Designation: A1039/A1039M – 13

Standard Specification for Steel, Sheet, Hot Rolled, Carbon, Commercial, Structural, and High-Strength Low-Alloy, Produced by Twin-Roll Casting Process[1]

This standard is issued under the fixed designation A1039/A1039M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers commercial and structural steel sheet in coils and cut lengths produced by the twin-roll casting process.

1.2 The steel sheet is available in the designations listed in Section 4.

1.3 The material is available in the following sizes:

Thickness—0.027 in. [0.7 mm] to 0.078 in. [2.0 mm]
Width—up to 79 in. [2000 mm]

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

NOTE 1—A description of the Twin-Roll Casting Process is included in Appendix X1.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A568/A568M Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for

A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

3. Terminology

3.1 *Definitions*—For definitions of other terms used in this specification refer to Terminology A941.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *twin roll casting process, n*—production of steel sheet directly from liquid metal.

3.2.1.1 *Discussion*—The properties of the steel sheet are the result of the control of the casting conditions, and in some cases, through a combination of the casting process and hot rolling of the sheet.

4. Classification

4.1 Twin-roll cast steel sheet is available in the following designations:

4.1.1 Commercial steel (CS Types A, B, and D),

4.1.2 Drawing steel (DS Types A, B, and D),

4.1.3 Structural steel (SS Grades 30 [205], 33 [230], 36 [250] Types 1 and 2, 40 [275], 45 [305], 50 [340], 55 [380], 60 [410], 70 [480], and 80 [550]), and

4.1.4 High-Strength Low-Alloy steel (HSLAS, classes 1 and 2 in grades 45 [310], 50 [340], 55 [380], 60 [410], 65 [450], 70 [480] and 80 [550].

5. Ordering Information

5.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to describe the required material. Examples of such information include, but are not limited to, the following:

5.1.1 ASTM specification number and year of issue,

5.1.2 Name of material and designation (direct cast or hot rolled sheet) (include grade and class, and limits for Cu, Ni, Cr, and Mo as appropriate, for CS, DS, SS, and HSLAS) (see 4.1),

5.1.2.1 When a type is not specified for CS, Type B will be furnished,

5.1.2.2 When a type is not specified for DS, Type B will be furnished,

5.1.2.3 When a class for HSLAS is not specified, Class 1 will be furnished.

5.1.2.4 When limits for Cu, Ni, Cr, and Mo are not specified, limit H (see Table 1) will be furnished.

5.1.3 Finish (see 9.1),

5.1.4 Type of edge (see 9.3),

5.1.5 Oiled or not oiled, as required (see 9.2),

---

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.19 on Steel Sheet and Strip.

Current edition approved Feb. 1, 2013. Published February 2013. Originally approved in 2004. Last previous edition approved in 2012 as A1039/A1039M – 12. DOI: 10.1520/A1039_A1039M-13.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

TABLE 1 Chemical Requirements[A,B] for Twin Roll Cast Hot Rolled Steel Sheet Designations SS and HSLAS

