THE INFLUENCE OF THE DESIGN OF PIPES USED IN THE ENERGY INDUSTRY ON THE SLOWLY OF EROSION / CORROSION PROCESSES

Lecturer PhD. eng. Florin CIOFU,
Engineering Faculty, "Lucian Blaga" University of Sibiu

ABSTRACT: Interruptions in the operation of the installations and machines in the energy industry are caused in most cases by the inevitable effects of erosion / corrosion processes in pipes, basins, reservoirs or heat exchangers. The materials (metals or alloys) used in the construction of energy equipment and not only are in contact with the different chemical media with which they interact (atmospheric air, water, steam, chemicals), the result of this interaction being erosion and corrosion of the metal product. The simultaneous action of the mechanical stresses and the corrosive environment manifests differently on the metallic materials, depending on the nature of the metal-environment couple, leading to substantial changes in their behavior towards the situation where the influence of the working environment was neglected or it was considered inert. In order to ameliorate these defects, several design solutions have been analyzed and proposed so as to avoid such phenomena by extending the service life of the component parts of the energy machines.

KEY WORDS: erosion, corrosion, pipe, energy, fracture

1. INTRODUCTION

The deterioration during the operation of the component parts of the energy equipment (pipes, basins, reservoirs, turbines, heat exchangers, joints) can be found in all energy plants, having both consequences on the safety conditions in operation and on the additional costs with repair. and restart. Faults that have been reported and reported by both power plants and regulatory agencies have indicated that certain pipeline systems have deteriorated and deteriorated especially when exceeding the pressure limits, mainly caused by cracks caused by erosion / corrosion processes or fatigue [1], [2], [3].

Erosion / corrosion is a form of degradation of a metal material caused by the flow of a fluid, which initially wears the protective film of oxide due to the rapid flow of water or steam (the erosion process) and then continuously dissolves the remaining material discovered (the corrosion process).).

Carbon steel pipes are more vulnerable to erosion / corrosion than austenitic steels. Two examples of typical piping systems that suffer erosion / corrosion defects in electrical plants are those from the water supply system and the external steam generator cooling system [4]. Fatigue, which leads to the cracking process, is another form of degradation of metallic materials, being caused by cyclic loads that produce surface or depth cracks as well as discontinuities of the material, especially in welds. Both low and high cycling loads contribute to fatigue breakdown.

Joints (fittings) welded to joints for small diameter pipes are more exposed to damage than continuous joints, the explanation being the inherent stress created by undetectable welding defects (incomplete filling of the welding joint or the root of the weld. If both processes erosion / corrosion and cracking occur at the same site of the pipeline, the degradation and destruction of the material are accelerated concomitantly, in order to estimate the residual life of the power plant installations, the inspection, surveillance, monitoring and testing of models are used during the operation [5].

The present work offers some design solutions of the pipe joints, which will prolong the operating life in safe conditions and prevent the occurrence of erosion / corrosion or fatigue cracking phenomena.

2. INITIATION OF DATA COLLECTION

A prerequisite for developing a model of degradation during operation and for calculating the detection of defects in the estimation of the residual life is the collection of design data of the pipes and the conditions of effective installation and the record of their loads during operation [6].

2.1. Design data for pipelines and installation conditions

To begin with, it is necessary to evaluate the design and the conditions of installation of the pipes, including the results of the load analysis and the record of the exceedance of the effort limits in the pipes. The analysis of the load implies the knowledge of the maximum load capacity, the thermal dissipation, the dynamic demands. In the case of pipes of similar geometry, such as different elbows of the water supply pipes, the results taken from all similar points can be compared with the most critical of them, which will be selected.

2.2. Analysis of pipe loading operations

The analysis of the loading operations of the pipes includes those defects that were not taken into account from the design point of view, when designing them. This analysis includes:

- Erosion / corrosion - current methods of preventing erosion / corrosion damage are focused on the inspection / surveillance programs of the plants, for the evaluation of the residual life.

- Minimum operating temperature - if a portion of the pipeline analyzed is exposed to overheating or is outdoors, then the planned minimum ambient temperature should be determined to find the mechanical cracking data within the estimated lifetime.

