BAOSTEEL

2019 DATA BOOK OF BAOSTEEL ADVANCED HIGH STRENGTH STEEL

宝钢先进高强钢数据手册

（英文版）

创享改变生活

CREATION BEYOND VISION

宝钢汽车板

Baosteel Automotive Sheet

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Baosteel Advanced High Strength Steel (AHSS) Family >>

1.1 Introduction

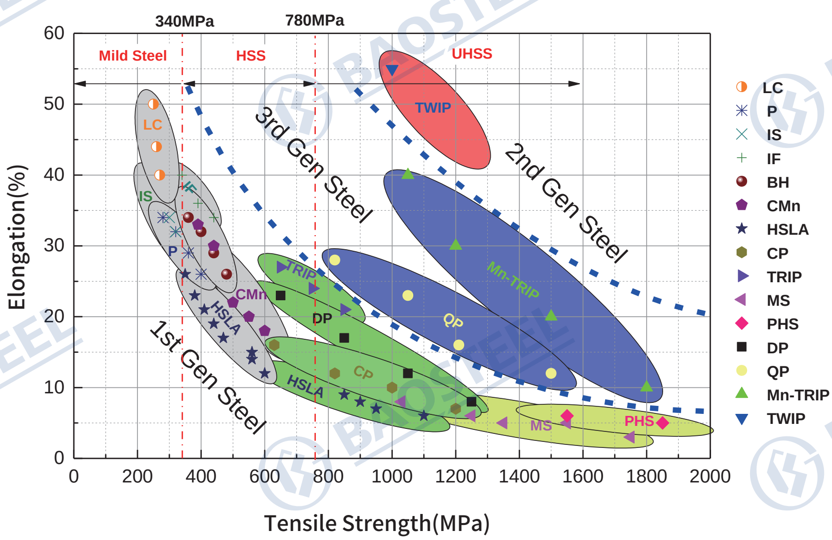
Baosteel has been committed to R&D and production of high-level automotive sheets. In recent years, in order to meet requirements of car body light-weighting and environmental-friendly development, Baosteel has vigorously developed various kinds of high-strength automotive steel sheet, especially advanced high-strength steel (AHSS) sheet. The strength and plasticity combination of AHSS is better than that of ordinary high strength steel. It has both high strength and good formability, especially high work hardening exponent, which is beneficial to improve energy absorption property during crash. These characteristics are helpful to realize weight reduction and safety improvement at the same time.

AHSS are mainly used in structural parts and safety parts of car body. By optimizing the application of AHSS, the vehicle weight can be reduced, safety can also be enhanced, and the cost is still able to be optimized. AHSS sheet represents the development trend of automotive steel sheet in the future.

High strength steel application in Baosteel concept car body (BCB)

1.2 Product Category

AHSS sheet mainly refers to a kind of steel sheet with phase transformation strengthening as its main strengthening mode, including dual phase steel (DP), transformation-induced plasticity steel (TRIP), twinning-induced plasticity steel (TWIP), complex phase steel (CP) and martensitic steel (MS), etc., as shown in the figure below. In addition, there are press hardened steel and high specific strength steel. AHSS for automobiles can be classified by processing into cold-rolled, hot-dip galvanized and electro-galvanized products respectively. At present, Baosteel can produce the first, second and third generation of high strength steel products. The highest strength of cold rolling is 1700 MPa, 1180 MPa for hot-dip galvanizing, 780 MPa for electro-galvanizing.



1.3 Properties and Test Methods

1.3.1 Mechanical Properties and Hardening Curves

Quasi-static tensile test can measure the strength and plastic parameters of materials, and provide evidence for material evaluation and material selection, which is one of the most important methods in mechanical properties testing of metal. Quasi-static tensile tests were carried out on various steels produced by Baosteel with material electronic universal testing machine. The test speed within 2% strain was 3 mm/min, and then the test speed was 30 mm/min. The mechanical properties (yield strength, tensile strength, elongation, n value, r value) and engineering stress-strain curves were obtained. The hardening curves of materials are obtained by transforming the engineering stress-strain curves.

Test standards

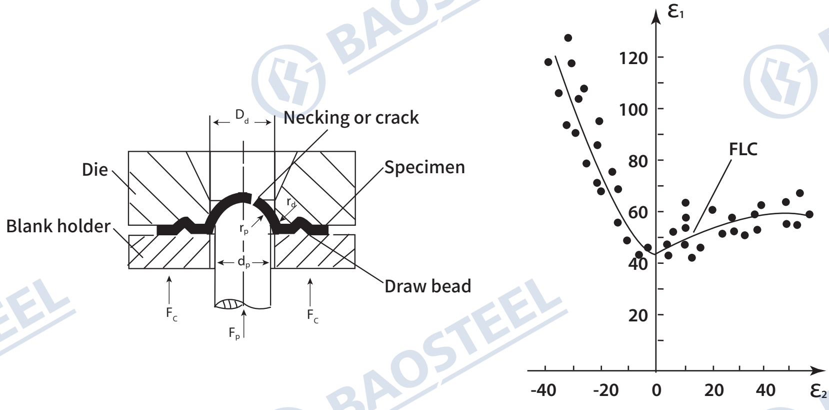
- GB/T 228.1—2010 Metallic Materials—Tensile test—Part 1: Test methods at room temperature
- GB/T 5027—2016 Metallic materials—Sheet and strip—Determination of plastic strain ratio
- GB/T 5028—2008 Metallic materials—Determination of tensile strain hardening exponent
- GB/T 24174—2009 Steel—Determination of Bake-Hardening-Index (BH_2)
- JIS Z 2241:2011 Metallic materials--Tensile testing--Method of test at room temperature

1.3.2 Forming Limit

Forming limit diagram (FLD) is the most simple and intuitive method for judging and evaluating the formability of steel sheets. The evaluation results of safety margin of forming parts are directly affected by its accuracy. For mild steel and traditional high strength steel, FLD research has been quite mature. At present, empirical formulas have been established through a large number of experiments. Based on the n value and thickness t of materials, FLC can be calculated. For the newly developed ultra-high strength steel sheet, the forming limit should be determined by test. By using hemispherical bulging die, the limit strain under different strain states can be obtained by changing the width of specimen.

Test standard

- GB/T 15825.8—2008 Sheet metal formability and test methods—Part 8: Guidelines for the determination of forming-limit diagrams



Schematic of forming limit test and forming limit curve

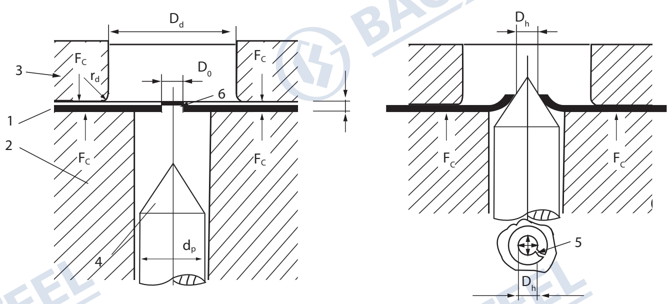
1.3.3 Hole Expansion Ratio

Hole expansion test is an effective method to evaluate the flanging property of high strength steel, especially AHSS. Taking Baosteel' s mass-produced steel sheet as the research object, the hole expansion tests of high strength steel and ultra-high strength steel were carried out to obtain the data of the hole expansion ratio which can be used to predict and evaluate the trend of edge cracking.

Hole expansion test is carried out on the forming test machine. The round hole is prefabricated by means of punching. The diameter of the round hole is 10 mm. Hole expansion test was carried out with conical punch. The head taper of the punch is 60 degrees, the outer diameter of the cylinder of the punch is 50 mm, and the inner diameter of the die is 50 mm. In the test, the burr formed by punching is opposite to the outside of the punch. The test speed is 0.3 mm/s. The hole edge of the specimen is monitored by optical instrument, and the test is stopped when a crack occurs across the thickness section of the specimen.

Test standard

- GB/T 15825.4—2008 Sheet metal formability and test methods—Part 4: Hole expansion test

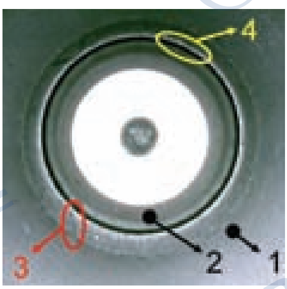


a.Becore test

b.After test

1. Specimen
2. Blank holder
3. Die
4. Conical punch
5. Crack
6. Punching burr

Schematic of hole expansion test



1. Specimen
2. Punch
3. Crack through thickness section of specimen
4. Non-penetrating crack

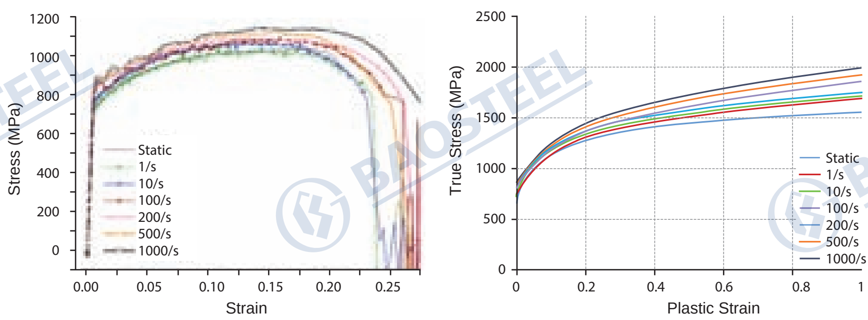
Schematic of hole expansion test under optical instrument monitoring

1.3.4 Dynamic Mechanical Properties

The application of high strength steel to automotive body design requires that engineers should accurately know, at the design stage, the mechanical properties of materials under high strain rate and the energy absorbed at high speed deformation. High-speed tensile test is the most direct and effective method to obtain the mechanical behavior characteristics of materials at high strain rates. The dynamic stress-strain curve fitted to the test data at different speeds of high-speed tension can be used in the simulation at the car body development stage and evaluate the crash-worthiness of high-strength steel parts, assemblies and vehicles.

Test standards

- GB/T 30069.2—2016 Metallic materials—Tensile testing at high strain rates—Part 2: Servo-hydraulic and other test systems
- ISO 26203-2-2011 Metallic materials - Tensile testing at high strain rates - Part 2: Servo-hydraulic and other test systems



Tensile curves at different speeds and dynamic stress-strain curves after fitting

1.3.5 Fatigue Properties

Fatigue failure is one of the main failure modes of automotive body parts which are often operated under alternating stress. Its characteristic is that the working stress value is low. The fatigue properties of materials need to be considered at the design stage. At present, the basic approach for evaluating the fatigue properties of metal materials is to determine the S-N curve (fatigue curve) by experiment method, that is, to establish the relationship between the maximum stress or stress amplitude and the corresponding cycles of fracture. Fatigue curve is obtained by fatigue test of a group of standard specimens and statistical treatment.

Test standard

- GB/T 3075—2008 Metallic materials—Fatigue testing—Axial-force-controlled method

1.3.6 Delayed Fracture Properties

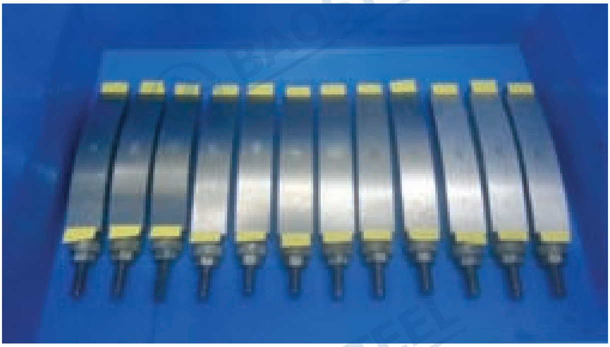
Delayed fracture is a sudden cracking phenomenon of metal materials or components after hydrogen and stress acting on metal together for a period of time. Such fracture generally has no precursor and can occur under stresses far below the yield strength. Ultra-high strength steels for automotive are mostly used for structural or safety parts of car body. In order to minimize the risk of delayed fracture and improve the safety of vehicles and passengers, it is necessary to evaluate the delayed fracture properties of ultra-high strength steel or parts for car body with tensile strength greater than 980 MPa.

The main factors affecting delayed fracture are environment, stress, material' s micro-structure and composition, etc. The preventive measures in practical application mainly include:

- Prevent pickling of parts or dehydrogenation after pickling;
- Optimize the shape and structure design of parts to avoid local stress concentration;
- Effective anti-corrosion measures are adopted to prevent cracking due to corrosion and hydrogen absorption.

Delayed fracture property evaluation can be divided into two kinds, i.e. material evaluation and parts evaluation. At present, there is no uniform evaluation method and standard. For the evaluation of ultra-high strength automotive steel sheet, U-shaped bending specimen or constant stress specimen can be placed in a specific environment for a certain period of time to observe whether cracks occur. For the evaluation of ultra-high strength steel automotive parts, the formed parts can be placed in a specific corrosion environment for a certain period of time to observe whether cracks occur.

Delayed fracture property test of U-shaped bending specimens (0.1mol/L HCl solution, 300 h)



Constant stress delayed fracture test specimens
(0.1mol/L HCl solution, 300 h)

Delayed fracture property test of parts
(0.1mol/L HCl solution, 1000 h)

1.4 Baosteel Automotive Sheet Data Service

After years of data accumulation, Baosteel has established a relatively complete property database of automotive sheet, and through continuous testing and research of testing method, the database has been updated termly. Baosteel can provide users with a series of data support from basic properties, forming and processing properties, to service performance.

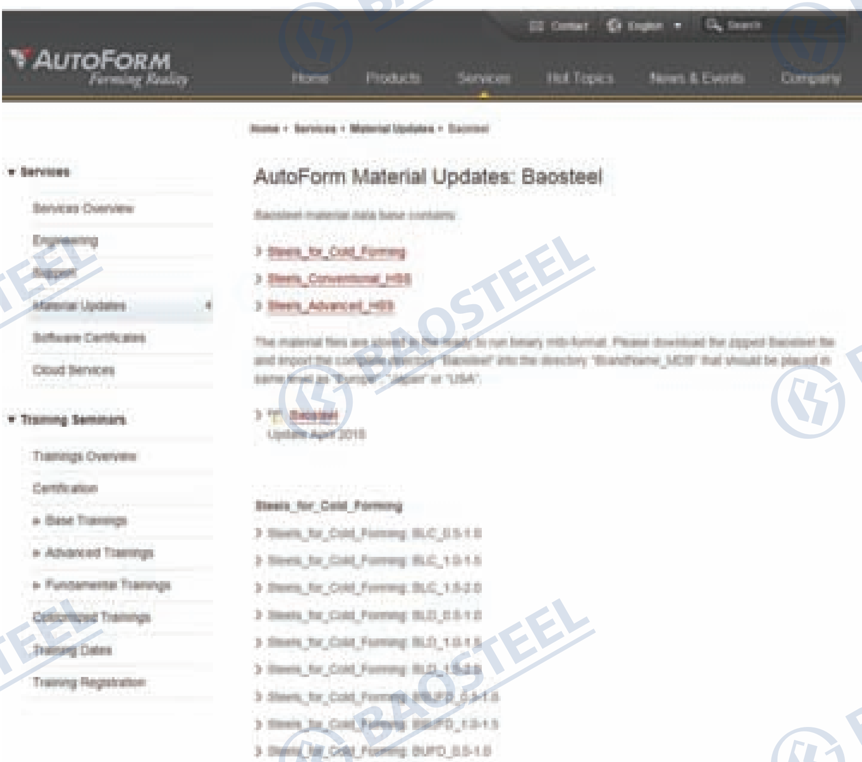
According to the diversified needs of customer, Baosteel can provide various modes of data and technical solutions such as property index and original curve data, material data package and material card for CAE application.

In 2017, Baosteel cooperated with AutoForm, the most widely used part stamping process simulation software in the global automotive industry. The stamping simulation material database which integrated the latest research results and accurately reflects the properties of Baosteel products was embedded into AutoForm software. Baosteel material database is issued synchronously with the new version of AutoForm, providing a uniform and effective standard material database for the industry, and assisting users such as automotive manufacturers, parts and die manufacturers to develop parts and dies.

Baosteel material database is also shared and termly updated on AutoForm global website and Baosteel Huichuang platform. For more information, please visit the AutoForm website and Baosteel Huichuang platform.

https://www.autoform.com/en/services/material-updates/baosteel/

http://www.ibaosteel.com



Dual Phase Steel (DP) >>

2.1 Introduction

Dual phase (DP) steels have low YS/TS ratio and relatively high work hardening rate. DP steels have higher ultimate tensile strength than high strength low alloy (HSLA) steels of similar yield strength, and hence become one of the preferred materials for structural components. DP steels are widely used for automotive safety parts and structural parts, such as A-pillar, B-pillar, door sill plate, door impact beam and can be also extended to application for outer panels.

