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Software Developed for Predicting Remaining Strength Factor (RSF) Under Pitting for Drilling Risers

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ABSTRACT

A software developed for determining the remaining strength factor (RSF) on drilling risers in the presence of pitting corrosion is presented in this paper. The software follows the methodology provided on API 579-1/ASME FFS-1 Part 6 and is adapted specifically to drilling risers. It bypasses API 579 level 1 assessment approach, based on visual comparison against pitting chart images, by the more stringent methodology proposed by API 579 level 2 assessment (pit couples' interaction). Using 3D scanned internal surface images where pitting is present, pits are categorized and modeled in terms of maximum diameters, maximum depths and minimum distance between pits. Moreover, using image acquisition and optimization subroutines, pit couples were selected based on the shortest distance among pits. Minimum ligament distance for pit couple's selection and a significant pit population are considered conservative methods for estimating the RSF under pitting. This software is intended for evaluating RSF on widespread pitting surfaces; however, it could also be used for localized pitting, pitting within a locally thin area, and a locally thin area in a region of widespread pitting. The software is intended to be an aid for inspectors and NDE engineers during fit for service evaluation of drilling risers under pitting. When pitting corrosion is above the threshold limits established for a level 2 assessment, a level 3 assessment involving Finite Element Analysis (FEA) is still required.

Key words: Pitting, fit-for-service, remaining strength factor, RSF, optimization, pit couples, image acquisition, traveling salesman, algorithm, subroutine, software.

INTRODUCTION

Depending on the operating conditions, drilling risers can encounter several types of internal corrosion mechanism, among them pitting corrosion. In the occurrence of pitting corrosion, the capacity of the riser to hold its design strength might decrease. The ratio between the reduced strength capacity as a result of wall thickness loss and the designed strength capacity is called remaining strength factor (RSF). ASME FFS 1/API 579 Part 6 is a recognized industry method for estimating pipes and pressure vessels' RSF under pitting. Depending on their severity, pits can be evaluated visually against pitting comparison charts (level 1 assessment), or by measuring pit dimensions and distance between pits (ligament interaction/pit couples-level 2 assessment) or using finite element analysis (FEA-level 3 assessment).

The software presented follows API 579-1/ASME FFS-1 Part 6¹ methodology adapted specifically to drilling risers. It bypasses API 579 Part 6 level 1 approach, based on visual comparison against pitting chart images, and instead follows the methodology proposed in API 579 Part 6 level 2 by measuring pit dimensions and establishing pit couples' interaction. API 579 Part 6 level 2 does not prescribe a specific methodology for pit measurements as it relies on the NDE inspector's judgement for selecting a representative pitting surface, determining the pitting type (widespread, localize, etc.), dimensional measurements, and entering the information into a database. It is important to note that the minimum number of recommended pit couples' measurements for assessing widespread pitting per API 579 Part 6 part 2 is 10. When evaluating pitting corrosion, one of the most challenging aspects is to obtain accurate pit measurements. Precise pit measurements on drilling riser can be lengthy, yielding to inaccurate results. Furthermore, most of the commercial programs for Fit-for-Service assessment (asset integrity programs)^{2,3} that follow API 579 Part 6 Level 2 pitting assessment guidelines, start their evaluation once pits dimensions are input manually into the program.

With this software, a 3D scanning tool⁴ was used for measuring the pit dimensions (internal surface mapping). The images obtained by the mapping tool were suitable for developing an API 579 Part 6 level 2 assessment. The internal surface topography was scanned in the X (longitudinal), Y (circumferential) and Z (depth) directions with a resolution for X=1 mm, for Y=1 mm and for Z=0.2 mm, respectively. The 3D scanned images were then exported as CSV files for post processing.

The post processing subroutine was performed using an in-house program, generated using Matlab®⁵. Image acquisition algorithms were used to process pit dimensions and distances among pits. A modified version of the traveling salesman optimization algorithm (TSA) was used to establish the minimum distance between pits and selecting the appropriate pit couples.

EXPERIMENTAL PROCEDURE

Process Overview

The overview of the process is as follows:

- Import image file and store it as an m type file matrix.
- Establish minimum pit depth assumption.
- Input initial operating conditions.
- Generate a tabulated matrix of pit dimensions.
- Run optimization subroutine for establishing the closest pit locations and determine pit couples.
- Input operational parameters
- Up to this point the program has calculated the up to date RSF. Next, the program can run a remaining life assessment unless instructed otherwise.
- Input the expected general corrosion rate for the remaining life.
- HTML Report is generated.

An overview of the methodology is shown in the following schematic:

