Chapter 4
Fatigue Fracture, CTOD, and CVN Testing in Heat-Affected Zone of High Strength Low Alloy Steels

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ABSTRACT

High strength low alloy steels (HSLA) are currently used in large quantities for constructions in the North Sea and elsewhere. For success operation under such rigorous conditions, it is essential to ensure adequate weld metal toughness at temperatures of -10ºC or even lower is used. To comply with this high requirement, the heat input control is needed to avoid forming martensitic microstructure in high strength low alloy steels (HAZ) near to the fusion line during weldment cooling. This work carried out CTOD tests to ensure that, under welding conditions, the fatigue crack, toughness, hardness, and resilience in the HAZ are acceptable with the standards. Crack size in accordance with number cycles will be represented as the crack growth rate da/dN vs. stress intensity factor amplitude.

DOI: 10.4018/978-1-7998-3246-1.ch004

INTRODUCTION

One problem that design of these steels of high resilience have shown is their low toughness in the HAZ Schuller, R., *et al.* (2015), when they are welded with a high heat input (HI). In this work we have studied nine specimens that have been welded under three different process:

SAW (submerged arc welding), SMAW(shield metal arc welding), GSFC(gas shield flux core arc welding) controlling the welding parameters and checking in the HAZ of such specimens, critical tensions (σ_{cr})at the ends of the cracks, the critical cracks lengths (a_{cr}) and stress intensity factors (K_{IC}).It is intended to check that the parameters that indicate the values of fracture mechanics: $(\sigma_{cr}, a_{cr}, K_{IC})$, da/dN=A ΔK^m, etc.,) in the HAZ, after heat cycle to which the steel has undergone, under a process with a maximum "heat input" of 2.327kJ /mm (see Table 5 below), are still valid, with the welding parameters applied. It is checked a correlation between the theoretical values and those obtained experimentally. Experimental work, here conducted, we intend to ensure that these parameters regulating the mechanism of fracture, remain valid under the rules compatible with the design of the base material and that as far as possible be established a correlation between welding parameters and those obtained in fracture tests, so that if the results of the tests are not satisfactory, we could apply the appropriate solution in welding for the parameters governing fracture tests were acceptable. We will check as the HAZ region behave as ferritic-Pearlitic steels complying with the equation:

$$\frac{da}{dN} = 5.01 \times 10^{-12} (\Delta K)^{3,1} m \,/\, cycle$$

$$206.9 N \,/\, mm^2 < \sigma_{ys} < 344.8 N \,/\, mm^2$$

The tests of CTOD, resilience and hardness were carried out on the panel numbered as CTOD HAZ. Said panel, 60 mm thick, 980 mm weld length and 750 mm wide, was tested under "As welded" conditions (without post-weld heat treatment); and it was used to test the HAZ. The welding was done in K and V, in three different process Shield Metal Arc Welding (SMAW) in the panel 3 AW where from taken the samples 01-1(1), 01-2(2) and 01-3(3). The second process was Gas Shield Flux Core (GSFC) in the panel 7 AW where from were taken the specimens 02-01(4), 02-02(5) and 02-03(6) and the third in the process Submerged Arc Welding (SAW) the panel 01 AW where from the following panel were taken 01-10(7), 01-11(8) and 01-12(9). The base metal was BS 7191(1979) 450 EMZ TYPE 2.

The thermal cycle to which these test pieces were subjected, for the effects of the transformation products that are produced in the cooling inside the HAZ with a contributed maximum energy of 2.327 KJ / mm, a peak fusion temperature is obtained 1,527 °C, a cooling time $\Delta t_{8/5}$, practically constant for the entire HAZ, of 10 seconds, as shown by Rosenthal's theoretical cycle for this thick plate process, González-Palma *et al* (2006). The physical characteristics of the 450 EMZ micro alloy steel are given in the casting certificate.

The life of the components of a structure containing premature cracks, can be governed by the degree of subcritical crack propagation. To this end, the many destructive and non-destructive testing can collaborate to establish any cracks before commissioning. Thus, knowledge of crack propagation through the concepts of fracture mechanics calculation to determine the fatigue of the structure is necessary.