The main features of DP steels

- Continuous yielding, continuous and smooth stress-strain curve, and absence of yield point elongation. Hence, the tension strain trace at the surface of formed parts can be avoided, and no additional finishing process is required ;
- High work hardening rate, especially the initial working hardening rate. Flow stress of DP steels can reach to 500 - 550 MPa at strain below 5% ;
- Absence of room temperature aging ;
- Bake hardening index of 35 - 80 MPa;
- Low YS/TS ratio (0.5 - 0.65);
- Good spot welding capability and laser welding capability. Good weldability can be realized by simple welding process. Spot welded joint with good ductility can be done by normal spot welding parameters ;

2.2 Grades and Naming Methods

The common grades of DP steels are HC340/590DP, HC420/780DP, HC500/780DP. Taking HC340/590DPD+Z as an example, the naming method for steel grades is illustrated. H stands for high strength steels; C represents cold-rolled steel substrate; 340 shows the minimum required yield strength ($R_{p0.2}$ or R_{eL}); 590 shows the minimum required tensile strength (R_m); DP represents dual phase steel; D stands for hot-dip galvanizing, followed by the type of coating, of which +Z represents coating of pure zinc.

2.3 Grades Comparison

Comparison of steel grades of Baosteel cold-rolled products with other

Q/BQB 418-2018	EN 10338:2015	SAE J2745-2007	VDA 239-100:2016	JIS G3135-2006
HC250/450DP	HCT450X	DP 440T/250Y	-	-
HC290/490DP	HCT490X	DP 490T/290Y	CR290Y490T-DP	-
HC340/590DP	HCT590X	DP 590T/340Y	CR330Y590T-DP	SPFC590Y
HC420/780DP	HCT780X	DP 780T/420Y	CR440Y780T-DP	SPFC780Y
HC500/780DP	-	-	-	-
HC550/980DP	HCT980X	DP 980T/550Y	CR590Y980T-DP	SPFC980Y
HC650/980DP	-	-	-	-
HC700/980DP	HCT980XG	-	CR700Y980T-DP	-
HC820/1180DP	HCT1180X	-	-	-

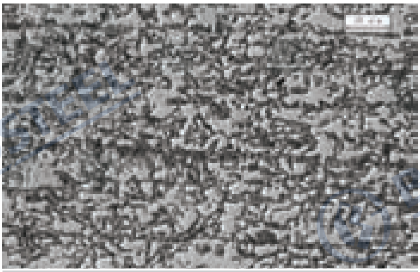
Comparison of steel grades of Baosteel galvanized products with other

Q/BQB 420-2018	EN 10346:2015	VDA 239-100:2016	SAE J2745-2007
HC250/450DPD+Z HC250/450DPD+ZF	HCT450X	-	DP 440T/250Y
HC300/500DPD+Z HC300/500DPD+ZF	HCT500X	CR290Y490T-DP	DP 490T/290Y
HC340/590DPD+Z HC340/590DPD+ZF	HCT600X	CR330Y590T-DP	DP 590T/340Y
HC420/780DPD+Z HC420/780DPD+ZF	HCT780X	CR440Y780T-DP	DP 780T/420Y
HC500/780DPD+Z HC500/780DPD+ZF	-	-	-
HC550/980DPD+Z HC550/980DPD+ZF	HCT980X	CR590Y980T-DP	DP 980T/550Y
HC650/980DPD+Z HC650/980DPD+ZF	-	-	-
HC820/1180DPD+Z HC820/1180DPD+ZF	-	-	-

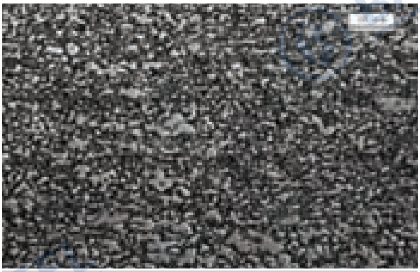
2.4 Microstructure

The microstructure of DP steels mainly contains ferrite and martensite, with island-shape martensite dispersed in the ferrite matrix. The ferrite in DP steels is soft phase while the hard martensitic phase acts as the strengthening phase. The strength of DP steels increases with the amount of martensitic phase.

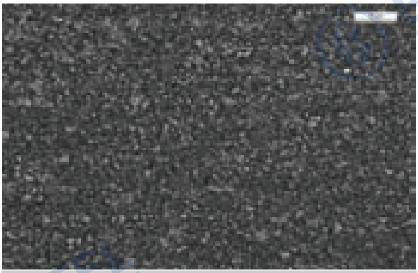
HC340/590DP



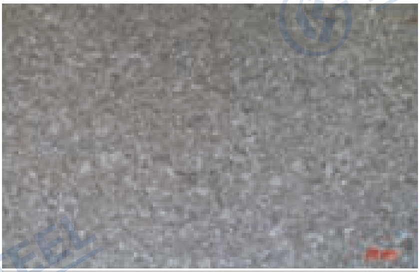
HC420/780DP



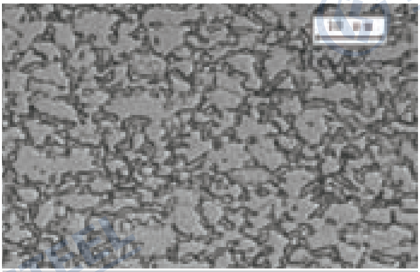
HC550/980DP



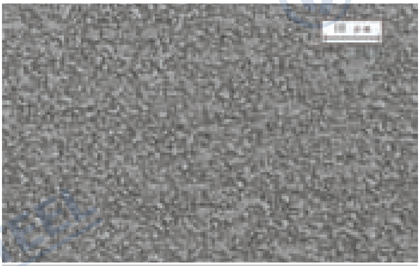
HC700/980DP



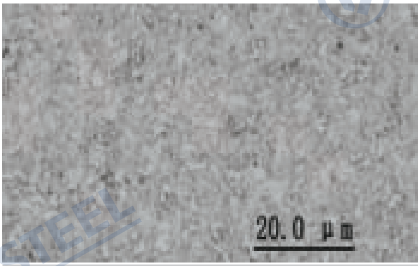
HC820/1180DP



HC420/780DPD+Z



HC650/980DPD+Z



HC820/1180DPD+Z

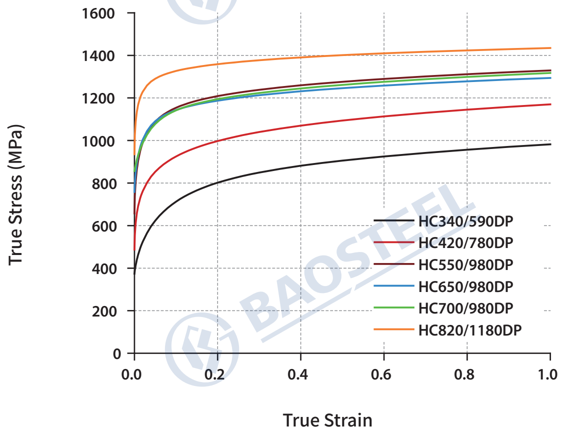
2.5 Mechanical Properties

Mechanical Properties of Cold-rolled DP Steels

Steel	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	n	r_0	r_{45}	r_{90}
HC340/590DP	365	641	26	0.17	0.93	0.89	0.99
HC420/780DP	494	849	17	0.13	0.71	0.93	0.79
HC550/980DP	740	1051	12	0.09	0.71	0.91	0.8
HC700/980DP	758	1042	11	0.08	0.64	1.05	0.7
HC820/1180DP	866	1192	8	-	-	-	-

Note: The property value is the reference value, not the supply basis.

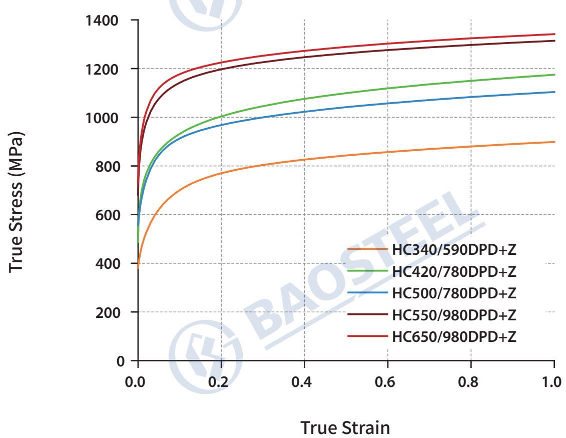
Hardening Curves of Cold-rolled DP Steels



Mechanical Properties of Hot-dip Galvanized DP Steels

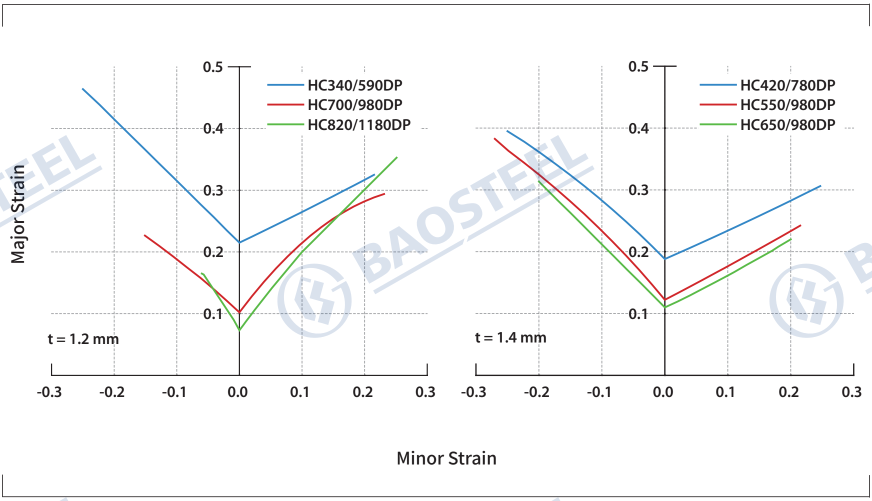
Steel	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	n	r_0	r_{45}	r_{90}
HC340/590DPD+Z	380	640	23	0.174	0.93	0.89	0.99
HC420/780DPD+Z	487	843	15	0.14	0.7	0.9	0.78
HC500/780DPD+Z	563	826	15	0.143	0.6	1.1	0.85
HC550/980DPD+Z	682	1036	12	0.13	0.68	0.88	0.84
HC650/980DPD+Z	731	1071	11	0.129	0.72	0.9	0.82
HC820/1180DPD+Z	929	1211	6	0.09	0.75	0.85	0.85

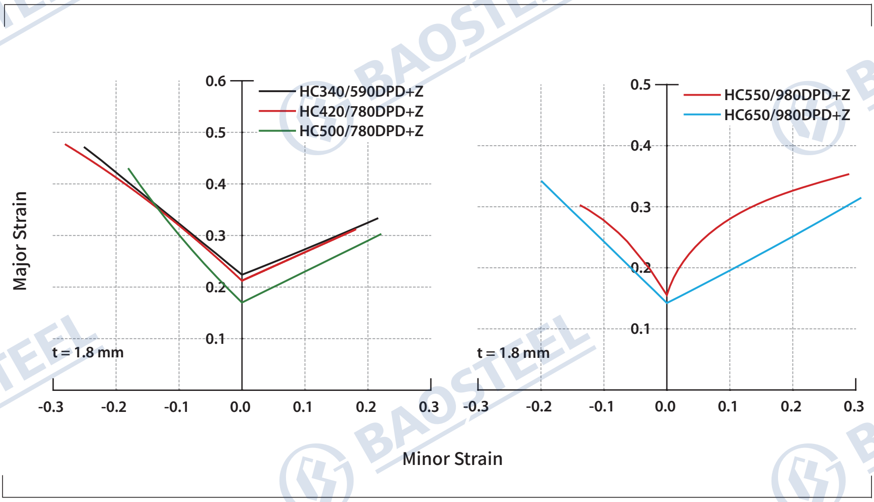
Hardening Curves of Hot-dip Galvanized DP Steels



2.6 Forming Properties

2.6.1 Forming Limit





2.6.2 Hole Expansion Ratio

Steel	Thickness (mm)	Hole expansion ratio (%)
HC340/590DP	1.2	47
HC500/780DP	1.4	33
HC550/980DP	1.4	34

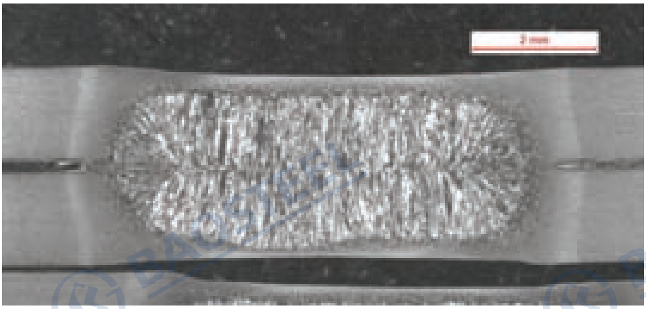
Note: Property value is reference value

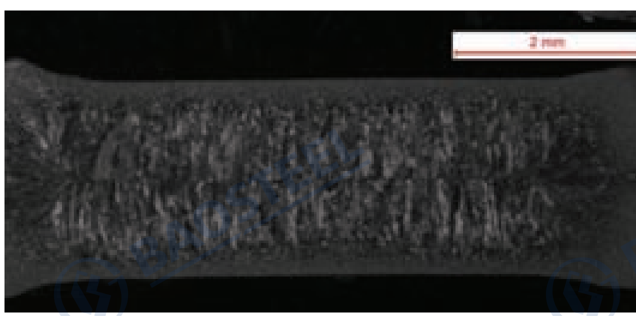
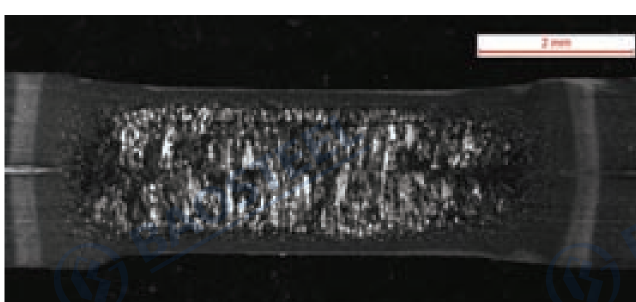
2.7 Spot Welding Properties

Steel	Thickness (mm)	Electrode diameter (mm)	Welding pressure (kN)	Welding time (cyc)	Weldable current interval (kA)			TSS		CTS	
					Min.	Max.	width	Joint strength (kN)	Nugget diameter (mm)	Joint strength (kN)	Nugget diameter (mm)
HC340/590DP	1.4	6	4.3	14	7.3	10.6	3.3	17.4	7.0	12.1	6.7
HC420/780DP	1.0	6	2.6	8	5.8	8.1	2.3	10.5	4.0	6.5	4.0
HC550/980DP	1.0	6	2.6	8	5.7	8.3	2.6	11.2	4.0	5.6	4.0
HC820/1180DP	1.2	6	2.6	9	5.2	7.9	2.7	11.6	4.0	4.1	4.0
HC340/590DPD+Z	1.2	6	2.6	14	7.4	9.9	2.5	9.6	4.0	6.2	4.0
HC420/780DPD+Z	1.25	6	2.6	14	6.1	9.3	3.2	11.8	4.0	7.6	4.0
HC550/980DPD+Z	1.0	6	2.6	12	6.5	9.4	2.9	10.4	4.0	4.8	4.0
HC820/1180DPD+Z	1.2	6	2.6	14	5.7	9.1	3.4	10.9	4.0	3.7	4.0

Note: Property value is reference value

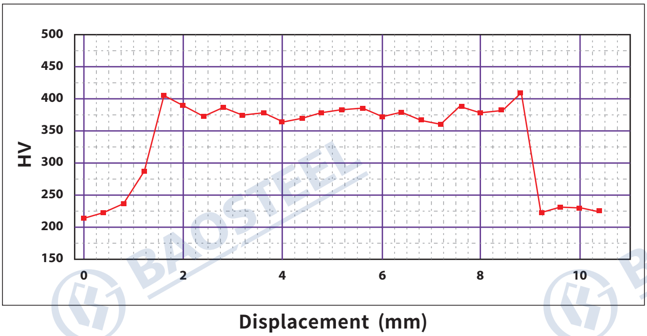
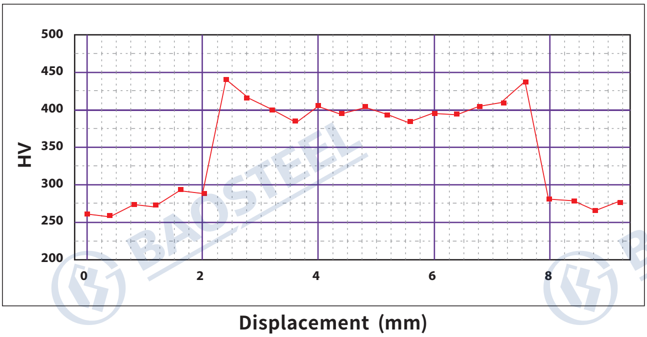
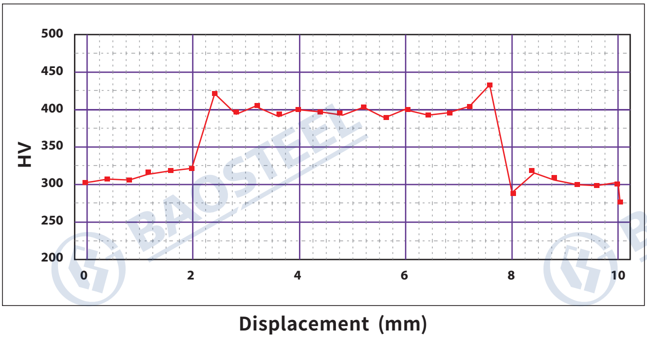
Microstructure of Welding Spot

