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THE EXPERT KNOWLEDGE IN THE OPTIMIZATION OF THE BULK-CARRIERS CORROSION WASTAGE CONTROLLING

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ABSTRACT
In this paper, well-known and structured Monte Carlo simulation technique has been employed in predicting the amounts of the corrosion wastage over some bulk carriers' structural elements in the relatively short exploitation period of one year. As a base for the realization of the simulations, the appropriate statistical data collected over the group of ten bulk carriers are used. In the relative consideration both longitudinal and transversal ships' hull structural elements have been taken. Due to the expert knowledge in this domain, the critical hull zones are identified and certain interventions are suggested in the pre-processing of the Monte Carlo method, all with an aim of achieving better correspondence between simulation results and the experts' expectations.
Keywords: corrosion, experts' knowledge, bulk carrier, Monte Carlo method

1. INTRODUCTION

Bulk carriers are intensively used in transportation of coal, iron ore, grain and other bulk cargoes. It is indicative that during the period 1990-1997, twenty five bulk carriers foundered or sank with an average age of 20.4 years [1-3]. Though, it is useful in practice to be able to predict when, where, and to what extent, both fatigue and corrosion will affect the structural integrity of a bulk carrier at future times [4]. In this regard, it may be necessary to develop more refined databases of survey thickness data with clearer discrimination of the operational and internal parameters that influence bulk carrier hull structure corrosion time-dependant wastage. Knowledge of the type of metal being corroded, temperature, humidity, different sea and ballast water admixtures affecting corrosion, other conditions of a corroding environment, external abrasion, mostly caused by cargo grabbing, and other factors, is necessary for understanding corrosion phenomenon and predicting its time-dependent variability.

2. PROBLEM DEFINITION

Within this paper an attempt to develop a kind of predictive model of corrosion wastage for aged bulk carriers being more than 20 years in exploitation, by the application of Monte Carlo simulation method, has been done. The employed database in the related simulations and analysis contains the data collected during the past 10 years by Invar-Ivosevic Company[1]. Also, the applied simulation model has been augmented by the experts' knowledge in this domain.

3. CONCERNING THE NUMERICAL EXAMPLE

In this paper, ten bulk carriers have been analyzed by scanning the amounts of steel that might be removed/replaced over most sensitive areas of the ships' hull structure, after 15, 20 and 25 years of their exploitation. The data being taken into the consideration were collected by Invar-Ivosevic Company. Namely, this company has realized all required measurements of corrosion wastage during

[1] More information could be found at the Company official web site: http://www.invar.me/index.html.

the whole period of observation. As most sensitive areas of bulk carriers' hull structure, due to the Invar-Ivosevic Company experts' knowledge, web frames (WF), transversal bulkheads (TB), and inner bottom platings (IBP) have been taken into the consideration. The amounts of steel in tons that had to be removed/replaced at each of three previously identified areas are given in Table 1.

Table 1. Steel amounts [t] being removed/replaced over most sensitive bulk carriers' member locations during the time (years of exploitation)

Years	15			20			25		
Ship/Area	WF	TB	IBP	WF	TB	IBP	WF	TB	IBP
Ship 1	1	0	0	2.5	0.5	1	4.5	1.5	4
Ship 2	0	0	20	2	10	200	7	55	330
Ship 3	2	1	0	7	5	2	10	13	4
Ship 4	2	0	0	5	5	5	15	8	45
Ship 5	0	0	0	0	3	5	0	14	15
Ship 6	5	0	0	20	5	50	50	15	250
Ship 7	0	0	0	8	5	10	22	35	25
Ship 8	0	0	0	0	0	5	0	0	20
Ship 9	1	0	0	1	6	20	4	10	90
Ship 10	0	0	35	0	0	165	30	170	450

Legend: WF - web frames, TB - transversal bulkheads, IBP - inner bottom platings

Monte Carlo simulation method has been employed in developing predictive model of the expected amounts of steel to be removed over web frames (WF), transversal bulkheads (TB), and inner bottom platings (IBP) member locations after 15, 20 and/or 25 years of bulk carriers' exploitation life. The simulations have been realized separately, for each of the above listed bulk carriers' hull member locations, and for three pre-specified different time periods of exploitation, throughout 1000 trials or runs. Some of the obtained results by the simulations are given in Table 2.

