AN OVERVIEW OF THE NDE FLAW ACCEPTANCE STANDARDS BASED ON THE R6 ASSESSMENT

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The general objectives set for the study were: NDE Standards comparison and the identification of differences in NDE national flaw acceptance criteria within the framework of a future common european standard. It refers to standards applicable in Europe (ASME,CPFC,BS,DIN) for manufacturing. Comparisons were made using Fracture Mechanics tools. The paper sets out a general guideline of the method and the results show the significance of the Fracture Mechanics approach.

BACKGROUND

National codes are sets of rules that represent a long-established national experience, and, as such, are diverse from nation to nation. Within the context of a Common European Community, however, it is necessary to extablish common or, at least, compatible standards acceptable to all the community members. In order to obtain that end, it is useful to develop a tool adeguate to make comparisons and to identify differences between the existing national standards. This study, sponsored by the EEC, refer to NDE applicable standards in Europe and their flaw acceptance criteria. The reference standards and procedures used, deal only with the radiographic and ultrasonic inspections performed during manufacturing.

Direct comparisons, between acceptable levels, different in standards and techniques, may be insignificant and, in some cases, might be arbitrary. It is possible, however, to make comparisons using an objectively based, quantitative approach. These comparisons can be made by comparing level damages induced in a structure by acceptable flaw; damage can be evaluated by Fracture Mechanics.

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APPROACH

It is important to recall, at the outset, that in a comparison of the NDE flaw acceptance standards, the problems related to NDT are generally determined by the techique used and by the geometrical size of the zone being subjected to control. It is necessary when using an evaluation by Fracture Mechanics, however, to have both the geometrical size and the operative conditions of the possible or actual defective structures.

It is necessary, therefore, to define the geometry of of the component and its functional frame. In turn, these means a set of conditions that being inherently coherent are correctly delimited but still maintain a general character. The chosen structure reference is a full-penetration, grinded, butt welded joint in a class 1 component of a Liquid Metal Fast Breeder Reactor. Joint thicknesses are considered to be significant when in the 10 to 70 mm range.

The standards examined were ASME (1), CPFC (2), BS (3), DIN (4). By selecting the NDT - ultrasonic and radiographic techniques - it was possible, by referring the flaw acceptance criteria of the standards, to determine the "maximum allowable defects". In other words to establish the maximum dimensions of the flaw that might possibly be found in a structure that has undergone a non-destructive inspection.

Regarding the mechanical properties of the joint material, it is sufficient to consider a set of "verisimilar" values (yield strenght, ultimate strenght and fracture toughness). It is understood that "verisimilar" values were chosen with the aim of constituting a set that is congruent within itself, and suitable as a reference that agrees with the data widely employed in the technical field.

The joints studied were made of austenitic stainless steel (type AISI 316) and, for comparison, of ferritic steel (type A533). Both room and indicative temperature for the service conditions (for the austenitic 370°C, for the ferritic 260°C), were used.

The loading conditions and the consequent stress state were set in reference to the standards, in particular to the design codes. The values for primary stresses are coherent with the maximum design stresses. In relation to secondary stresses, comprising the residual ones, the physical limit - flow stress - that they can reach, is taken as reference value. The stress state is obtained by combining of the membranal and bending stresses. The resulting reference stress states, though not exhausting all the possible combinations, does furnish a comprehensive set of significative data utilizable in successive elaborations.

After the frame has been determined, it is possible to use Fracture Mechanics to assess the integrity of the defective structure based on the flaw acceptance standards. When all the frames are defined, the safety margin of the structure can be said to characterize the standard, and, in addition, can be used in successive analyses and comparisons.

Because general versatility characteristics were desidered, our study used the CEGB R6 approach (5,6,7).

RESULT AND DISCUSSION

After setting out the problem terms: structure type, stress state and properties of the materials (base, weld material and HAZ), each case is defined by means: NDE standard, control technique, joint thickness, type, whether internal or superficial to the joint, and location. When the R6 approach is used, each case is represented by a set of points in the FAD area (Fig. 1).

