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A contribution to new material standards for Ductile Irons and Austempered Ductile Irons

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Some results of material characterization activities, dedicated to classical and fracture mechanics fatigue and elasto-plastic properties, have already been published. Others have not yet been published.
The possible use of all of these results in new standards is here discussed.

Keywords: *Ductile Iron, ADI, IDI, Notch Mechanics, Material Standard.*

1. Introduction

The structural design of castings is mainly based on normative properties measured with the conventional tensile test and other informative properties (the most important is fatigue strength).

The conventional tensile test is representative of the material properties when applied to test probes taken from separately cast test bars, supposed free from defects.

Defects in castings are principally influencing the local fatigue strength. The plastic deformation of the casting as a whole is usually affected at a minor extent by small defects. For this, the tensile test done on test probes taken from the casting not always represents the material design properties.

This paper consider the ductile iron material family, collectively referred as XDIs, including the new "Silicon Solution Strengthened Ferritic Ductile Iron" grades and the " Isothermed Ductile Iron IDI", a patented pearlitic-ferritic grade obtained by heat treating (austenitization in the intercritical temperature range and quenching into a salt bath) a unalloyed ferritic ductile iron casting.

All material properties are referred to test probes taken from Lynchburg 25 mm dia and/or Y 25 mm cast test samples.

2. Fatigue design in presence of defects

The Kitagawa diagram and the Murakami approach for the determination of the equivalent defect size offer a practical approach for the estimation of the fatigue strength in presence of small defects. For this, supported by the Dpt. of Mechanical Engineering, University of Padova, Italy, we calculated some "threshold value for the stress intensity factor" ΔK_{th} [MPa $m^{0.5}$] [2,3,4].

3. The uniaxial tensile curve

When comparing XDIs with steels, little consideration is generally given to the fact that the plastic deformation pattern of XDIs and steels are different. Generally speaking, the plastic deformation design should consider the engineering tensile test up to the UTS R_m and not in the necking plastic instability range.

Using the Voce approach for different grades of XDIs and for different grades of commercial Q&T steels, co-author[4] developed indicators able to discriminate the strain hardening shape of ADIs from those of ferritic-pearlitic DIs and/or steels.

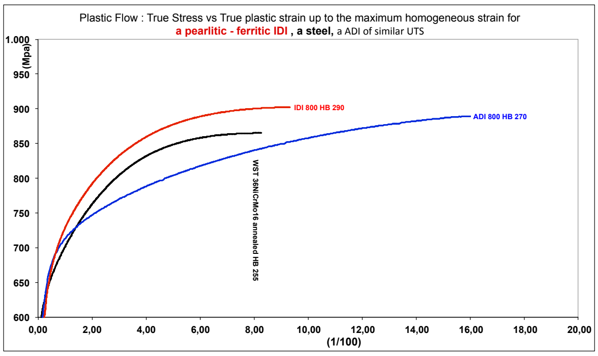

Fig. 1 Plastic flow of an IDI, a steel and a ADI

4. The low temperature and high strain behavior

Co-authors[3] performed uniaxial tensile characterization for the grade ADI UTS min 1050 MPa over the temperature range comprised between

-60°C and +70°C, and for a strain rate ranging from 0.001 and 1000 s^{-1}). Results showed 15% increase of the flow stress at 1000 s^{-1}.

5. Proposals for an improved approach to the standards

A new XDIs material standard is proposed, based on the following dimensions:

1. GRADE: minimum R_m and/or HB
2. UNIFORMITY: range $HB_{max} - HB_{min}$
3. QUALITY

In most ferritic-pearlitic DIs existing material standards, the designation table communicates to designers a brittle or quasi-brittle behavior for all grades, except for the fully ferritic ones. The designation values are so poor because they consider a wide range of hardness. Since the beginning (90s) of his activity in the standardization committees, the author claims [1] (unsuccessfully) that the existing designation approach is not appropriate, proposing the use of a " $R_m A_5$ Material Quality Index MQI".

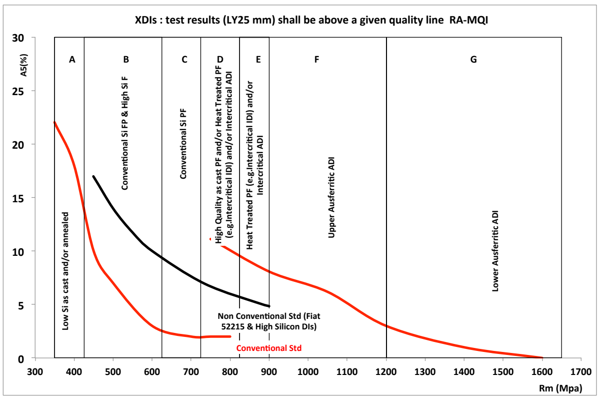

Fig. 2 XDIs plane R_m A_5 and RA-MQI index

The inappropriate definition of grades in most standards is one of the reasons for the predictable success of the "Silicon Solution Strengthened Ferritic Ductile Irons SiSSFDIs". The main difference between SiSSFDIs and conventional Ferritic Pearlitic DIs lies in the different ratio between UTS (Rm) and Yield Strength (Rp0.2).

Because of the importance in safety factors definition, it should be recommended also a specified range for the Rm/Rp0.2 ratio.

The highest SiSSFDI grade Rm min = 600 MPa Rp0.2 min = 470 MPa A5 min = 10% has no alternative in the conventional standards. In fact, to get a similar Rp0.2 min, it is necessary to adopt a fully pearlitic grade, which cannot achieve a satisfactory elongation. This is anyway possible with the adoption of the patented IDI grade $R_{m\ min}$ = 800 MPa $R_{p0.2\ min}$ = 480 MPa $A_{5\ min}$ = 6%, offering a lower elongation but a higher UTS.

When material properties (including possible defects influence) are required from test probes taken from the casting, a finite life minimum number of cycles at a given stress level should be required, instead of minimum properties to be achieved on a tensile test.

Conclusions

A new normative approach, based on material grade and material quality, has recently been submitted to the attention of CEN TC 190 WG 07 working on prEn1563.

A fatigue strength calculation based on the Kitagawa diagram, generalized to blunt notches by mean of the University of Padova Atzori-Lazzarin approach, is included in the proposal.

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