Designation	% Heat Analysis, Element Maximum Unless Otherwise Shown									
	C	Mn	P	S	Al[C]	Si[C]	V	Cb	Ti	N
SS:[D]										
Grade 30 [205]	0.25	0.90	0.035	0.04	. . .	. . .	0.008	0.008	0.008	. . .
Grade 33 [230]	0.25	0.90	0.035	0.04	. . .	. . .	0.008	0.008	0.008	. . .
Grade 36 [250] Type 1	0.25	1.35	0.035	0.04	. . .	. . .	0.008	0.008	0.008	. . .
Grade 36 [250] Type 2	0.25	1.35	0.035	0.04	. . .	. . .	0.008	0.008	0.008	. . .
Grade 40 [275]	0.25	1.35	0.035	0.04	. . .	. . .	0.008	0.008	0.008	. . .
Grade 45 [305]	0.25	1.35	0.035	0.04	. . .	. . .	0.008	0.008	0.008	. . .
Grade 50 [345]	0.25	1.35	0.035	0.04	. . .	. . .	0.008	0.008	0.008	. . .
Grade 55 [380]	0.25	1.35	0.035	0.04	. . .	. . .	0.008	0.008	0.008	. . .
Grade 60 [410]	0.25	1.35	0.035	0.04	. . .	. . .	0.008	0.008	0.008	. . .
Grade 70 [480]	0.25	1.35	0.035	0.04	. . .	. . .	0.008	0.008	0.008	. . .
Grade 80 [550]	0.25	1.35	0.035	0.04	. . .	. . .	0.008	0.008	0.008	. . .
HSLAS:[C]										
Grade 45 [310] Class 1[D]	0.22	1.35	0.04	0.04	. . .	. . .	0.005 min	0.005 min	0.005 min	. . .
Grade 45 [310] Class 2	0.15	1.35	0.04	0.04	. . .	. . .	0.005 min	0.005 min	0.005 min	. . .
Grade 50 [340] Class 1[D]	0.23	1.35	0.04	0.04	. . .	. . .	0.005 min	0.005 min	0.005 min	. . .
Grade 50 [340] Class 2	0.15	1.35	0.04	0.04	. . .	. . .	0.005 min	0.005 min	0.005 min	. . .
Grade 55 [380] Class 1[D]	0.25	1.35	0.04	0.04	. . .	. . .	0.005 min	0.005 min	0.005 min	. . .
Grade 55 [380] Class 2	0.15	1.35	0.04	0.04	. . .	. . .	0.005 min	0.005 min	0.005 min	. . .
Grade 60 [410] Class 1	0.26	1.50	0.04	0.04	. . .	. . .	0.005 min	0.005 min	0.005 min	. . .
Grade 60 [410] Class 2	0.15	1.50	0.04	0.04	. . .	. . .	0.005 min	0.005 min	0.005 min	. . .
Grade 65 [450] Class 1	0.26	1.50	0.04	0.04	. . .	. . .	0.005 min	0.005 min	0.005 min	[E]
Grade 65 [450] Class 2	0.15	1.50	0.04	0.04	. . .	. . .	0.005 min	0.005 min	0.005 min	[E]
Grade 70 [480] Class 1	0.26	1.65	0.04	0.04	. . .	. . .	0.005 min	0.005 min	0.005 min	[E]
Grade 70 [480] Class 2	0.15	1.65	0.04	0.04	. . .	. . .	0.005 min	0.005 min	0.005 min	[E]
Grade 80 [550] Class 1	0.26	1.65	0.04	0.04	. . .	. . .	0.005 min	0.005 min	0.005 min	[E]
Grade 80 [550] Class 2	0.15	1.65	0.04	0.04	. . .	. . .	0.005 min	0.005 min	0.005 min	[E]

[A] Where an ellipsis (. . .) appears in the table, there is no requirement but the analysis shall be reported.
[B] The limits for copper, nickel, chromium and molybdenum are shown in Table 3.
[C] HSLAS steels contain the strengthening elements columbium (niobium), vanadium, titanium, and molybdenum added singly or in combination. The minimum requirements only apply to the microalloy elements selected for strengthening of the steel.
[D] For each reduction of 0.01 % below the specified carbon maximum, an increase of 0.06 % manganese above the specified maximum will be permitted up to a maximum of 1.50 %.
[E] The purchaser has the option of restricting the nitrogen content. It should be noted that, depending on the microalloying scheme (for example, use of vanadium) of the producer, nitrogen is permitted as a deliberate addition. Consideration should be made for the use of nitrogen binding elements.

5.1.6 Dimensions (thickness, width, and whether cut lengths or coils),

5.1.7 Coil size (inside diameter, outside diameter, and maximum weight),

5.1.8 Copper bearing steel, (if required),

5.1.9 Quantity,

5.1.10 Application (part identification and description),

5.1.11 A report of heat analysis will be supplied, if requested, for CS or DS. For materials with required mechanical properties, SS or HSLAS, a report is required of heat analysis and mechanical properties as determined by the tension test, and

5.1.12 Special requirements (if any).

5.1.12.1 When the purchaser requires thickness tolerances for ⅜ in. [10 mm] minimum edge distance (see Supplementary Requirement in Specification A568/A568M), this requirement shall be specified in the purchase order or contract.

