ArcelorMittal USA

ArcelorMittal

Plate

Spartan™: A710, Navy HSLA-80/100 and HPS 100W Steels

Introduction

ArcelorMittal USA is offering Spartan™ high strength (to over 100 ksi (690 MPa) minimum yield strength), high toughness, improved weldability steels as alternatives to traditional quenched and tempered alloy steels. The Spartan™ family of steels are low carbon; copper precipitation hardened steels based upon the original efforts that led to the development of ASTM A710 Grade A. Spartan steels can be produced to meet the requirements of the existing ASTM A710 Grade A and A736 Grade A specifications and Navy Specification MIL-S-24645A, now covered under NAVSEA Technical Publication T9074-BD-GIB-010/0300 (HSLA-80 and HSLA-100), as well as unique customer specifications in a variety of strength and toughness levels.

Because of their improved weldability, ArcelorMittal's Spartan™ steels have been used to replace traditional high strength alloy steels (ASTM A514 and A543) in a number of applications. These include U.S. Navy aircraft carriers, cruisers and submarines, as well as mining and dredging equipment, high reliability lifting hardware, offshore drilling platforms, large valves and heavy duty truck frames. The Spartan V chemistry is being considered for bridge applications where it is known as ASTM A709 HPS 100W.

Chemistry

Spartan™ steels are produced to low carbon and restricted phosphorus levels. These steels are melted at our Coatesville, PA facilities using the ArcelorMittal's Fineline® Double-O-Five, low sulfur, calcium treated, and inclusion shape control practices. The chemical requirements for the five chemistries of the Spartan steel family are summarized below:

Heat Analysis, weight percent

		Chemistry*						
		C**	Mn	Cr	Ni	Mo	Cu	Current Application
Spartan™ I	Min.	--	0.40	0.60	0.70	0.15	1.00	Navy HSLA-80
	Max.	0.07	0.70	0.90	1.00	0.25	1.30	ASTM A710A
Spartan™ II	Min.	--	0.75	0.45	1.50	0.30	1.00	Navy Thin HSLA-100
	Max.	0.07	1.15	0.75	2.00	0.55	1.30	
Spartan™ III	Min.	--	0.75	0.45	3.35	0.55	1.15	Navy Thick HSLA-100
	Max.	0.07	1.15	0.75	3.65	0.65	1.75	
Spartan™ IV	Min.	--	0.75	0.45	2.40	0.45	1.00	Navy Intermediate
	Max.	0.07	1.15	0.75	3.00	0.65	1.30	HSLA-100
Spartan™ V ***	Min.	--	0.90	0.40	0.65	0.40	0.90	Bridges
	Max.	0.08	1.50	0.65	1.00	0.65	1.20	HPS 100W

* *All grades .40 max. Si and .02-.06 Cb. Baseline maximum of .015% P and .005% S, lower specified maximums will be considered upon request.*

** *More restrictive levels are available when specified.*

*** *.05 - .07V, .01-.03Cb*

Metallurgy

Spartan™ steels take advantage of the copper precipitation hardening reaction. The other alloy additions contribute to either the precipitation reaction, improve the hardenability or provide solid solution or carbo-nitride strengthening. Selection of the appropriate Spartan™ chemistry depends on the strength, toughness and thickness requirements of the application.

Spartan™ steels are used primarily in the water quenched and precipitation heat treated (aged) condition. In the as-quenched condition, all of the copper is in solution; subsequent aging treatments cause epsilon iron-copper to precipitate leading to strengthening of the alloy. These grades can also be provided in the normalized and aged or as-rolled and aged conditions depending on strength, toughness and thickness requirements. In contrast to the martensitic metallurgical microstructures of traditional high-strength alloy steels, the microstructures of Spartan™ steels range from ferritic-pearlitic, to ocicular ferritic, to martensitic depending on composition, thickness and heat treatment.

Mechanical Properties

Because of the nature of the metallurgy of the Spartan™ alloys, there is flexibility in achieving a variety of strength and toughness requirements. Spartan™ steels have been produced with 50 to 120 ksi (345-827 MPa) minimum yield strength depending on thickness and toughness requirements. Thicknesses from 3/16" to 12" have been produced. The following table shows a sample of the properties that can be specified.

