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SCANNING THE FUEL TANKS' CORROSION LOSS OF SOME AGED BULK CARRIERS DUE TO THE SECURITY REASONS

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ABSTRACT
This paper deals with modeling corrosion wastage over the fuel tanks' structures at the exemplar of ten aged bulk carriers. In this paper employed method might be treated as a long term one, and it is based on some Weibull distribution and its parameters analysis. The purpose of these analyses is optimal assessing of the average corrosion losses for the bulk carriers' fuel tanks areas at different points of time during the whole circle of the exploitation, within the ultimate goal of uprising the structural stability and safety of bulk carriers in operation.
Key words: bulk carriers, fuel tanks, corrosion wastage, Weibull distribution analysis

1. INTRODUCTION
It is well-known that the corrosion is a serious problem for anything built of metal and exposed to the elements, but for any kind of ships, including here bulk carriers, it can be fatal. Corrosion is likely to be more extensive here and work more rapidly than on other structures, simply because the bulk carriers are under the complex influence of salt water, and simultaneously exposed to some unpredictable atmosphere, cargo and ballast effects. More precisely, aggressive environment, specifics of the trade routes, dry and wet ballast circles, ratio of ballast and cargo, frequencies of cargo loading/unloading operations, manipulative techniques, etc. often affected serious bulk carriers' deteriorations caused by the corrosion. It is also to be emphasized that the corrosion might be intensified by the negative effects of some cargoes, especially those like iron ore and coil [1]. Though, during the past two decades, several casualties of bulk carriers have occurred while they were under operation and the possible causes for such casualties is thought to be the structural failure affected by the corrosion being intensified by rough sea and weather conditions. While protective paintings, cathode protection, and (or) tanks careful washing out are often employed, this is not always the case and, for variety of reasons, they may not be wholly effective. Thus, the particular attention is to be given to the harsh nature of the cargoes, loading/unloading operational procedures, as well as, to the regular measurements and reporting on the ships' structural deterioration due to the corrosion. These, however, is much easier to say than to done [2;3;4].

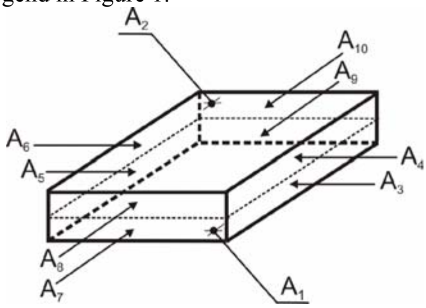
2. THE PROBLEM DEFINITION
For the purpose of this research work a large data base has been provided by the experienced ultrasonic measurements Company[1]. These data were collected through the standardized, numerous, and very detailed measurements over all hull structure members of the group of ten aged bulk carriers. However, in this article, only bulk carriers' fuel tanks time-dependant deteriorations caused by the general corrosion have been analyzed in some detail. The main reason for this, lies in the fact that such kind of problem is not enough covered by the previous research works in the field, due to our knowledge [10;11] and some literature surveys [1-4;6-9]. Previously were treated mostly cargo holds

[1] INVAR-Ivošević Ltd. Company, and some more data about the Company are available at URL: http://www.invar.me/index.html.

and ballast tanks [8;9]. This paper contains the Weibull probability analysis upon some cumulative negative time-dependant fuel tanks corrosion effects in long terms, i.e. during the whole period of their exploitation, or in other words, within the complete time interval between the 5th and the 25th year of the vessels' operating. Let us note here that the corrosion process usually does not start before the 5th year of the exploitation [6-9].

3. THE INPUT DATA SET BRIEF DESCRIPTION

In accordance with the corrosion measuring standards and some characteristic operational parameters, the considered bulk carriers' fuel tanks are analyzed here throughout ten different segments, areas, or member locations. The analyzed segments are presented schematically and listed below in the form of the legend in Figure 1.



Legend:
A_1 – Bottom plate
A_2 – Inner bottom plate
A_3 – Pipe tunnel (water tight), lower
A_4 – Pipe tunnel (water tight), upper
A_5 – Side (water tight) girder, lower
A_6 – Side (water tight) girder, upper
A_7 – Floor after (water tight), lower
A_8 – Floor after (water tight), upper
A_9 – Floor fore (water tight), lower
A_{10} – Floor fore (water tight), upper

Figure 1. The basic structural scheme of a bulk carrier's fuel tank areas (A_1 to A_{10})

The cumulative data on the general corrosion lost expressed in percentages (%) of the standard average steel thickness (which is usually between 11-16 [mm]), collected through the regular measurements (inspections on site), during the previous decade by the survey Company[1], are given in Table 1. The data are gathered over each of the previously noted area of the analyzed bulk carriers (BC) fuel tanks, through 10 ($BC_{1,7-10}$), or 20 different sections (BC_{2-6}), depending of the number of fuel tanks, with total 3,356 gauged points, for both the left, or portside (P) and the right, or starboard (S) side of the considered bulk carriers (BC_{1-10}). The data were collected by the regular, intermediate and special surveys, in a way that each tank has been divided into 5 sections: two sections for after and fore ends, and three sections at equal mutual distances in the middle, between ends of tanks. The bulk carriers: BC_1, and BC_{7-10} are of the different construction than the rest of the examined vessels. Though, since they do not have, in fact, the areas A_5 and A_6, as the constitutive parts of their fuel tanks, they were in these segments partly excluded from some of the simulation analysis.