NOTE 2—A typical ordering description is as follows: ASTM A1039/A1039M steel sheet, CS Type A, pickled and oiled, cut edge, 0.075 by 36 by 96 in, 100 000 lb, for part no. 6310, for shelf bracket, or

ASTM A1039/A1039M, hot rolled steel sheet, SS Grade 40, pickled and oiled, cut edge, 1.5 by 117 mm by coil, ID 600 mm, OD 1500 mm, max weight 10 000 kg, 100 000 kg, for part number A4885 for lower housing.

6. General Requirements for Delivery

6.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A568/A568M for steel sheet.

7. Chemical Composition

7.1 The heat analysis of the steel shall conform to the chemical requirements of the appropriate designation shown in Table 2 for CS, Table 1 for SS and HSLAS, and Table 3 for Cu, Ni, Cr, and Mo.

7.2 Each of the elements listed in Tables 1 and 2 shall be included in the report of the heat analysis. When the amount of copper, nickel, chromium, or molybdenum is less than 0.02 %, the analysis shall be reported as "<0.02 %" or the actual determined value. When the amount of vanadium, columbium, or titanium is less than 0.008 %, the analysis shall be reported as "<0.008 %"or the actual determined value.

7.3 Sheet steel grades defined by this specification are suitable for welding if appropriate welding conditions are selected. Certain welding processes may require more restrictive composition limits than those included in Table 2 or Table 1, and in these cases, the restrictive limits shall be reviewed with the producer at the time of inquiry and ordering.

NOTE 3—The twin-roll cast product may be deoxidized using either silicon or aluminum.

8. Mechanical Properties

8.1 *CS:*

8.1.1 Typical, non-mandatory mechanical properties for CS are found in Table 4.

8.1.2 The material shall be capable of being bent at room temperature in any direction through 180° flat on itself without cracking on the outside of the bent portion (see section on bend test of Test Methods and Definitions A370).

8.2 *SS and HSLAS:*

8.2.1 The available grades and corresponding mechanical property requirements for SS and HSLAS steels are shown in Table 5.

8.2.2 *Tension Tests:*

8.2.2.1 *Requirements*—Material as represented by the test specimen shall conform to the mechanical property requirements specified in Table 5.

8.2.2.2 *Number of Tests*—Two tension tests shall be made from each heat or from each 50 tons [45 000 kg]. When the amount of finished material from a heat is less than 50 tons [45 000 kg], one tension test shall be made. When material rolled from one heat differs 0.050 in. [1.27 mm] or more in thickness, one tension test shall be made from the thickest and thinnest material regardless of the weight represented.

8.2.2.3 Tension test specimens shall be taken at a point immediately adjacent to the material to be qualified.

8.2.2.4 Tension test specimens shall be taken from the full thickness of the sheet as rolled.

8.2.2.5 Tension test specimens shall be taken from a location approximately halfway between the center of sheet and the edge of the material as-cast or as-rolled.

8.2.2.6 Tension test specimens shall be taken with the lengthwise axis of the test specimen parallel to the rolling direction (longitudinal test).

8.2.2.7 *Test Method*—Yield strength shall be determined by either the 0.2 % offset method or the 0.5 % extension under load method unless otherwise specified.

8.2.3 *Bending Properties:*

8.2.3.1 The suggested minimum inside radii for cold bending are listed in Appendix X2. More detail on this topic is provided in the section on Mechanical Properties of Specification A568/A568M. Where a tighter bend radius is required, or where curved or offset bends are involved, or where stretching or drawing are also a consideration, the producer shall be consulted.

