

Ferrite in weld metal: Schaeffler Diagram and WRC 1992 Constitution Diagram

Ferrite Number

To facilitate international communication (specifications, certifications), the internationally accepted term Ferrite Number (FN) has been introduced to indicate a delta-ferrite content in stainless steel weld metal.

The Ferrite Number is often used as an indicator of resistance to weld metal hot cracking. This aspect and other engineering properties have been correlated with the FN value of the weld metal. For various service conditions the following typical levels reflect good experiences:

- fully austenitic weld metal:
 - high corrosion resistance in severe oxidizing and reducing acidic and chloride containing media: FN < 0.5
 - fully austenitic CrNiMoN weld metal, non-magnetic: FN < 0.5
 - low ferrite CrNiN and CrNiMoN weld metal, cryogenic applications: FN 3-6 or < 0.5
- general purpose stainless steel weld metal with corrosion resistance and high resistance to hot cracking and microfissures: FN 6-15
- buffer layer of austenitic/ferritic weld deposits for dissimilar joints and buffer layers in clad steel: FN 15-35
- austenitic/ferritic weld metal with high stress and pitting corrosion resistance as well as a balanced structure for toughness and corrosion: FN 30-70

Control of welding of constructions often requires the determination of the Ferrite Number (FN).

Ferrite Measurement

An internationally accepted standardized method to determine the ferrite content is based upon an arbitrarily defined relationship between a magnetic force and weld ferrite content. This is necessary because an absolute and correct determination of the ferrite content is not available as a result of inherent inaccuracy of metallographic examination and the nonexistence of a calibration method for the absolute ferrite content in stainless steel. The attracting force between a defined permanent magnet and weld metal, containing delta-ferrite is measured by means of a torsion balance. The values are in fact compared with the values obtained in measurements using the same magnet, attracting a carbon steel base plate with a nonmagnetic copper coating of a specified thickness. A calibration method provides the necessary linear relation. The principles are accepted as the international standard ISO 8249 and AWS A4.2-91. The European Standardization will adopt the ISO standard.

The range in the revised standards has been extended to 100FN (originally 0-28FN).

Coated thickness standards are available from the "U.S. National Institute of Standards and Technology" (NIST). A precision torsion balance or the commercially available "Magne Gage" (fig.3) are suitable for the determination of the Ferrite Number under laboratory conditions (horizontal position). A permanent magnet of defined dimensions and magnetic strength, according ISO 8249, shall be used.

Secondary standards for the checking and calibration of field equipment in the range 0-100FN are available from NIST.

Calculation of ferrite content

The ferrite content is estimated on the basis of calculation, using the as deposited weld metal chemical composition. The Cr- and Ni-equivalent is plotted in diagrams, based on the metallographic studies, such as:

- the Schaeffler Diagram¹⁾, published in 1949, is considered as most suitable for a general picture of weld metal structures for a wide range of compositions, but not accurate for ferrite containing austenitic weld metals;
- the DeLong Diagram (1973)²⁾, widely used up to 1985, for a limited range of CrNi (Mo, N)-stainless steel weld metal grades;
- the WRC 1992 Constitution Diagram (1992), published by Kotecki and Siewert (1992)³⁾ has been based upon the WRC 1988 Constitution Diagram, earlier published by Siewert, McCowan and Olson⁴⁾ as a result of a review and of more than 950 weld metal sample analyses and FN determinations (including data from Lincoln Electric). For this diagram, a better accuracy has been reported due to the accurate determination of the effect of Mn, Si, C, N and Nb.
- Also reference is made to the ESPY Diagram⁵⁾ for the calculation of the ferrite content.