EVALUATION OF SOME METHODS FOR LOWER BOUND DETERMINATION IN THE TRANSITION REGION OF FERRITIC STEELS

C. BEREJNOI[1], J.E. PEREZ IPIÑA[2]

[1]Fac. de Ingeniería, Univ. Nac. de Salta, 4400 Salta, Argentina
berejnoi@unsa.edu.ar
[2] Grupo Mec. de Fractura, Univ. Nac. del Comahue / CONICET, 8300 Neuquén, Argentina
pipina@uncoma.edu.ar

***Abstract*- Fracture toughness characterization of ferritic steels in the ductile to brittle transition region is problematic due to the observed scatter. This scatter makes not possible to obtain a single toughness value, although some statistical methods presented in the literature allow to manage it and indeed to have a lower bound value.**

The ability of some of these proposals to give a technological lower bound value from experimental sets of data was studied. Data from literature and our research were used for this purpose. One hundred random combinations of reduced number of elements from each data set were taken, repeating this procedure for different number of elements. The lower bound value dependence on sample size and the minimum number of specimens needed for a technological lower bound value determination were studied. The SPRÖDZON Method seems to give the best estimation of a technological lower bound LB.

***Keywords* – Lower bound, ductile-to-brittle transition, brittle fracture, Weibull statistics**

I. INTRODUCTION

Interpretation of fracture toughness results of welded joints and ferritic steels in the ductile to brittle transition region becomes problematic due to the great scatter observed. This is generally attributed to a probabilistic effect, resulting from the distribution of low toughness triggering points for cleavage initiation in the volume surrounding the crack front. Specimen size plays an important role on the measured fracture toughness becauseit would influence not only the exposed material volume but also different thickness, causing differences in constraint.

The statistical data treatment has been preferably performed by means of Weibull statistics. The two-parameter Weibull w the first distribution used (Landes and Shaffer, 1980), although afterwards the three-parameter Weibull distribution (Landes and McCabe, 1982) was also employed. Kim Wallin (1989a, b) proposed a three-parameter Weibull distribution with fixed threshold and shape parameters, with toughness results corrected both by large-scale plasticity and stable crack growth. In this way, the number of specimens necessary to calculate an acceptable Weibull distribution could be reduced, because only the scale parameter was necessary to be estimated.

The Weibull distribution is often associated to the weakest link model (**WLM**). However, it is not clear which regime this model would be valid in. Heerens *et al.* (1993) stated that the **WLM** is invalid when previous ductile crack growth (**DCG**) or constraint loss are present, or in cases where there is no evidence of an unique cleavage initiation point. They proposed to split the whole data set into two zones by means of a Border Line. One of these zones corresponds to the tests that satisfy **WLM**. Landes (1993) explained the nature of the fracture toughness scatter in the transition regime of ferritic steels by means of a two criteria statistical model: the Weibull statistics (associated to the **WLM**) in the middle temperature range of the transition and a normal statistical distribution (associated to a critical damage accumulation) in the early part of the transition.

Anderson *et al.* (1994) expressed that the **WLM** is a necessary but not a sufficient condition for the occurrence of cleavage, and demonstrated that the probability distribution of the **WLM** corresponds to a two-parameter Weibull distribution (shape parameter equal to 4 when **K** is used as fracture toughness parameter). According to these authors, in spite of the fact that the three-parameter Weibull distribution describes in a good way the sets of experimental data, it has no theoretical basis. Experimental results had to be corrected for stable crack growth and large scale plasticity. In disagreement with Wallin`s constant value of threshold parameter, they proposed a temperature-dependent threshold equal to the arrest toughness (K_{ia}). Censoring the highest toughness data, or applying different-from-Weibull statistical functions were also proposed (Moskovic, 2002; Heerens *et al.*, 2001).

From a technological point of view, it is very convenient to determine only one value of fracture toughness in order to characterize the toughness of the material for a given temperature. Obviously this must be related to a lower bound (**LB**) value.

Many proposals for calculating **LB** of ferritic steels in the transition region can be found in literature. Some of them are:

A. Proposals of Iwadate *et al.*

Iwadate *et al.* (1983) proposed that the following relation must be verified to have a valid **LB** value in a set of **N** specimens:

$$N.\, B \geq constant.\, \frac{Jc_{min}}{\sigma_y} \qquad (1)$$

Constant value is 1000 or 3000, depending on the presence or absence, respectively, of ductile crack growth previous to cleavage. It has been shown (Perez Ipiña *et al.*, 1994) that the **NB** value obtained by using Eqn. (1) does not correspond to the thickness limit given by **ASTM**.

The minimum toughness value (J_{Cmin}) in a set of **N** specimens is analyzed. If this Jc_{min} satisfies Eqn. (1), then it is considered as **LB**. More tests must be performed when the minimum toughness value in the set does not satisfy Eqn. (1).

This proposal considers two situations: temperatures at which stable crack growth precedes brittle fracture, and temperatures at which no stable crack growth is present at the moment of fracture. It is well