Designation: A1066/A1066M – 11 (Reapproved 2015)$^{\varepsilon 1}$

Standard Specification for High-Strength Low-Alloy Structural Steel Plate Produced by Thermo-Mechanical Controlled Process (TMCP)[1]

This standard is issued under the fixed designation A1066/A1066M; 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.

ε^1 NOTE—Editorial corrections were made to Table 1 in September 2015.

1. Scope

1.1 This specification covers steel plates produced by the thermo-mechanical controlled process (TMCP). Five grades are defined by the yield strength: 50 [345], 60 [415], 65 [450], 70 [485], and 80 [550]. The plates are intended primarily for use in welded steel structures.

1.2 The TMCP method consists of rolling reductions and cooling rate controls that result in mechanical properties in the finished plate that are equivalent to those attained using conventional rolling and heat treatment processes, which entail reheating after rolling. A description of the TMCP method is given in Appendix X1.

1.3 The maximum thicknesses available in the grades covered by this specification are shown in Table 1.

1.4 Due to the special combination of mechanical and thermal treatment inducing lower rolling temperatures than for conventional hot rolling the plates can not be formed at elevated temperatures without sustaining significant losses in strength and toughness. The plates may be formed and post-weld heat-treated at temperatures not exceeding 1050°F [560°C]. Higher temperatures may be possible if proven that minimum mechanical characteristics are retained after tests with specimens in the post-weld heat treatment (PWHT) condition. For flame straightening higher temperatures can be used in accordance with the steel manufacturer's recommendations.

1.5 If the steel is to be welded, a welding procedure suitable for the grade of steel and intended use or service is to be utilized. See Appendix X3 of Specification A6/A6M for information on weldability.

1.6 Supplementary requirements are available but shall apply only if specified in the purchase order.

1.7 The values stated in either inch-pound-units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system is to be used independently of the other, without combining values in any way.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A6/A6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

A673/A673M Specification for Sampling Procedure for Impact Testing of Structural Steel

3. General Requirements for Delivery

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A6/A6M.

4. Materials and Manufacture

4.1 The steel shall be killed.

4.2 The plates shall be produced by the thermo-mechanical controlled process.

5. Chemical Composition

5.1 The chemical composition on heat analysis shall conform to the requirements given in Table 1.

5.2 The steel shall conform on product analysis to the requirements prescribed in Table 1 subject to the product analysis tolerances in Specification A6/A6M.

5.3 The carbon equivalent on heat analysis shall not exceed the limits listed in Table 2. The chemical analysis (heat analysis) of the elements that appear in the carbon equivalent

[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 A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock and Ships.

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[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.

TABLE 1 Chemical Requirements (Heat Analysis)

Element	Content in [%]				
	Grade 50 [345]	Grade 60 [415]	Grade 65 [450]	Grade 70 [485]	Grade 80 [550]
Thickness	Max 4 in. [100 mm]	Max 4 in. [100 mm]	Max 3 in. [75 mm]	Max 2 in. [50 mm]	Max 1 in. [25 mm]
Carbon, max	0.14[A]	0.16	0.16	0.16	0.16
Manganese	0.70–1.60	0.80–1.70	0.80–1.70	0.80–1.70	1.00–2.00
Phosphorus, max	0.030	0.030	0.030	0.030	0.030
Sulfur, max	0.020	0.020	0.020	0.020	0.020
Silicon	0.15–0.50	0.15–0.50	0.15–0.50	0.15–0.50	0.15–0.50
Copper, max	0.35	0.35	0.35	0.35	0.35
Nickel, max	0.30	0.70	0.70	0.70	0.70
Chromium, max	0.30	0.30	0.30	0.35	0.40
Molybdenum	0.10	0.20	0.25	0.30	0.40
Columbium, max	0.05	0.05	0.05	0.05	0.10
Vanadium, max	0.08	0.08†	0.08	0.09	0.09
Aluminium, min	0.020 total or 0.015 soluble[B]	0.020 total or 0.015 soluble[B]	0.020 total or 0.015 soluble[B]	0.020 total or 0.015 soluble[B]	0.020 total or 0.015 soluble[B]
Boron, max	0.002	0.002	0.002	0.002	0.002

† Editorially corrected.

[A] When Supplementary Requirement S75 is ordered the carbon content is 0.16 % max.

[B] By agreement the steel may be produced with titanium, in which case the minimum aluminum content shall not apply. When this option is exercised, the titanium content, by heat analysis, shall be 0.006 % to 0.02 %, and the actual titanium content shall be reported on the test report.

TABLE 2 Maximum Carbon Equivalent (Heat Analysis)

	Maximum Carbon Equivalent in [%]				
	Grade 50 [345]	Grade 60 [415]	Grade 65 [450]	Grade 70 [485]	Grade 80 [550]
Thickness	Max 4 in. [100 mm]	Max 4 in. [100 mm]	Max 3 in. [75 mm]	Max 2 4 in. [50 mm]	Max 1 in. [25 mm]
CE	0.40	0.43	0.45	0.47	0.50

TABLE 3 Tensile Requirements

Grade		Yield Point, min		Tensile Strength, min		Elongation, min	
		ksi	[MPa]	ksi	[MPa]	8 in. [200 mm], %	2 in. [50 mm], %
50	[345]	50	[345]	65	[450]	18	20
60	[415]	60	[415]	75	[520]	16	18
65	[450]	65	[450]	80	[550]	15	17
70	[485]	70	[485]	85	[585]	14	16
80	[550]	80	[550]	90	[620]	13	15

formula and the actual carbon equivalent shall be reported. For the calculation of the carbon equivalent the following formula shall be used:

$$CE = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Cu + Ni)}{15}$$

6. Mechanical Properties

6.1 *Tensile Properties*—The material as represented by the test specimens shall conform to the tensile properties given in Table 3.

