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NEW CORROSION MODEL TO PREDICT STEEL STRENGTH

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ABSTRACT

In order to ensure a safe design of a ship's hull, it is necessary to accurately evaluate the capacity of the hull girder considering extreme loads and effect of steel corrosion. The goal of this work is to perform the new model of steel corrosion, to analysis the strength structural element of steel.

From the model described phenomenon of the corrosion, a model has been introduced. This model is based on the approach which was taken from (Shengping Qin and Weicheng, 2002); it used to develop a methodology to predict reduction of thickness of structural elements due to corrosion. The results obtained using the prediction methods were verified against the experimental data. The effect of corrosion to section modulus and section area of cargo deck was investigated, as a function of time and exponential depth of corrosion. However the relationship between weight and ratio of section modulus during 25 year service of the tanker were involved. It has been found the reduction of the section modulus and the section area of the deck cargo follow polynomial model of the sixth order, and it has been lost 5% of section modulus the deck cargo during 15 years of life ship service, and for mean section area, 9.3% has been lost it.

Keywords: corrosion, strength analysis, least square method.

INTRODUCTION

Corrosion is an important industrial problem, wish considered as indirect consequences of accidents and is estimated at mondial1 2% of the gross proceeds. Each second, it is about 5 tons of steel which are thus transformed into iron oxide.

Various models of the corrosion ship structures are discussed, following the basic equation cf.(Eq.1) specifying the evolution of corrosion depth and concrete model has been developed (M.A.Shama, 2005).

In the present paper the least squares method has been employed to evaluate the parameters of Weibull distribution well the results are verified against with reference data given in (Offshore Technology Conference, 5 May-8May 2003). Basically, a model is considered to be a representation of some object, behaviour, or system that one wants to understand. Models are abstract vehicles for learning about the world. With a well-developed model, significant parts of scientific investigation could be carried out the results are verified by experiments.

The tangible results extradite from LMS method explain the very large prediction regarding to data. A new model has been developed based to approach given by Paik/al Eq. (1), in fact the equation of model has been described using Taylor series with keeping the terms up to second order. Their results compared to these obtained with candidate models formulated by Melchers, Guedes Soares/Garbatov, and Paik/al.

The goal of work is to define the lost depth of steel plate, to assess the section and area modulus of structural element. Many works has been done before (Yao T. et al. 2000), however it can be more complicated to evaluate degradation of plate unction time because many parameters infected.

Once validated, corrosion models can support a variety of analyses, such as estimating the required interval between maintenance and repair actions, gauging the effectiveness of various corrosion mitigation approaches, aiding in the selection of materials and coatings, and performing sensitivity analysis regarding the basic assumptions and the initial; boundary conditions used in a corrosion analysis.

THE NEW CORROSION MODEL

Existing Models

One of the key aspects in investigation of corrosion is the evolution and degradation of plating. In the initial phase a linear dependency is observed between corrosion wastage and time (Emi H, Yuasa M, Kumano A, Arima T, Yamamoto N, Umino M. A). Corrosion wastage can be therefore calculated:

If $t > T_{st}$

$$d(t) = d_{\infty}\left[1 - \exp\left(-\left(\frac{t-T_{st}}{\eta}\right)^{\beta}\right)\right] \quad (1)$$

If β=1, the Guedes Soares/Garbatov model has been obtained:

$$d(t) = d_{\infty}\left[1 - \exp\left(-\left(\frac{t-T_{st}}{\eta}\right)\right)\right] \quad (2)$$

Substituting η=1, expanding the equation in the Taylor series and keeping only the linear term we obtain the Paik /al model:

$$d(t) = d_{\infty}(t - T_{st})^{\beta} \quad (3)$$

Finally, for β=0.6257, and T_{st} =0 the Melcher model has been described:

$$d(t) = 0.1207t^{0.6257} \quad (4)$$

Developed New Model for predicting the wastage corrosion of steel

Discussing the concept of the basic equation of the corrosion evolution another procedures are proposed in the present paper regarding to parameters β, η, T_{st} and d_{∞}.