Table 2. Input data and Monte Carlo simulation outcomes for the period after 25 years of bulk carriers exploitation

WF	[t]	0	4.25 (4+4.5)/2	8.5 (7+10)/2	**22.33** (15+22+30)/3	50	
	Frequency	2	2	2	3	1	
	Runs	199	219	185	299	104	
	%	19%	22%	19%	**30%**	10%	
TB	[t]	0.75	9 (8+10)/2	**14** (13+14+15)/3	35	55	170
	Frequency	2	2	3	1	1	1
	Runs	201	199	280	109	106	105
	%	20%	20%	**28%**	11%	11%	10%
IBP	[t]	4	20	45	90	**343.33** (250+330+450)/3	
	Frequency	2	3	1	1	3	
	Runs	193	316	91	78	322	
	%	19%	32%	9%	8%	**32%**	

Legend: WF - web frames, TB - transversal bulkheads, IBP - inner bottom platings

In aim to increase the frequency of appearing some similar amounts in the model, the average values have been taken into the consideration. For example, the amounts 4 and 4.5 [t] for web frames after 25 years of exploitation have been treated as average amount of 4.25 [t] (=(4+4.5)/2=4.25) appearing, thus, twice in the model. The analog procedure has been used in some other cases in the model, as well. The question is: why we used in fact Monte Carlo simulation? - It is always used when the real experiment is time and money consuming one. Here, it would be very unpractical and costly to wait for measuring corrosion wastage over another group of ten or more bulk carriers during 15, 20 or 25 years period. However, it is true, we can calculate mathematical expectations or the average amounts of steel that are to be replaced throughout some member locations due to the data collected by Invar-Ivosevic Company, but it works in the case of long term predictions. Owing to the Monte Carlo simulation results, it becomes possible to give an idea to the bulk carrier owner what is the steel amount he(she) should have to remove/replace over certain ship's hull area during a year, e.g. It is to be noted that in this case we should divide Monte Carlo simulation results by 15, 20 or 25 years respectively in aim to obtain relevant, most likelihood, data on the year level. The graphical presentations of some simulation results and those obtained by the application of the conventional expressions for mathematical expectation or average amount of steel in long term period are confronted in Figures 1 and 2.

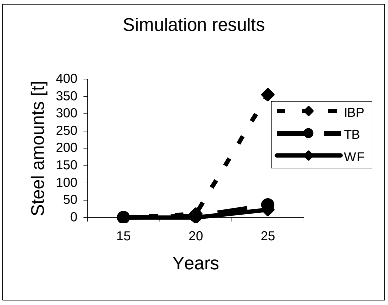

Figure 1. The simulation results

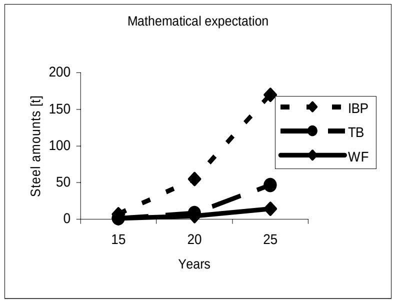

Figure 2. The average values

It is obvious the historical (empirical) data collected by the Invar-Ivosevic company are mostly heterogeneous like in numerous other investigations in this domain [5-9]. Consequently, the obtain results show the large scale of variations in the steel amounts expected to be replaced/removed during the periods of bulk carriers' exploitation circles. Thus, there is necessity for some more extensive and deeper investigations in this field. Deeper, in a sense that some qualitative analysis are to be introduced, i.e. that some relevant bulk carriers' operational and internal structural corrosion factors are to be considered and also some of their mutual correlations must be established as a base for better understanding the corrosion occurrences and progression.