6.2 Charpy V-notch tests shall be made in accordance with Specification A673/A673M, Frequency H.

6.2.1 The test results of full-size specimens taken from the longitudinal direction of the product shall meet an average value of 35 ft-lbf [48 J] at –10°F [–23°C]. Subsize specimens are permitted as allowed by Specification A673/A673M.

6.2.2 Charpy-V-notch test requirements varying from the value specified in 6.2.1 or other test temperatures are subject to the agreement between the purchaser and the producer.

7. Keywords

7.1 steel plates; high-strength low-alloy steel; thermo-mechanical controlled rolling; structural steel; welded construction

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order or contract. Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A6/A6M. Those that are considered suitable for use with this specification are listed by title.

S1. Vacuum Treatment,
S2. Product Analysis,
S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,
S14. Additional Tension Test,
S5.2. Charpy V-Notch Impact Test, and
S8. Ultrasonic Examination.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

In addition, the following special supplementary requirements are also suitable for use with this specification.

S75. *Maximum Yield Point to Tensile Strength Ratio: Grade 50 and Grade 60*—The maximum yield to tensile ratio shall be 0.87 for grade 50 and 0.90 for grade 60. In this case the maximum carbon content on the heat analysis can be raised to 0.16 % for grade 50.

S76. *Maximum Tensile Strength*—The maximum tensile strength shall be 91 ksi [630] for grade 50, 98 ksi [680] for grade 60, 105 ksi [720] for grade 65, 110 ksi [750] for grade 70, and 115 ksi [800] for grade 80.

APPENDIX

(Nonmandatory Information)

X1. THERMO-MECHANICAL CONTROLLED PROCESSING (TMCP)

X1.1 *Introduction*—The Thermo-Mechanical Controlled Processing, commonly referred to as "TMCP" has evolved from the "controlled rolling" (CR) processes. TMCP produces fined-grain steel by a combination of chemical composition and integrated controls of manufacturing processes from slab reheating to post-rolling cooling, thereby achieving the specified mechanical properties in the required plate thicknesses. TMCP requires accurate control of both the steel temperature and rolling reductions, and does not involve coiling after post-cooling.

X1.2 *Outline of TMCP*—As shown in Fig. X1.1, TMCP may incorporate three processes as follows:

X1.2.1 *Thermo-Mechanical Rolling (TMR)*—Steels of fine grain size are produced by rolling in the recrystallisation and non-recrystallisation regions of austenite, and sometimes in the dual-phase temperature region of austenite and ferrite. Generally, a high proportion of rolling reduction is performed close to, or below, the temperature at which austenite begins to transform to ferrite during cooling (Ar3) and may involve rolling in the lower portion of the temperature range of the intercritical dual-phase region.

X1.2.2 *Accelerated Cooling (AC)*—Steels meeting the specified requirements are produced by controlled cooling (accelerated cooling by water or air cooling) through the dual-phase temperature region immediately after final CR or TMR operation.

X1.2.3 *Direct Quenching and Tempered (DQT)*—Steels meeting the specified requirements are produced by promoting grain refinement and increasing hardness through direct quenching immediately after final CR or TMR operation. Subsequent to direct quenching the plates are tempered.

X1.3 The selection, from the above, of the method to be used is made by the steel producer depending upon chemical composition, the plate thickness, and the required properties.

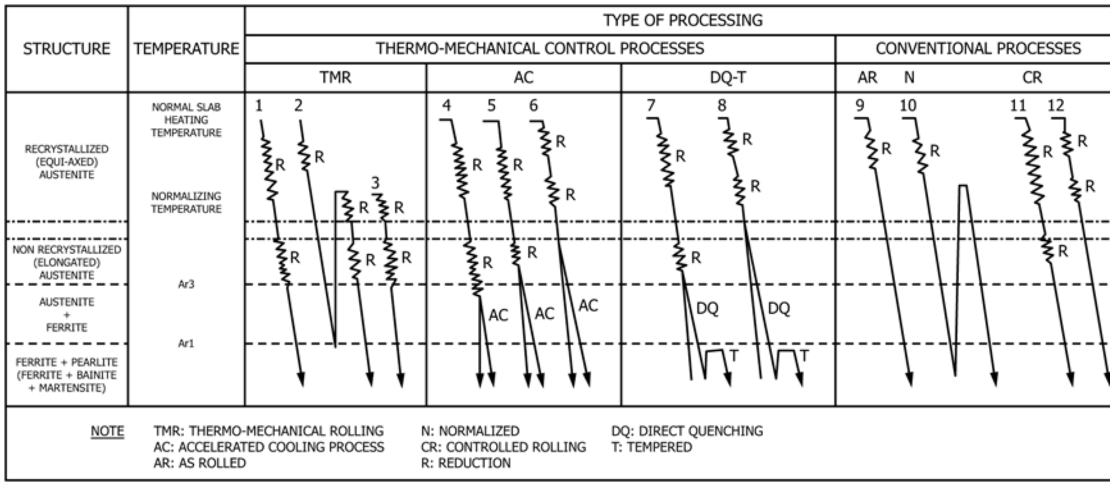

FIG. X1.1 Schematic Diagrams of Thermomechanical Control and Conventional Process for Steel Plate