Minimum Yield Strength, ksi (MPa)
Transverse CVN Toughness of 40 ft-lbs. at –60°F

Thick (in.)	(mm)	Spartan™ I	II, IV	III, V
2	(51)	80 (552)	100 (690)	120 (827)
4	(102)	65 (448)	80 (552)	100 (690)

The variety of capabilities of these alloys is further demonstrated in Figures 1 and 2.

Welding

Spartan™ steels are readily weldable by all welding processes because of their low carbon content compared to traditional high strength structural steels, as shown in Figure 3. A significant amount of information is available on the recommended welding practices for Spartan™ steels (5-11). In some applications, it has been found that they can be welded with little or no preheat. However, for very high strength applications, the welding consumable that is used may control whether preheat is required. "Under-matched" welding consumables may be considered to allow lower preheat requirements.

AWS D1.1 gives welding guidelines for A710A (75 ksi minimum yield strength). For 100 ksi yield strength applications, the AWS D1.1 guidelines for A514 can be used as conservative starting points. It is important to consult with the electrode manufacturer regarding the need for preheat for their products. New welding consumables are in development for a variety of these high strength applications. ArcelorMittal USA Plate metallurgists recommend use of low hydrogen welding practices for all Spartan™ grades. Please consult with ArcelorMittal USA Plate offices for the latest information that is available. Also refer to "Guidelines for Fabricating and Processing Plate Steel" for information on low hydrogen welding practices.

It has been found that these alloys are susceptible to stress relief cracking in laboratory testing (7,8). If stress relief (post-weld heat treatment) of these alloys is being considered, the fabricator is cautioned to thoroughly investigate his welding procedures.

Forming

The Spartan™ steels are readily formable in either the hot or cold conditions. Because of the range of strength levels involved, specific formability guidelines will vary. Contact ArcelorMittal USA Plate offices for more specific information.

Figure 1: Yield Strength of Spartan Steels vs. Aging Temp. for 1-1/4" (32 mm) Thick Plates

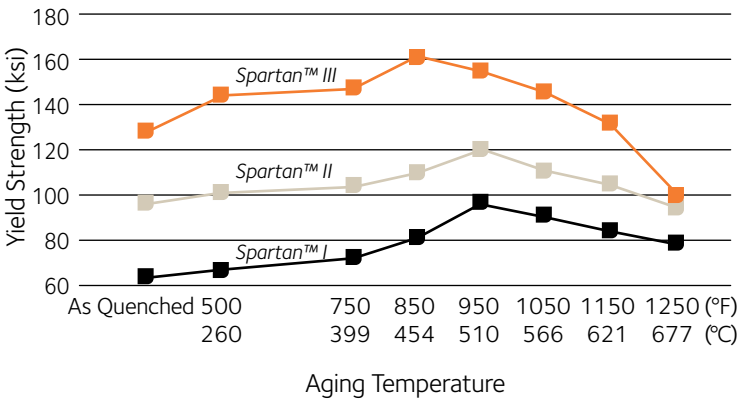


Figure 2: CVN Toughness at -120°F (-84°C) for Spartan™ Steels vs. Aging Temp. for 1-1/4" (32 mm) Thick Plates

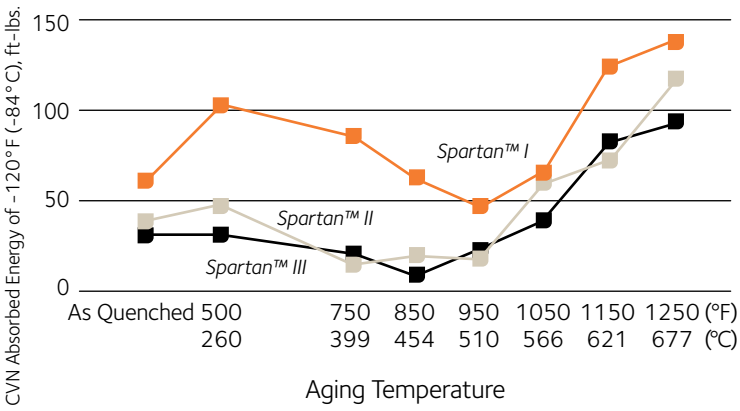
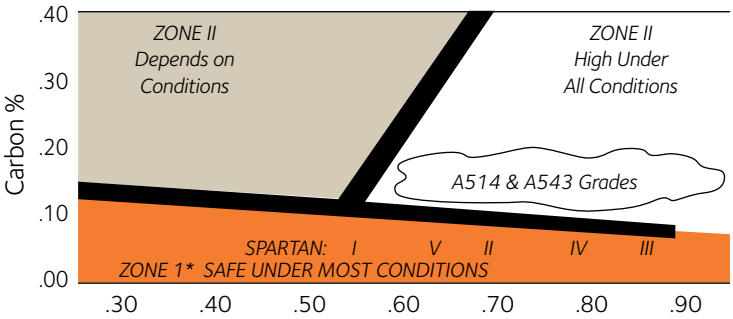


