INFLUENCE OF AGING ON THE FRACTURE TOUGHNESS PROPERTIES OF AUSTENITIC STAINLESS STEEL MATERIALS

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INTRODUCTION

The aim of this study was to obtain fracture toughness of austenitic stainless steel and welds in the prior state and after a thermal embrittling treatment representative of a long aging time occuring in structure of fast neutron reactor.

A comparison with classical mechanical properties and in particular Charpy U results was made, to establish a correlation with a greater numberof results precedently obtained. In other hand, the influence of the structure on fracture toughness was considered before and after embrittlement.

EXPERIMENTAL PROGRAM

Materials

Type 16.8.2 and 316 L manual arc welds and a 316 L base metal were studied. In order to study the influence of aging on the fracture toughness, specimens were aged at different times and temperatures for the base metal and one weld or embrittled at 750 °C during 100 heures for the welds.

The steel is representative of the lowest toughness value compatible with the specifications. One of the weld is volontary out of specification to have a high embrittled tendancy.

Mechanical tests

Tensile tests and Charpy impact were performed in aged and unaged conditions. The fracture toughness tests were performed with side grooved CT specimens by partial unloading compliance method.

EFFECT OF METALLURGICAL PARAMETERS AND TEMPERATURE OF TESTS

Effect of metallurgical parameters

In the unaged condition, the fracture toughness J0.2 of the welds are in relation with the inclusion content and in particular with the oxyde content (FIG. 1). A good appreciation

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of this inclusion content is given by the Franklin formula :

$$V\ \% = K_o \text{ oxygen Wt } \% \text{ with } K_o = 5$$

For the base metal the inclusion content (sulfate and silicate) is also the predominant phenomenom for the fracture toughness value.

After thermal embrittlement, the most important factor is the initial ferrite content, in relation with the formation of brittle phase (σ in particular) (FIG. 2). However, for the welds, the reason of another part of the decrease of the fracture toughness is the softening of the yield strength.

Effect of test temperature

On the base metal, tests were made at different temperatures in the unaged and aged conditions. The decrease of the fracture toughness observed with the augmentation of the temperature tests is probably in relation with the lowering of the yield strength (FIG. 3). That is in agreement with a prediction based on the local criteria approach :

$J_{1C} = 4{,}5\ \sigma_y\ (\Delta a)_C \ \mathrm{Ln}\ (R/R_o)_C$, where $(R/R_o)_C$ is the critical growing rate of the cavities and $(\Delta a)_C$ is a structural parameter.

RELATION BETWEEN THE TOUGHNESS KCU AND THE FRACTURE TOUGHNESS J0.2

It is possible to have a relation between KCU and J0.2 (FIG. 4) at room temperature, i.e. :

$$J0.2\ (KJ/m^2) = 3.2\ KCU\ (J/cm^2)$$

It is impossible to have a prediction of the evolution of J0.2 with the temperature by the utilisation of KCU values which are not sensitive to this factor. However, if J0.2 is dependant of σ_y a possible relation is

$$J0.2\ (t)\ (KJ/m^2) = \frac{\sigma_y\ (t)}{\sigma_y\ (20\ °C)} \times 3.2\ KCU\ (J/cm^2)$$

Good results are obtained in the case of the base metal, but other results are necessary to improve this relation, in particular with the unaged and aged welds.

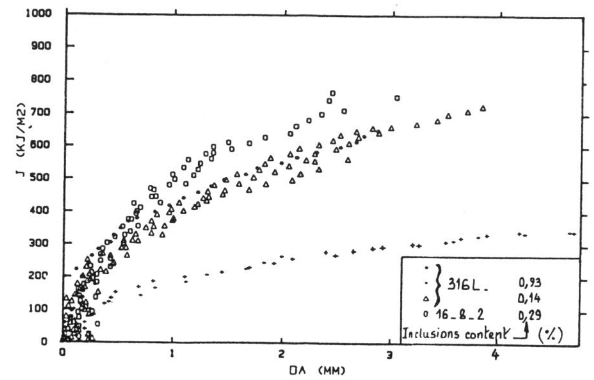

FIG. 1 - J-Δa CURVES OF UNAGED WELDS

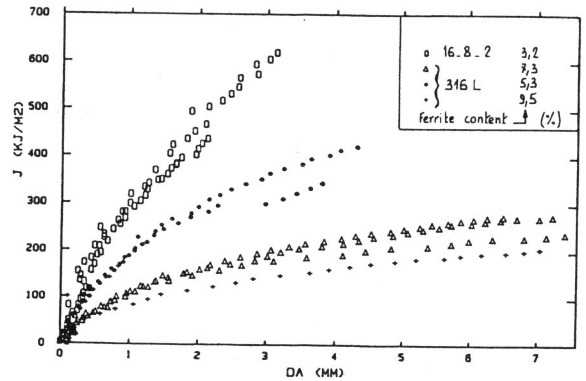

FIG. 2 - J-Δa CURVES OF WELDS AGED 750 °C - 100 h

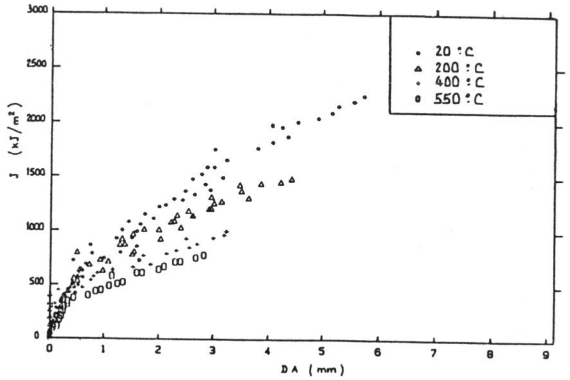

FIG. 3 - INFLUENCE OF TEMPERATURE TESTS ON UNAGED 316 L STEEL

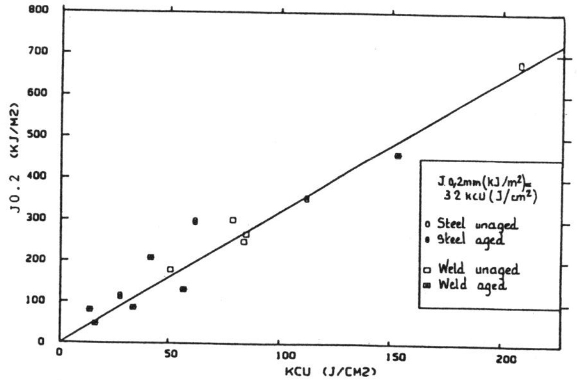

FIG. 4 - RELATION BETWEEN FRACTURE TOUGHNESS (J0.2) AND TOUGHNESS (KCU) TESTS AT 20 °C