STRESS CONCENTATION IN WELDED JOINTS AND THE GOVERNING PARAMETER FOR FATIGUE

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It is well known that stress concentration effects in welded joints dominate the fatigue life of welded joints. However, the determination of the stress concentration factors (SCF) for typical welded joints have been difficult, regardless of using experimental techniques or finite element models. This is due to the fact that the stress distributions at geometric discontinuities such as weld toes are strongly influenced by stress singularities. As a result, the stress concentration factors using strain gage measurements are strongly dependent upon the measurement positions. In the same way, if finite element models are used, the stresses calculated at or near the weld toe are strongly dependent upon the mesh size and design at the weld toe. For this season, the SCFs derived using a particular measurement technique or finite element procedure for one joint cannot be related to those obtained in other joints. Consequently, in fatigue data generation in new product development, different joint types are required to be tested to generate multiple S-N curves for each joint configuration. Such testing can be very costly. Furthermore, such multiple S-N curves can be very difficult to use in today's computer aided engineering (CAE) environment in automated fatigue life prediction, since the nominal stresses upon which a SCF is based on cannot be readily defined in a complex CAE model under realistic service loading conditions.

In the paper, a mesh-size insensitive structural stress definition is presented in this paper. The structural stress definition is consistent with elementary structural mechanics theory and provides an effective measure of a stress state that pertains to fatigue behavior of welded joints in the form of both membrane and bending components. Numerical procedures for using conventional finite element models are presented and their mesh-size insensitivity in extracting the structural stress parameter are demonstrated. With the same principle, experimental measurement techniques are also developed for measuring the structural stress parameter. To further illustrate the effectiveness of the present structural stress procedures, a collection of existing weld S-N data for various joint types were processed using the current structural stress procedures. As shown in Fig. 1, the results strongly suggest that S-N data from different joint configurations and loading conditions can be effectively consolidated into a single band or curve. In addition, the implications on the governing parameter for fatigue behavior in welded joints are discussed. Detailed comparison of the structural stress based SCFs will given for various joint types. The major findings are summarized as follows:

1. Stress concentration factors for welded joints can be consistently calculated in a mesh-insensitive manner using the present structural stress method

2. Such structural stress parameters can be directly measured by using strain gages located in some characteristics locations

3. A structural stress based fatigue parameter can effectively consolidate S-N data collected from various joint types and test loading conditions
4. Repeated testing for different joint types can now be minimized or even eliminated due to the transferability of the present structural stress based SCF parameter

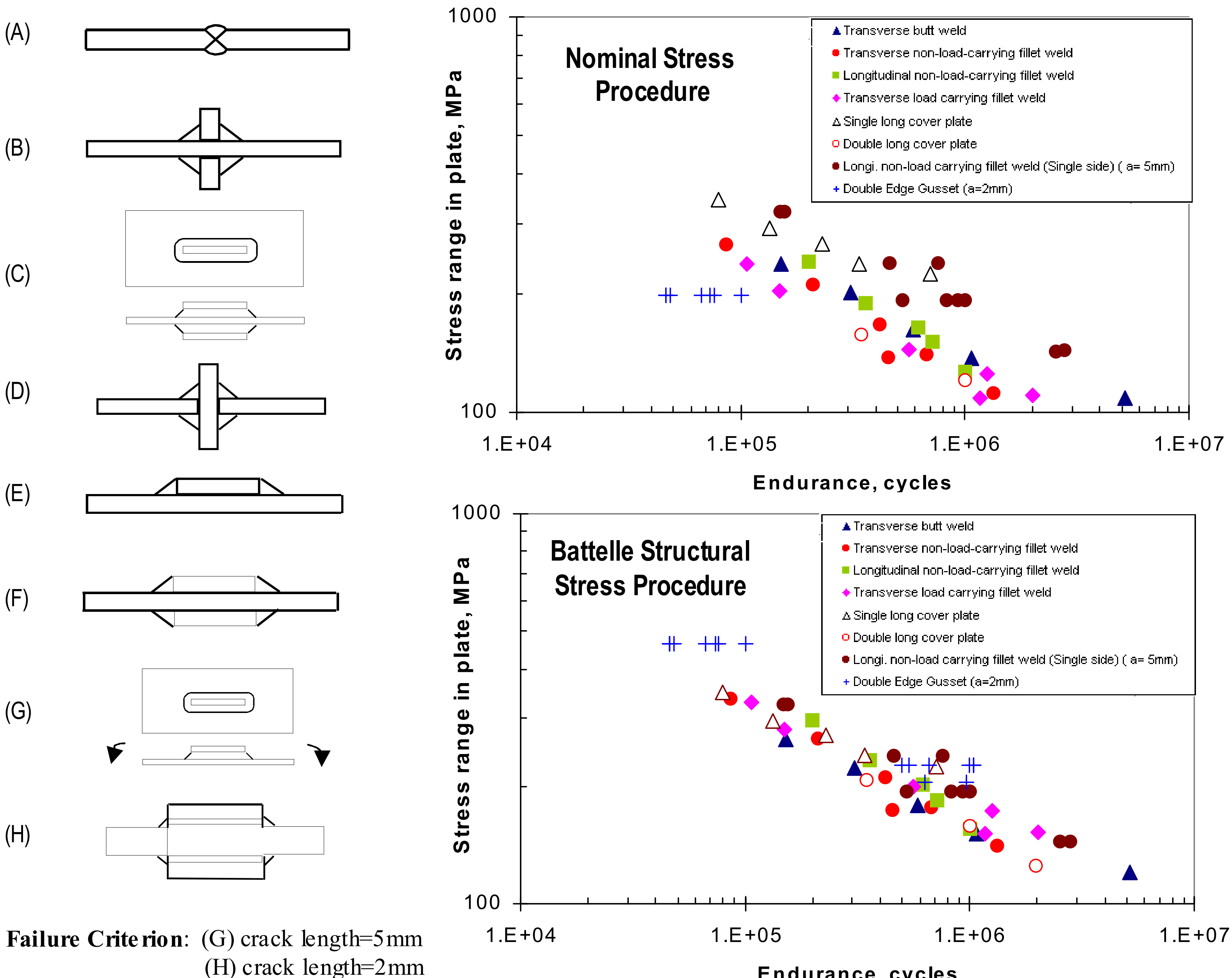
(A)
(B)
(C)
(D)
(E)
(F)
(G)
(H)
Failure Criterion: (G) crack length=5mm
(H) crack length=2mm
Nominal Stress Procedure
Stress range in plate, MPa
Endurance, cycles
1000
100
1.E+04
1.E+05
1.E+06
1.E+07
Transverse butt weld
Transverse non-load-carrying fillet weld
Longitudinal non-load-carrying fillet weld
Transverse load carrying fillet weld
Single long cover plate
Double long cover plate
Longi. non-load carrying fillet weld (Single side) (a= 5mm)
Double Edge Gusset (a=2mm)
Battelle Structural Stress Procedure
Stress range in plate, MPa
Endurance, cycles
1000
100
1.E+04
1.E+05
1.E+06
1.E+07
Transverse butt weld
Transverse non-load-carrying fillet weld
Longitudinal non-load-carrying fillet weld
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Fig. 1