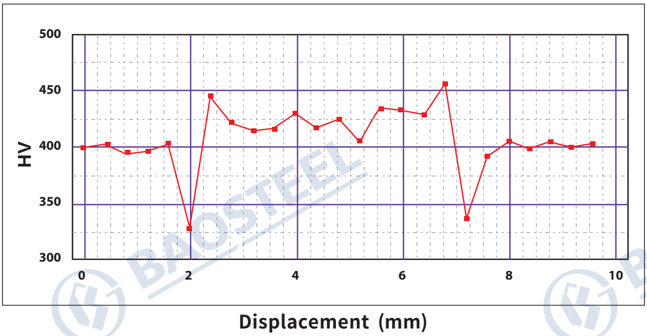
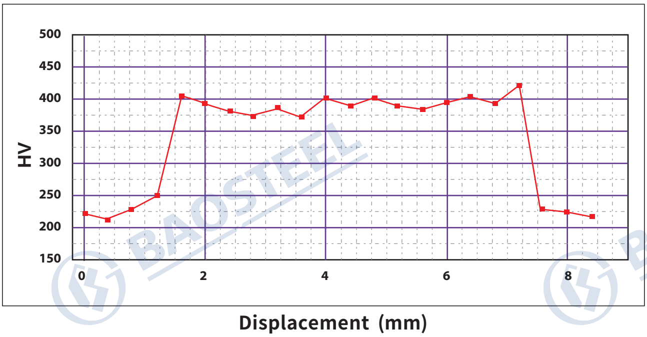
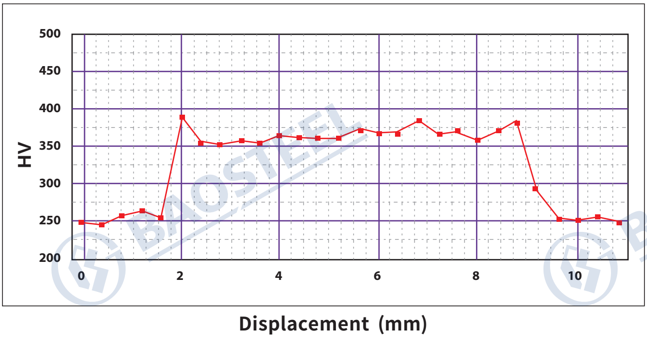
Steel	Microstructure of welding spot
HC340/590DP	
HC420/780DP	
HC550/980DP	

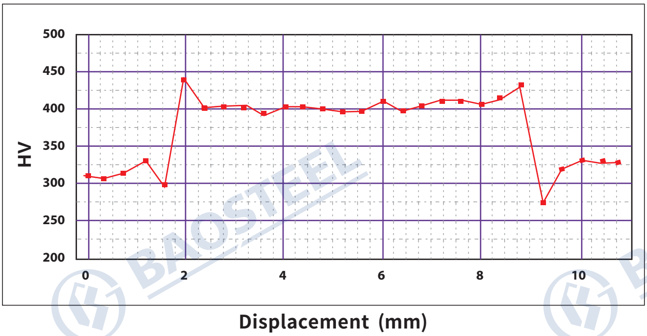
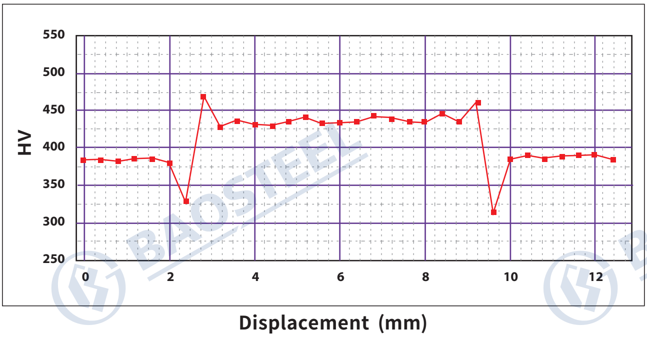
Steel	Microstructure of welding spot
HC820/1180DP	
HC340/590DPD+Z	
HC420/780DPD+Z	

Steel	Microstructure of welding spot
HC550/980DPD+Z	
HC820/1180DPD+Z	

Microhardness Distribution of Welding Spot

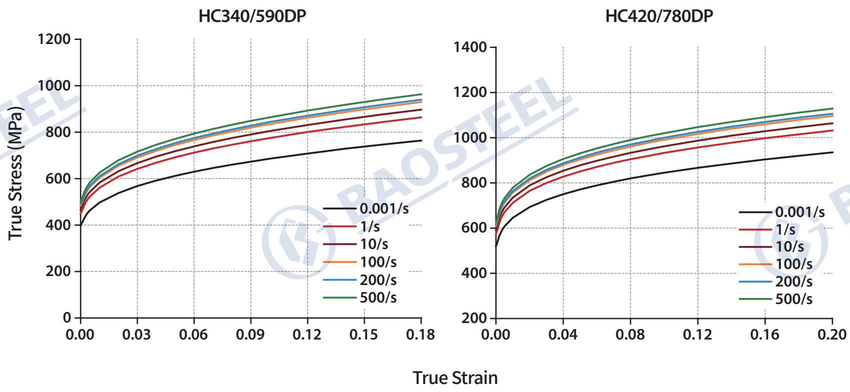
Steel	Microhardness distribution of welding spot
HC340/590DP	
HC420/780DP	
HC550/980DP	

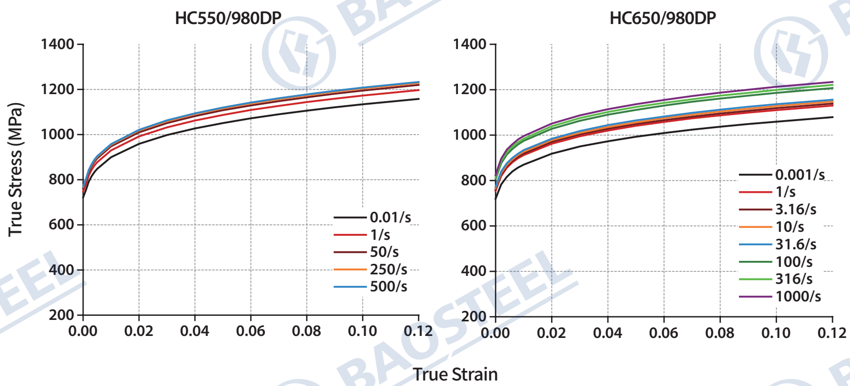
Steel	Microhardness distribution of welding spot
HC820/1180DP	
HC340/590DPD+Z	
HC420/780DPD+Z	

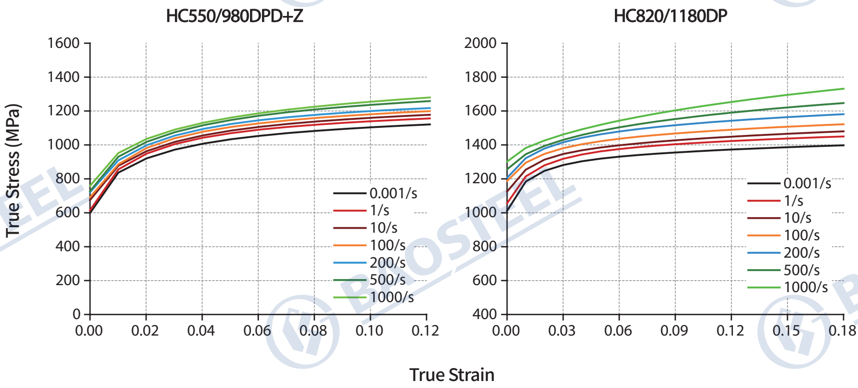
Steel	Microhardness distribution of welding spot
HC550/980DPD+Z	
HC820/1180DPD+Z	

2.8 Service Performance

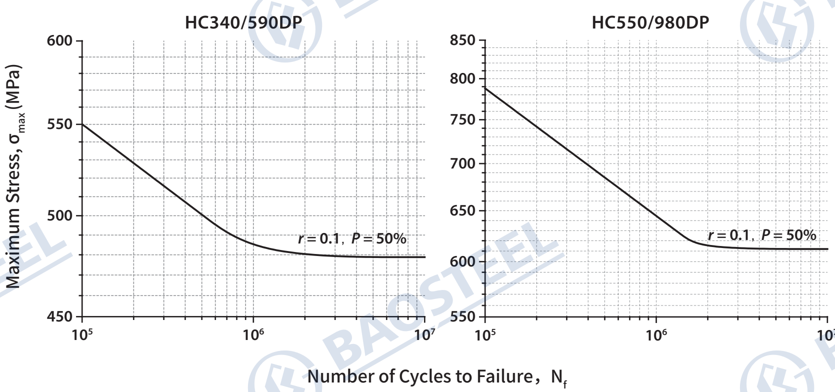
2.8.1 Dynamic Mechanical Properties

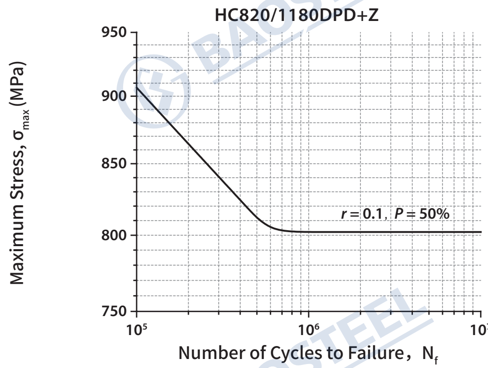






2.8.2 Fatigue Properties

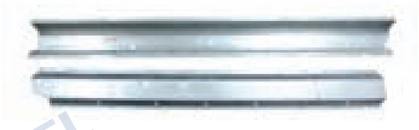




2.8.3 Delayed Fracture Properties

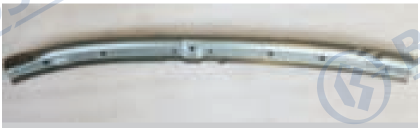
Steel	Specimen type	Environment	Time/h	Crack or not
HC550/980DP	U bending	0.1mol/L HCl	300	No
HC700/980DP	U bending	0.1mol/L HCl	300	No
HC820/1180DP	U bending	0.1mol/L HCl	300	No
HC550/980DPD+Z	U bending	Air	720	No
HC650/980DPD+Z	U bending	Air	720	No

2.9 Applications



Reinforcement sill
(HC550/980DPD+Z, thickness of 1.4 mm)

Reinforcement door inner
(HC550/980DPD+Z, thickness of 1.2 mm)

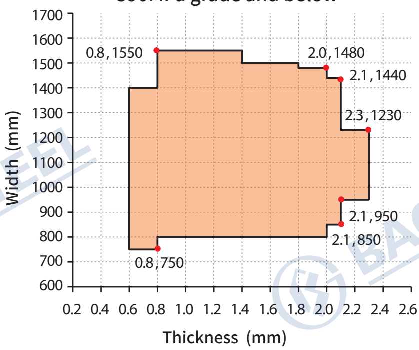


Reinforcement cantrail inner
(HC550/980DPD+Z, thickness of 1.5 mm)

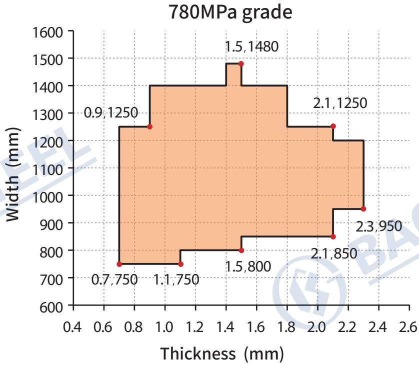
2.10 Available Dimensions

■ Available Dimensions of Cold-rolled DP Steels

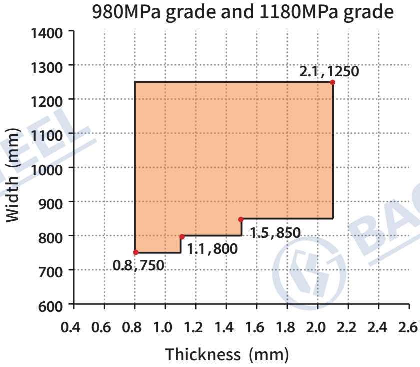
590MPa grade and below



780MPa grade

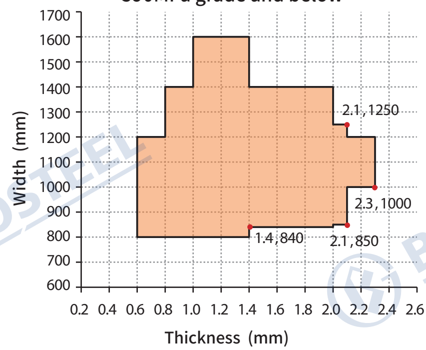


980MPa grade and 1180MPa grade

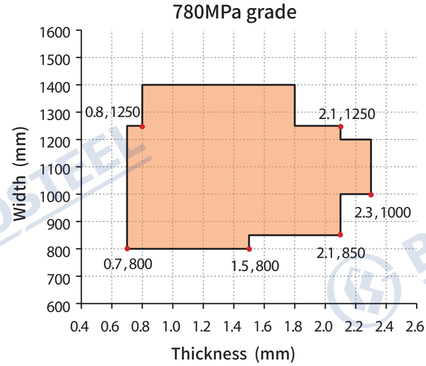


■ Available Dimensions of Hot-dip Galvanized DP Steels

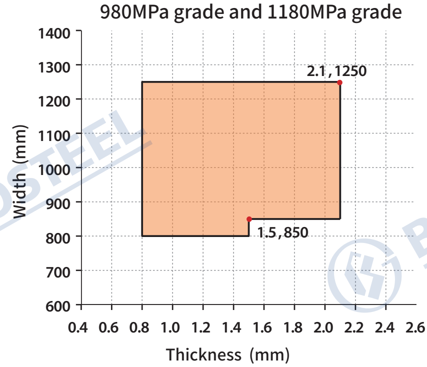
590MPa grade and below



780MPa grade

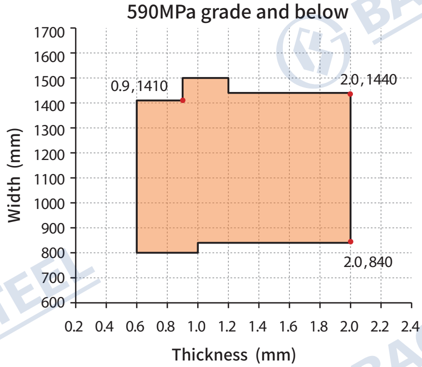


980MPa grade and 1180MPa grade

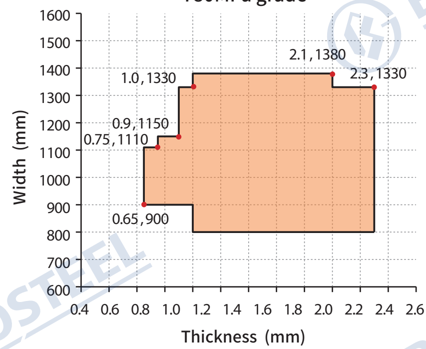


Available Dimensions of Hot-dip Galvannealed DP Steels

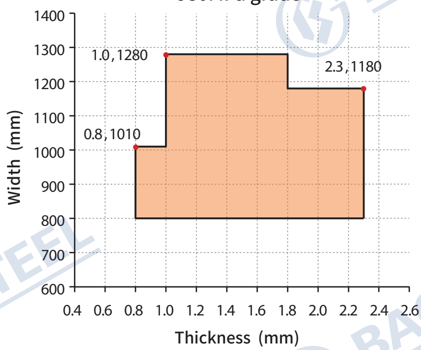
590MPa grade and below



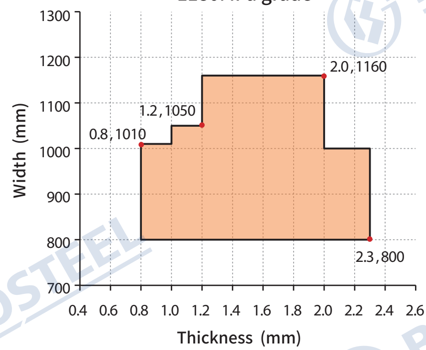
780MPa grade



980MPa grade

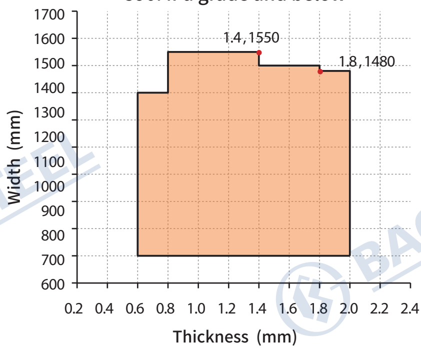


1180MPa grade

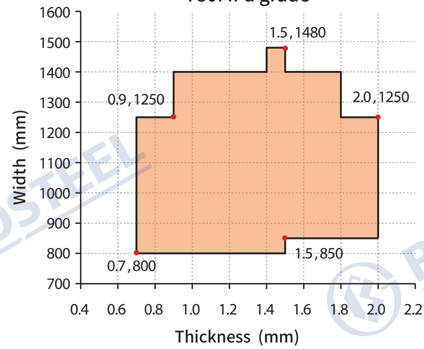


Available Dimensions of Electro-galvanized DP Steels

590MPa grade and below



780MPa grade



Note: If the required material dimensions are beyond the scope, specific consultation may be conducted.