- Thermal transition - are not explicitly evaluated for all types of pipes in the specialized documentation.

- Stationary vibrations during cyclic loading - it is necessary to determine the effect of the possible stationary vibrations in the installed pipes, especially for small diameter pipes.

2.3. Defining material properties and defects

The information received from the power plants and regulatory agencies that describe the properties of the base material and the welding material are analyzed for a relist selection, but preserving both the standard strength parameters of the material (flow resistance, elasticity) according to ANSI and the reference data of the cracking mechanics (fracture resistance, impact test).

Of particular importance is the analysis of the material damage data due to erosion / corrosion and aging in an aggressive environment.

3. ESTIMATION OF RESIDUAL LIFE

The residual life of the degraded pipes in operation, in terms of the remaining thickness of the "t_f" pipe walls is estimated at the end of a certain period of operation. The remaining thickness of the walls is evaluated based on the increase in radial degradation currently measured "a_m" and the extrapolated growth "a_e" during the future operating period. The minimum permissible wall thickness is expressed in terms of the nominal wall thickness "t" divided by the required reduction factor of the "R_F" wall thickness, taken from the plant design or the maintenance specification in case of erosion / corrosion wall thinning. or fatigue breakdown. The remaining wall thickness for a safe life is acceptable if it is greater than the minimum permissible wall thickness calculated by the formula [6]:

$$t_f = (t - a_m - a_e) \geq 1/R_F \quad (1)$$

3.1. Modeling the cross section of the damage

Based on the data taken from the cases of malfunctions that occurred during operation, the main types of degradation and defects are:

- Local channels inside pipes and pipe fittings, erosion / corrosion products through flowing fluids;

- Cracks of welded joints, caused by low or high cyclic loads. The low critical cyclic loads are: the thermal transit during the heating / cooling of the pipes and the high cyclic loads are the stationary vibrations that are transmitted from the rotating subassemblies or from the flow of fluids through the pipes.

In the example of deterioration caused by erosion / corrosion shown in figure 1, the specific extension of the deterioration in circumferential and longitudinal directions was considered.

