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APPROACH TO EVALUATION OF TIME TO THE CRITICAL DEGRADATION OF SHIP PIPELINES

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Abstract

In the article an approach to the problem of estimating time to the critical degradation of ship pipelines is considered. Such an assessment would consist of six stages. The fundamental idea is to include to the estimation of time to failure of pipelines such elements like: materials that the pipelines are made, destructive physical phenomena taking place in them and applied means of protection. The result of that evaluation should be mean time to critical degradation of pipeline. The mean time should be given with the measure of the spread like the standard deviation. Another possibility is to express the time to failure in the form of a fuzzy number. This would indicate uncertainty of the estimation.

Key words: *reliability, pipeline, critical degradation, destructive phenomena*

1. Introduction

This article is a continuation of the work presented in [1]. The final goal is to develop a method to assess the reliability of marine pipelines. The method should take into account the destructive physical phenomena taking place inside and outside of pipelines. The input data for the created model should be: properties of transferred media, properties of the surroundings, pipeline material properties and undertaken means of protection. The computational model can be based on hypothesis of deterioration of the mechanical characteristics of material which leads to the use of the rights of oxidation kinetics of metals.

Assuming in advance, that it will not be possible to precisely determine the degradation rate of the pipeline elements leading to system failure events, the possibility of application of fuzzy logic is also taken into account. The article is the next step to further, more detailed considerations how to solve a given problem.

2. Time to critical degradation of the pipeline

The marine pipelines include numerous and different types of devices such as pumps, filters, heat exchangers. In addition: pipes, fittings, pipe connections, gaskets and control - measurement equipment. At the beginning let confine ourselves to the elements not very complex like tubes and fittings.

The critical degradation of a component of a pipeline can be understood as the occurrence of perforations, achieving the minimum wall thickness or achieving an unacceptable size of the damage.

The expected mean time to failure should be given with the measure of the spread like the standard deviation or should be expressed in the form of a fuzzy number. It is very important to indicate uncertainty of the estimation. Evaluation of the time to failure is done in order to make decisions about the preventive maintenance. A large standard deviation of mean time to failure makes it difficult to determine the appropriate time to maintenance. A small standard deviation makes it easy to specify the time for preventive maintenance, what is shown in the Fig.1.

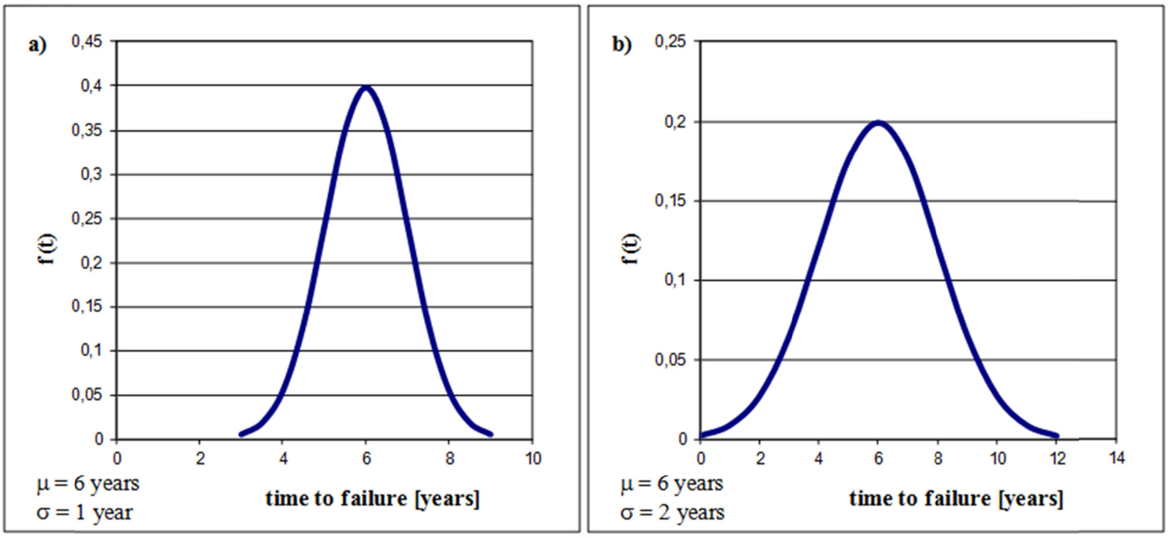

Fig.1. The importance of standard deviation for making decisions about time to preventive maintenance

In the case a) it is easy to conclude that the time for preventive maintenance should be about 4 years. In the case b) it is very difficult to make the right decision.