The least squares method is employed and Eq. (1) has been solved. Well $d_{\infty} = 3.3$ mm, T_{st}=5 years. The model (1) is giving by formula:

$$d(t) = d_{\infty}\left[1 - \exp\left\{-\left(\frac{t-T_{st}}{26}\right)^{0.2}\right\}\right] \quad (5)$$

Where β, and η:

$$\hat{\beta} = \frac{\left\{n\sum_{i=1}^{n} Ln(t_i) LnLn\left[\frac{1}{1-\frac{i}{n+1}}\right]\right\} - \left\{\sum_{i=1}^{n} LnLn\left[\frac{1}{1-\frac{i}{n+1}}\right]\sum_{i=1}^{n} Ln(t_i)\right\}}{\{n\sum_{i=1}^{n}(Ln(t_i))^2\} - \{\sum_{i=1}^{n} Ln(t_i)\}^2}$$

$$\hat{\eta} = \exp\left(\bar{y} - \frac{\bar{x}}{\hat{\beta}}\right)$$

Second method was investigated which to expand Eq. (2) to second order of Taylor series. Model (2) has been defined following Eq. (6):

$$d(t) = d_{\infty}\left[\left(\frac{t-T_{st}}{\eta}\right)^{\beta} - \frac{1}{2}\left(\frac{t-T_{st}}{\eta}\right)^{2\beta}\right] \qquad (6)$$

Results obtained using models (2) are compared with those produced by Paik/al model for various values of β.

To compare results produced by the candidate models, and the model (1) and (2), the reference data mentioned in the Fig. (1) is followed.

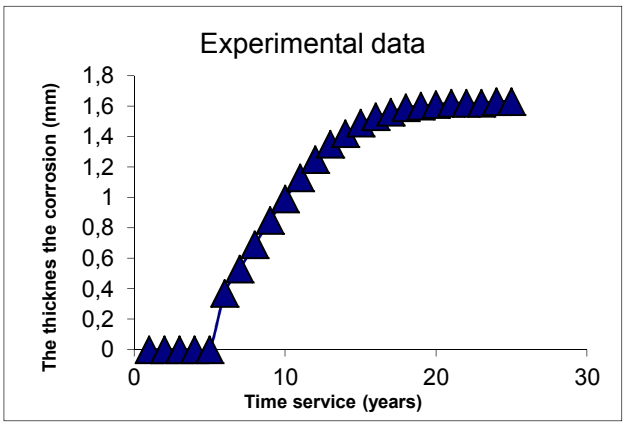

Fig. 1 - Corrosion evolution: the experimental data (Shengping Qin and Weicheng, 2002).

The corrosion wastage equal to the 3.3 mm for deck section area (cf. Fig.2), and evolution of atmospheric corrosion has been discussed.

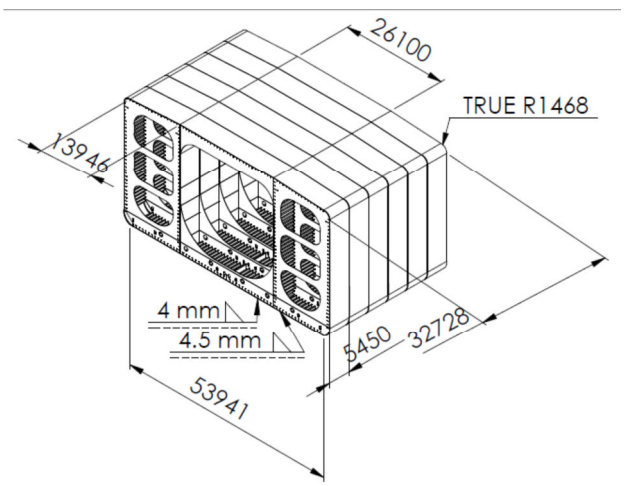

Fig. 2 - Description geometric of amidships section, deck section has been considered.

The Comparison of the Models

The results of model (2) are more closed to experimental data. In other hand the results of Melcher, Paik/al, and Soares models far way to experimental data (cf. Fig.3); for β= [0.62, 0.7] the ratio of parameters β, η has been set and equal to: $\frac{\eta}{\beta} = 30$.

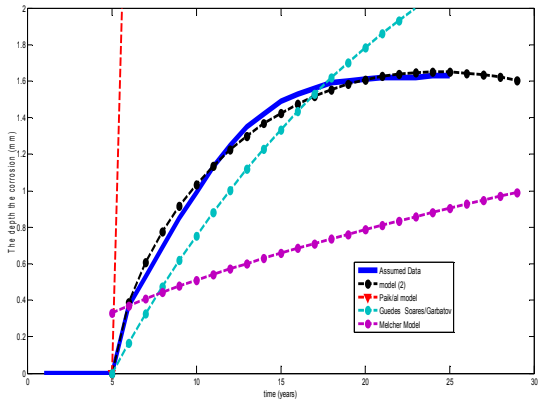

Fig. 3 - The comparison the results between model (2), Soares, Paik/al, Melcher, and the assumed data.