Quenching and Partitioning Steel (QP) >>

3.1 Introduction

Quenching and partitioning (QP) steels are produced in specialized Baosteel production lines for ultra high strength steels. In the continuous annealing line after cold-rolling process, a microstructure of martensite plus austenite is obtained after quenching an austenized material to a temperature between M_s and M_f, followed by reheating to partitioning temperature allowing for carbon partitioning. During the partitioning process, the untransformed austenite can be enriched and thus stabilized by carbon that diffuses from the formed martensite. The stabilized austenitic phase can be retained after cooling, forming a final microstructure of martensite + retained austenite or ferrite + martensite + retained austenite.

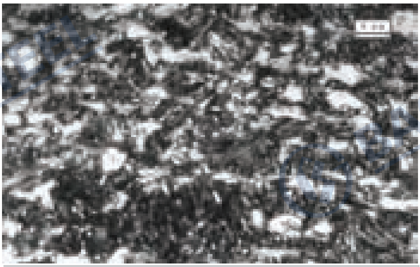
Apart from high strength, QP steels are also featured by high n value and elongation, and hence possess better formability. Good weldability of QP steels can be realized by simple adjustment of welding parameters.

3.2 Grades and Naming Methods

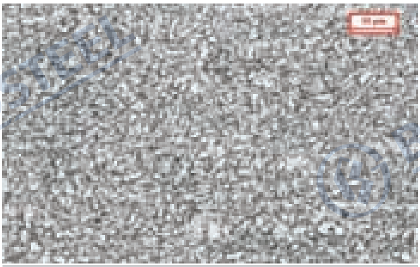
The common grades of QP steels are HC600/980QP, HC600/980QP-EL, HC820/1180QP, HC820/1180QP-EL. Taking HC600/980QP-ELD+Z as an example, the naming method for steel a grade is illustrated. H stands for high strength steels; C represents cold-rolled steel substrate; 600 shows the minimum required yield strength ($R_{p0.2}$ or R_{eL}); 980 shows the minimum required tensile strength (R_m); QP stands for quenching and partitioning steel; EL means high elongation; D stands for hot-dip galvanizing, followed by the type of coating, of which +Z represents coating of pure zinc.

3.3 Microstructure

QP steels contain martensite, ferrite and retained austenite.



HC600/980QP



HC820/1180QP

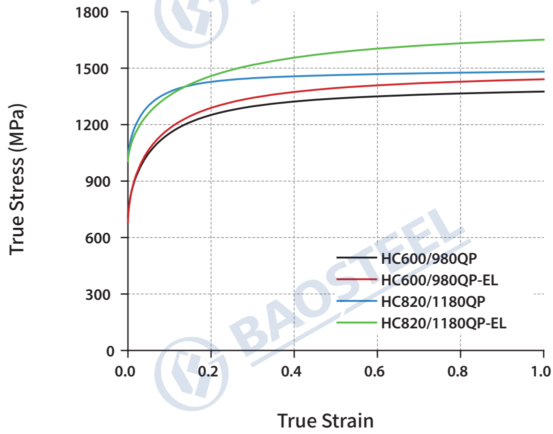
3.4 Mechanical Properties

Mechanical Properties

Steel	Thickness (mm)	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	n	r_0	r_{45}	r_{90}
HC600/980QP	1.2	708	1047	18	0.145	0.78	0.9	0.95
HC600/980QP-EL	1.4	682	1074	21	0.156	0.85	0.91	1.03
HC820/1180QP	1.4	1027	1248	15	0.096	0.7	0.8	0.9
HC820/1180QP-EL	1.2	1005	1226	16	0.098	0.8	0.8	0.9

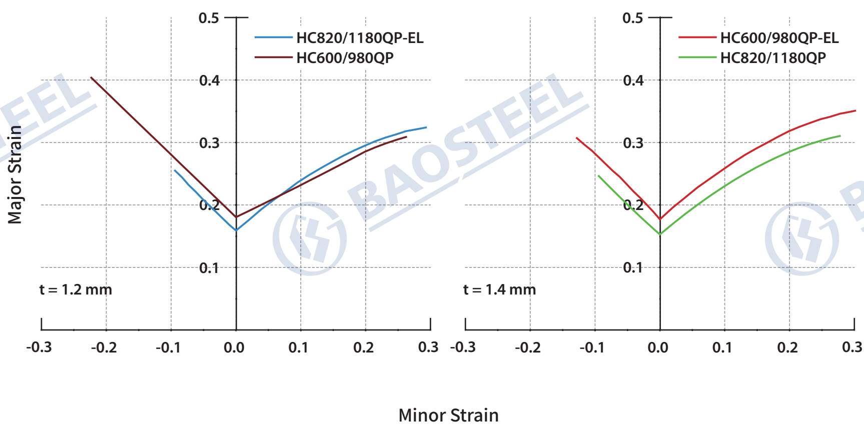
Note: The property value is the reference value, not the supply basis.

Hardening Curves

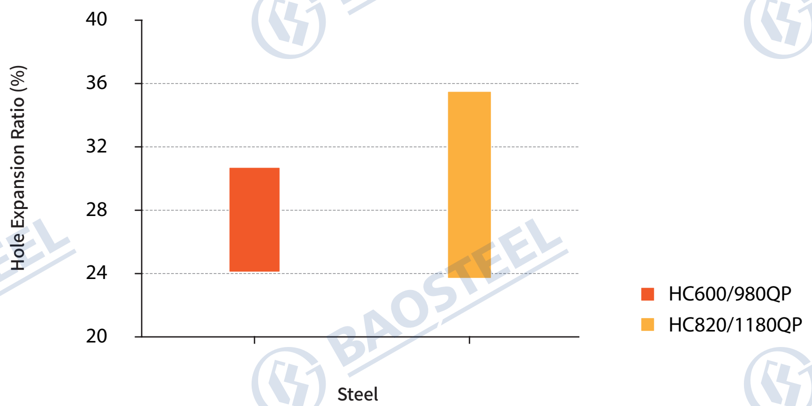


3.5 Forming Properties

3.5.1 Forming Limit



3.5.2 Hole Expansion Ratio



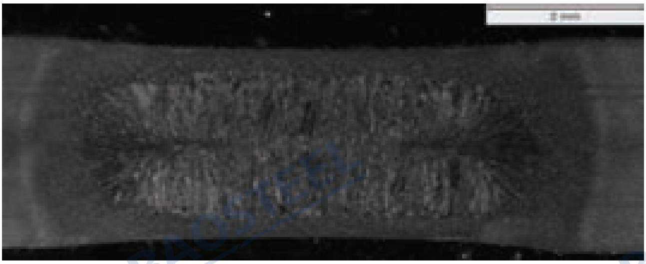
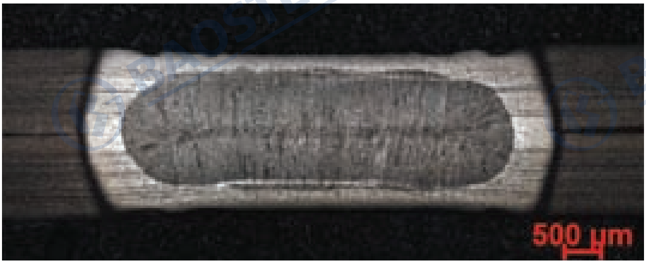
Note: The property value is the reference value, not the supply basis.

3.6 Spot Welding Properties

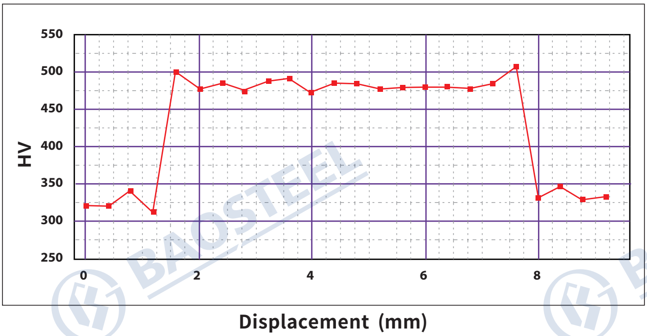
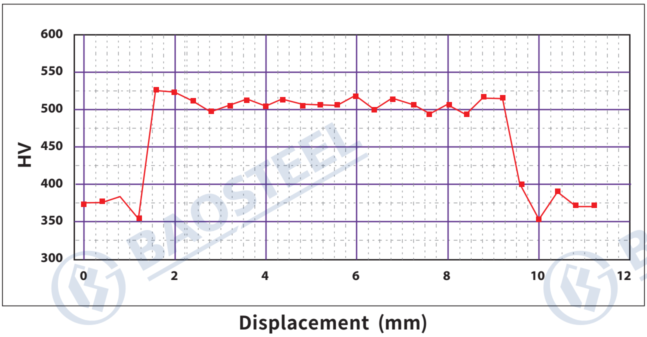
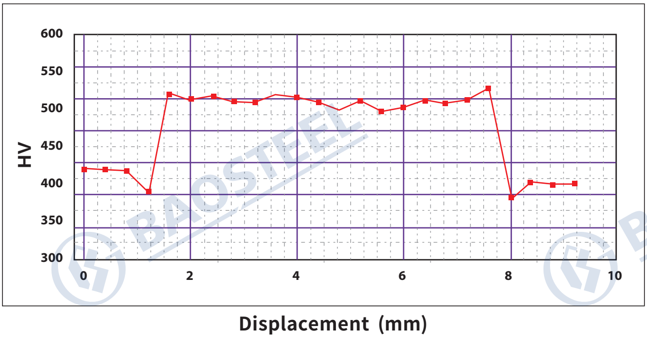
Steel	Thickness (mm)	Electrode diameter (mm)	Welding pressure (kN)	Welding time (cyc)	Weldable current interval (kA) Min.	Max.	Width	TSS Joint strength (kN)	TSS Nugget diameter (mm)	CTS Joint strength (kN)	CTS Nugget diameter (mm)
HC600/980QP	1.6	6	3.6	12	5.8	7.9	2.1	19.5	5.0	5.9	5.0
HC600/980QP-EL	1.6	6	3.6	12	5.9	8.6	2.7	17.4	5.0	5.5	5.0
HC820/1180QP	1.2	6	2.6	9	4.4	7.0	2.6	11.8	4.3	2.9	4.3
HC820/1180QP-EL	1.6	6	3.6	12	5.7	8.6	2.9	17.8	5.0	4.9	5.0
HC600/980QPD+Z	1.0	6	2.6	13	6.4	8.4	2.0	11.9	4.0	3.5	4.0
HC600/980QP-ELD+Z	1.2	6	2.6	14	5.6	8.0	2.4	18.8	6.0	6.2	6.0
HC820/1180QP-ELD+Z	1.2	6	2.6	14	5.5	8.2	2.7	20.4	6.0	5.3	6.0

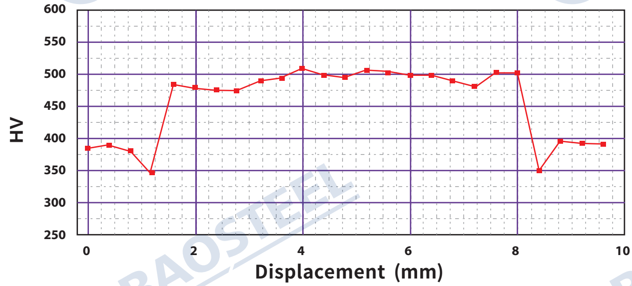
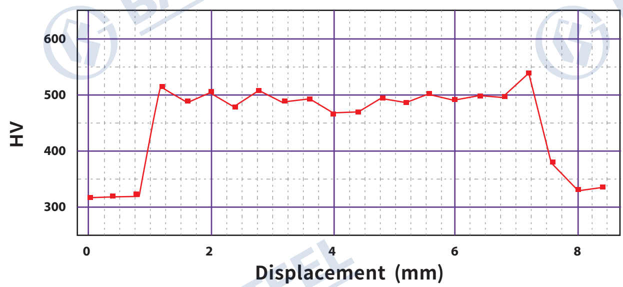
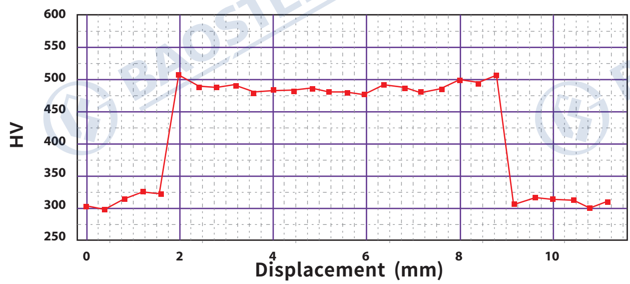
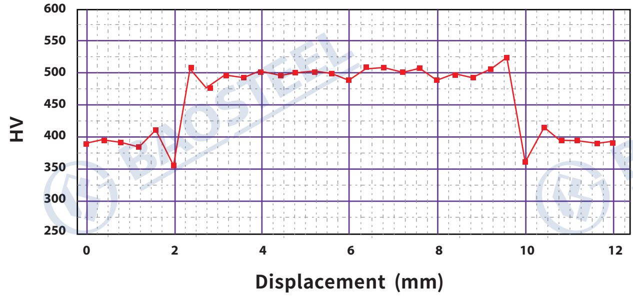
Note: Property value is reference value.

Microstructure of Welding Spot

Steel	Microstructure of welding spot
HC600/980QP	
HC600/980QP-EL	
HC820/1180QP	
HC820/1180QP-EL	

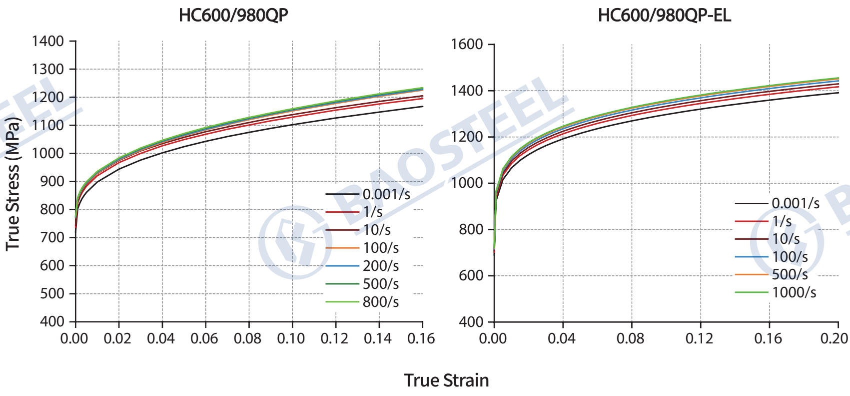
Microstructure of Welding Spot

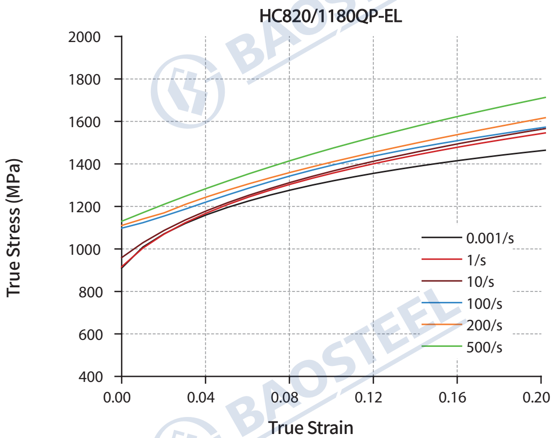
Steel	Microhardness distribution of welding spot
HC600/980QP	
HC600/980QP-EL	
HC820/1180QP	

Steel	Microhardness distribution of welding spot
HC820/1180QP-EL	
HC600/980QPD+Z	
HC600/980QP-ELD+Z	
HC820/1180QP-ELD+Z	