Some comparisons and analyses were made "analogically" through a suitable manipulation of cloud data points. The cloud position is identificable by its centre of gravity and its shape by an ellipis. The axis of the ellipsis characterize the point dispersion in respect to the gravity centre.

Fig. 2 shows an example of the approach, each cloud (or ellipsis) represents all the centres of gravity for the cases related to a specific material. As the figure clearly demonstrates, all the points, relative to a specific material, are very densely packed, the other materials show distinct type clouds. This demonstrates that the material is unimportant in a comparison of standards modifing the cloud position, but not the mutual relationship between the points that constitute the cloud (Fig. 3).

Comparisons, using induced damage levels in the structure, can be made by passing from the set of points to the distribution of the safety margins values relative to each point. The safety margins can be determined in conform with R6. By setting out a functional, a harmonic mean, it is also possible to characterize the distribution and the dispersion. Fig. 4 gives the functional values for some of the NDE analyzed.

The given outline is an example of possible analyses and demonstrates the significance of a Fracture Mechanics approach. When analyses of NDE are made with Fracture Mechanics, quantitative values become an integral part of the evaluation. It is possible therefore to draw comparisons, identify hierarchies and point out the meaning and the significance of the choices. For this reasons Fracture Mechanics represent a possible starting point for a critical, objective analysis of the standards and represents a tool useful for reexamination and unification of the standards.

REFERENCES

(1) ASME Boiler and Pressure Vessels Code, Section III, "Rules for construction of nuclear vessels"

(2) ELECTRICITE' DE FRANCE, "Cahier des prescriptions de fabrication et de controle", Edition Javier, 1976 et son correttif

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(4) AD - Merkblatt HP 5/3, "Manifacturing and testing of pressure vessels - Minimum requirements for non-destructive testing processes", 1975

(5) Milne I. et alii, "Assessment of the integrity of structures containing defects", R/H/R6 rev. 3, CEGB, 1986

(6) Milne I. et alii, "Background to and validation of CEGB report R/H/R6 rev. 3", R/H/R6 rev. 3 validation, CEGB, 1987

(7) Miller A.G. "Review of the limit loads of structures containing defects", Rep. TPRD/B/0090/NB2 rev. 1, 1987

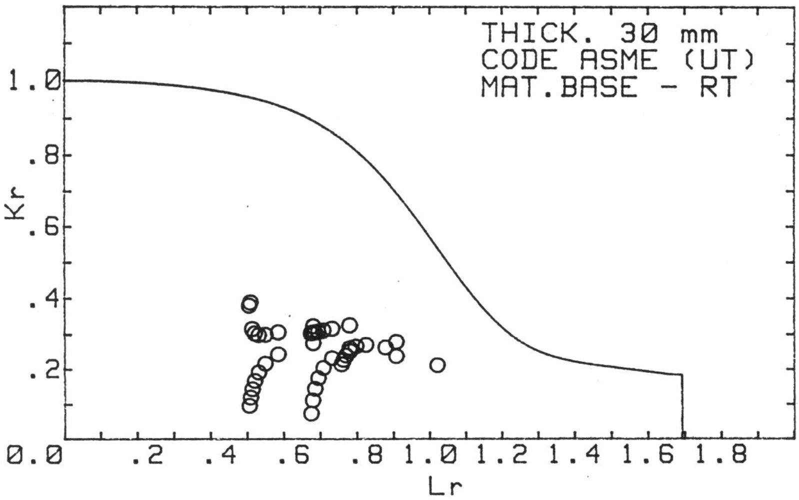

Fig. 1 - Points representing the analysis of the allowable defects - in accordance with the ASME ultrasonic inspection - in the base material of a 30 mm thick joint in an austenitic stainless steel