Figure 3: Influence of Carbon Level and Carbon Equivalent on Susceptibility to HAZ Cracking of Plate Steels (from Graville)



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

** High Strength Welding Consumables May Require Additional Care*

Further Information

For more information on ArcelorMittal USA Plate mill's guarantee levels for a specific application of Spartan™ steel, call Alex Wilson at ArcelorMittal USA at +1 610 383 3105 or email at: alex.wilson@arcelormittal.com. The following references provide more detailed background on the development and application of Spartan™ steels. They can be obtained by contacting the Customer Technical Service Department at +1 610 383 3372.

1. *"A710A: A High Strength, Low Carbon Alloy Steel for Offshore Application", A. D. Wilson and W. G. Taylor, Offshore Technology Conference, May 1985, OTC5071.*
2. *"High Strength, Weldable Precipitation Aged Steels", A. D. Wilson, Journal of Metals, March 1987.*
3. *"Production and Properties of Copper, Aged Hardened Steels", E. G. Hamburg and A. D. Wilson, TMS AIME Symposium, Pittsburgh, November 1987.*
4. *"Properties and Microstructures of Copper, Age Hardened Steels", A. D. Wilson, E. G. Hamburg, D. J. Colvin, S. W. Thompson, G. Krauss, ASM International, 8811-006, September 1988.*
5. *"An Improved High Yield Strength Steel for Shipbuilding", L. G. Kvidahl, Welding Journal, July 1985.*
6. *"The Benefits of New High Strength, Low-Alloy (HSLA) Steels", T. L. Anderson, J. A. Hyatt and J. G. West, Welding Journal, September 1987.*
7. *"Postweld Heat Treatment Cracking in HSLA Steels', C. D. Lundin and R. Menon, AWS Annual Convention, Chicago, March 1987.*
8. *"The Effect of Welding and Fabrication Operations on the Toughness of A710 Steel", W. Bollinger, R. Varoghese, E. Kaufman, W. Qin, A. W. Pense and R. D. Stout, ASM International, 8811-010, September 1988.*
9. *"High Strength Low Alloy Steels in Naval Construction", T. W. Montemarano. B. P. Sack. J. P. Gudas, M. G. Vassilaros and H. H. Vndervelt, Journal of Ship Production, August 1986.*
10. *"Development and Certification of HSLA-100 Steel for Naval Ship Construction", E. S. Czyryca, R. E. Link, R. J. Wong, D. A. Aylor, T. W. Montemarano, J. P. Gudas, Naval Engineers Journal, May 1990.*
11. *"Weldability of Low Carbon Micro-Alloyed Steels for Marine Structures", C. D. Lundin, T.P.S. Gill, C.Y.P. Qiao, Y. Wang, K. K. Khan, Welding Research Council, WRC 359, December 1990.*
12. *"Development of an Improved HPS 100W Steel for Bridge Applications", A. D. Wilson, J. H. Gross, R. D. Stout, R. L. Asfahani and S. J. Manganello, ASM International Conference on Microalloyed Steels, October, 2002, Columbus, OH.*

ArcelorMittal USA
Corporate Office
1 South Dearborn Street
18th Floor
Chicago, IL 60603-9888
USA

T +1 800 422 9422
www.arcelormittal.com

ArcelorMittal USA
Plate
ARC Building
139 Modena Road
Coatesville, PA 19320-0911
USA

T +1 800 966 5352
www.arcelormittal.com

ArcelorMittal USA
Plate
250 West U.S. Highway 12
Burns Harbor, IN 46304-9745
USA

T +1 800 422 9422
www.arcelormittal.com

December 2010