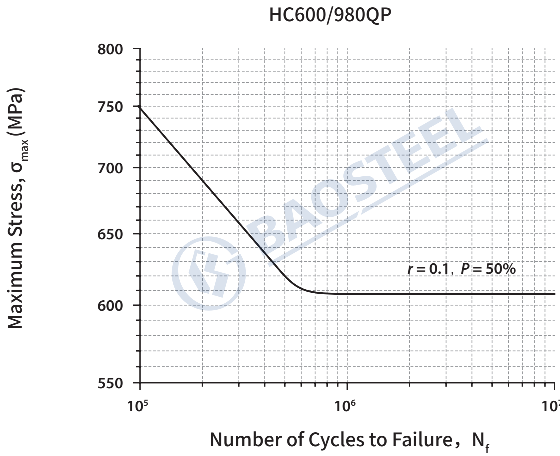
3.7 Service Performance

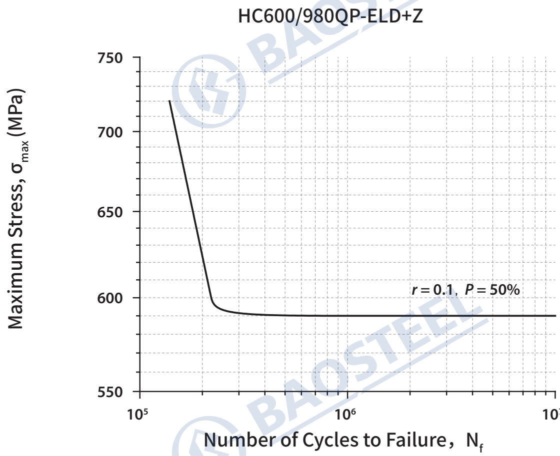
3.7.1 Dynamic Mechanical Properties





3.7.2 Fatigue Properties



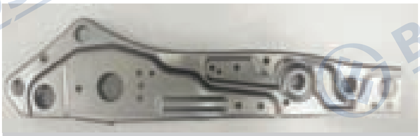


3.7.3 Delayed Fracture Properties

Steel	Specimen type	Environment	Time/h	Crack or not
HC600/980QP	U bending	0.1mol/L HCl	300	NO

3.8 Applications

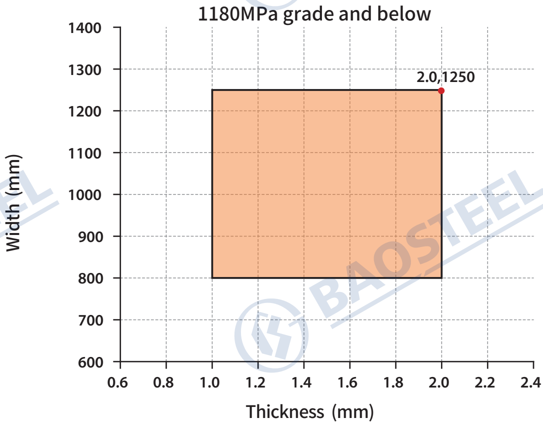
Side rail
(HC600/980QPD+Z, thickness of 1.8 mm)



Cushion side panel
(HC820/1180QP, thickness of 1.2 mm)

3.9 Available Dimensions

- Available Dimensions of Cold-rolled QP Steels and Hot-dip Galvanized QP steels



Note: If the required material dimensions are beyond the scope, specific consultation may be conducted.

Martensitic steel (MS) >>

4.1 Introduction

Martensitic steels are produced in specialized Baosteel ultra high strength steel production lines. The ultra high strength of cold-rolled martensitic steels is attributed to their martensitic microstructure, which is obtained after quenching process of the continuous annealing line.

Owning to the high tensile strength, high YS/TS ratio and some formability, martensitic steels are widely applied to automotive parts with high demand for stiffness, such as bumper beams and reinforcements, side intrusion beams and other structural parts for safety purpose.

Martensitic steels have high strength but low ductility, and hence are suitable for bending instead of tensile forming. The ideal forming method for martensitic steels is roll forming. For steel grades of HC700/980MS, HC950/1180MS, HC1030/1300MS, HC1150/1400MS and HC1200/1500MS, the bending angle is suggested to be below 90 degree, with the inner bending radius r⩾4t (t is sheet thickness). Springback issue occur during forming of martensitic steels, and thus springback control and compensation need to be well considered during mold design and usage.

Martensitic steels have low carbon equivalent and thereby good spot weldability. Good spot weld joint can be obtained by normal welding process. No evident behavior of softening in heat affected zone of the weld of such steels.

4.2 Grades and Naming Methods

The common grades of martensitic steels are HC700/980MS, HC950/1180MS, HC1030/1300MS. Taking HC950/1180MS as an example, the naming method for steel a grade is illustrated as follow: H stands for high strength steels; C represents cold-rolled steel substrate; 950 shows the minimum required yield strength ($R_{p0.2}$ or R_{eL}); 1180 shows the minimum required tensile strength (R_m); MS stands for martensitic steel.

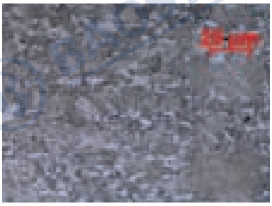
4.3 Grades Comparison

Comparison of steel grades of Baosteel cold-rolled products with other

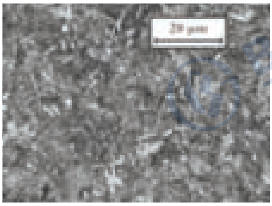
Q/BQB 418-2018	SAE J2340-1999	SAE J2745-2007	VDA 239-100:2016
HC700/980MS	1000 M	-	-
HC950/1180MS	1200 M	-	-
HC1030/1300MS	1300 M	MS 1300T/1030Y	CR1030Y1300T-MS
HC1150/1400MS	1400 M	-	-
HC1200/1500MS	1500 M	MS 1500T/1200Y	CR1220Y1500T-MS
HC1350/1700MS	-	-	CR1350Y1700T-MS

4.4 Microstructure

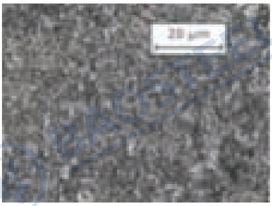
Martensitic steels consist of mainly lath martensite.



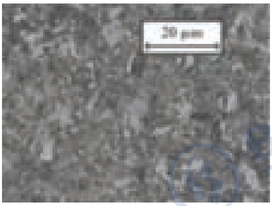
HC950/1180MS



HC1030/1300MS



HC1150/1400MS



HC1200/1500MS

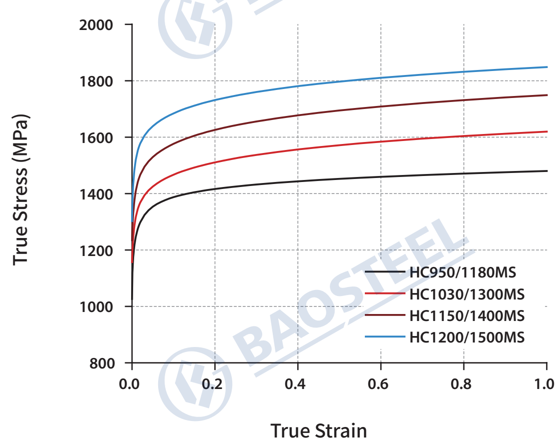
4.5 Mechanical Properties

Mechanical Properties

Steel	Thickness (mm)	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)
HC700/980MS	2	859	1085	7.2
HC950/1180MS	1.6	1029	1289	6.6
HC1030/1300MS	1.2	1158	1326	6.2
HC1150/1400MS	1	1237	1432	5.8
HC1200/1500MS	1.2	1264	1532	5.2

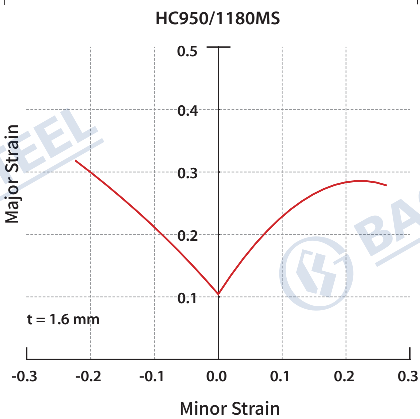
Note: The property value is the reference value, not the supply basis.

Hardening Curves



4.6 Forming Properties

4.6.1 Forming Limit



4.6.2 Hole Expansion Ratio

Steel	Thickness (mm)	Hole expansion ratio (%)
HC700/980MS	1.6	20
HC950/1180MS	1.4	30
HC1030/1300MS	1.4	35

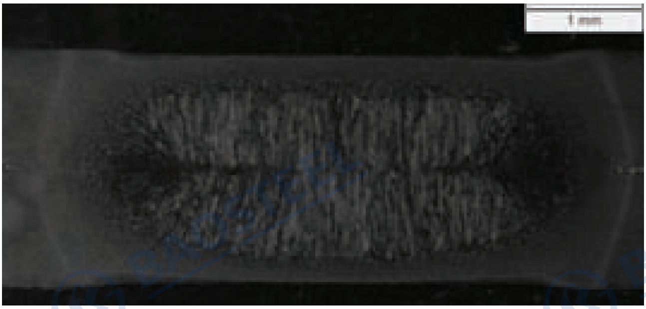
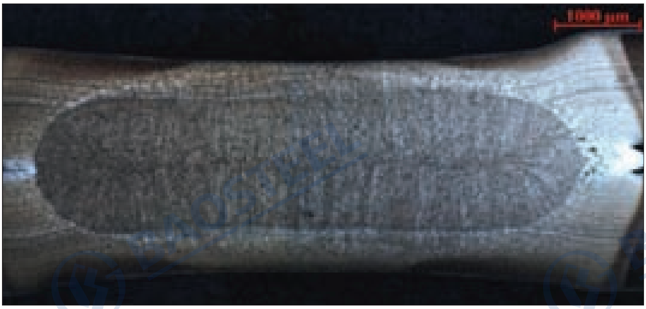
Note: Property value is reference value

4.7 Spot Welding Properties

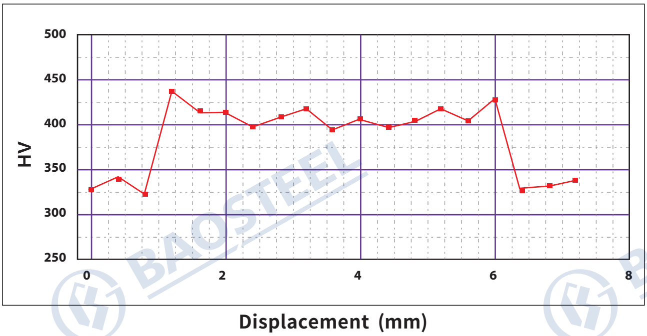
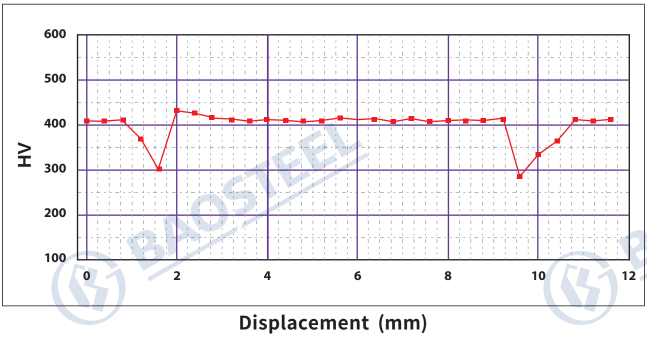
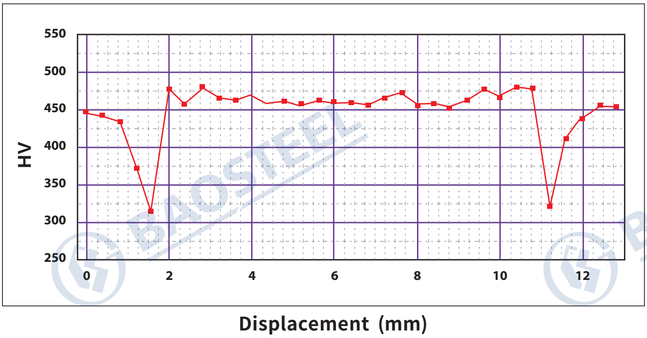
Steel	Thickness (mm)	Electrode diameter (mm)	Welding pressure (kN)	Welding time (cyc)	Weldable current interval (kA)			TSS		CTS	
					Min.	Max.	Width	Joint strength (kN)	Nugget diameter (mm)	Joint strength (kN)	Nugget diameter (mm)
HC700/980MS	1.0	6	2.6	8	5.4	8.0	2.6	10.1	4.0	4.2	4.0
HC950/1180MS	1.4	6	4.3	11	6.0	9.5	3.5	18.2	5.0	6.9	5.0
HC1030/1300MS	1.45	8	8.9	21	7.2	11.4	4.2	34.4	8.5	12.5	8.5

Note: Property value is reference value

Microstructure of Welding Spot

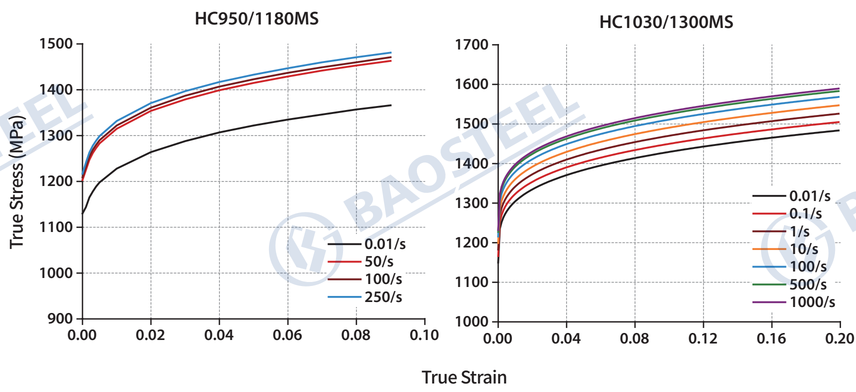
Steel	Microstructure of welding spot
HC700/980MS	
HC950/1180MS	
HC1030/1300MS	

Microhardness Distribution of Welding Spot

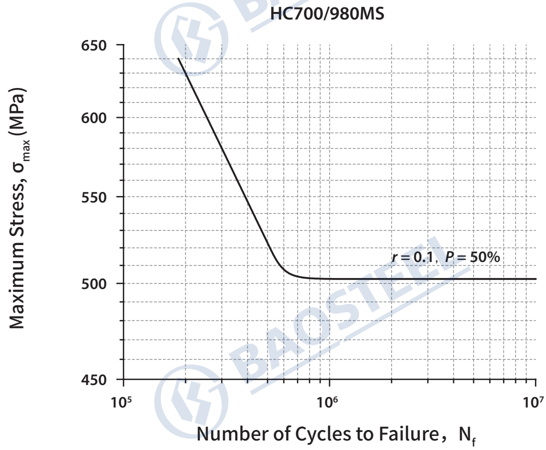
Steel	Microhardness distribution of welding spot
HC700/980MS	
HC950/1180MS	
HC1030/1300MS	

4.8 Service Performance

4.8.1 Dynamic Mechanical Properties



4.8.2 Fatigue Properties



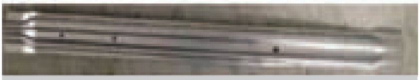
4.8.3 Delayed Fracture Properties

Steel	Specimen type	Environment	Loading stress	Time/h	Crack or not
HC700/980MS HC950/1180MS HC1030/1300MS	Constant stress specimen	0.1mol/L HCl	100% YS	300	No

4.9 Applications

Rear bumper
(HC1030/1300MS, thickness of 1.6 mm)

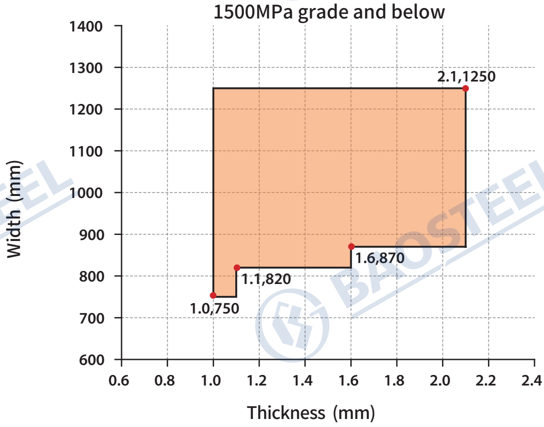
Reinforcement door inner
(HC1030/1300MS, thickness of 1.6 mm)



Rear bumper
(HC1200/1500MS, thickness of 1.2 mm)

4.10 Available Dimensions

■ Available Dimensions of Cold-rolled MS Steels



Note: If the required material dimensions are beyond the scope, specific consultation may be conducted.

Complex Phase Steel (CP) >>

5.1 Introduction

Complex phase (CP) steels have high YS/TS ratio, with typical tensile strength of above 600 MPa. The yield strength of CP steels is much higher while the uniform elongation is lower than that of DP steels and TRIP steels with similar tensile strength. The CP steels are characterized by good bendability and hole expansion, as well as high energy absorption and high residual deformation capacity. CP steels are mainly used for chassis suspension components, B-pillar, bumper beams, seat rails etc.