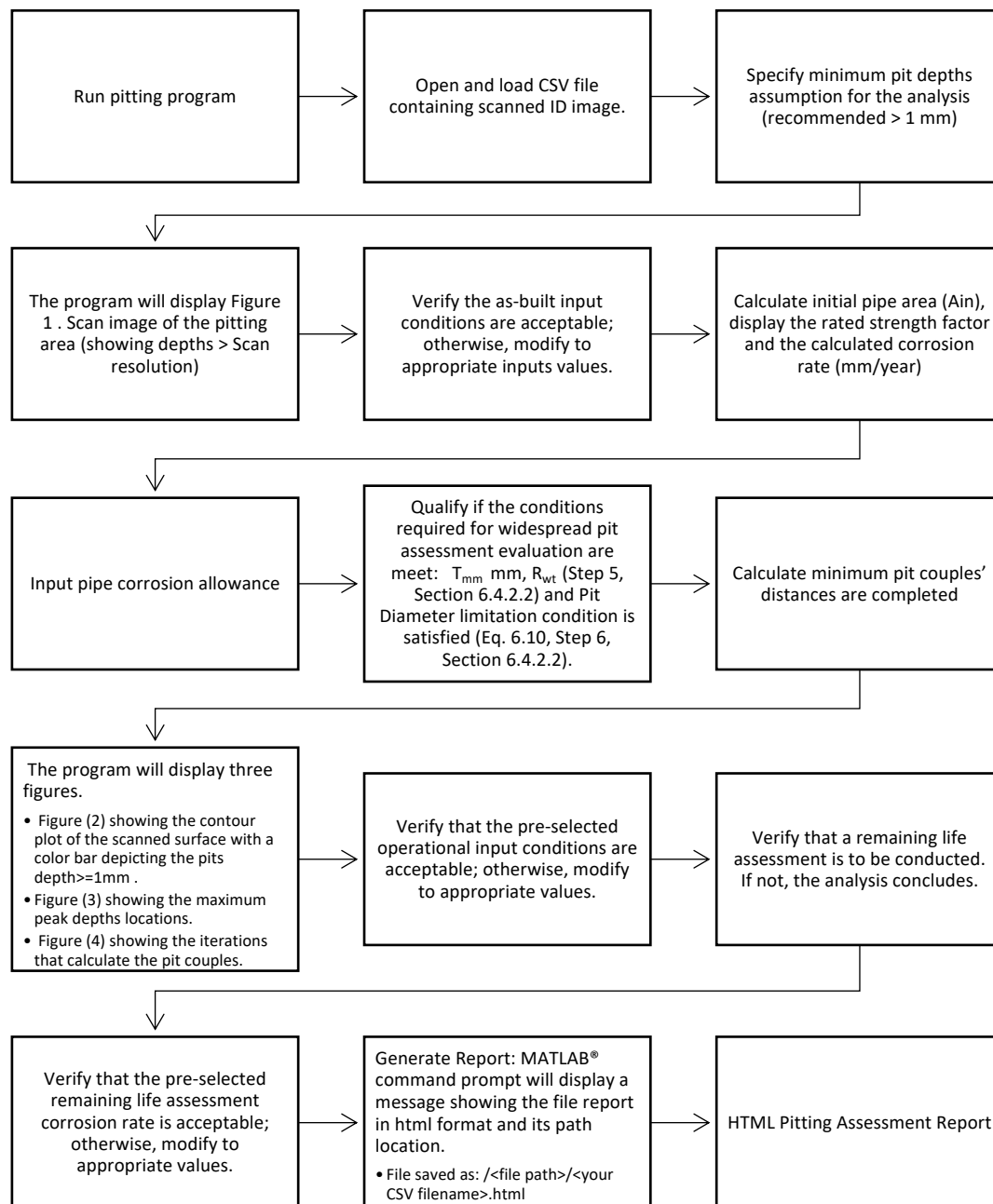


Figure 1: Program Sequence

API 579 Part 6 Level 2 Procedure Modified for Drilling Risers

This section presents the adaptations made of API 579 Part 6 Level 2 for evaluating the remaining strength factor of drilling risers. API 579 PART 6 Level-2 assessment provides a detailed analysis of pitting by considering pitting couples and its orientation with respect to the pipe axial direction.

The procedure for establishing the RSF under widespread pitting consists in 12 steps.

Step 1. Determine/measure pits diameter. Specify future corrosion allowance (FCA), current pipe wall thickness away from pitting area measure at the time of inspection.

Step 2. Establish the future corroded wall thickness away from the pitting area.

Step 3. Determine the pit-couple sample for the assessment. The geometrical parameters describing the pits utilized within this assessment level are diameter, depth, spacing and angle between pits.

Pit couples are then identified on the basis of the proximity among for each pit. Pit couples number are counted and referred by k , and corresponding pits are referred to by i and j . For each couple, P_k is the spacing between the two pits and Θ_k is the orientation of the line linking of two pits with respect to the pipe axis, $d_{i,k}$, $d_{j,k}$ are the diameters⁶.

Step 4. Determine the minimum measured thickness of each pit where $w_{i,k}$, $w_{j,k}$ are the depths of the two pits forming the pit couple.

Step 5. Determine the ratio of the remaining wall thickness to the future wall thickness for each pit.

Step 6. Check for pit diameter limitations.

Step 7. Determine the ratio of the remaining wall thickness to the future wall thickness for each pit couple.

Step 8. Calculate the components of the primary membrane stresses (longitudinal and axial directions).

Step 9. Determine the maximum allowable working pressure.

Step 10. Compute the RSF for each pit couple following Equations 6.13 thru 6.20 of API 579.

Step 11. Compute the average value of the Remaining Strength Factors of all the pit couples measured.

Step 12. Evaluate if the RSF results are acceptable by comparing with the allowable RSF.

The modification made for evaluating drilling risers are the following:

- a) Use of Von mises stress instead of membrane stress for evaluation.
- b) Use of calculated corrosion rate for calculating the FCA
- c) Calculation of as-built capacity at construction condition as allowable stress times the cross-sectional area of the rise.
- d) Ability for de-rating riser capacity, the required rating after de-rating is an input. Where the de-rated allowable RSF is equal to the derated capacity divided by the as built Capacity. This de-rated RSF is the allowable RSF for de-rated condition, and the calculated RSF for the next inspection should be higher than de-rated allowable RSF for the de-rated condition.
- e) Results are tabulated at the end of the report until the de-rated RSF is reached and also includes the pitting corrosion rate used for each year.

Methodology for Estimating RSF in Drilling Risers

This section presents the methodology used for estimating the remaining strength factor under pitting for drilling risers.