TABLE 2 Chemical Requirements[A] for Twin Roll Cast Hot Rolled Steel Sheet Designations CS and DS

	Composition, % Heat Analysis, Element Maximum Unless Otherwise Shown													
	C	Mn	P	S	Al[B]	Si	Cu[C]	Ni	Cr	Mo	V	Cb	Ti	N
CS Type A[D]	0.10	0.70	0.030	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	0.008	. . .
CS Type B	0.02 to 0.15	0.70	0.030	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	0.008	. . .
CS Type D	0.15	0.80	0.030	0.035	. . .	. . .	0.50	0.30	0.30	0.15	0.008	0.008	0.008	. . .
DS Type A[D]	0.10	0.60	0.030	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	0.008	. . .
DS Type B	0.02 to 0.15	0.60	0.030	0.035	. . .	. . .	0.20	0.20	0.15	0.06	0.008	0.008	0.008	. . .
DS Type D	0.15	0.60	0.030	0.035	. . .	. . .	0.50	0.30	0.30	0.15	0.008	0.008	0.008	. . .

[A] Where an ellipsis (...) appears in the table, there is no requirement, but the analysis shall be reported.
[B] When aluminum deoxidized steel is required, it may be ordered to a minimum of 0.01 % total aluminum.
[C] When copper steel is specified, the copper limit is a minimum of 0.20 %.
[D] Specify Type B to avoid carbon levels below 0.02 %.

TABLE 3 Chemical Requirements: Cu, Ni, Cr, and Mo for Structural Steels and High-Strength Low-Alloy Steels

% Heat Analysis, maximum Unless Otherwise Specified					
Designation	Limits	$Cu^{A,B}$	Ni^{B}	$Cr^{B,C}$	$Mo^{B,C}$
SS:					
All grades	L	0.35	0.20	0.15	0.06
	H	0.50	0.30	0.30	0.16
HSLAS:					
All grades and classes	L	0.35	0.20	0.15	0.06
	H	0.50	0.30	0.30	0.16

[A] When copper is specified, a minimum of 0.20 % is required. When copper steel is not specified, the copper limit is a maximum requirement.
[B] For limit H steels, the sum of copper, nickel, chromium, and molybdenum shall not exceed 1.00 % on heat analysis. When one or more of these elements are specified by the purchaser, the sum does not apply; in which case only the individual limits on the remaining elements shall apply.
[C] For limit H steels, the sum of chromium and molybdenum shall not exceed 0.32 % on heat analysis. When one or more of these elements are specified, the sum does not apply; in which case, only the individual limits on the remaining elements shall apply.

TABLE 4 Typical Ranges of Mechanical Properties[A] (Nonmandatory)[B] for Twin Roll Cast Hot Rolled Steel Sheet Designations CS and DS

Designation	Yield Strength		Elongation in 2 in. [50 mm] %[C]
	ksi	MPa	
DS Types A and B	35 to 45	[240 to 310]	26
DS Type D	35 to 55	[240 to 380]	24
CS Types A and B	35 to 50	[240 to 340]	22
CS Type D	35 to 60	[240 to 410]	20

[A] The yield strength tends to increase and the elongation tends to decrease as the sheet thickness decreases. These properties represent those typical of material in the thickness range of 0.050 in. [1.27 mm] to 0.065 in. [1.65 mm].
[B] The typical mechanical property values presented here are non mandatory.
[C] Yield strength and elongation are measured in the longitudinal direction in accordance with Test Methods and Definitions A370.

9. Finish and Appearance

9.1 *Surface Finish:*

9.1.1 The material shall be furnished as-cast or as-rolled, (that is, without removing the surface oxide or scale), unless otherwise specified.

9.1.2 When required, the material shall be specified as pickled or blast cleaned (descaled).

9.2 *Oiling:*

9.2.1 Unless other specified, as-cast or as-rolled material shall be furnished not oiled (that is, dry), and pickled or blast cleaned material shall be furnished oiled.

9.3 *Edges:*

9.3.1 Steel sheet is available with mill edge or cut edge.

10. Retests and Qualification

10.1 The procedures for conducting testing in instances where the initial test results indicate non-conformance with specification requirements are described in A568/A568M.

11. Certification

11.1 A report of heat analysis shall be supplied, if requested, for CS and DS steels. For product with required mechanical properties, SS and HSLAS, a report is required of heat analysis and mechanical properties as determined by the tension test.

11.2 The report shall include the purchase order number, the ASTM designation number and year date, product designation, grade, and type, as applicable.