5.2 Grades and Naming Methods

The common grades of CP steels are HC570/780CP, HC780/980CP, HC900/1180CP, HD680/780CP. Taking HC570/780CPD+Z as an example, the naming method for steel a grade is illustrated as follow: H stands for high strength steels; C represents cold-rolled steel substrate; 570 shows the minimum required yield strength ($R_{p0.2}$ or R_{eL}); 780 shows the minimum required tensile strength (R_m); CP stands for complex phase steel; D stands for hot-dip galvanizing, followed by the type of coating, of which +Z represents coating of pure zinc. For steel grade of HD680/780CP, D stands for hot-rolled steel substrate.

5.3 Grades Comparison

Comparison of steel grades of Baosteel cold-rolled products with other

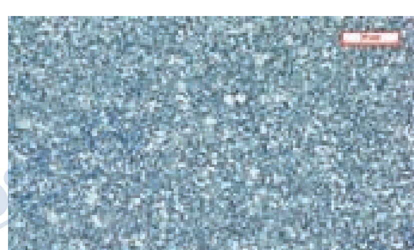
Q/BQB 418-2018	EN 10338:2016	VDA 239-100:2016
HC570/780CP	HCT780C	CR570Y780T-CP
HC780/980CP	HCT980C	CR780Y980T-CP
HC900/1180CP	-	CR900Y1180T-CP

Comparison of steel grades of Baosteel galvanized products with other

Q/BQB 420-2018	EN 10346:2015	VDA 239-100:2016
HC570/780CPD+Z HC570/780CPD+ZF	HCT780C	CR570Y780T-CP
HC780/980CPD+Z HC780/980CPD+ZF	HCT980C	CR780Y980T-CP
HC780/980CPD+Z	-	-
HD680/760CPD+Z	HDT780C	-
HD680/780CPD+ZF		
HD720/950CPD+Z	HDT950C	-
HD720/950CPD+ZF		

5.4 Microstructure

The microstructure of CP steels contains bainite, martensite, ferrite and small amount of retained austenite. The matrix of CP steels consists of fine grain hard martensite and bainite. The micrograph of the typical microstructure of a CP steel is shown below.



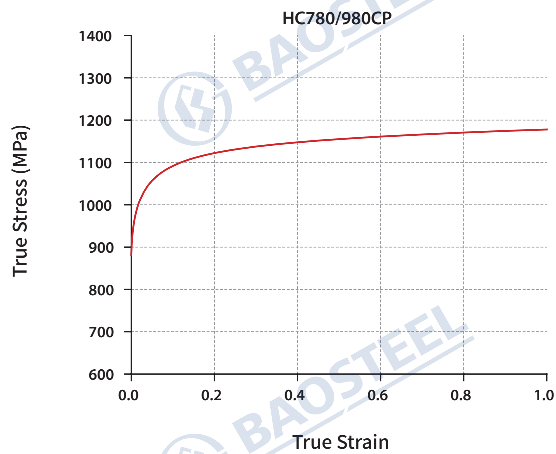
5.5 Mechanical Properties

Mechanical Properties

Steel	Thickness (mm)	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	n	r_0	r_{45}	r_{90}
HC780/980CP	1.2	881	1005	10.7	0.06	0.49	0.9	0.65
HC570/780CPD+Z	1.5	647	801	15.1	0.075	0.8	0.82	1.0

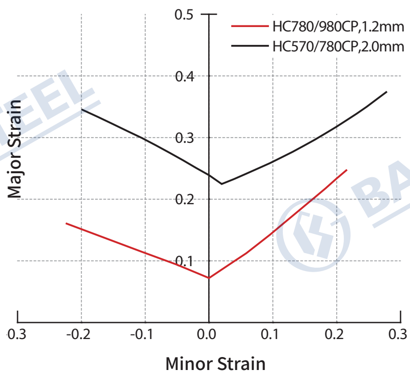
Note: The property value is the reference value, not the supply basis.

Hardening Curve



5.6 Forming Properties

5.6.1 Forming Limit



5.6.2 Hole Expansion Ratio

Steel	Thickness (mm)	Hole expansion ratio (%)
HC570/780CP	2.0	62
HC570/780CPD+Z	1.5	53
HC780/980CP	1.6	55

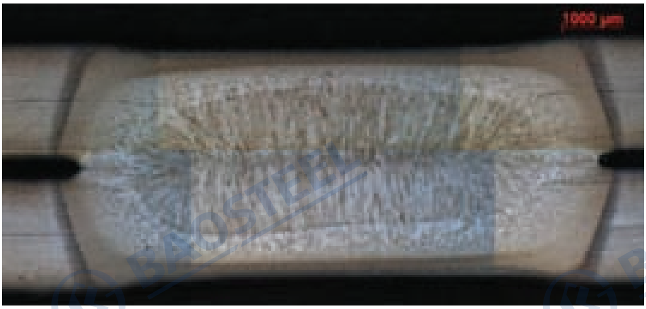
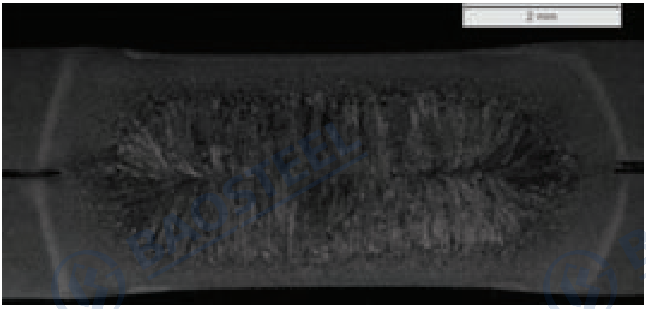
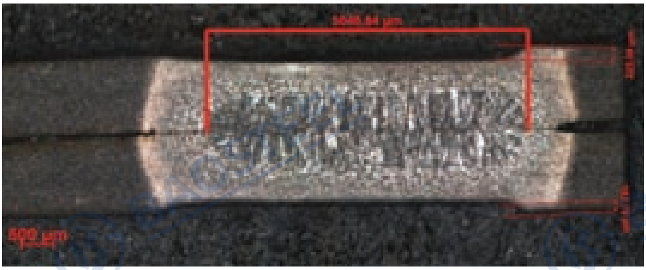
Note: Property value is reference value

5.7 Spot Welding Properties

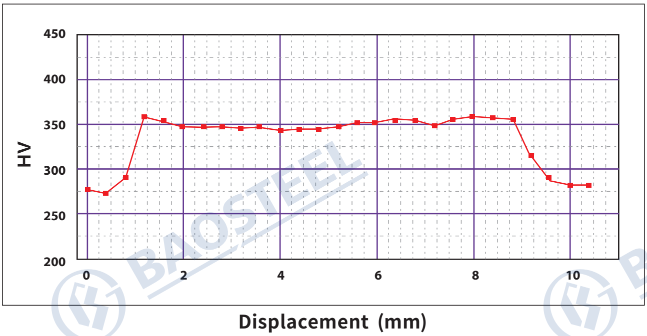
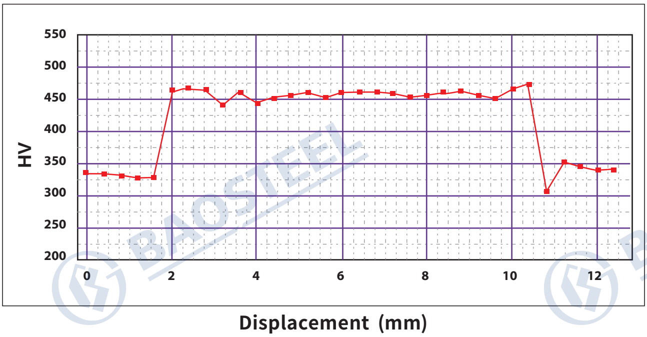
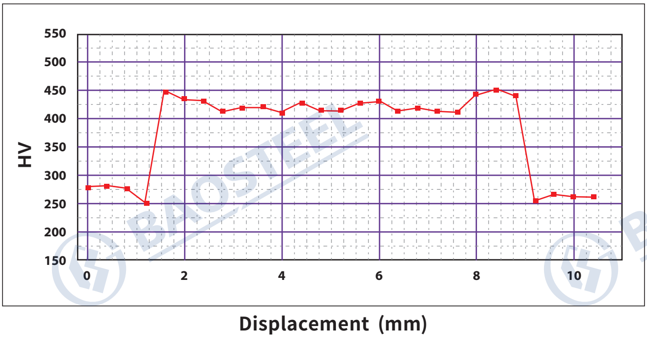
Steel	Thickness (mm)	Electrode diameter (mm)	Welding pressure (kN)	Welding time (cyc)	Weldable current interval (kA)			TSS		CTS	
					Min.	Max.	Width	Joint strength (kN)	Nugget diameter (mm)	Joint strength (kN)	Nugget diameter (mm)
HC570/780CP	2.0	8	7.2	32	7.6	12.5	4.9	35.2	8.4	21.2	8.4
HC780/980CP	1.5	8	4.6	11	6.2	8.2	2.0	22.9	6.0	10.6	6.0
HC570/780CPD+Z	1.2	5.5	4.0	16	6.6	8.4	1.8	12.1	4.4	5.8	4.4
HC780/980CPD+Z	1.2	6	4.0	18	6.2	8.6	2.4	19.7	7.0	8.5	7.0

Note: Property value is reference value

Microstructure of Welding Spot

Steel	Microstructure of welding spot
HC570/780CP	
HC780/980CP	
HC570/780CPD+Z	

Microhardness Distribution of Welding Spot

Steel	Microhardness distribution of welding spot
HC570/780CP	
HC780/980CP	
HC570/780CPD+Z	

5.8 Applications

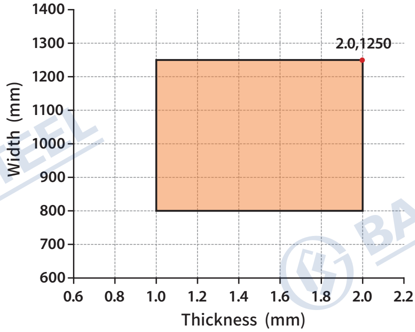
Control arm
(HD680/780CP, thickness of 3.2 mm)

Seat rail
(HC780/980CP, thickness of 1.4 mm)

5.9 Available Dimensions

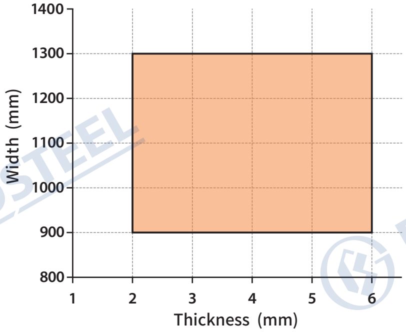
- Available Dimensions of Cold-rolled CP Steels and Hot-dip Galvanized CP steels

980MPa grade and below



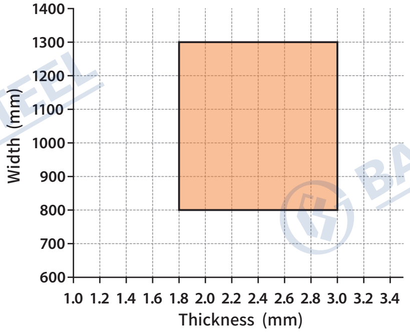
- Available Dimensions of Hot-rolled and Hot-rolled Pickled CP Steels

780MPa grade



- Available Dimensions of Hot-dip Galvanized CP Steels with Hot-rolled Substrates

780MPa grade and below



Note: If the required material dimensions are beyond the scope, specific consultation may be conducted.

Transformation-induced Plasticity Steel (TRIP) >>

6.1 Introduction

During deformation of TRIP steels, the retained austenite transforms into martensite, resulting in good uniform deformation and good combination of strength and ductility. Compared with traditional high strength steels, TRIP steels have higher work hardening rate and tensile strength, lower YS/TS ratio, higher elongation and bake hardening index, and contain larger amount of alloying elements.

TRIP steels exhibit excellent crash energy absorption, high strength-ductility balance, high n value and good formability. Thus, TRIP steels can be used as structural and safety components.

Good welding behavior of TRIP steels can be obtained by slight adjustment of normal welding parameters.

6.2 Grades and Naming Methods

The common grades of TRIP steels are HC380/590TR, HC400/690TR, HC420/780TR. Taking HC420/780TRD+Z as an example, the naming method for steel a grade is illustrated as follow: H stands for high strength steels; C represents cold-rolled steel substrate; 420 shows the minimum required yield strength ($R_{p0.2}$ or R_{eL}); 780 shows the minimum required tensile strength (R_m); TR stands for transformation-induced plasticity steel; D stands for hot-dip galvanizing, followed by the type of coating, of which +Z represents coating of pure zinc.

6.3 Grades Comparison

Comparison of steel grades of Baosteel cold-rolled products with other

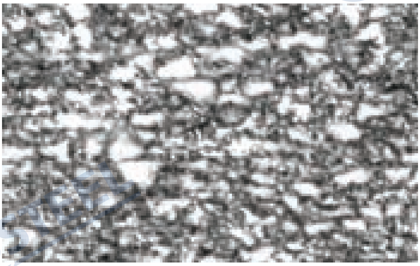
Q/BQB 418-2018	EN 10338:2015	VDA 239-100:2016	SAE J2745-2007
HC380/590TR	-	-	TRIP590T/380Y
HC400/690TR	HCT690T	CR400Y690T-TR	TRIP690T/400Y
HC420/780TR	HCT780T	CR450Y780T-TR	TRIP780T/420Y

Comparison of steel grades of Baosteel galvanized products with other

Q/BQB 420-2018	EN 10346:2015	VDA 239-100:2016	SAE J2745-2007
HC380/590TRD+Z HC380/590TRD+ZF	-	-	TRIP590T/380Y
HC400/690TRD+Z HC400/690TRD+ZF	HCT690T	CR400Y690T-TR	TRIP690T/400Y
HC420/780TRD+Z HC420/780TRD+ZF	HCT780T	CR450Y780T-TR	TRIP780T/420Y

6.4 Microstructure

The microstructure of TRIP steel consists of ferrite, bainite and retained austenite.



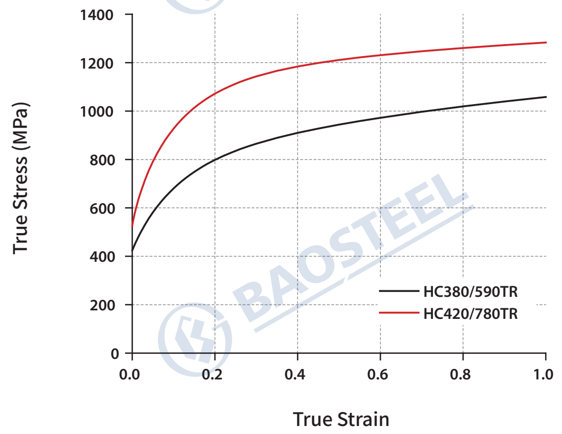
6.5 Mechanical Properties

■ Mechanical Properties

Steel	Thickness (mm)	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	n	r_0	r_{45}	r_{90}
HC380/590TR	0.8	424	654	29.0	0.189	0.90	0.90	1.10
HC420/780TR	1.2	526	878	27.0	0.202	0.80	0.78	1.00

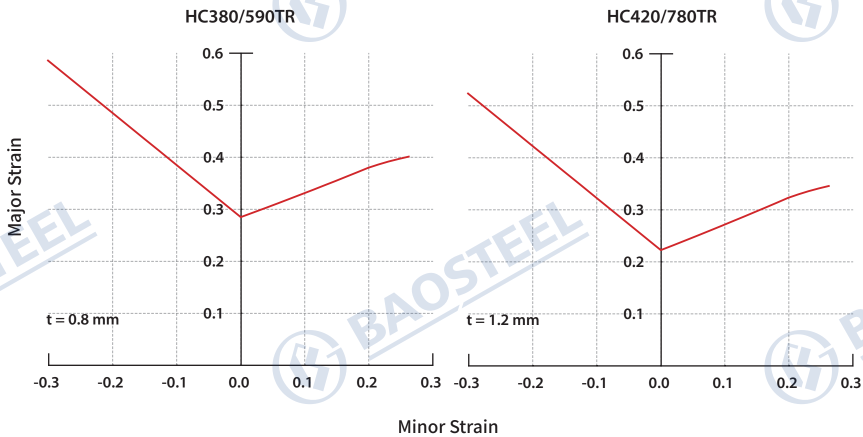
Note: The property value is the reference value, not the supply basis.