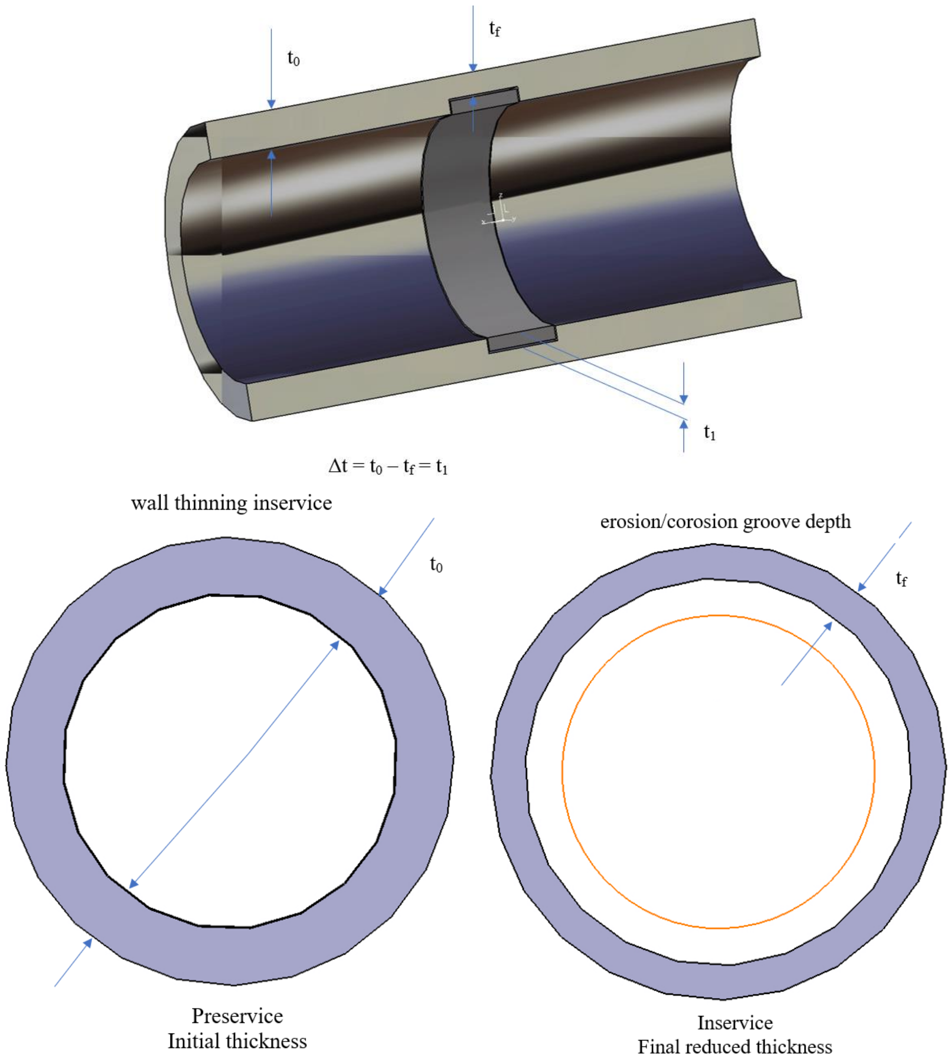
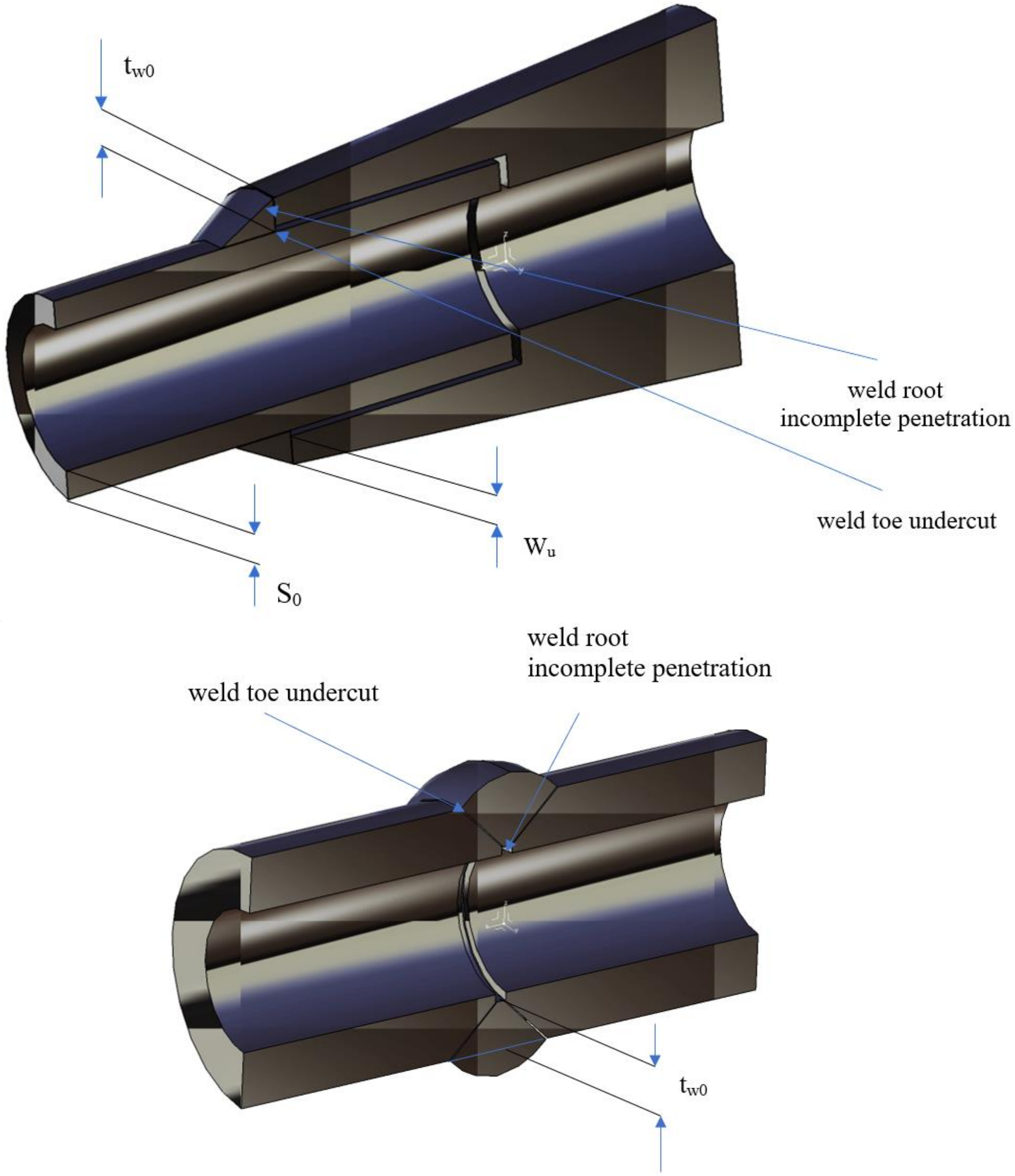


