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Proposal of reference stress for a surface flaw on a cylindrical component from a review-with-comparison of the local metal loss assessment rule between API 579-1 and the *p-M* diagram method

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ABSTRACT

The Remaining Strength Factor (RSF) approach in Part 5 of API 579-1/ASME FFS-1 is an assessment method for a cylindrical component with a local metal loss based on surface correction factors. Also, reference stress solutions that are applied in the Failure Assessment Diagram (FAD) method for a cylindrical component with a crack-like flaw are provided in Annex D using surface correction factors. In the recently-developed *p-M* diagram method, the reference stress solution for local metal loss evaluation in a cylindrical component is derived using bulging factors, which are similar but not identical to the surface correction factors used in API 579-1/ASME FFS-1. This paper describes the results of a comparative study among the RSF approach, reference stress solutions for the FAD method, and the *p-M* diagram method, in terms of plastic collapse evaluation of a cylindrical component. These results were compared with the FEA and experimental results to confirm how these estimated stresses could be validated. This study also involves recommended reference stress solutions for a cylindrical component with a crack-like flaw or a local metal loss, which should be adopted as fitness-for-service rules, and a discussion on the influence of the design margin of the construction code on allowable flaw depth.

1. Introduction

The *p-M* diagram method is a fitness-for-service rule to evaluate a local metal loss subjected to internal pressure and external bending moment, which has been developed by Konosu, one of the authors, and adopted as in the Japanese Ibaraki FFS rule [1]. The *p-M* diagram method takes advantage of reference stress solutions for crack-like flaws. The validity of the application of such reference stresses to the assessment of a local metal loss is ascertained in references [2,3].

Derivation of the reference stress solutions given in the *p-M* diagram method is made clear and those solutions are considered to be a lower bound to the plastic limit loads. The plastic limit load indicates a load where appreciable plastic deformation (almost equal to general yielding and not necessarily the physical collapse load of the vessel) occurs at a local metal loss area, determined by applying twice-elastic slope (TES) as recommended by ASME [4]. It was clarified that there is good agreement between the predicted limit loads and finite element analysis (FEA) and experimental results [3].

On the other hand, the RSF approach for a local metal loss in Part 5 of API 579-1/ASME FFS-1 [5] is based on surface correction factors [6] and physical collapse loads in whole cylinders. So, the evaluations count on margins from the plastic instability loads (physical collapse loads of components and not from the plastic limit loads at a local metal loss area) and consequently, the loads obtained by the RSF approach results in far lower stress levels than the general yielding at a local metal loss area in some cases due to taking a larger safety factor into account. The plastic instability loads are strongly dependent on not only flaw dimensions but also on cylinder sizes, strain-hardening properties and so on. However, adequate levels of integrity and safety would be assured when margins from the plastic limit load (general yielding) at a local metal loss area are used. Because keeping stress levels at the local metal loss area below the plastic limit load (general yielding) can preclude secondary damage such as ratcheting due to general yielding of the local metal loss area, which is detailed in reference [7].

A comparative study between API 579-1/ASME FFS-1 and the *p-M* method is introduced in this paper. This shows that the RSF approach in the level 1 and 2 assessments of Part 5 of

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