■ Hardening Curves



6.6 Forming Properties

6.6.1 Forming Limit



6.6.2 Hole Expansion Ratio

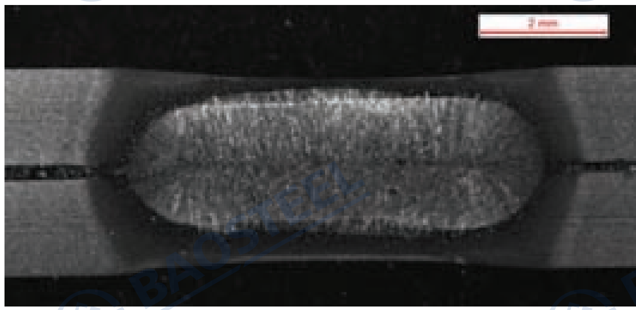
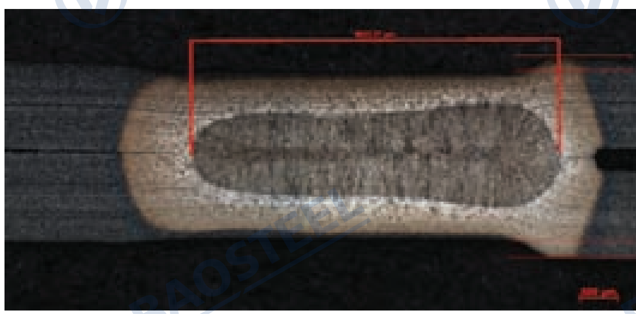
Steel	Thickness (mm)	Hole expansion ratio (%)
HC420/780TR	1.75	19
HC400/690TRD+Z	1.75	24

Note: Property value is reference value

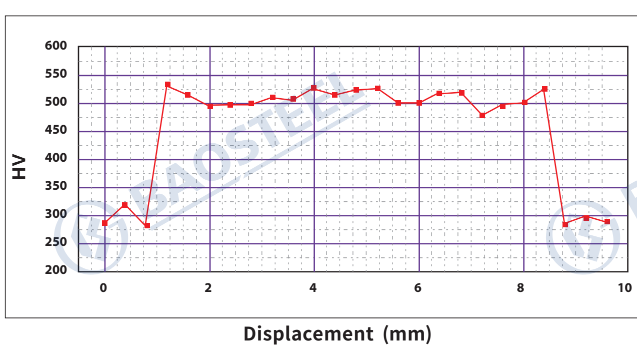
6.7 Spot Welding Properties

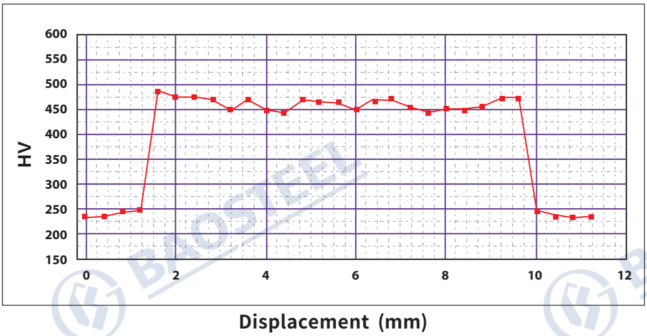
Steel	Thickness (mm)	Electrode diameter (mm)	Welding pressure (kN)	Welding time (cyc)	Weldable current interval (kA)			TSS		CTS	
					Min.	Max.	Width	Joint strength (kN)	Nugget diameter (mm)	Joint strength (kN)	Nugget diameter (mm)
HC380/590TR	1.4	6	4.0	15	6.6	8.4	1.8	20.8	6.5	12.0	6.5
HC420/780TR	1.6	7	4.0	15	5.8	8.2	2.4	27.4	6.5	11.4	6.5
HC400/690TRD+Z	1.2	5.5	4.0	16	6.5	8.1	1.6	12.6	5.0	5.8	5.0

Microstructure of Welding Spot

Steel	Microstructure of welding spot
HC420/780TR	
HC400/690TRD+Z	

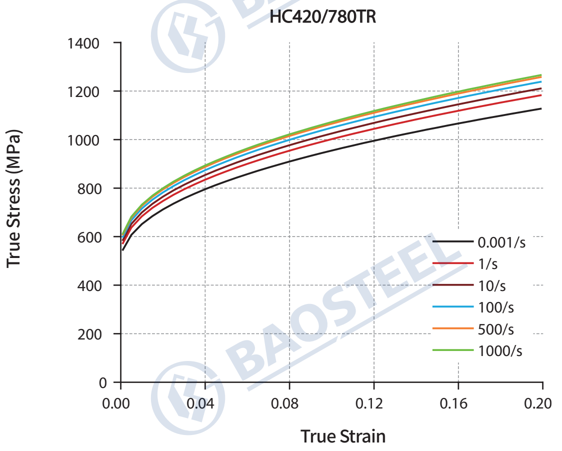
Microhardness Distribution of Welding Spot

Steel	Microhardness distribution of welding spot
HC420/780TR	

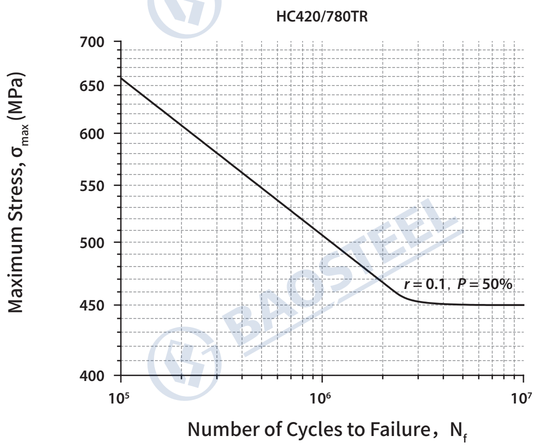
Steel	Microhardness distribution of welding spot
HC400/690TRD+Z	

6.8 Service Performance

6.8.1 Dynamic Mechanical Properties



6.8.2 Fatigue Properties



6.8.3 Delayed Fracture Properties

Steel	Specimen type	Environment	Time/h	Crack or not
HC420/780TR	U bending	0.1mol/L HCl	300	No

6.9 Applications

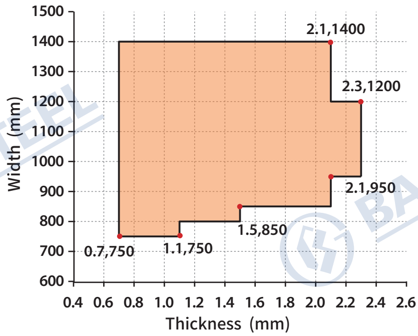
Side rail-TWB
(HC400/690TRD+Z 1.2mm + HC600/980QP 1.4mm)

Door ring
(HC420/780TR, thickness of 1.6 mm)

6.10 Available Dimensions

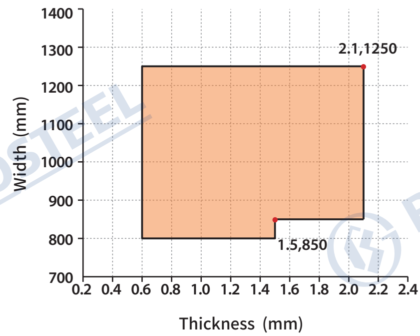
■ Available Dimensions of Cold-rolled TRIP Steels

780MPa grade and below



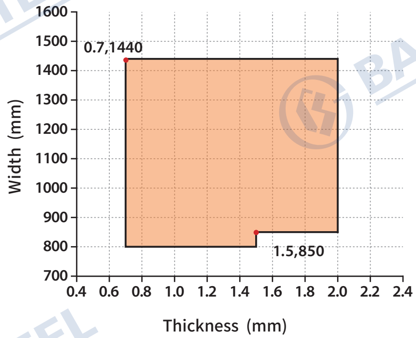
■ Available Dimensions of Hot-dip Galvanized TRIP Steels

780MPa grade and below



■ Available Dimensions of Electro-galvanized TRIP Steels

780MPa grade and below



Note: If the required material dimensions are beyond the scope, specific consultation may be conducted.

Twinning-induced Plasticity Steel (TWIP) >>

7.1 Introduction

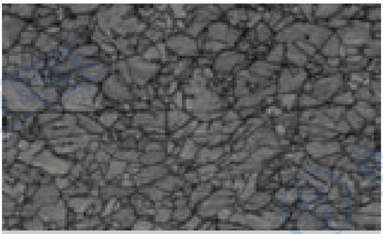
TWIP steels are new ultra high strength automotive steels which are alloyed by high amount of C, Mn and Al. A fully austenitic structure of TWIP steels at room temperatures is obtained by adding high amount of alloying elements. Excellent ductility as well as high strength of TWIP steels are made possible by the twinning-induced plasticity. TWIP steels with tensile strength of 1000 MPa can reach an elongation of above 50%. TWIP steels show great prospect in automotive applications due to their superior mechanical behavior and simple alloy composition without addition of expensive alloying elements.

7.2 Grades and Naming Methods

The common grades of TWIP steels are HC450/950TW, HC450/950TWD+Z. H stands for high strength steels; C represents cold-rolled steel substrate; 450 shows the minimum required yield strength ($R_{p0.2}$ or R_{eL}); 950 shows the minimum required tensile strength (R_m); TW stands for twinning-induced plasticity steel; D stands for hot-dip galvanizing, followed by the type of coating, of which +Z represents coating of pure zinc.

7.3 Microstructure

TWIP steels are composed of full austenite.



HC450/950TW

7.4 Mechanical Properties

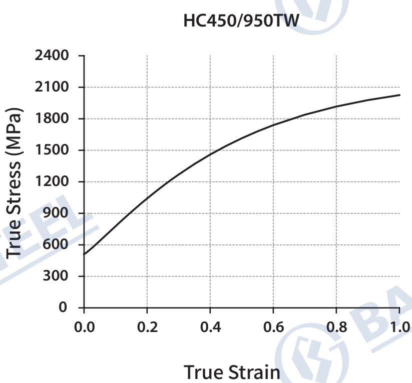
Mechanical Properties

Steel HC450/950TW

Thickness (mm)	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)
2	511	982	59.6
n	r_0	r_{45}	r_{90}
0.35	0.81	1.12	1.22

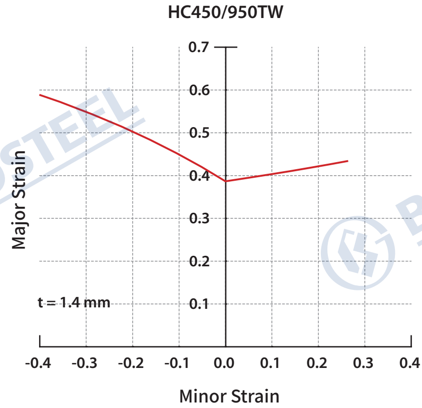
Note: The property value is the reference value, not the supply basis.

Hardening Curve



7.5 Forming properties

7.5.1 Forming Limit



7.5.2 Hole Expansion Ratio

Steel HC450/950TW

Thickness (mm)	Hole expansion ratio (%)
1.2	40

Note: Property value is reference value

7.6 Spot Welding Properties

Steel	Thickness (mm)	Electrode diameter (mm)	Welding pressure (kN)	Welding time (cyc)	Weldable current interval (kA)			TSS		CTS	
					Min.	Max.	Width	Joint strength (kN)	Nugget diameter (mm)	Joint strength (kN)	Nugget diameter (mm)
HC450/950TW	1.0	6	2.6	8	4.6	6.4	1.8	11.6	6.0	7.7	6.0

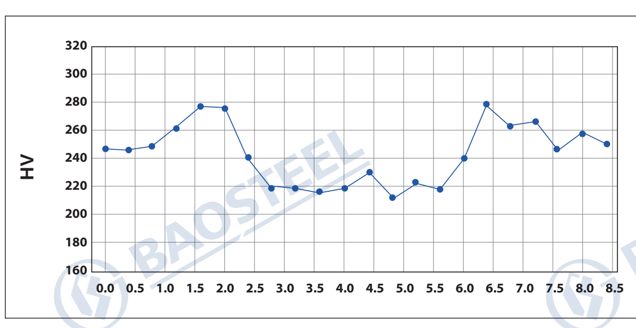
Note: Property value is reference value

Microstructure of Welding Spot

HC450/950TW

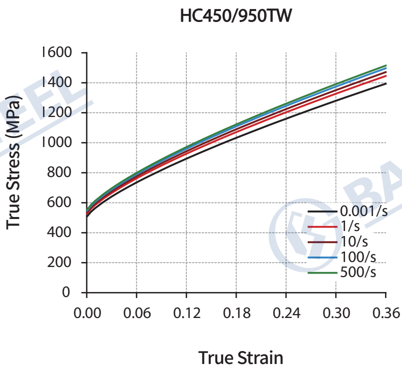
Microhardness Distribution of Welding Spot

HC450/950TW



7.7 Service Performance

7.7.1 Dynamic Mechanical Properties

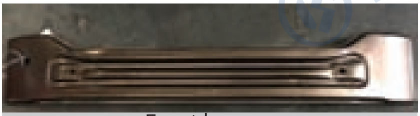


7.7.2 Delayed Fracture Properties

Steel HC450/950TW

Specimen type	Environment
U bending	0.1mol/L HCl
Time/h	Crack or not
300	No

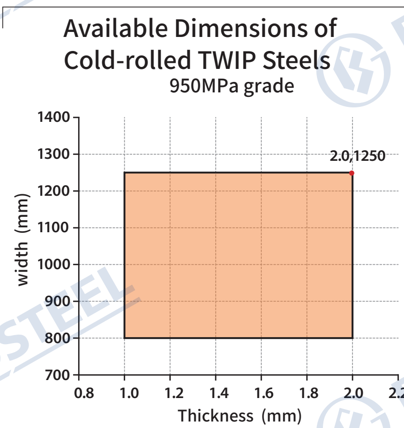
7.8 Applications



Front bumper
(HC450/950TW, thickness of 1.6 mm)

Shocktower
(HC450/950TWD+Z, thickness of 2.0 mm)

7.9 Available Dimensions



Note: If the required material dimensions are beyond the scope, specific consultation may be conducted.

Press Hardened Steel >>

8.1 Introduction

Press hardened steels are those that require hot forming process for final application. During the hog stamping process, the steel is first heated to above austenization temperature, and then quickly moved to the mold for stamping at which the forming and quenching of steels are done at the same time. Compared with the cold stamping process, the hot stamping process can obtain automotive parts with ultra high strength. Hot stamping process can obtain better material formability and requires less press capacity from the equipment, and the springback behavior of materials can be easily controlled during deformation. Components made by hot stamping process exhibit high dimensional precision, surface hardness, dent resistance and stiffness.

8.2 Grades and Naming Methods

The common grades of Press hardened steels are HC950/1300HS(B1500HS), B1800HS, HD950/1300HS(BR1500HS). Taking the steel grade of HC950/1300HS+AS as an example, H stands for high strength steels; C represents cold-rolled steel substrate (D for hot-rolled steel substrate); 950 shows the minimum required yield strength ($R_{p0.2}$ or R_{eL}); 1300 shows the minimum required tensile strength (R_m); HS represents hot stamping, +AS stands for Al-Si coating.

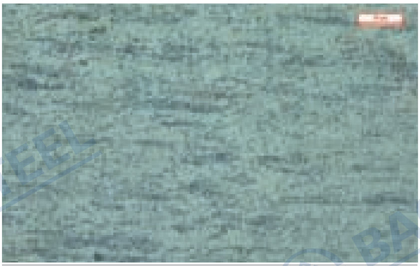
8.3 Grades Comparison

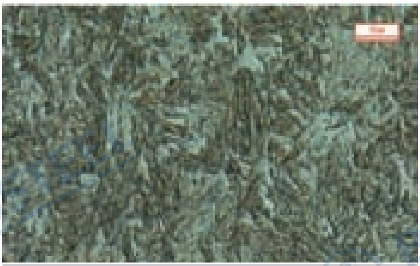
Comparison of steel grades of Baosteel cold-rolled products with other

Q/BQB 409-2018	EN 10083-3:2006
HC950/1300HS (B1500HS)	20MnB5
B1800HS	-
HC950/1300HS+AS	-

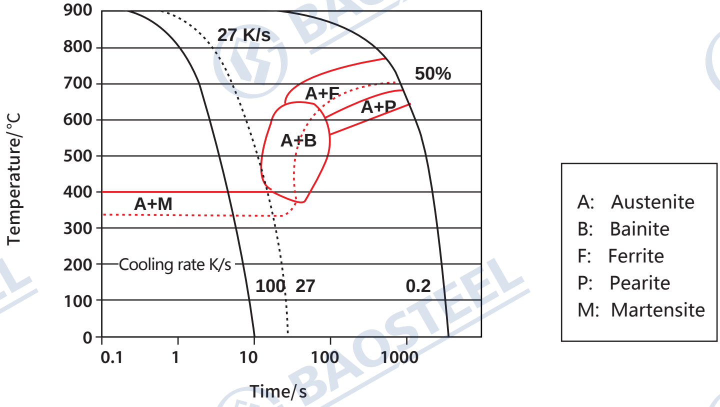
8.4 Microstructure

The microstructure of as received press hardened steel before any heat treatment consists of ferrite and pearlite, and transforms into martensite after heat treatment.