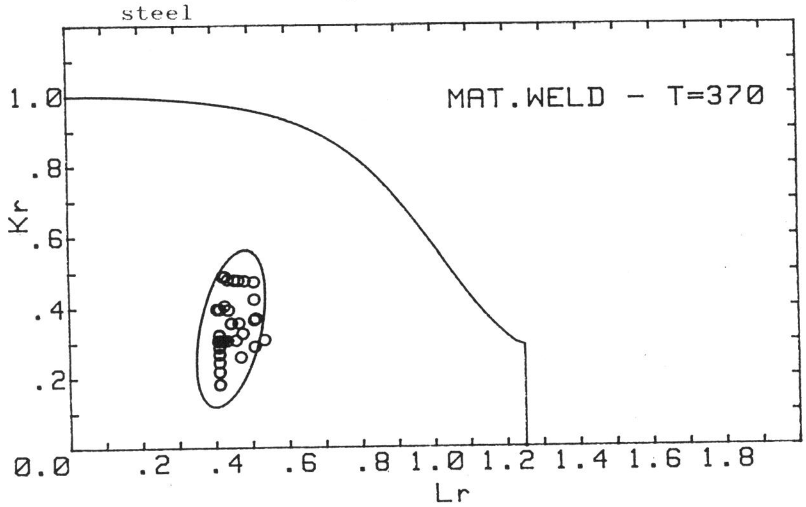

Fig. 2 - The points represent the centres of gravity of all the points resulted from the analyses performed about all the allowable defects on the weld material of the joint in austenitic stainless steel.

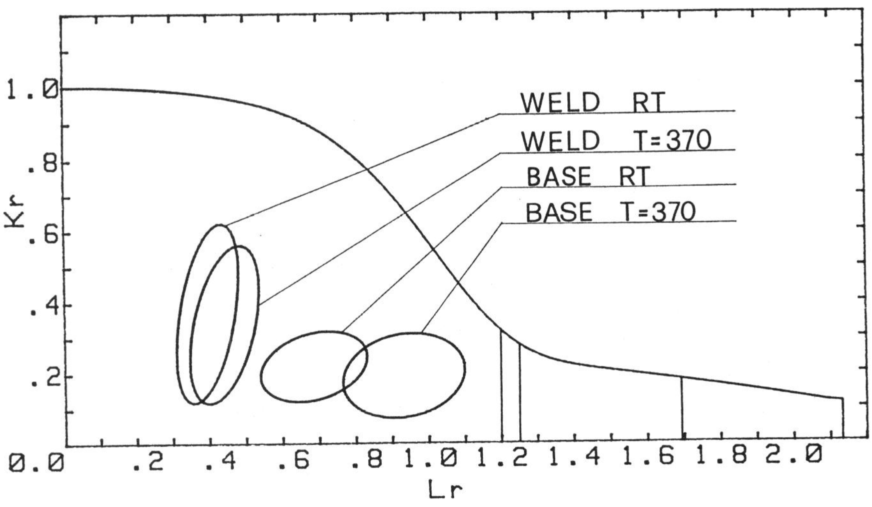

Fig. 3 - All the ellipses, like that of Fig. 2, evaluated for the joints in austenitic stainless steel.

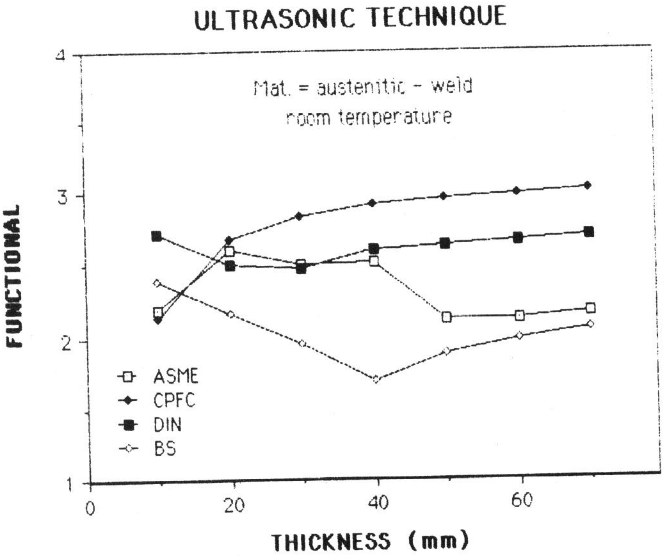

Fig. 4 - Functional values for some of the analyzed NDEs.