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Industrial Member Report Summary – Key Findings for Industry

Effects of Mechanical Loading on Residual Stress and Fracture: A Re-examination of the BS 7910 Rules and FEA

TWI Core Research Programme

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Industrial need

The current version of BS 7910 (2005 edition, including Amendment 1) gives advice on the assumptions that can be made about the magnitude and distribution of welding residual stress in as welded joints, including the effects of mechanical loading (either as a result of proof testing or during the initial loading of an as-welded structure), which is assumed to bring about a relaxation in residual stress. These rules date back to PD6493:1991, one of the forerunner documents to BS 7910.

Conversely, R6 contains a warning on the 'limited validation' of the BS 7910 approaches for stress relaxation and suggests that they should be used 'with caution'. There is a clear need to understand the reasons for the different approaches of the two procedures, and to unify the approach in future if possible.

Key Findings

The main conclusions from this report are:

- The residual stress relaxation clauses of BS 7910:2005 (including Amendment 1) date back to the 1991 edition of PD6493 and have not changed substantially since then.
- A considerable programme of work was carried out by TWI at the time to justify and validate the clauses, using a range of experimental and numerical work. This included analysis of work carried out by the CEGB (a forerunner of EDF Energy) and used by them in the validation of the R6 procedure. The full underlying details of the work have not hitherto been available in the public domain; a key report written by Leggatt in 1987 was never published outside TWI (although the conclusions arising from it were published in 1988). It is believed that this is the reason that R6 describes the work as having 'limited validation'. The approach proposed in BS 7910 combines 'global' relaxation of residual stress (Q_m) under high mechanical load with 'local' enhancement of crack tip driving force through the adoption of a simplified primary/secondary stress interaction factor, ρ. This is different from the method adopted by R6, but seems to be equivalent to allowing negative values of ρ under conditions of high primary stress.
- A re-analysis of Leggatt's work, using the BS 7910:2005 clauses, has shown nothing to contradict the approach. Whilst there are minor anomalies in the way it is presented, and it is arguably counter-intuitive to have one term (ρ) increasing crack tip driving force and another (Q_m) reducing it, the current (2005) approach represents a workable engineering solution to the problem of how to analyse residual stress effects in as-welded structures rapidly and reasonably realistically.

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