Before heat treatment


After heat treatment

8.5 Continuous Cooling Transformation (CCT) Curve



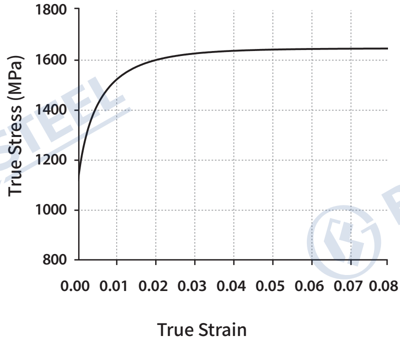
8.6 Mechanical Properties

Mechanical properties of press hardened steel of B1500HS before hot forming are as follows.

Steel	B1500HS (HC950/1300HS)		
Thickness (mm)	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)
1.8	324	506	30.1

Note: The property value is the reference value, not the supply basis.

The hardening curve of hot press hardened steel of B1500HS after hot forming is as follows.

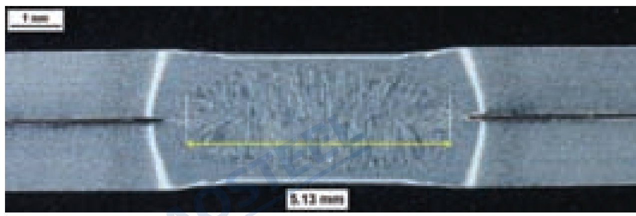


8.7 Spot Welding Properties

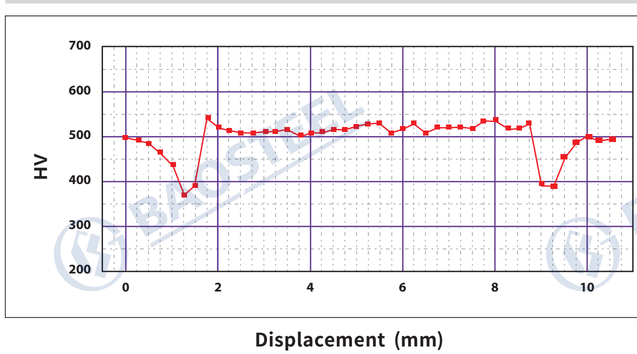
Steel	Thickness (mm)	Electrode diameter (mm)	Welding pressure (kN)	Welding time (cyc)	Weldable current interval (kA)			TSS		CTS	
					Min.	Max.	Width	Joint strength (kN)	Nugget diameter (mm)	Joint strength (kN)	Nugget diameter (mm)
B1500HS	1.3	6	4.0	15	5.9	7.7	1.8	17.8	5.0	4.3	5.0
B1800HS	1.4	6	4.3	12	5.4	8.6	3.2	22.9	6.2	4.2	6.2

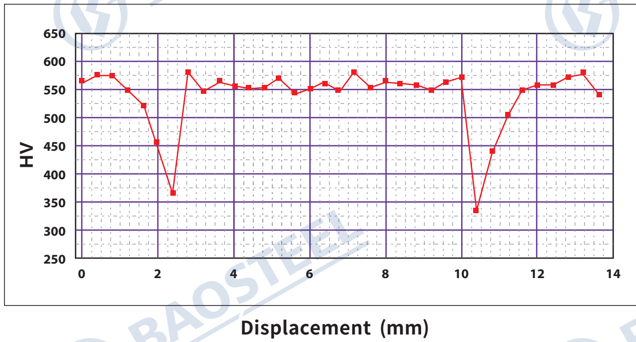
Note: Property value is reference value

Microstructure of Welding Spot

Steel	Microstructure of welding spot
B1500HS	
B1800HS	

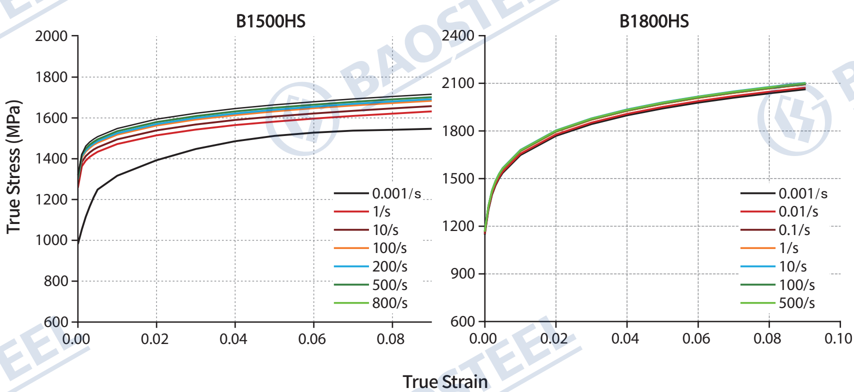
Microhardness Distribution of Welding Spot

Steel	Microhardness distribution of welding spot
B1500HS	

Steel	Microhardness distribution of welding spot
B1800HS	

8.8 Service Performance

8.8.1 Dynamic Mechanical Properties



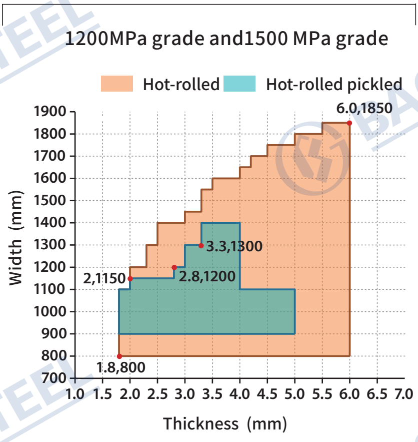
8.9 Applications

Hot stamped front bumper
(B1800HS, thickness of 1.2 mm)

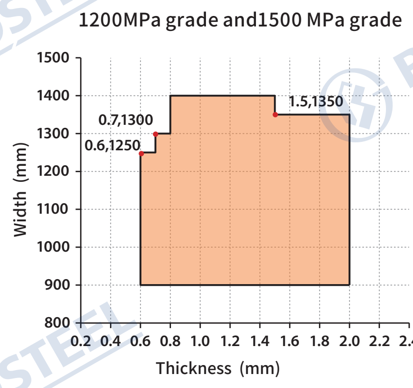
Hot-stamped B-pillar with variable strength
(B1500HS, thickness of 1.2 mm)

8.10 Available Dimensions

- Available Dimensions of Hot-rolled and Hot-rolled Pickled Press Hardened Steels



- Available Dimensions of Cold-rolled Press Hardened Steels



Note: If the required material dimensions are beyond the scope, specific consultation may be conducted.

Parts and Process Design Guidelines of High-Strength Steel Parts

9.1 Product Design Guidelines

High-strength steel has the characteristics of higher tensile strength, higher yield strength, lower elongation, n value and low r value. It is characterized by large springback, easy cracking and wrinkling. We must pay attention to these characteristics, and distinguish it from traditional steel in design concept and product feature processing to meet the manufacturability and debuggability of the product.

Product design should focus on meeting the following requirements

1) Considering the forming direction and ensuring that the drawing angle of the side wall and the feature is more than 6°, the main purpose is to make the product have enough springback processing angle;

2) The product should be designed as an open, simple shape, considering the way of bending or pressing. This type of scheme has fewer defects and can simplify the following springback processing work;

3) The parts are designed to avoid violent transitions or connections. Too sharp shape changes can cause defects such as wrinkles or cracks, and complicate the springback;

4) For the design of TRB or VRB parts, the welding line or transition zone should be placed in a simple shape, no shape transition or a smooth transition zone;

5) As with the design of ordinary mild steel, high-strength steel should also pay attention to the optimization of product boundaries to ensure the trimming state and optimization of the whole stamping process;

6) The larger the product fillet, the better the forming result, and the easier it is to avoid the wrinkles and cracks. However, the larger the part fillet, the larger the springback, especially the fillets of the “hat” shaped part and the flange. Therefore, under the premise of meeting the molding requirements, the fillet should be as small as possible; Generally, 3 times thickness fillets are required;

7) Add ribs at appropriate locations and areas to reduce or even eliminate local springback;

8) For high-strength steel parts, too much features, especially small features, can greatly increase forming force, and thus the force of the mold and the manufacturing cost. Therefore, reasonable product design should avoid complicated shapes and small features.

9.2 Stamping Process Design Guidelines

Compared with stamping process of mild steel, the forming scheme of high-strength steel should not only consider the controllability of forming process, the cracks and wrinkles of the parts after forming, but also need to focus on reasonable schemes to reduce springback, and consider its adjustments and controllability during the try-and-out.

The process design of high-strength steel should focus on the following points:

1) The drawbead coefficient of high-strength steel should not be set too large, and it is best to use kind of drawing sill. Due to the high tensile strength and high yield strength, too large drawbead coefficient will result in a larger blanking force when forming the drawbead, which may lead to the drawbead cannot be formed, resulting the material on the pressing surface cannot be controlled, and the wrinkles and stacking occur. When the blank thickness exceeds 1.8mm, no drawbead is recommended;

2) The binder surface and the punch should simultaneously touch the blank during drawing process, and the uneven contact of the punch and blank is easy to cause the workpiece distorted;

3) Optimize the shape of the sheet as much as possible, and too much material on binder will cause large inner stress of the sheet, resulting irregular springback such as distortion;

4) For parts with flanges and deep drawing depth, distortion of side wall would smaller when flange is placed on punch than binder, while this will reduce material utilization. For such parts, the process is preferred to place flange on the punch to reduce springback of the side wall;

5) For parts with small sidewall angles, in order to make enough springback processing for compensation, it is necessary to add the strike process;

6) Due to the lower elongation of high-strength steel, forming and bending processes should be firstly considered for simple parts. This will reduce springback and make the control of springback much easier. However, it should be noted that this method should be used with caution for parts with spatial curvature and high dimensional requirements;

7) High-strength steel parts should be formed in one process. Because the parts are formed and hardened after forming, the secondary forming makes the parts easier to crack and wrinkle. In addition, high-strength steel need large forming force, and is also likely to cause redistribution of workpiece stress and springback;

8) In order to control springback, the "stake bead" can be designed to post-stretch the material before hit the bottom, causing another 2% deformation, changing the stress distribution along the thickness direction which has a significant effect on angular and curler springback;

9) For important zones such as the welding flange area, the strike process should be arranged as much as possible. This will first flat the surface of the part, it also facilitates the modification of springback;

10) In order to reduce the compensation of springback, experience and CAE analysis will be considered together for processing with springback in the design phase. At this time, modification of springback should be based on the process scheme without forming defects, a stable springback trend and values.

9.3 Stamping Die Design Guidelines

For the mold design of high-strength parts, not only to meet the requirements of traditional molds, such as strength, stiffness, casting, processing and manufacturing, but also to fully consider the late springback control. The use of a reasonable mold structure, so that the later springback modification can be achieved, easy to modify with small modification.

The following are some specific aspects:

1) The forming force of high strength steel is larger. For in the mold structure, it is necessary to consider increasing the strength of the anti-lateral force structure and retaining wall to avoid the instability of the mold gap caused by the local deformation of the mold;

2) Requirements for mold materials are high for high-strength steel. Generally, all the OEMs will make requirements for material of the working area of the mold according to the sheet material and thickness. Work areas with large material flow require high-strength, more wear-resistant materials such as SKD11, and coatings such as TD, composite PVD, and so on;

3) The mold structure should fully consider the scheme of springback processing. Adopting reasonable installation and fastening methods for the working parts to avoid excessive repairing amount of the mold in the late stage;

4) For the subsequent flanging and striking mold, it is necessary to increase the binder force to avoid distortion and springback of the parts caused by the flow of blank;

5) High-strength steel has higher requirements for trimming and punching die, the trimming angle is strictly 10 degrees compared with mild steel; The trimming adopts the form of successive cutting to reduce the repairing force and the on-site noise.

9.4 Mold Processing, Debugging and Pay off Guidelines

A reasonable order of mold processing is needed. It is recommended to first process and debug the forming dies sequently. Processing drawing, draw die-debugging, make prototypes, laser cutting parts, tests, processing forming mold (do compensation according to the test results), to scan the workpiece after debugging and make the trimming CAD model. This can ensure the conformance of the workpiece and mold, while reducing the adjustment of the mold, saving processing and debugging costs.

Mold debugging is basically part of the end of mold production. Mold coloring and defect rectification are carried out at this stage.

For high-strength steel parts, the most important and time-taking work is modification of springback.

The following aspects should be focused on for the spring-back treatment and the late mold pay off.

1) For mild steel, sheet material with lower limit mechanical properties would be used when debugging in order to improve the margin of mass production. For high-strength steel, typical value is recommended because the use of the lower limit or upper limit may make its springback state very different due to the large yield and tensile strength fluctuation;

2) Handling of the springback must be based on the stability of the mold and formability of the workpiece. Mold State stability is mainly reflected in the mold guidance and coloring State meeting the requirements. The stability of the forming state mainly refers to that there are no defects such as wrinkles and cracks of the parts; the size of the sheet and the location is determined; and the material inflow is stable, which are the premise of the springback treatment;

3) For most parts, detection of springback in different states would be quite different for the same workpiece. When doing springback processing, it is necessary to obtain the springback results under different positioning states, finding the ideal state, and then carry out springback processing in this state. Remember not blindly do springback processing with unreasonable results in a hurry;

4) After the determination of the springback state of the workpiece, it is necessary to study the whole process and mold scheme to find the most suitable operations for springback processing. Thus it can often achieve the effect of twice the effort with small amount of modification;

5) For the pay off of high-strength steel molds, we should focus on the welding status of parts and assemblies, abandoning the concept of qualified rate of individual parts. This is more conducive to getting better workpiece and assembly quality. If necessary, we can optimize the body connection by amplifying unreasonable tolerances or changing parts that match the high-strength parts.

At present, due to the inaccuracy of springback calculation, we cannot avoid late mold reprocessing, but through reasonable parts optimization, process optimization, mold structure optimization and standardized processing, commissioning process and norms, we can greatly reduce the amount of springback processing amounts and cycles, saving mold development costs. Nowadays, many professors and institutions at home and abroad have recognized the error and influencing factors of springback analysis, and a lot of work has focused on the material model, CAE simulation software optimization and so on, and do lots of efforts to improve the accuracy of springback analysis. In the future, with the research and optimization of material constitutive equations, the improvement of CAE simulation accuracy, the development of processing, debugging means and specifications, CAE software can accurately predict and compensate the springback. Ideally, the springback can be processed and compensated in the design phase, and the accuracy of the workpiece can meet the design requirements through reasonable processing and commissioning processes. In this way, we do not need to carry out the complex, time-consuming, laborious reprocessing of springback , but to reach this stage, we still have a long way to go.

Baosteel Test Equipment

● Electronic Universal Material Testing Machine

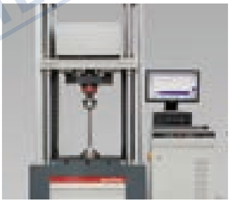
The maximum tensile force is 200 kN. It is equipped with a non-contact optical full-field strain measurement system, which can be used to measure mechanical properties and obtain engineering stress-strain curve, n value, r value and other data.

● Forming Test Machine

The maximum forming force is 600 kN. The system is equipped with a non-contact optical full-field strain measurement system, which can complete the forming limit, hole expansion and cupping tests.

● High Speed Tensile Testing Machine

The maximum load is 100KN and the tensile speed is 0.1m/s~20m/s. The mechanical properties of the material at different strain rates are evaluated.



● High Frequency Fatigue Testing Machine

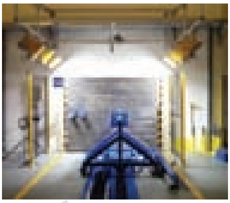
The maximum static load is 150 kN, the alternating load is 75 kN, and the resonance fatigue is 0-300 Hz. It is used to evaluate the ultimate fatigue strength and S/N curve of materials.

Joining Technology Testing Equipment

Including laser tailor-welded testing machine, spot welding testing machine, arc welding testing machine, self-piercing riveting testing machine, glue welding testing machine, shearing machine, punching machine, convex welding machine, seam welding machine, butt welding machine, etc.

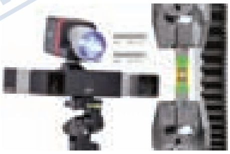
High Strength Steel Forming Press

It can provide maximum 600 t forming force and 250 t blank holder force.



Parts Crash Testing System

Maximum speed 64 km/h, crash for car of 500 kg-900 kg. Assess the impact performance of parts or simulations made of different materials or processes.



Optical Measurement Technology

Including optical mesh strain measurement and analysis system, optical three-dimensional full-field strain measurement system, optical three-dimensional full-field scanning system, sheet metal forming limit (FLC) measurement and analysis system.

Simulation Technology

Forming and Springback Analysis: AutoForm, PAM-Stamp
CAD Styling Design: UG NX, CATIA
CAE Modeling, Mesh Generation, Crash and Springback Analysis: HyperWorks, LS-Dyna, ABAQUS, MSC/Marc etc.
Rolling Process Design and Finite Element Analysis: COPRA RF/FEA
Welding Process Design and Finite Element Analysis: SORPAS
Product Process Simulation: JMatPro

Research Institute (R&D Center) of Baoshan Iron & Steel Co., Ltd.
State Key Laboratory of Development and Application Technology of Automotive Steel

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