the first batch of National Enterprise Technical Centers in 1993, and became Enterprise Postdoctoral Science and Research base in Liaoning Province in 2007. There are 5 senior engineers at professor level as well as 30 senior engineers in Technical Center, which is the largest in size and highest in specializing level among Enterprise Technical Centers.

Ultra–high strength steel products have been produced with the variety from several to almost one hundred and the annual output from dozens of tons to over 4,000 tons based on consistent efforts of several generations of FSSS. The ultra–high strength steel products are widely used in the fields such as aviation, aerospace, weapons, warships, petrochemicals, moulds, automobiles, nuclear power and wind power.

There is one Ultra–high Strength Steel Research office in technical center of FSSS, which is the only research office in ultra–high strength steel among special steel enterprises in China. Several new kinds of material have been co–developed and imitated with several domestic institutes of science and research such as Central Iron &Steel Research Institute, and some of the materials have been initiated for the first time in the military field, for which National Scientific and Technological Progress Prize and Scientific and Technological Prize of former Metallurgical Department etc have successively been awarded.

FSSS is advanced in the purity of ultra–high strength steel products with some products attaining or approaching the actual level of foreign materials such as the products from USA or Russia. Many kinds of high–strength steel such as D406A,980,F141（18Ni Series）,300M,30CrMnSiNi2A,D6AC, which were developed and imitated as early as the beginning of 1960s, have stable quality and technology with the equivalent level of the same kind of materials of home and abroad, and they are still the mass–production materials for key types of military industry. Many new products like AF1410, TM210A, F154, A–100, C250–350, T250 and DT300, which were developed and imitated as early as the beginning of 1980s, have already been extended and applied to several New Types of military industry. At present, only FSSS has the stable process and mass–production capacity for several types of ultra–high strength steel products like martensitic aging steels and second hardening ultra–high strength steels.

Manufacturing Process



Low–alloy Ultra high Strength Steel

Low–alloy ultra high strength steel has the strength ranging from 1500MPa up to 2000MPa, and it can be melted by processes with different levels in accordance with the service demand, so as to meet different requirements on purity, plasticity and toughness from users. The range of applications include high pressure vessels, bulletproof, armor materials, key structural parts, pressure resistance shells, conventional weapons, as well as key components in the industries of petrochemical, wind power, nuclear power and automobile; and in addition, it can be made into force–loading structural parts of large equipments, such as main axles and blots for excavators, gas turbine .

Steel Grade	Melting Process	Mechanical Property						Application
		$R_{P0.2}$ (MPa)	Rm (MPa)	A5 (%)	Z (%)	KU2 (J)	K_{1C} $MPam^{1/2}$	
4340	EAF	≥882	≥980	≥12	≥45	≥55		Key force–loading structural components, bolts, shafts for large equipments, principle for shaft flue gas turbine, connecting parts, fasteners, bulletproof steel, pressure–resisting shell
	EAF+ESR	≥980	≥1080	≥12	≥45	≥47		
	UHP+LF+VD	≥885	≥980	≥12	≥45	≥65		
	VIM+ESR or VIM+VAR	≥1497	≥1794	≥6	≥25			
406	EAF+ESR	≥1372	1666–1862	≥8.5	≥35	≥39.2	≥74.4	Pressure–resisting case and structural components
30SiMnCrMoVE (D406A)	VIM+VAR	≥1325	≥1620	≥9.0	≥40	≥40	≥86.7	Pressure–resisting shell and structural parts
D6AC	VIM+ESR or VIM+VAR	≥1420	≥1520	≥9.0	≥35	≥35	≥80	Elastic shafts for heavyequipment, pressure–resisting shell
GC–4	AIM+ ESR EAF+ESR		≥1800	≥8	≥35	≥47		Shafts, supporting parts, force–loading structural parts and bulletproof plates
25CrNiWV	AIM+ ESR EAF+ESR	≥1175	≥1420	≥9	≥40	≥35		Structure parts and pressure resistance shell
30CrNiWV	AIM+ ESR EAF+ESR	≥1390	≥1650	≥8	≥35	≥35		Structural parts and pressure–resisting shell
40Si2Ni2CrMoVA (300M)	VIM+ VAR	≥1515	≥1860	≥8	≥30	≥39.2		Large supporting parts, shafts for large equipment, bulletproof steel
30CrMnSiNi2A	VIM+ESR		≥1570	≥9	≥45	≥47.2		Large supporting parts, force–loading structural parts, shafts, and warhead steel
4130	VIM+ESR	≥685	≥860	≥17	≥55		≥120	Pressure–resisting shell and structural parts

