CORROSION AND FITNESS FOR SERVICE

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ABSTRACT

Corrosion can be responsible of many different damage situations for industrial components. Following API 579 (Fitness For Service) procedure, several types of damage can be due, or influenced by, corrosion. However, different corrosion mechanisms can be responsible for each damage form.

To estimate the residual life of an industrial component, the damage evolution must be described with a simple law, or model; the component stability is assessed taking into account the damage evolution.

In the design phase, the procedure outlined above is applied considering general corrosion as the active design mechanism. In such a situation, corrosion rate data for a given material-environment couple are available; corrosion allowance is estimated as an increase of the requested component thickness, and depends on the desired service life. Assessments are possible during life, depending on the inspection results (measure of thickness).

For localized forms of damage, only a limited number of data are available; materials can be qualified following their resistance to service conditions. When localized corrosion is influenced by mechanical and fluid dynamic parameters, provisional models often give scarcely reliable prediction of corrosion rate. In such cases, a probabilistic rather then deterministic approach can be suitable for the assessment of residual life and for inspection planning. Risk based inspection can be a powerful tool for dealing with corrosion damage.

INTRODUCTION

A possible definition of corrosion is: “A process due to chemical and/or electrochemical reactions occurring on a material (usually metal or alloy) in contact with an aggressive enviroment, that result in the degradation of the material properties”.

Corrosion is recognized as one of the most serious problems in modern industries and the resulting losses each year are in the hundreds of billions of dollars. Cost of corrosion studies have been undertaken by several countries (including, the United States[1], the United Kingdom, Japan[2], Australia, Kuwait, Germany, Finland, Sweden, India, and China). The studies have ranged from formal and extensive efforts to informal and modest efforts. The common finding of these studies was that the annual corrosion costs ranged from approximately 1 to 5 percent of the Gross National Product (GNP) of each nation. In Oil and Gas production, approximately 25 to 40% of failures are due to corrosion.

Assessment of residual life of old plants becomes of increasing importance due to strict environmental and/or safety requirements. In Fig.1, the fundamental steps of life prediction of industrial components are outlined.

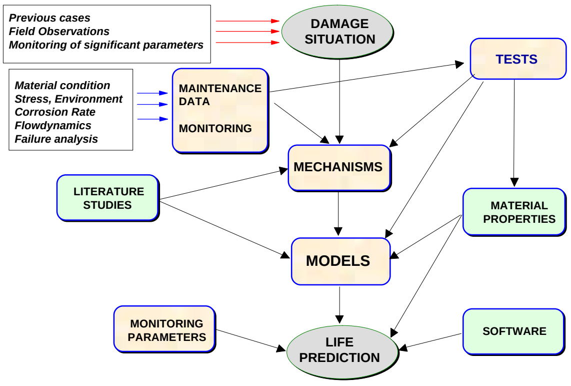
API 579 (Fitness For Service) procedure makes reference to several types of damage. The majority of them can be due, or influenced by, corrosion. They are:

- Tickness reduction
- Localized tickness reduction
- Pitting
- Blister / delamination
- Cracks

Each form of damage can be due to different corrosion mechanisms.

For components working in aggressive environments, the approach of FFS is considered in a simple way in the design phase. Corrosion allowance is estimated as an increase of the requested component thickness, and depends on the desired service life. In the design phase, localized corrosion is ignored, save for material selection. The procedure consists in selecting materials “immune” from the potential damage mechanisms. In inspection and maintenance, the assessment of the material behaviour during life are crucial. Field observation and studies provide tools for life prediction; however, while for engineering assessment of structural stability one can deal with reliable procedures and sound knowledge, when environmental effects are present the prediction of components life is difficult. There is a need of implementing the knowledge of models and damage mechanisms, making reference to previous experience. A probabilistic approach can be undertaken, which shows increasing reliability.

Fig.1: Schematics of life prediction



EXAMPLE - DESIGN PROCEDURE

Design of an industrial components is mainly compatible with a “safe life” philosophy: the components is expected to have a finite life, and only a few damage mechanisms are considered. These are – when applicable:

- General corrosion
- Erosion
- Creep
- Embrittlement

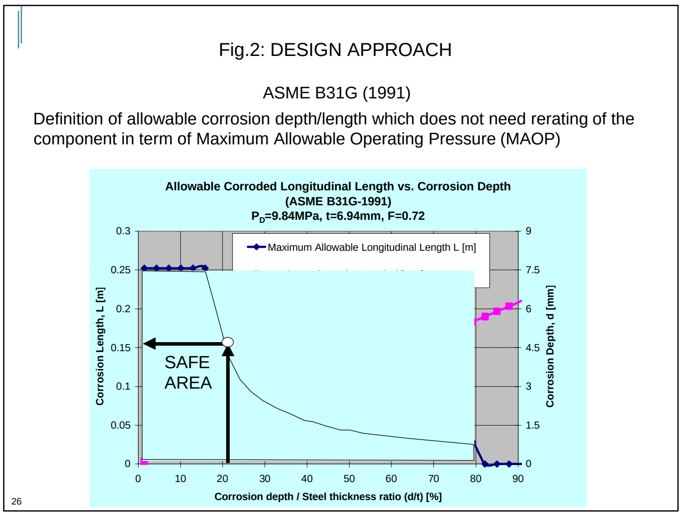


Fig.2: DESIGN APPROACH

ASME B31G (1991)

Definition of allowable corrosion depth/length which does not need rerating of the component in term of Maximum Allowable Operating Pressure (MAOP)

General corrosion, for instance, results in decrease of thickness. In the design phase, the total thickness of the component is calculated as the minimum necessary to ensure structural stability, increased by a safety factor, plus an extra thickness (corrosion allowance) which is estimated as a function of the requested life, provided that data are available of corrosion rate of the selected material in the process environment.

