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THE POSSIBILITIES OF ESTIMATING THE RELIABILITY OF SHIP PIPELINES' ELEMENTS INCLUDING DESTRUCTIVE PHENOMENA ACTING ON THEM

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Abstract

In the article an approach to the problem of estimating reliability data based on physical models is proposed. The possibility of reliability assessment for selected elements of ship pipelines, based on the recognition of the destructive physical phenomena taking place in them, is discussed. To do this, an overview of these phenomena has been made. In addition, a preliminary review of existing measures of destruction of materials has been made to check their suitability for possible use them to solve a given problem. The article is an introduction to further, more detailed considerations.

Key words: *reliability, pipeline, ship power plant, a destructive phenomena*

1. Introduction

The article is related to the works on designing marine power systems on the given reliability level. To solve the problem it is necessary to show the ways of building mathematical models of reliability and methods of obtaining reliability data, which are the inputs to the models.

In the author's opinion, the first sphere of issues related to the construction of such models is already well developed. In the available literature the methods for quantitative assessment of reliability are widely described. The models are based on the reliability structure methods, fault tree and event tree methods. A much bigger problem is obtaining the necessary reliability data for the items included in the pipe systems located in ship power plants. Therefore on this issue it is worth to pay much more attention.

In previous works, the author's attention was focused on solving the problem of obtaining reliability data based on the small number of data, using a variety of methods, including fuzzy logic and the possibility theory.

In the article a different approach to the problem is proposed. The possibility of reliability assessment for selected elements of ship pipelines, based on the recognition of the destructive physical phenomena taking place in them, is discussed. To do this, an overview of these phenomena has been made. In addition, a preliminary review of existing measures of destruction of materials has been made to check their suitability for possible use them to solve a given problem. The article is an introduction to further, more detailed considerations.

2. Is it worth to deal with reliability of pipes and fittings?

The marine pipelines include different types of devices such as pumps, filters, heat exchangers. In addition: pipes, fittings, pipe connections, gaskets and control - measurement equipment. Pipelines are essential for the transport of liquids and gases, which are necessary for the operation of the main engines, generators, boilers, and many other marine systems. The pipelines are located in the machinery space but also out over the deck and in the holds.

Due to limited access, the marine crews don't pay proper attention to the technical condition of pipelines with the exception of mandatory surveys. Such situation leads to an unexpected failures of the pipelines that can cause adverse effects such as fire, harm for people, equipment damage, environment pollution, flooding of ship compartments, or in the worst case, even total loss of the vessel.

The rules of classification societies focus on pumps and filters. For the main engine systems the redundancy of pumps is required. The use of duplex filters or self-cleaning filters is required to avoid the need to stop the main engine during the cleaning of filters. These requirements are reasonable, because pumps and filters are the most unreliable elements of ship pipelines.

The author's intention is to focus on the other components used in the piping systems such as straight sections of pipes and fittings. They also are very important from the point of view of the reliability of the ship power plant. To prove it, it's enough to compare the reliability data published in [1]. The average failure rate for pumps, heat exchangers and valves is given in the Table 1.

Tab.1. Failure rate for pumps, heat exchangers and valves [1]

Item	Failure rate	Reference time
Pumps	$\lambda = 106.03 \cdot 10^{-6}\ h^{-1}$	calendar time
	$\lambda = 217.09 \cdot 10^{-6}\ h^{-1}$	operating time
Heat exchangers	$\lambda = 6.03 \cdot 10^{-6}\ h^{-1}$	calendar time
	$\lambda = 9.08 \cdot 10^{-6}\ h^{-1}$	operating time
Valves	$\lambda = 12.39 \cdot 10^{-6}\ h^{-1}$	calendar time
	$\lambda = 16.99 \cdot 10^{-6}\ h^{-1}$	operating time

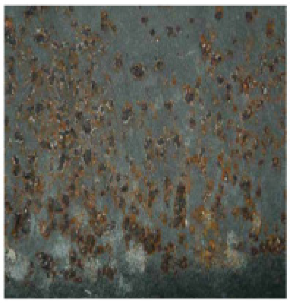
Looking at the results shown in the Tab. 1 it can be seen that: 9 valves connected in series gives a failure rate of greater than one pump (taking into account the calendar time), 13 valves connected in series gives a failure rate of greater than one pump (taking into account the operational time). Because in marine pipelines they are usually installed one, two or four pumps and a few or more than dozen of valves, so we can conclude that their reliability is very important for the reliability of operation of these systems. Responding to raised at the beginning of the chapter question we can say with certainty, that it is worthwhile to pay attention to the reliability of fittings and pipes.