11.3 A signature is not required on the test report. However, the document shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report.

11.4 A Material Test Report, Certificate of Inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM standard, of the purchaser and of the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

12. Product Marking

12.1 In addition to the requirements of Specification A568/A568M for sheet, each lift or coil shall be marked with the designation shown on the order CS Type A, B, or D, DS Type A, B, or D, SS (Grade), or HSLAS (Grade and Class). The designation shall be legibly stenciled on the top of each lift or shown on a tag attached to each coil or shipping unit.

13. Keywords

13.1 as-cast sheet; carbon steel sheet; commercial steel; high-strength low-alloy steel; hot rolled steel sheet; steel sheet; structural steel

TABLE 5 Mechanical Property Requirements for Twin Roll Cast Hot Rolled Steel Sheet Designations SS and HSLAS

Designation	Yield Strength ksi [MPa] min	Tensile Strength ksi [MPa] min	Elongation in 2 in. [50 mm], min % for Thickness	
			Under 0.078 in. [2.0 mm] to 0.064 in. [1.6 mm]	Under 0.064 in. [1.6 mm] to 0.027 in. [0.7 mm]
SS:				
Grade 30 [205]	30 [205]	49 [340]	24	21
Grade 33 [230]	33 [230]	52 [360]	22	18
Grade 36 [250] Type 1	36 [250]	53 [365]	21	17
Grade 36 [250] Type 2	36 [250]	58-80 [400-550]	20	16
Grade 40 [275]	40 [275]	55 [380]	20	15
Grade 45 [305]	45 [305]	60 [450]	18	13
Grade 50 [340]	50 [340]	65 [450]	16	11
Grade 55 [380]	55 [380]	70 [480]	14	9
Grade 60 [410]	60 [410]	70 [480]	13	8
Grade 70 [480]	70 [480]	80 [550]	12	7
Grade 80 [550]	80 [550]	90 [620]	11	6
HSLAS:			0.078 [2.0 mm] to 0.064 [1.3 mm]	Less than 0.064 [1.3 mm]
Grade 45 [310] Class 1	45 [310]	60 [410]	18	18
Grade 45 [310] Class 2	45 [310]	55 [380]	18	18
Grade 50 [340] Class 1	50 [340]	65 [450]	15	15
Grade 50 [340] Class 2	50 [340]	60 [410]	15	15
Grade 55 [380] Class 1	55 [380]	70 [480]	13	13
Grade 55 [380] Class 2	55 [380]	65 [450]	13	13
Grade 60 [410] Class 1	60 [410]	75 [520]	11	11
Grade 60 [410] Class 2	60 [410]	70 [480]	11	11
Grade 65 [450] Class 1	65 [450]	80 [550]	11	11
Grade 65 [450] Class 2	65 [450]	75 [520]	11	11
Grade 70 [480] Class 1	70 [480]	85 [585]	8	8
Grade 70 [480] Class 2	70 [480]	80 [550]	8	8
Grade 80 [550] Class 1	80 [550]	90 [620]	8	7
Grade 80 [550] Class 2	80 [550]	90 [620]	8	7

APPENDIXES

(Nonmandatory Information)

X1. TWIN-ROLL CASTING PROCESS

X1.1 Overview of the Twin-Roll Casting Process for the Production of Steel Sheet

X1.2 Twin-Roll Casting Process Development

X1.2.1 Sir Henry Bessemer originally conceived and patented the concept of casting sheet and strip directly from liquid metal about 150 years ago. Despite decades of research and development, twin-roll casting has now achieved commercial success for the production of plain-carbon steel sheet. Key breakthroughs in the areas of mold/refractory materials, a better understanding of the fundamentals of metal solidification, and process control have contributed to the successful commercialization of this process. Twin-roll cast material has been produced and successfully manufactured into a range of steel products. As-cast, hot rolled and cold rolled steel sheet coils have been successfully formed into square tubes, decking, and other structural products. Initial trials by users of these products include manufacturers of metal building and agricultural products. These customers report that the twin-roll cast material performed satisfactorily and that manufacturing equipment did not require adjustments to accommodate the twin-roll cast product.