Fig.1. Defects that occur during erosion / corrosion

The cases in which the crack is caused by fatigue in the welded joints and which have discontinuities of the surfaces, detected or not, are shown in figure 2. The deterioration of the wall will appear in the eventual discontinuities of material at welds. The internal deterioration of the weld is caused by the incomplete penetration of the weld root.



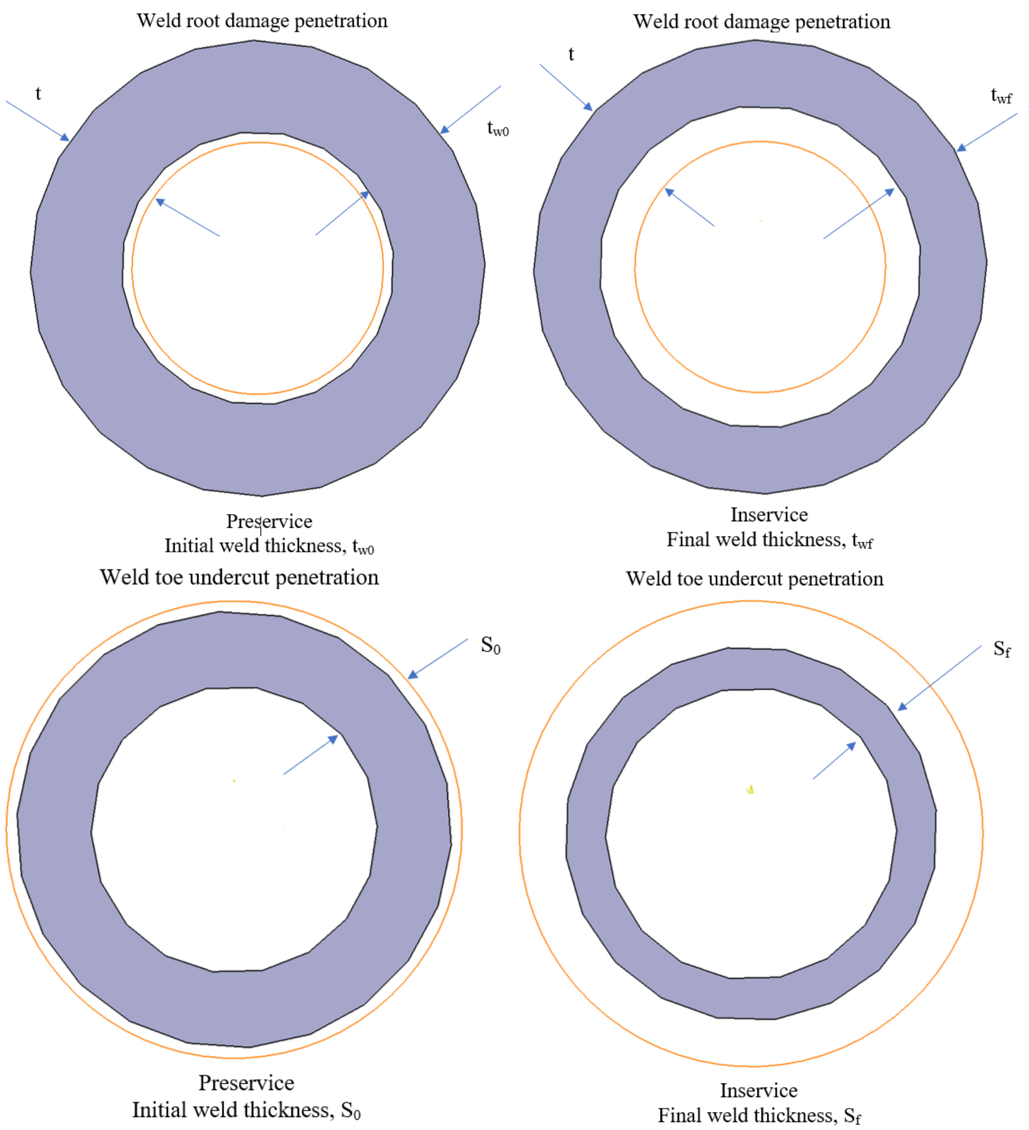


Fig.2. Defects that occur due to the design of welded joints: a - socket weld; b - butt weld.

3.2. Calculation of penetration by extrapolation of penetration

The penetration of the degradation in the identified critical section is determined based on the specific rate of erosion / corrosion (da / dt) and the rate of cyclic growth of the crack in fatigue (da / dN), where "a" is the penetration of the existing degradation, "t" is time and "N" is the number of loading cycles. The erosion / corrosion rate of steels is not constant over time and varies with the exposure time.

Correct penetration is obtained by extrapolating the successive measurements of the specific thickness of the pipe wall. The analytical methods developed by Sanchez-Keck are used for a preliminary estimation of the deterioration. The worst damage penetration rate is configured according to the graphical solution of the function [7]:

$$da/dt = f(pH, O_2, T, v, G, C_0) \quad (2)$$

where:

pH = water aggression;

O_2 = amount of dissolved oxygen;

T = fluid temperature;
v = fluid flow rate;
G = flow geometry;
C_0 = resistance of the material to erosion / corrosion expressed by the standard chemical composition.

The subcritical penetration of the crack for the given operating period is evaluated on the basis of the "Paris law" of the increase of the cyclical flow:

$$dA/dN = A[K_1(max) - K_1(min)]^m \quad (3)$$

where:
K_1 (max) and K_1 (min) = limits of fluctuation of stress intensity factors;