Low-alloy Ultra-high Strength Steel

Steel Grade	Melting Process	Mechanical Property						Application
		$R_{P0.2}$ (MPa)	Rm (MPa)	A5 (%)	Z (%)	KU2 (J)	K_{1C} $MPam^{1/2}$	
37SiMnCrNiMoV	VIM+ ESR	≥1400	≥1670	≥8	≥35	≥35		High-pressure vessel, armor steel, shafts, force-loading structural parts
30Cr3WA	VIM+ ESR	≥835	≥980	≥15	≥50	≥78		Bolts for large equipment, and force-bearing structural parts
36NiCrMo16	VIM+ VAR	≥880	≥980	≥12	≥48	≥50		Seal parts for high-pressure system of petrochemical industry, bear-loading structural parts and fasteners for nuclear power
35Cr2Ni4MoA	AIM+ ESR EAF+ ESR	≥1030	≥1230	≥8	≥40	≥25		Shaft parts and force-loading structural parts
30Cr3SiNiMoVA	VIM+ ESR	≥1370	≥1715	≥9	≥40	≥47		Pressure-resisting shell and structural parts
32SiMnMoV	AIM+ ESR EAF+ ESR	≥1372	≥1666	≥8.5	≥35	≥39.2		Force-loading structural parts
18CrMn2MoBA	AIM+ ESR EAF+ ESR	≥835	≥1080	≥10	≥45	≥65		Force-loading structural parts
DT300	VIM+VAR or EAF+Secondary Refining +VAR	≥1400	≥1750	≥8	≥40	≥64		Warhead steel, force-bearing structural parts, and die materials
35CrMnNi2MoVA	EAF+ ESR	≥1225	Actual inspection		≥20	Charpy≥15 Mayer≥35		Thin-wall artillery barrel
25Cr3Mo3NiNbZr	EAF +VHD +ESR	≥882			≥40	Key hole ≥45 (J/cm^2, 20℃) ≥25 (J/cm^2, −40℃)	≥62	Rapid-firing artillery barrel
10CrMnNi2Mo	VIM+VAR	Brittle inclusion ≤Class 2.5, plastic inclusion ≤Class 2.5, and the sum ≤Class 4.0						Special welding materials
10SiMnCrNi2MoV	VIM+VAR	Brittle inclusion ≤Class 1.5, plastic inclusion ≤Class 1.5, and the sum ≤Class 2.5						Special welding materials

Bulletproof Steel Plate

The series of bulletproof steel is applied to bulletproof vests, helmets and money–carriers. It has advanced bulletproof property, which is higher than that of the imported materials. It is characterized by its stability in property and thinner thickness while compared to other domestic and imported materials at the same bulletproof class. Meanwhile, the steel can be made into shells of rocket motors and high–pressure vessels.

Steel Grade	Melting Process	Mechanical Property					
		$R_{p0.2}$ (MPa)	Rm (MPa)	A5 (%)	Z (%)	KU2 (J)	K_{1C} ($MPam^{1/2}$)
28Cr3SiNiWMoV	VIM+ ESR	≥1420	≥1720	≥8	≥35	≥35	≥80
35Cr3SiNiWMoV	VIM+ ESR	≥1450	≥1820	≥8	≥35	≥35	
39Cr3SiNiWMoV	VIM+ ESR	≥1520	≥1800	≥9	≥35	≥35	
43Si2CrNi2MoV	VIM+ ESR	≥1550	≥1980	≥7	≥30	≥25	
38Cr2Mo2VA	VIM+ ESR	≥1490	≥1680	≥9	≥35	≥35	
F207	EAF+Secondary Refining+ESR	≥1400	1700–2200	8–12			
40SiMnCrNiMoV	EAF+Secondary Refining +ESR		≥1780	≥8			

Martensitic Aging Steel

Martensitic aging steel is characterized by its high purity and strength, good plasticity and toughness and especially high yield strength and fracture toughness with yield strength ratio over 95 percent. The heat treatment process is simple, no carburization can be achieved, deformation after quenching can be controlled to small extent, and cold forming as well as machinability is rather good. The steel can be made into large load–bearing parts, parts and components, pressure–resisting shells, power rotating shafts, high–pressure vessels, moulds, springs and deep–punching parts.