X1.3 Overview of Process Fundamentals

X1.3.1 The twin-roll process directly casts a solid strip approximately 0.038 in. [1 mm] to 0.075 in. [2 mm] thick directly from liquid metal. Solidification of liquid steel occurs over two counter-rotating water-cooled rolls as schematically illustrated in Fig. X1.1.

X1.3.2 Twin-roll casting facilities are equipped with one or more rolling stands whereby the thickness of the as-cast strip is further reduced by hot reduction (see Fig. X1.2).

X1.3.3 In comparison to conventional slab casting processes, twin-roll casting produces significantly higher interfacial heat transfer rates resulting from the direct contact of the steel with the casting roll surface (see Table X1.1). This rapid solidification results in the production of unique microstructures that can be manipulated to produce conventional low-carbon steels as well as steels not easily produced from conventional sheet steel production (for example, thick slab

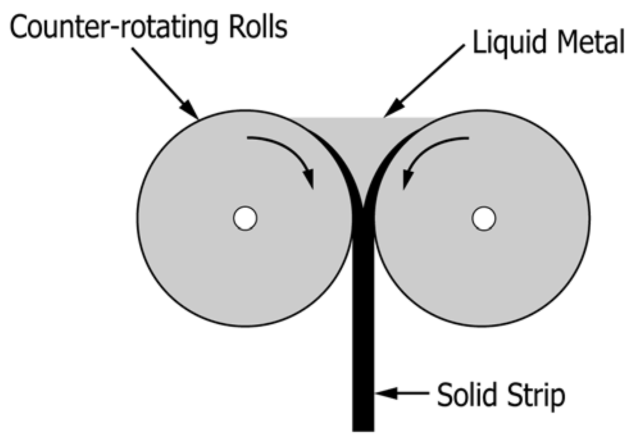

FIG. X1.1 Schematic of the Twin-Roll Casting Process Showing Shell Formation Over the Two Rolls and Joining of the Two Shells to Form the Strip

casting and thin slab casting processes coupled with conventional hot rolling mills).

X1.4 Overview of Product Attributes

X1.4.1 Product attributes of twin-roll cast material are comparable to conventional hot strip mill products with regard to strength levels, elongation, mechanical property variation within a steel designation, surface quality, and dimensional tolerances. A significant quantity of twin-roll cast material has been successfully roll formed, punched, welded, cold rolled in both tandem and reversing mills, galvanized, and painted.

X1.5 Mechanical Property Variation

X1.5.1 Variation of mechanical properties was determined during an extended production run at the Australian development plant for twin roll casting technology. Mechanical testing was performed on 143 coils and the results compared to available data from a similar low-carbon commercial steel designation produced on a conventional hot rolling mill. The results are shown below in Table X1.2.

X1.6 Surface Condition

X1.6.1 The surface condition of twin-roll cast products has been shown to be satisfactory for direct processing into pipe and tube, cold rolled products, and coated products. As with conventional processes, surface defect formation can be controlled with adequate process control. Surface roughness of twin-roll cast and hot rolled material is slightly smoother than hot rolled produced by a conventional 5 to 7 stand hot mill as indicated in Fig. X1.3.

X1.7 Tolerances

X1.7.1 Thickness tolerances for twin-roll cast products are similar to conventional hot rolled products, with total thickness variation (centerline variation + profile) less than half of the current ASTM thickness tolerance in accordance with Specification A568/A568M.

X1.8 Internal Soundness/Inclusions

X1.8.1 Full width X-ray mapping has been used to characterize internal soundness. Twin-roll cast material has been produced free of porosity.

X1.8.2 Inclusion size distributions were obtained from SEM analysis. Typical inclusion size is very fine (5 to 8 µm) due to rapid solidification.