It has been considered second order of the Taylor series and relationship between β and η equal to 30, in condition as β= [0.62, 0.7], good agreement observed between model (2), and experimental data. Regarding to the rate function of model(2), the rate function tend to infinite according to the second order of the model(2), by other way the depth corrosion goes to zero, when the time tend to infinite.

$$\lim_{t\to\infty} r(t) = \lim_{t\to\infty} d_\infty \frac{\beta}{\eta}\left(\frac{t-T_{st}}{\eta}\right)^{\beta-1} \mathrm{Exp}\left[-\left(\frac{t-T_{st}}{\eta}\right)^{\beta}\right] = 0 \quad (7)$$

$$\lim_{t\to\infty} r(t) = \lim_{t\to\infty} d_\infty \frac{\beta}{\eta}\left\{\left(\frac{t-T_{st}}{\eta}\right)^{\beta-1} - \left(\frac{t-T_{st}}{\eta}\right)^{\beta}\right\} \to \infty \quad (8)$$

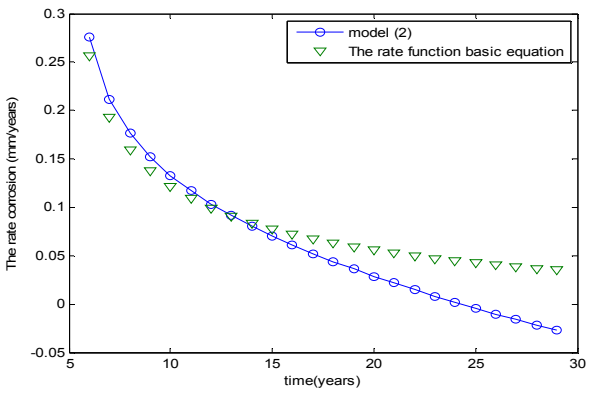

Fig. 4 - The flexibility of the basic equation, and the model (2).

By study the flexibility of model (2), regarding to the basic equation of depth corrosion, when time tend to infinite the speed of corrosion has been neglected, the rate function the basic

equation goes to zero. For that reason the validity of model (2) has been fixed until 25 years when speed of corrosion equal zero.

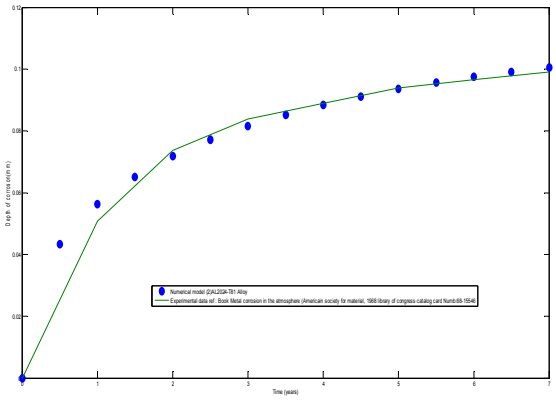

Fig. 5 - Depth of corrosion versus time for Al2024-T-81 Alloy
(The continuous line: experimental data, discontinuous point the model describe the evolution the depth)

By fitting the curve (cf.Fig4), we received the model describe the depth of aluminium corrosion versus time:

$$d(\mathrm{t}) = 0.215\left[\left(\frac{\mathrm{t}}{13.5}\right)^{0.45} - \frac{1}{2}\left(\frac{\mathrm{t}}{13.5}\right)^{0.9}\right] \quad (9)$$

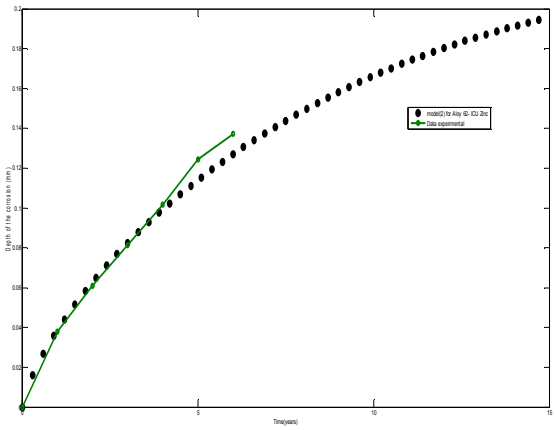

Fig. 6 - Depth of corrosion versus time for Alloy 62-ICU Zinc
(The continuous line: experimental data, discontinuous point the model describe the evolution of depth)