Martensitic aging steel can be produced with the high–purity melting process involving various kinds of domestic and foreign grades, and a new type of martensitic aging steel without Cobalt has already been developed, which can attain the quality of 300 class martensitic aging steel with cheaper price but better quality.

Steel Grade	Melting Process	Mechanical Property						
		$R_{p0.2}$ (MPa)	Rm (MPa)	A5 (%)	Z (%)	KU2 (J)	K_{1C} ($MPam^{1/2}$)	HRC
CM – 1	VIM+VAR	≥2156	≥2254	≥7.0	≥40	≥19.6	≥37	≥52
CM – 2	VIM+VAR	≥1715	≥1862	≥7.5	≥45	≥31.4	≥77	≥48
TM210A	VIM+VAR	≥1940	≥2040	≥7.5	≥45	≥30.4	≥62	≥51
C200	VIM+VAR	≥1379		≥8.0		≥35 (for V–notch specimen)	≥110	
C250	VIM+VAR	≥1655	≥1720	≥6.0	≥25		≥80	≥48
C300	VIM+VAR	≥1910		≥5.0	≥30	≥30	≥62	≥50
C350	VIM+VAR	≥2200	≥2300	≥5.0	≥30	≥19		≥52
T250	VIM+VAR	≥1655	≥1760	≥6.0				≥48

High–alloy Ultra–high Strength Steel

High–alloy ultra–high strength steel is characterized by its ultra high strength and toughness. 16Co14Ni10Cr2MoE steel can be made into shafts, large bolts etc.

9Ni–4C o series of steel can be widely made into pressure resistance shell, bear force structure parts, armor plates, high pressure vessel etc.

Steel Grade	Melting Process	Mechanical Property						Application
		$R_{p0.2}$ (MPa)	Rm (MPa)	A5 (%)	Z (%)	KU2 (J)	K_{1C} (MPam$^{1/2}$)	
23Co14Ni12Cr3MoE	VIM+VAR	⩾1930	⩾1620	⩾10	⩾55		⩾115	Landing gears, shafts, structural parts, warhead steel
F206	VIM+VAR	⩾1482 (in the longitudinal direction)	⩾1620	⩾12	⩾60	⩾61 (for V –notch specimen in the longitudinal direction)	⩾143	Large supporting shafting parts, bolts
		⩾1482 (in the transverse direction)	⩾1620	⩾12	⩾55			
9Ni–4Co–20	VIM+ ESR	⩾1150	⩾1280	⩾12	⩾40	⩾45		Pressure–resisting shells, key structural parts, armored plates
9Ni–4Co–25	VIM+ ESR	⩾1180	⩾1300	⩾12	⩾40	⩾40		
9Ni–4Co–30	VIM+ ESR	⩾1300	⩾1500	⩾8	⩾25	⩾20		
9Ni–4Co–35	VIM+ ESR	⩾1550	⩾1850	⩾5	⩾20	⩾20		
9Ni–5Co–20	VIM+ ESR	⩾1270	⩾1420	⩾10	⩾40	⩾48		

Metallurgical Equipments

Special Melting Production Line

VIM

VAR

Inert Gas Protective ESR

Forging Line

3150t Hydraulic Open–die Forging Press(SIEMPELKAUP)

3500t Hydraulic Open–die Forging Press(MEER)

2000t Hydraulic Open–die Forging Press(MEER)

1800t Radial Forging Machine(GFM)

D53K–5000 Type Ring Rolling Machine

Rolling Line

24–stand Continuous Rolling Mill(POMINI)

WF5–40 Square and Flat near finish Rolling Mill

Central Laboratory

Central Lab of FSSS takes on the tasks of testing and determining of purchased raw materials as well as inspecting the quality of steel products, and has passed the attestations of CNAS and Nadcap respectively in 2006 and 2007.