X1.9 Grain Morphology and Size

X1.9.1 The twin-roll process produces substantially larger austenite grains than conventional hot rolling processes (see Table X1.3 for the differences in austenite microstructures)

X1.9.2 The coarse austenite grains in twin-roll cast material can be easily transformed to a variety of ferrite microstructures by varying the cooling practice on the rolling mill run-out-table. For this reason, the strength of the material can be manipulated more easily than conventional hot rolled material. Low-carbon, manganese steels with appropriate run-out-table cooling rates can be produced with strength levels ranging from 45 to 80 ksi yield strength, utilizing the twin-roll strip cast process. Please see Fig. X1.4 for details of the strength-cooling rate relationship.

X1.10 Manganese Limits in Twin-Roll Cast Products

X1.10.1 The upper limit of manganese for most commercial and structural steels is currently 0.60 or 0.90 %. The stability of the twin-roll casting process is governed by the heat transfer rates in the vicinity of the meniscus. Manganese tends to affect the nature of the initial contact between the steel and the roll surface and thus plays a key role in both heat transfer and meniscus stability. As a result, the manganese levels utilized for steel sheet production via the twin-roll casting process are generally slightly higher than the traditional low-carbon heats. Consequently, the upper level of the manganese specification is increased for some twin-roll cast grades.

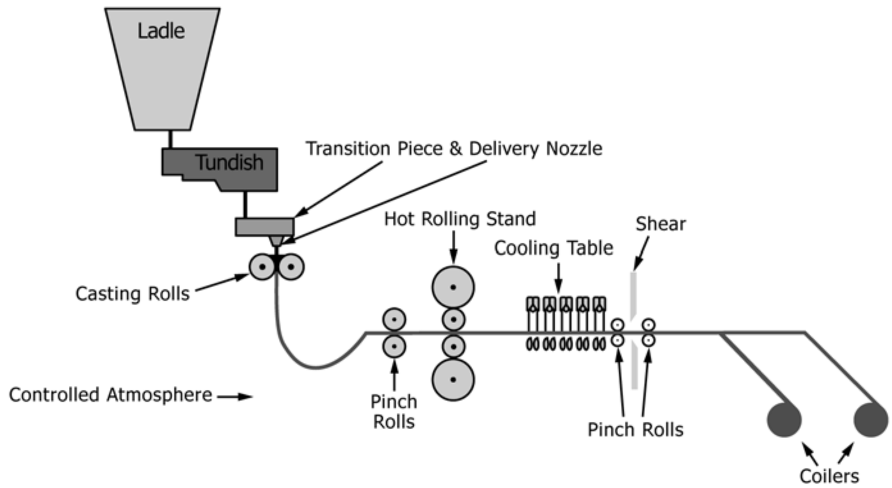

FIG. X1.2 Layout of a Twin-Roll Casting Machine Showing the In-Line Hot Rolling Mill

TABLE X1.1 Comparison of Typical Process Parameters of Twin-Roll Casting, Thin Slab Casting and Thick Slab Casting

	Twin Roll Process	Thin Slab	Thick Slab
Strip thickness, mm	1.6	50	220
Casting speed, m/min	80	6	2
Average mould heat fluxes, MW/m^2	14	2.5	1.0
Total solidification time, s	0.15	45	1070
Average shell cooling rate in mould, °C/s	1700	50	12

TABLE X1.2 Mechanical Property Comparison—Twin-Roll Cast and Conventional Hot Rolling Mill Product

	Yield Strength Average (ksi)	Standard Deviation (ksi)	Tensile Strength Average (ksi)	Standard Deviation (ksi)	% Elongation Average	Standard Deviation (%)
Twin-roll process	44.1	3.34	64.4	2.90	25	3
Hot rolling mill	46.7	2.53	61.8	2.01	32	2

