INFLUENCE OF GIRTH WELD FLAW AND PIPE PARAMETERS ON THE CRITICAL LONGITUDINAL STRAIN OF STEEL PIPES

Celal Cakiroglu
University of Alberta, Department of Civil and Environmental Engineering
PO Box 52201, Garneau, T6G 2T5, Edmonton, AB, Canada
E-mail: cakirogl@ualberta.ca
Phone: 780-394-9489

Kajsa Duke
University of Alberta, Department of Mechanical Engineering
4-9 Mechanical Engineering Building, Edmonton, AB, T6G 2G8, Canada
E-mail: kkduke@ualberta.ca
Phone: 780-492-4710

Marwan El-Rich
University of Alberta, Department of Civil and Environmental Engineering
Office: 3-016 Markin/CNRL Natural Resources Engineering Facility
E-mail: elrich@ualberta.ca
Phone: 780-492-6678

Samer Adeeb
University of Alberta, Department of Civil and Environmental Engineering
Office: 3-021 Markin/CNRL Natural Resources Engineering Facility
E-mail: adeeb@ualberta.ca
Phone: 780-710-9006
Affiliations: Professional Engineer, Association of Professional Engineers, Geologists, and Geophysicists of Alberta (APEGGA)

Roger Cheng
University of Alberta, Department of Civil and Environmental Engineering
Office: 3-029 Markin/CNRL Natural Resources Engineering Facility
E-mail: roger.cheng@ualberta.ca
Phone: 780-492-2992

Millan Sen
Enbridge Pipelines Inc., 10201 Jasper Ave, T5J 3N7, Edmonton, AB, Canada
E-mail: Millan.Sen@enbridge.com
Phone: 780-378-2372
Fax: 780-420-8801

ABSTRACT

The design of steel pipelines against longitudinal loading induced by soil movement and temperature requires an understanding of the strain demand induced by the environment in comparison with the strain resistance of the pipes. Girth weld flaws have been identified as the potential location of failure under longitudinal tensile strains due to being the least ductile. Strain based design for the prediction of the longitudinal tensile strain capacity of steel pipes have been extensively studied by Wang, et al and included in the Canadian standards association code of practice CSA Z662.11. The extensive track record of tests have culminated into two sets of equations for the critical strain in girth welded pipes with surface breaking and buried defects as functions of the different pipe and flaw parameters.

The CSA Z662.11 strain capacity equations were developed using wide plate tests with the obvious limitation of the inability to consider the effect of the internal pressure of the pipe. However, recent studies by Wang et al led to the development of a new set of equations that predict the tensile strain capacity for pipes with an internal pressure factor of 0.72.

This paper analyses the two critical strain equations in CSA Z662-11 to understand the effect of different girth weld flaw and pipe parameters on the expected behavior of pipes. Also the critical strain equations developed in (6) have been analysed and compared to the equations in CSA Z662-11. Using the equations

in CSA Z662-11, a 3^4 and 3^6 full factorial experimental design was conducted for the planar surface-breaking defect and the planar buried defect respectively. For the case of surface breaking defects the dependence of the tensile strain capacity ($epsilon_t^{crit}$) on apparent CTOD toughness ($delta$), ratio of defect height to pipe wall thickness (eta), ratio of yield strength to tensile strength ($lambda$) and the ratio of defect length to pipe wall thickness (xi) has been studied. $epsilon_t^{crit}$ has been evaluated at the maximum, minimum and intermediate values of each parameter according to the allowable ranges given in the code which resulted in the evaluation of $epsilon_t^{crit}$ for 81 different combinations of the parameters. The average value of $epsilon_t^{crit}$ at the maximum, minimum and middle value of each parameter has been calculated. The visualization of the results showed that eta, $delta$ and xi have the most significant effect on $epsilon_t^{crit}$ among the four parameters for the case of surface breaking defect.

Similarly for buried defects the dependence of $epsilon_t^{crit}$ on $delta$, eta, $lambda$, xi, and the pipe wall thickness (t) has been studied. The evaluation of $epsilon_t^{crit}$ for all possible combinations of the maximum, intermediate and minimum values of the 6 parameters resulted in $epsilon_t^{crit}$ values for 729 different combinations. The variation of the average $epsilon_t^{crit}$ over the maximum, intermediate and minimum values of the parameters showed that $delta$, psi, xi and eta are the parameters having the greatest effect on $epsilon_t^{crit}$ for the case of a buried defect.

Further investigations could be carried out to determine suitable upper and lower bounds for the parameters for which no bounded range is defined in the CSA Z662-11 code.