Central Lab possesses 300 sets of the inspecting equipments and instruments of the state of art which can satisfy the inspecting requirements of users on chemical composition analysis, microstructure and mechanical property as follows: Photoelectric Direct-reading Spectrometer, Infrared Carbon and Sulphur analyzer, Joint Measurement of Oxygen and Nitrogen analyzer, X-ray fluorescence Spectrometer, Hydrogen analyzer, Analytic Balance, Spectrophotometer, Mass Spectrometer, ICP Spectrum Analyzer, Precision Microscope, Scanning Electron Microscope(SEM), Electro-hydraulic Servo Universal Testing Machine, Electronic Tensile Testing Machine, High-temperature Tensile Testing Machine, Endurance Testing Machine, Impact Tester for Metallic Materials, Various Hardness Tester, Computer group Controlled Heating treatment Furnace.


中国合格评定国家认可委员会
实验室认可证书
（注册号：CNAS L2689）

CNAS Attestation(in 2006)


Nadcap

In accordance with SAE Aerospace Standard AS7003, to the revision in effect at the time of the audit, this certificate is granted and awarded by the authority of the Nadcap Management Council to:

Fushun Special Steel Co Ltd

No.8 East of Anshan Road
Fushun, 113001
China

This certificate demonstrates conformance and recognition of accreditation for specific services, as listed in www.eAuditNet.com on the Qualified Manufacturers List (QML), to the revision in effect at the time of the audit for:

Materials Testing

Joseph G. Pinto
Vice President and Chief Operating Officer

Nadcap Attestation(in 2007)

Quality Testing Equipments

Equipment Items	Type No.	Main Purpose	Photographs
Electro-hydraulic Servo Universal Testing Machine	DDL series	Suitable for testing the mechanical properties of metallic materials	
High-frequency Fatigue Tester	GPS100	Suitable for testing the fatigue property and mechanical property after fracture at the condition of tension, shrinkage, preset crack as well as tension and pressure alternating loads at high frequency for metallic materials, components and parts.	
Electronic Creep and Endurance Testing Machine	PDW30050 Mode involving two types of RD50 and RD50A	Suitable for testing the properties of endurance, creep and strain slack for metallic materials	

Quality Testing Equipments

Equipment Items	Type No.	Main Purpose	Photographs
Infrared Carbon and Sulphur analyzer	CS–600 Type (LECO)	Suitable for determination of the contents of carbon and sulphur using infrared method for iron and steel, and superalloys	
ICP Spectrum Analyzer	Axios Pw4400 Type (PANalytical B.V.); S8TIGER Type (Bruck)	Suitable for determination of the contents of elements such as Mn, Si, P, Ni, Cr, W, V, Mo, Al, Ti, Cu, Co, Nb and Fe in Fe–base alloy, Ni–base alloy and Co–Base alloy and high–alloy steel	
Atomic Absorption Analyzer	Z–2000 Type (HITACHI)	Suitable for analysis of trace elements such as Cu, Co, Ni, Mg, Pb, Ca in superalloys and raw materials; suitable for analysis of five deleterious elements, Ag, Se and Te.	
Oxygen and Nitrogen Analyzer	TC–600 Type (LECO)	Suitable for determination of the nitrogen content in various types of high–alloy steels and low–alloy steels, superalloys and ferroalloys using the testing method of pulse heating the inert gas fusion thermal conductivity. Suitable for analysis of oxygen content ranging from 0.05ppm to 5.0 percent, and analysis of nitrogen content ranging from 0.05ppm to 3.0 percent	
Inverted Microscope	GX51 (OLYMPUS)	Equipped with PE and CIR analysis software from Clemex Compay of Canada, of which PE software is for analyzing various kinds of metallurgical structures such as grain size, decarburization layer, the content of the second phase area, spheroidizing rate, granule size, dimension and surface roughness,and CIR is mainly for testing the non–metallic inclusions	
SEM (Scanning Electron Microscope)	EVO18 (ZEISS)	Equipped with INCA Energy 450 spectrum as well as X–MAX20 Premuem Probe, the first domestic company to customize INCA MICS F with high solution of 124eV, the third generation of image selection and analysis processor, and the second generation of wave selection and processing analyzer of INCA X–Stream 2; Employing the spectrum analyzer with the highest solution capacity and analyzing function using the latest and the most advanced Navigator and various kinds of Intelligent software	

Environment-friendly Steel
Low Carbon Living

Fushun Special Steel Co.,Ltd.

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