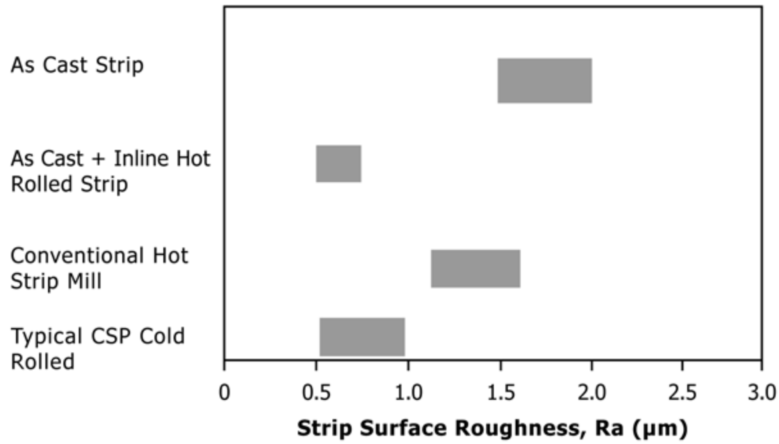

FIG. X1.3 Surface Roughness Comparison—Conventional and Strip Cast Material

TABLE X1.3 Differences in Austenite Grain Morphology and Size

	Twin-Roll Strip Casting	Hot Strip Mill
Prior austenite grain morphology	Columnar shape	Equiaxed
Grain size	100 to 250 μm wide 300 to 700 μm long	25 μm

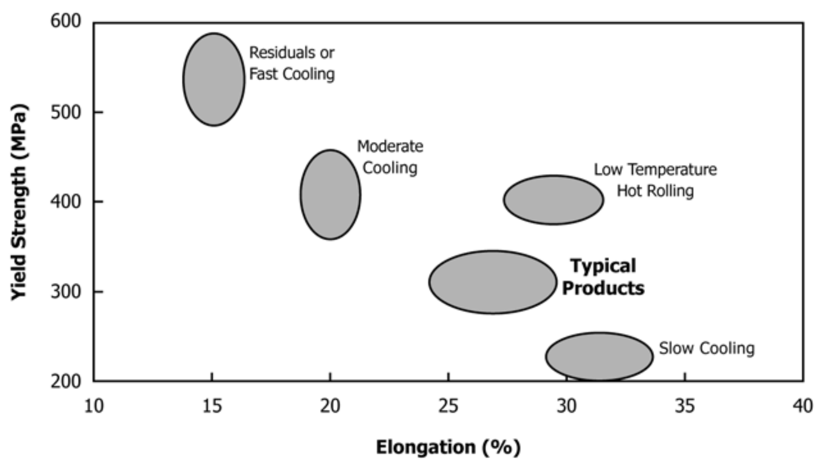

FIG. X1.4 Examples of Strength Versus Elongation with a Low-Carbon Steel Chemistry via the Twin-Roll Casting Process

X2. BENDING PROPERTIES

TABLE X2.1 Suggested Minimum Inside Radius for Cold Bending

NOTE 1—This table lists suggested minimum inside radii for cold bending.

NOTE 2—(t) equals a radius equivalent to the steel thickness.

NOTE 3—The suggested radius should be used as a minimum for 90° bends in actual shop practice.

NOTE 4—Material which does not perform satisfactorily, when fabricated in accordance with the above requirements, may be subject to rejection pending negotiation with the steel supplier.

Designation	Grade	Minimum Inside Radius for Cold Bending
Structural Steel (SS)	40 [275]	2t
	50 [340]	2½ t
	55 [380]	3t
	60 [410]	3t
	70 [480]	3½ t
	80 [550]	4t
High-Strength Low-Alloy Steel	Class 1	Class 2
45 [310]	1½ t	1½ t
50 [340]	2t	1½ t
55 [380]	2t	2t
60 [410]	2½ t	2t
65 [450]	3t	2½ t
70 [480]	3½ t	3t
80 [550]	4t	3½ t

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A1039/A1039M – 12) that may impact the use of this standard. (Approved Feb. 1, 2013.)

(1) Change in mechanical properties in Table 4 for CS.

Committee A01 has identified the location of selected changes to this standard since the last issue (A1039/A1039M – 11) that may impact the use of this standard. (Approved April 15, 2012.)

(1) Change in limits for C for CS-D and DS-D in Table 2.

Committee A01 has identified the location of selected changes to this standard since the last issue (A1039/A1039M – 10) that may impact the use of this standard. (Approved Nov. 15, 2011.)

(1) Grade 45 added to Section 4.

(2) Grade 45 added to Tables 1 and 5.