

A Strategy for Assessing Weld Metal Pop-In

J.D.G. Sumpter

Admiralty Research Establishment, St Leonard's Hill, Dunfermline, United Kingdom

ABSTRACT

Interpretation of CTOD weld data is often complicated by the occurrence of pop-in. This paper argues that existing procedures for classifying the severity of pop-in are inadequate. An alternative strategy based on crack arrest toughness is suggested and illustrated by practical example.

INTRODUCTION

Weld metal toughness is commonly measured by the CTOD (Crack Tip Opening Displacement) test. A serious problem with this test is the interpretation of pop-ins (short arrested brittle cracks). A typical example is shown in Fig. 1. Current practice is to designate such events as δ_c , the critical toughness of the weld. Thus the weld in Fig. 1 has a δ_c of 0.029 mm. A δ_c value this low effectively prevents the weld from being used in any high integrity structural application. However, this condemnation can be questioned given the high overall toughness shown once the pop-in has arrested.

The most recently issued CTOD test standard (ASTM E1290-89) contains a recommended procedure for distinguishing between "significant" and "insignificant" pop-ins based on the change in load and displacement during the pop-in event. A pop-in is judged to be insignificant if the inferred load drop at constant clip gauge displacement is less than 5%. There are two serious problems with this recommendation. Firstly, the size of the pop-in which can be excluded is very small (the pop-in in Fig. 1 is "significant" by a wide margin). Secondly, the procedure fails to address the true structural significance of pop-in. It is implied that once a pop-in has been judged to be insignificant its existence may be forgotten in the structural safety justification. This is clearly incorrect, since had a similar pop-in occurred at a slightly higher load level, it would have been subjected to a higher crack driving force and might not have arrested.

Pop-ins are real events which indicate a problem in the weld (local brittle zones with low resistance to cleavage crack initiation). Once a weld is known to exhibit pop-in, its fracture safety needs to be argued on the basis of crack arrest toughness. Ideally arrest toughness should be measured on a separate, specially designed test piece; but under some circumstances, as will be shown in this paper, it may be possible to deduce arrest toughness from the CTOD test itself. If the arrest toughness can be shown to be high, a safety case for accepting pop-ins can be established. By way of illustration, this paper presents such a safety justification for the weld of Fig. 1.

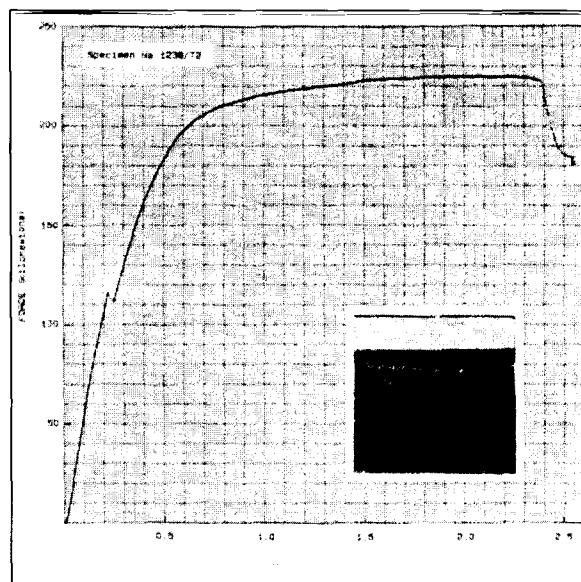


Fig. 1 Unacceptable pop-in by ASTM E1290-89 (1). Load drop at constant clip gauge displacement is 18%. δ_c is .029 mm.

EXPERIMENTAL DATA

The weld was made by the pulsed MIG process in HY80 steel 50 mm thick. A total of 35 weld runs were deposited through the thickness, including those lost by backgouging.

The properties of the weld were measured at both surface layers by tensile, Charpy and CTOD testing. Results are summarised in Table 1.

The following points should be noted in connection with these data.

- (i) Tensiles were extracted longitudinal to the weld with their axis 5 mm below the weld surface.
- (ii) Charpy specimens were extracted with one surface 2 mm below the weld surface and through notched with respect to the weld direction.
- (iii) CTOD specimens had thickness, B , equal to depth, W , of 45 mm. Specimens were notched from the surface of the weld to a crack depth, a , of around 12.5 mm ($a/W = 0.3$).

From the above it follows that the Charpy and CTOD results are not directly comparable since the specimens do not sample the weld at the same position. However, this does not alter the overall

Received February 22, 1991; revised manuscript received by the editors July 20, 1991. The original version (prior to the final revised manuscript) was presented at The First International Offshore and Polar Engineering Conference (ISOPE-91), Edinburgh, United Kingdom, August 11-16, 1991.

KEY WORDS: Fracture, weld metal, CTOD, pop-in.