Validated Methodology for Assessment of Welded Steel Structures by Nonlinear Finite Element Analysis

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Nonlinear finite element analysis is a powerful tool for the determination of ultimate capacities of steel components. To produce reliable predictions with high confidence of structural strength, it is of fundamental importance that nonlinear finite element analyses are based on a validated methodology. This paper presents a validated methodology with statistically calibrated failure (fracture) criteria providing either a characteristic or mean level of capacity/response for the detailed finite element assessment of strength of typical structural details forming a part of offshore structures. More than 60 large-scale physical tests representing plated details/joints as well as tubular joints form the basis of the developed methodology.

INTRODUCTION

The response of an offshore structure can be divided into global and local responses. Figure 1 illustrates how the global loading of a jacket results in the local response of a joint with corresponding local failure modes all feeding back to the overall global capacity of the jacket. Hence, when the overall capacity of a redundant structure is to be determined, an accurate description of the local response is of fundamental importance. The prediction of a local response in the form of a load-deformation response for tensile failure modes using nonlinear finite element analysis (FEA) is the objective with the developed methodology. This includes three major ingredients: (1) modelling of material yielding and hardening, (2) damage and failure model, and (3) failure criteria—all three thoroughly dealt with in this paper.

One of the challenges is that the fracture strain for pure plate tearing is (much) less than the fracture strain for plate bending. The fracture strain in pure plate tearing is less than that in plate bending because tearing involves a more localized and abrupt mode of failure, whereas bending allows for distributed deformation and greater energy absorption before failure occurs. As it can be hard to distinguish the two scenarios, designers and code guidance often lean toward the most conservative criteria. On top of this, FEA failure criteria are sensitive to the finite element (FE) element size and formulation. This makes the accurate setting of FE tension failure criteria a general shortcoming in industry today.

The way to progress the development to the next level is through extensive validation against physical tests targeting the local conditions in the highly strained areas. Similar views are put forward by Czujko et al. (2018) for ultimate strength assessments of offshore structures as well as Liu and Soares (2023) for ship collision analysis.

Physical Testing Campaign

The physical testing campaign used for model calibration and methodology development consists of more than 50 physical tests.