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Influence of Variable Amplitude Loading on Crack Initiation in 410NiMo Filler Metal

Zachary Forget[1*], Myriam Brochu[1] , Pierre-Antony Deschênes[2], Daniel Paquet[2]
[1]Mechanical Engineering, Polytechnique Montreal, Montreal, Canada
[2]Institut de Recherche d'Hydro-Québec (IREQ), Varenne, Canada
*zacharyforget99@gmail.com

Hydro-Québec aims to increase its electricity production by optimizing the geometry of its hydraulic turbines. However, this approach is limited by the current understanding of fatigue damage mechanisms. The linear accumulation model, currently used to predict material life, overlooks essential factors such as loading sequence, load interaction, and the effect of low-amplitude stresses. Discontinuities in welds, such as inclusions, lack of fusion, and pores, promote crack initiation and exacerbate the influence of varying stress amplitudes. The main goal of this project is to develop a more accurate predictive tool for crack initiation.

Samples welded with a 410NiMo deposit will undergo fatigue tests at various stress amplitudes, like those experienced by Hydro-Québec's Francis turbines. For simplicity, uniaxial loading will be used, even though some in-service stresses are multiaxial. The sequence and number of loading blocks will be adjusted to observe their effect on the total number of cycles to failure. Point overloads will be incorporated into cyclic loading to simulate real conditions observed during load rejection. The contribution of stresses below the endurance limit, which account for over 90% of cycles recorded in service, will be examined. The results will be compared with predictions from six models in the literature, based on the average ratios of the number of experimental cycles to those predicted. The differences between these models primarily arise from the damage accumulation equation used.

Block tests confirm that the loading sequence influences damage accumulation. Among the six models compared, the three most accurate were Manson's, Aeran's, and Zhu's, with ratios of 1.00, 1.02, and 0.96, respectively. The Aeran model is considered the safest. Although Gao's model is favored in the literature, its predictions, while conservative, are the least accurate (ratio of 1.09), closely followed by Miner's model (ratio of 0.93).

The preliminary results show that the linear cumulative damage approach does not offer the most accurate predictions. Aeran's approach was chosen for its accuracy and conservative predictions. It appears that the accuracy of the models may depend on the material studied and the comparison criterion chosen, as observed in the literature. Additionally, a focus on the metallurgical aspects is important, as the material properties significantly influence the damage mechanisms. It is also crucial to use conservative models to avoid unexpected breakage. Future work will verify whether the chosen model is also the most accurate for other loading conditions.