3. Destructive phenomena in marine pipelines

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. Destructive phenomena described widely in the literature [2, 3, 4, 5, 6, 7] 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.

Uniform Corrosion spreads evenly over the surface of the metal. The intensity of corrosion depends on the humidity, temperature, salinity and oxygen availability. Pitting corrosion occurs in the areas where the layer of material protecting the pipe has been damaged. It is characterized by the formation of pits or holes of small diameter. Abrasion occurs when solid particles such as sand or other contaminants contained in the liquid stream rub against the tube material. In this way they destroy the protective layer, and this may result in uniform corrosion or pitting. Erosion is caused by the turbulent nature of the flow of liquid inside the pipeline, when the liquid hits the pipe material. Electrochemical corrosion is the result of contact between two different metals, if there is a possibility of current flow between them (via the electrolyte). Graphitic corrosion is typical for the cast iron. The iron in the cast iron gradually oxidizes and turns to rust, which together with the petals of graphite creates a porous coating inside the pipe. Water hammer is typical for steam pipes, but it can affect any pipe when the draining of fluid is not proper. Fatigue damage is caused by periodically varying stresses occurring in the material of the pipeline caused by connection with vibrating machines. The stress in the material of the pipe can also be caused by faulty assembly or temperature changes. An important problem is also the deposition of residues inside the pipe. The effects of destructive phenomena in pipelines are shown in Figure 1.

Uniform corrosion [2]



Pitting corrosion [2]

Abrasion [3]

Erosion [4]

Electrochemical corrosion [5]

Graphitic corrosion [6]

Expansion joints on a steam line that have been destroyed by water hammer [7]

Temporary wooden plug in steam line [2]

Fig.1. The effects of destructive phenomena in pipelines

4. Possibilities of shaping the reliability of pipelines by a designer

There are two groups of factors that determine the reliability of pipelines. In the first group, the designer has no impact on the reliability or that impact is very limited. In the second group of factors, decisions taken by a designer are very important and they have a significant impact on the final reliability of pipelines.

The first group includes the type of transported medium such as: sea water (cooling water, ballast water, water for vacuum evaporator); fresh water (cooling water, feed water for boilers and feed water for hydrophore system); fuel oil (heavy fuel oil, light fuel oil); gas (LNG); lubricating oil (cylinder oil, system oil); air (starting air, control air, intake air); the exhaust gases; steam; bilge water and others. In addition to the type of transported medium the lifetime of pipelines is determined also by physical parameters such as; pressure, temperature, salinity, content of impurities etc. Besides, the external conditions have an impact on the reliability of pipelines. Thus the designer possibilities here are very limited.

The second group includes: the material from which the pipes and fittings will be made; diameters and wall thickness of pipes; types of connections (joints, welds, flanges); types of seals; a way of laying the pipeline (number of bends, elbows); the contact of different metals; protection against corrosion (passive and active methods). It is clear, that in this group the designer decides of applied solutions. Therefore, the designer has a significant impact on achieved reliability level of ship pipelines.

5. Reliability assessment of pipelines including destructive phenomena acting on them

The idea of such an approach to reliability assessment the of marine pipelines stems from problems in obtaining the reliability data. The failure rate for pumps, heat exchangers and valves, used in the second chapter, has been estimated for the offshore installations. There is no such data for ship systems for public use. That' s why, in the previous works [16, 17], the author's attention was focused on solving the problem of obtaining reliability data based on the small number of data, using a variety of methods, including fuzzy logic and the possibility theory.

