Analysis of Carbon Equivalents in Steel Components

Using the Niton Apollo Handheld LIBS Analyzer

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Application

The weldability of a steel is primarily influenced by its carbon content. Additionally, the contribution of other elements, such as manganese (Mn), chromium (Cr), molybdenum (Mo), vanadium (V), copper (Cu), nickel (Ni), and silicon (Si) can also impact its carbon equivalence (CE). These additional elements add up in scrap fed electric arc furnace steels that now predominate the market and carry over into finished goods.

Carbon equivalence was originally developed to assign a numerical value for a given steel composition indicating the carbon content which would contribute to an equivalent level of hardenability for that steel. Even further, carbon equivalence represents the contribution of the materials composition to cold-cracking (hydrogen cracking) susceptibility of the steel.

In welding, carbon equivalent calculations are used to predict heat affected zone (HAZ) hardenability. By understanding any differences in chemistry through the carbon equivalence calculation, it can be determined if the properties of two materials being joined together via a filler metal component are compatible for the process. If the components are too dissimilar, or if the carbon equivalent approaches a higher, undesirable value (Table 1), then special precautions may be needed prior to and during the welding process.

Welding precautions may include prescriptive heat treatment, use of low hydrogen electrodes, and controlling heat input. Many of these guidelines are published in the NACE (National Association of Corrosion Engineers) standards

Carbon equivalence (CE) is an essential calculation prior to performing welding.

(NACE MR0175/ISO 15156 and NACE MR0103/ISO 17945). These standards were developed for offshore, petrochemical, and natural gas applications where carbon steels in the presence of hydrogen sulfide (H_2S, sour service) are susceptible to sulfide stress cracking (SSC) or hydrogen stress cracking (HSC).

There are two commonly used equations for expressing carbon equivalence developed by the International Institute of Welding (IIW), and American Welding Society (AWS).

International Institute of Welding (IIW)

$$CE = C+Mn/6+(Cr+Mo+V)/5+(Cu+Ni)/15$$

American Welding Society (AWS)

$$CE = C+(Mn+Si)/6+(Cr+Mo+V)/5+(Cu+Ni)/15$$

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Niton Apollo Handheld LIBS Analyzer

There's a new tool available to professionals performing material analysis. The Thermo Scientific™ Niton™ Apollo™ handheld LIBS analyzer utilizes Laser Induced Breakdown Spectroscopy (LIBS) to perform inspection of critical assets and carbon equivalent calculations. Weighing just 6.4 lbs. (2.9 kg.), the Niton Apollo specializes in measuring carbon content in a convenient, portable form factor – eliminating the need for bulky Optical Emission Spectroscopy (OES) carts in many situations.

Featuring an effective laser and high purity argon purge, the Niton Apollo delivers lab quality results in about 10 seconds. In addition to calculating carbon equivalents, users can identify alloy grades, perform advanced averaging, and program pseudo elements. Data is displayed in real time, to enable fast and efficient decision making.

Test Method and Results

Similar to other elemental technologies, sample preparation is required when using the Niton Apollo to ensure the most reliable performance and results. More information on sample preparation procedures can be found by visiting thermofisher.com/niton.

Several samples of carbon steels used in various applications were chosen for testing using the Niton Apollo. Chemistry and subsequent carbon equivalent calculations are shown using both IIW and AWS formulae as a measure of repeatability testing (Table 2).

Common CE Value Classifications	
Carbon Equivalent (CE)	**Weldability**
Up to 0.35	Excellent
0.36-0.40	Very Good
0.41-0.45	Good
0.46-0.50	Fair
Over 0.50	Poor

Table 1

Sample	CE-IIW	CE-AWS	C	Mn	Cu	Si	Ni	Cr	Mo	V	Ti	Al
X65	0.287	0.335	0.049	1.061	0.118	0.286	0.117	0.090	0.056	0.081	0.005	0.038
X65	0.306	0.352	0.042	1.209	0.118	0.279	0.095	0.087	0.064	0.087	0.005	0.024
X65	0.291	0.338	0.040	1.134	0.125	0.277	0.105	0.091	0.061	0.085	0.005	0.030
X65	0.290	0.338	0.042	1.116	0.118	0.284	0.112	0.096	0.065	0.077	0.005	0.031
X65	0.300	0.346	0.039	1.196	0.116	0.276	0.094	0.080	0.068	0.088	0.005	0.028
X65	0.294	0.341	0.034	1.171	0.113	0.280	0.102	0.092	0.078	0.083	0.005	0.030
X65	0.278	0.326	0.039	1.091	0.124	0.289	0.106	0.090	0.049	0.069	0.006	0.032
X65	0.295	0.340	0.046	1.127	0.116	0.273	0.109	0.087	0.063	0.081	0.005	0.034
X65	0.282	0.333	0.041	1.078	0.117	0.310	0.107	0.095	0.059	0.075	0.004	0.038
X65	0.280	0.325	0.036	1.115	0.110	0.275	0.098	0.089	0.053	0.079	0.005	0.034
AVG	0.290	0.337	0.041	1.130	0.118	0.283	0.105	0.090	0.062	0.080	0.005	0.032
STDEV	0.009	0.008	0.004	0.049	0.004	0.011	0.007	0.005	0.008	0.006	0.000	0.004
RSD	3.1%	2.4%	10.7%	4.3%	3.8%	3.8%	7.1%	5.1%	13.3%	7.2%	9.1%	13.7%

Table 2

Conclusion

The performance of the Niton Apollo handheld LIBS analyzer demonstrates the ability to accurately and repeatedly capture carbon content, as well as automatically calculate carbon equivalence using a prescribed formula via pseudo element feature. Whether working at heights in a refinery, offshore on an oil platform, or in a pipeline trench, the Niton Apollo is the ideal tool for analysis in many different industries offering the utmost safety and productivity.

Learn more at **thermofisher.com/NitonApollo**

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