Assessments are possible during life, depending on the inspection results which allows to change the input data on corrosion rate (measure of thickness), as shown in Fig.2.

For localized forms of damage, the knowledge of materials properties is partial and only a limited number of data are available; materials can be qualified by laboratory tests to assess their resistance to service conditions. As an example, pitting is considered in that phase by the PREN (Pitting Equivalente Resistance Number), which derives from material chemistry. Here is the value for austenitic stainless steels:

$$PREN = Cr + 3.3\,(Mo + 0.5W) + 16N$$

Materials are selected for specific service contions following the calculation of PREN (the highest PREN, the highest resistance to pitting).

Following the new legislation approach, aimed at increasing free circulation of goods and at a greater emphasis on safety, during design phases there is an increasing request toward risk analysis.

EXAMPLE – PIPELINE CORROSION

The internal corrosion of oil pipelines is an important problem when the transported oil contains a water phase and a gas phase where aggressive species, such as CO_2 and H_2S, are present. The general corrosion is in that case enhanced by flow dynamic effects, so that localized forms are often observed (mesa corrosion), whose velocity can vary of more than one order of magnitude in different situation. Models are available and under development to calculate the corrosion rate as a function of the main parameter which can be measured and/or controlled during operations. In Fig.3 an example of the results from different models are shown. Two examples, referring each to a different field conditions, are shown.

The differences between models is high in terms of output corrosion rate; consequences on the design phase, such as on the life prediction, can be of importance.

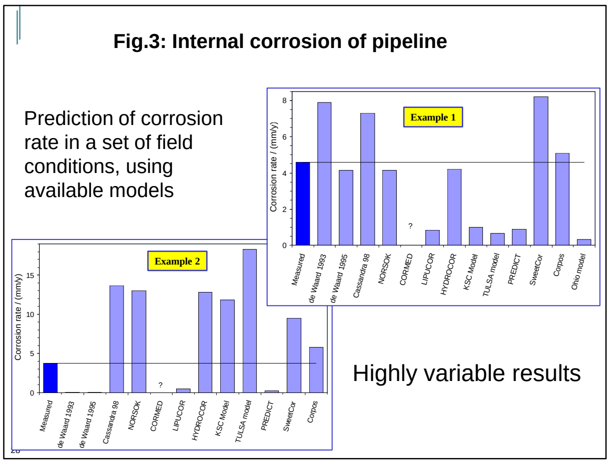


Fig.3: Internal corrosion of pipeline

Prediction of corrosion rate in a set of field conditions, using available models

Highly variable results

The deterministic approach described above can be however of easier use, if a probabilistic approach is also applied, as for Risk Based Inspection.

RISK BASED INSPECTION

Risk Based Inspection (RBI) is one of the most used method to manage risk, by making an informed decision on inspection frequency and level of detail[3]. The system can be applied for each mechanism that produces risk of failure (corrosion, mechanical, etc.). The calculated corrosion risk for a plant item is a combination of the estimated likelihood of failure due to corrosion and the consequence of that failure. When all the items have been evaluated, rankings can be developed by likelihood of failure and consequence results that can be plotted on a matrix, as the one shown in Fig.4, giving an indication of the level of risk for the unit being evaluated. A fully integrated RBI system should include inspection activities, inspection data collection, updating and continuous improvement of the system. The main advantages of RBI are:

- Better use of inspection resources
- Decrease of risk
- Cost reduction
- Contribution to change in standards and / or procedures

In fact, an amount of risk estimated as 80-90% of the total is associated with 10-20% of plant components.

Moreover, RBI can be applied to specific sets of items, such as for instance those where the same process is happening. RBI requires a multidisciplinary team and that is very useful in large plants.

Fig.4: Risk matrix

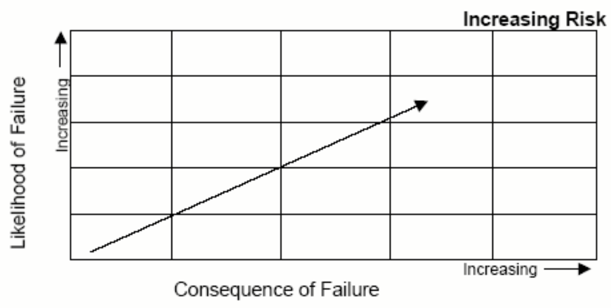


Figure 1. Generic Risk Matrix

CONCLUSIONS

Both in the design phase and in life prediction, it is necessary to know and model damage mechanisms. Corrosion is responsible of many different forms of damage, acting with different mechanisms.

If life prediction is based on structural stability of an inspected component, the engineering approach is simpler; when complex damage mechanisms depending on many variables, such as corrosion, the prevision of damage evolution is quite complex and much work is needed.

The use of a probabilistic approach instead than a deterministic one (RBI for instance, coupled with corrosion rate estimate) can be a useful tool for an integrated life prediction.

REFERENCES

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[1] www.corrosioncost.com

[2] “Survey of corrosion cost in Japan”, Committee on cost of corrosion in Japan, http://www.nims.go.jp/corrosion/Corrosion_Cost.htm

[3] Base Resource Document on Risk-Based Inspection, API 581, May ’96, Preliminary Draft