Table 1. The average corrosion loss per each area from A_1-A_{10}, for ten analyzed bulk carriers (BC_{1-10})

Area	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	Average
%	1,96	16.68	1.14	0.99	5.25	11.81	10.79	16.98	12.26	16.21	9,40

4. THE WEIBULL DISTRIBUTION IN DESCRIBING FUEL TANKS' CORROSION LOST

In aim to scan the behavior of the corrosion deterioration over the bulk carriers' oil tanks in long terms, the results of some probabilistic analyses based on Weibull distribution are given in this part of the paper. Namely, Weibull distribution can be successfully applied in describing the corrosion loss, i.e. the steel depth reduction [12], over different bulk carriers' fuel tanks member locations during the time. In general, Weibull distribution is suitable for engineering analysis when small number of samples is available, what is not the case with other statistical distributions. It allows in a manner *economic* engineering analysis and offers simple and very useful graphic for characteristic parameters scanning and analyzing. Though, Weibull distribution is widely used in (un)reliability analysis, including here examined problem of the bulk carriers' fuel tanks structural strength reliability that is commonly affected by the corrosion. The probability density function of the percentage of the damaged steel due to the standard (regular, normal) fuel tanks' steel depth (thickness) might be assumed to follow the most general three-parameter form of the Weibull distribution (1):

$$f(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} \exp\left[-\left(\frac{t-\gamma}{\eta}\right)^{\beta}\right] \qquad (1)$$

Where, η is scale parameter; β is shape parameter (or slope), and γ is location parameter. The ReliaSoft_Weibill++ program has been employed here for determining and analyzing Weibull distribution parameters. The available data set on the bulk carriers' fuel tanks thickness reduction due to the corrosion, collected during the time, i.e. from the 5th to the 25th year of the vessels' exploitation have been plotted at the Weibull paper, and the parameters β and η, as most relevant for this research, have been automatically calculated. In the Weibull graph the horizontal axis denotes the time of the considered vessels' exploitation, and it is in certain correlation to the steel degradation due to the corrosion over time. In other words, as time increases, the unreliability of the oil tanks integrity and structural stability decreases. Or, more simply, the older the vessel, the deeper the averaged steel depth caused by the corrosion. The vertical axis in Weibull graph represents the *life* of the steel, or the (critical) percentage of the steel that is to be removed and replaced by new steel at certain point of time. According to the results obtained for the parameters β and η by ReliaSoft_Weibill++ program, it can be concluded that approximately after 28 years of bulk carriers' exploitation, more than 60% (or exactly, 63.2%) of the fuel tanks areas constitutive steel is to be replaced (Table 2, Case $_2$). The parameter β, that is usually greater than 1, denotes the period of the intensified corrosion degradation. The data on the corrosion degradation versus time, under the assumptions that the corrosion process starts, e.g. at the 5th, 10th, or at the 15th year of vessels' exploitation, obtained by ReliaSoft_Weibill++ program, and linear regression method, are given in Table 2 (Cases$_{1\text{-}3}$).

Table 2. The bulk carriers' fuel tanks corrosion loss versus time and corresponding Weibull distribution parameters β and η, calculated by ReliaSoft_Weibill++ program

Case$_1$		Case $_2$		Case $_3$	
Years	Corrosion loss (%)	Years	Corrosion loss (%)	Years	Corrosion loss (%)
5	2 %	10	3 %	15	3 %
7.5	5 %	12.5	9 %	17.5	13 %
10	9 %	15	15 %	20	22 %
12.5	14 %	17.5	23 %	22.5	33 %
15	18 %	20	30 %	25	45 %
17.5	23 %	22.5	36 %		
20	28 %	25	42 %		
22.5	32 %				
25	39 %				
$\beta = 1.939$		$\beta = 3.049$		$\beta = 5.596$	
$\eta = 35.177$		$\eta = 28.640$		$\eta = 26.463$	

The considered vessels are classified by four classification societies: Bureau Veritas, Det Norske Veritas, L'loyds Register, and American Bureau Shipping. These societies have recommendations in their Rules for the levels of the acceptable corrosion deterioration for each element of the hull construction [12-16]. In the analyzed case, the deterioration for each area of the fuel tanks is in the boundaries between 20 and 25%, depending on the classification society. In the more restrictive conditions, i.e. in the situations when the fuel tanks are investigated as whole, the average amount of the damaged steel should not exceed 10% of the regular thickness. Under such, more rigorous condition, the parameters of the Weibull distribution differ than those obtained upon the real data collected on site, like in the previously presented cases. These additional oil tanks structural stability and safety requirements implies the smaller values of Weibull parameters β and η. Simply, in such strict conditions, more than 60% of the steel has to be removed/replaced over oil tanks structures during the 15th year of their exploitation lives, which is considerably earlier than in the previously presented cases.

5. CONCLUSION

In order to summarize, such approach based on the Weibull distribution parameters analysis might be recommended as a practical tool for determination of both scale and shape parameters, i.e. the time when more than half of the fuel tanks' structures in general will be seriously damaged by the corrosion and necessarily replaced by new steel, or it might denote the time when the bulk carrier should be retreating from operation. This is of up-most importance in controlling the structural strength and reliability of the fuel tanks and the whole bulk's hull structure, primarily due to the security and maritime safety reasons. Though, the practical aspect of such analysis must be emphasized and further, more extensive and more rigorous investigations in this direction are to be encouraged. Also, it must be noted that some areas of the bulk carriers' fuel tanks are not exposed in a great extend to the corrosion mechanisms, like A_1, A_3, A_4, and even A_5, A_7, and A_9, while some others, like A_2, A_6, A_8, and A_{10}, are seriously deteriorated. Accordingly, the analysts and the surveyors have to be aware that some deeper operational insight into this problematic is required besides pure statistical analysis. In other words, in addition to the simulations and statistical observations, some more detail qualitative analysis and discussions among the operators and experts are recommended.

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