3. The steps of determining time to critical degradation of the piping components

Ship pipelines are destroyed from the inside and from the outside. Piping degradation processes depend on the ambient conditions and on the nature of the transported medium. The intensity of degradation can be reduced by applying of protective measures. The idea of determining time to critical degradation of the piping components is presented in Fig.2.

In the first step we should to recognize the properties of the transported medium, the properties of the material the component is made and the properties of the component surroundings. Transported medium can be for example: sea water, fresh water, fuel oil, lubricating oil, air, exhaust gases, steam, bilge water. Important properties of a piping component may be: the material from which it was made, diameter, wall thickness, type of connection used, seals, shape, the presence of different metals. In the external environment can be the air, sea water, fresh water, bilge water, fuel oil, lubricating oil and so on.

However, it is not enough to determine what substances are inside and outside of the pipe. Equally important are their parameters such as temperature, pressure, flow speed. Their values vary with time. In the further work it will be necessary to decide whether to accept constant values of those parameters, or take into account their variability over time. The second approach seems to be more appropriate, but it may be too difficult. At the moment it seems reasonable to use the hypothesis: “Deterioration of the object’s state with varying parameters of factors affecting the object occurs with an average intensity, determined with the use the average values of those parameters."

In the second step destructive phenomena affecting the state of the pipeline should be reviewed. Those phenomena include: uniform corrosion, pitting corrosion, abrasion, erosion, galvanic corrosion, graphitic corrosion, fatigue damage, stresses imposed by the assembly or temperature changes, water hammer and other. The damaging impact of them was described widely in the literature [2, 3, 4, 5, 6, 7] and summarized in [1]. In order to simplify the future calculation model we should not considered all the phenomena. The final result of the second stage should be a set of the most important phenomena, from the point of view of the lifetime of the element in question.