Furthermore, the data contained in [1] does not take into account the type of material and thickness of the valve bodies. Use the failure rate as the reliability data - implies the necessity of the use of the exponential distribution for reliability assessment. This distribution is appropriate for components exposed to accidental damage, which have a constant failure rate in time. Meanwhile, the condition of ship pipelines mostly is deteriorating gradually as time goes, under the influence of destructive phenomena such as corrosion. Thus, the problem will be the object of consideration in further works.

Estimating the reliability of pipes and fittings, taking into account destructive phenomena occurring in them, should be based on the mathematical models developed for this purpose. The input data for computational models should consist of: the type of transported medium, the parameters of the medium, the material from which the considered element was made, the phenomena occurring inside the pipeline, environmental conditions outside the pipeline, means of active and passive protection used to protect the pipeline. The mathematical model should reflect the impact of those data on the lifetime of the pipeline component being under consideration. The output of the model should be: a time to reach the limit technical state of element (for example a wall thickness of the pipe or valve), and the time to perforation or other kind of damage.

According to preliminary considerations of the author - the estimation of reliability should consist of the following steps: determining the properties and parameters of the transported fluid or gas; determining the properties and parameters of the external environment; overview of pipes and fittings (material, wall thickness); overview of used passive and active protective means, creating a list of the most important phenomena degrading state of the protective means; estimating the velocity of the degradation of protective means; creating a list of the most important phenomena degrading state of the pipe's material or fitting's material; estimating the velocity of the degradation of the material; assessment of the acceptable time in service of the pipeline section being under consideration.

The creation of such models will be difficult. First of all, the conditions inside and outside the pipelines are variable in time. Secondly a lot of factors affect the lifetime of pipelines. The person making the analysis will have to choose the most important ones and evaluate their destructive potential. And that is the most essential task to perform in the future works.

Based on textbook [8] it is known that the average lifetime of marine pipelines transporting water is: 5 to 7 years - for galvanized steel pipes, 5 to 9 years - for copper pipes, 20 or more years - for copper and nickel alloys pipes, about 20 years - for the polyvinyl chloride pipes.

Such data are indicative. In order to estimate the reliability of the pipelines the degradation rate should be more accurately determined. Methods of corrosion rate calculation are good examples here. The rate of corrosion is the speed at which a metal deteriorates in a specific environment. The rate, or speed, is dependent upon environmental conditions as well as the type, and condition, of the metal [15]. Average corrosion rate can be expressed by: mass loss in g/m^2 ·24 h, the loss of the dimension of the test specimen in mm/year, and as a percentage. Corrosion resistance of the material shows Tab.2.

Tab.2. Corrosion resistance of material [11, 12]

Group	Average corrosion rate [mm/year]	Material resistance
I	0.001	completely resistant
II	0.001 - 0.01	very resistant
III	0.01 - 0.1	resistant
IV	0.1 - 1	less resistant
V	1 - 10	low resistant
VI	>10	not resistant

The ability to assess the loss of material in mm/year would be very useful in assessing the reliability of marine pipelines. However, one should develop a method that will take into account not only the corrosion. The method should take into account the previously discussed factors such as: material properties, the properties of the transported medium, environmental conditions, and of course destructive phenomena.

6. Final remarks

Ship piping systems are essential for the safe operation of the vessel. Hence the need to establish their reliability at a sufficiently high level. To do this, it is necessary to recognize the phenomena that occur inside and outside the pipelines. In addition, we should examine their destructive effect on the lifetime of pipelines.

This problem is complex and requires extensive theoretical and practical studies. It is necessary to consider a few of media being transported, many physical and chemical phenomena, many materials from which ship pipelines are built.

As it has been said above, the loss of material of pipe or fitting body expressed in mm/year seems to be a very useful measure in assessing the reliability of marine pipelines. But the problem arises - how to transfer the results of theoretical considerations, retrospective studies and studies made in laboratory conditions for real conditions during operation of pipes.

This article is an introduction to future research in this area.

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