A, m = material constant;

3.3. The acceptability

The residual life of the analyzed pipes is determined based on the conformity of the remaining wall thickness calculated with the acceptance criteria indicated in the regulations. If the penetrations of the surface deterioration calculated at all the cross-sections fall within the allowed limits, then the structural integrity of the analyzed pipes is accepted for use in the following operating conditions. Otherwise, the reduced cross section of the pipe / weld is unacceptable within the safety limits required in the design and the loads during operation.

4. CONCLUSION

The analysis method presented in this paper is applied for estimating the residual life of the pipes, taking into account two processes of deterioration of the pipe defects: corrosion / erosion and cracking caused by fatigue. In practical applications, this method recommends estimating minor surface damage, not detected by inspections, if no major wall degradation was measured. The estimation calculations must be validated by periodic inspections during operation.

REFERENCES

[1] ANSI B31.3, (2003), Code for Pressure Piping, American National Standard Institute.
[2] ANSI/API 575 (1995), Inspection of Atmospheric and Low-Pressure Storage Tanks, 1st Edition, American Petroleum Institute.
[3] ANSI/API 651 (1997), Cathodic Protection of Aboveground Petroleum Storage Tanks, 2nd Edition, American Petroleum Institute.
[4] API RP 577 (2004), Welding Inspection and Mettalurgy, 1st Edition, American Petroleum Institute.
[5] API RP 580 (2002), API Recommended Practice 580, Risk-Based Inspection, 1st Edition, American Petroleum Institute.
[6] Corrosion and Anticorrosive Protection, Vol.V, No.3, 2010, pag.22.
[7] API 570 (1998), Piping Inspection Code: Inspection, Repair, Alteration and Re-rating of In-service Piping Systems, 2st Edition, American Petroleum Institute.