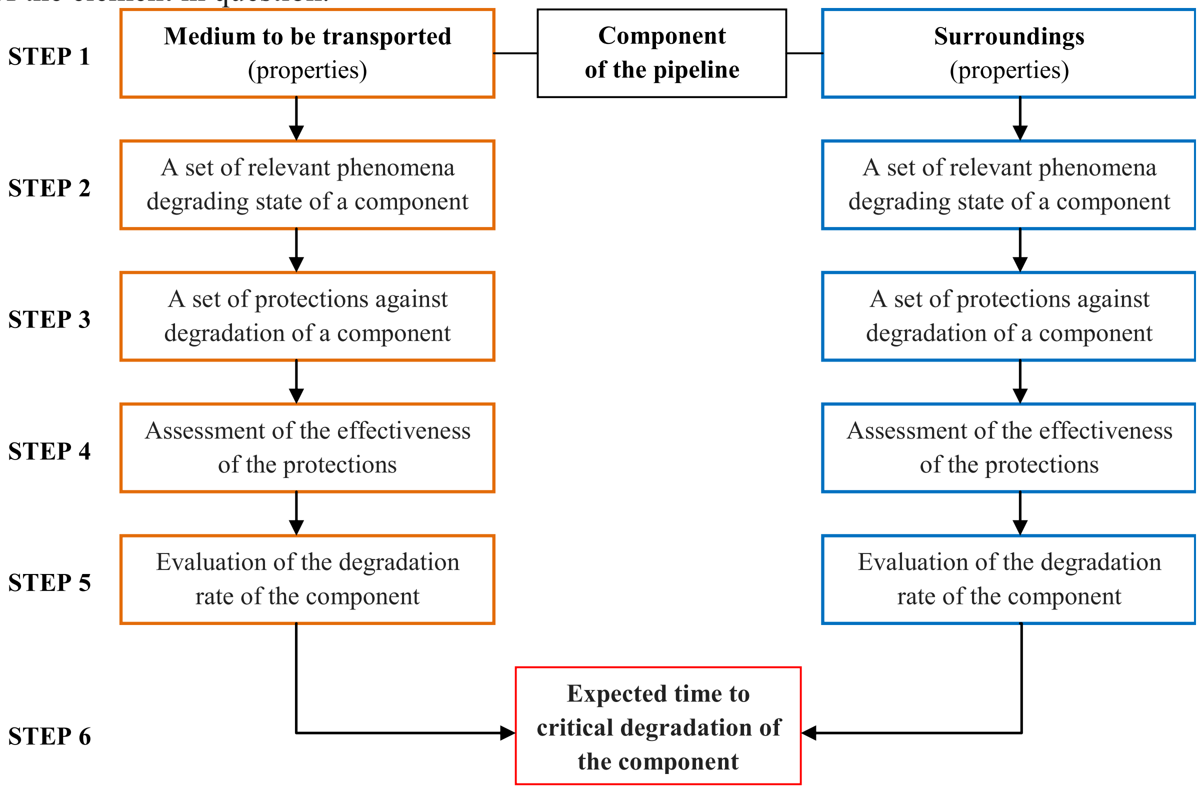

Fig.2. The steps of determining time to critical degradation of the piping components

The third step is to review possible means undertaken to protect the pipeline against damage. There are three possible ways to increase the lifetime of the object. The first is to increase strength (immunity) of the object. The second is to reduce the load on the object. The third is to reduce the speed of deterioration of the properties of the object. Reducing the rate of deterioration of object properties can be achieved by applying coatings (passive, active); protection (cathode, anode); modifying the environment (dehumidification, oxygen depletion, inhibitors); adequate medium flow velocity. The output result of the third step should therefore to be a list of the methods used to protect the considered component of the pipeline.

In the fourth step, it is necessary to assess the effectiveness of the selected protection means. The efficiency could be expressed as the ratio of the rate of degradation of the protected item to non - protected item. A good units of rate of degradation seems to be a decrease in diameter in mm/year, or loss of weight in g/year. The protectors, like a pipeline, are also subject to degradation during operation. The other important task then is to build models to assess the loss of effectiveness of protection means depending on the time and environmental conditions.

In the step five the rate of degradation of the element should be assessed. It must be taken into account previously discussed: materials that the pipelines are made, pipeline environment condition, destructive physical phenomena taking place in them, applied means of protection. The task will be difficult because of the complexity of the problem. The output of the fifth step should be in the form of equations similar to the metal oxidation kinetics lows. The linear oxidation low is given below [8]:

$$\frac{\Delta m}{S} = k_1 \cdot t + C \quad [\frac{g}{cm^2}] \tag{1}$$

where:
Δm [g] - the weight loss of the metal in time t,
S [cm^2] - the surface area of the metal exposed,
k_1 [$g/(cm^2 \cdot s)$] - linear rate constant for metal oxidation,
t [s] - time of exposure,
C [g/cm^2] – integration constant.

There are also described other metal oxidation lows like: parabolic, cubic, exponential and logarithmic oxidation lows [8]. To use such equations it is necessary to determine the values of the rate constants of oxidation and the nature of the law. It can be done only experimentally. Therefore there is a need to build test stand. Similar relationships must also be developed for the other destructive phenomena.

The last step is to calculate the mean time to critical degradation of pipeline's component. It will be possible knowing the rate of destruction. The mean time should be given with the measure of the spread like the standard deviation. If the determination of the standard deviation will not be possible then the other possibility is to express the time to failure in the form of a fuzzy number. This would indicate uncertainty of the estimation. Uncertainty is the result of the adequacy of the adopted model and the accuracy of determining the constant values of equations describing the destruction rate.

4. Final remarks

In order to solve the given problem the knowledge of the existing models to assess the degradation rate of the piping components related to the different variations of corrosion must be expanded. Models to assess the degradation of pipelines' components as a result of other destructive phenomena (erosion, abrasion etc.) should be created. The most difficult task will be to develop models to describe the degradation rate of the provided protection means of the pipeline and their effectiveness. The issue presented in this article opens up wide possibilities for further research, in the theoretical and experimental area.

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