4. METHODOLOGY

Though, in obtaining within the previous section presented numerical results for the steel amounts that are to be removed/replaced over certain bulk carriers structure member locations, Monte Carlo simulation method has been used. This method should be treated as an experiment in which we attempt to understand how something will behave in reality by imitating its behavior in an artificial environment that approximates reality as closely as possible. The Monte Carlo simulation conducts experiments that would be too costly and too time-consuming to perform in reality. It has been realized here by Excel embedded functions RN( ) and LOOKUP(…). The first one generates random numbers, while the second one automatically establish correlation between the steel amounts appearing in the model and random number intervals related to the probability of certain steel amount appearing in the model. Latter on, Excel imbedded function COUNTIF(…) has been used to count the number of appearing each steel amount existing in the input data set. The largest obtained value of COUNTIF(…) function gives the win policy, that is the most likelihood amount of steel to be removed/replaced over certain bulk carrier hull structure, after certain years of its exploitation. Since Monte Carlo simulation method generates random data, obtaining accurate results requires the simulation process to consist of a large number of repetitions, or runs. Here, we realized several 1000 runs, and picked randomly chosen one as optimal. However, the question of how many runs is enough is still left unanswered. In other words, since a simulation generates random data, there is no guarantee that the chosen result is actually the best one. Concerning this limitation, we have asked the Invar-Ivosevic Company experts to give us some suggestions about the amounts of the steel which are most commonly removed/replaced over bulk carriers web frames, transversal bulkheads and inner bottom platings during the time. Their suggestions might be helpful in pre-processing Monte Carlo simulations. More precisely, due to the experts' knowledge, it could be possible to conduct some interventions in real empirical data given in Table 1, in sense of increasing synthetically the frequencies of appearing most likelihood amounts of steel being devastated by the corrosion over considered areas (Figure 3). The detail description of this procedure with obtained improvements, in sense of achieving better convergence between simulation results and related experts' expectations, can be found in the reference [10].

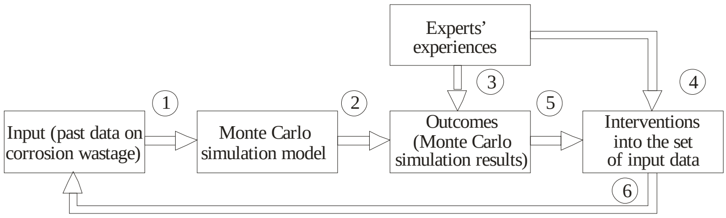

Figure 3. Upgrading the simulation model by the experts' knowledge

5. CONCLUSION

The amounts of steel devastated by corrosion over some structural member locations of aged bulk carriers are influenced by many factors and consequently they are highly variable. This variability is cased by type of the corrosion protection coats, porous cargoes, seawater, ballast water and their ratio, an enclosed atmospheric environment, abrasion from cargo handling equipment, etc. [4] Within this paper we dealt with the database of the registered amounts of the damaged steel (in tons) over web frames (WF), transversal bulkheads (TB), and inner bottom platings (IBP), during the life circle of ten bulk carriers' being in exploitation more than 25 years, trying to develop a predictive model (for one year period, e.g.) of corrosion damage over these areas. This model is to be presented in a proper time, as an idea, or as an indicator, of approximate corrosion wastage, to the ships' owner. What should enhance the reliability of this model is better understanding of mutual interdependences between previously mentioned factors that cause the corrosion and its time-dependent growing. Only by such deeper understanding of corrosion phenomenon, by employing some qualitative analysis of its carriers, it will be possible to develop really (in practice) applicable bulk carriers' corrosion wastage predictive model(s).

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