By fitting the curve (cf.Fig6), we register the model describe the depth of zinc corrosion versus time:

$$\mathrm{d}(\mathrm{t}) = 0.42\left[\left(\frac{\mathrm{t}}{22.5}\right)^{0.75} - \frac{1}{2}\left(\frac{\mathrm{t}}{22.5}\right)^{1.5}\right] \quad (10)$$

Effect the Corrosion to Reduce the Ratio the Section Modulus and the Section Area of the Deck Cargo

We consider Tanker VLCC ship our structure elements in this present work, we have such details:

The initial inertia equal to 9.43 1014 mm4, and the position of the neutral axis equal to 14.35 m. The initial section modulus was Z_0=5.87 1010mm3, we calculate at selection year the lost of the section modulus, and the section area. The evolution of the section modulus versus time follows the formula:

$$\mathrm{RSM} = 1 - 7.610^{-6}t^3 + 4.810^{-4}t^2 - 0.01t \quad (11)$$

Similar, the section areas vary follow the formula:

$$\mathrm{RSA} = 1.1 - 1.210^{-5}t^3 + 9.210^{-4}t^2 - 0.023t \quad (12)$$

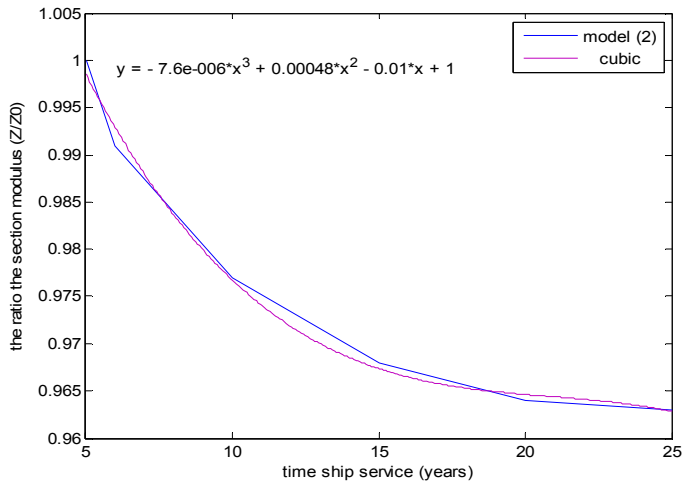

Fig. 7 - The fit the curve section modulus versus ship age, subject to the atmospheric corrosion.

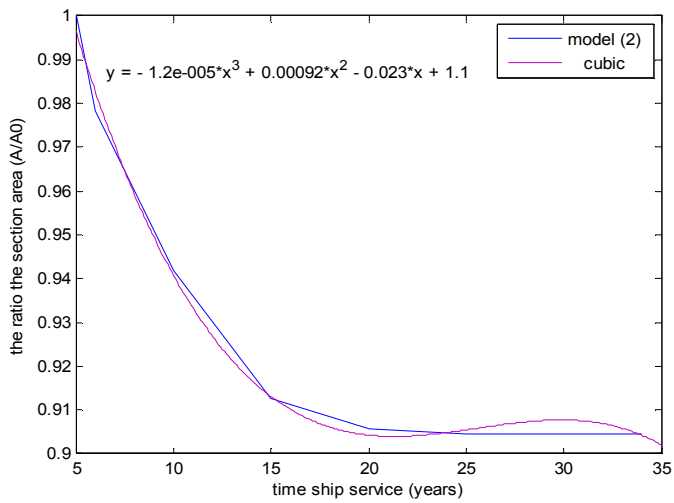

Fig. 8 - The fit the curve section area versus ship age, subject to the uniform corrosion.

We summary the results, we lost 5% the section modulus of the deck during 15 years the ship service, and for the mean section area we lost 9.3% during 25 years.

To assume the weight the structure of the deck, we propose the standard steel material has the density equal 7850 Kg/m3; and the yielding stress equal 320 MPa.

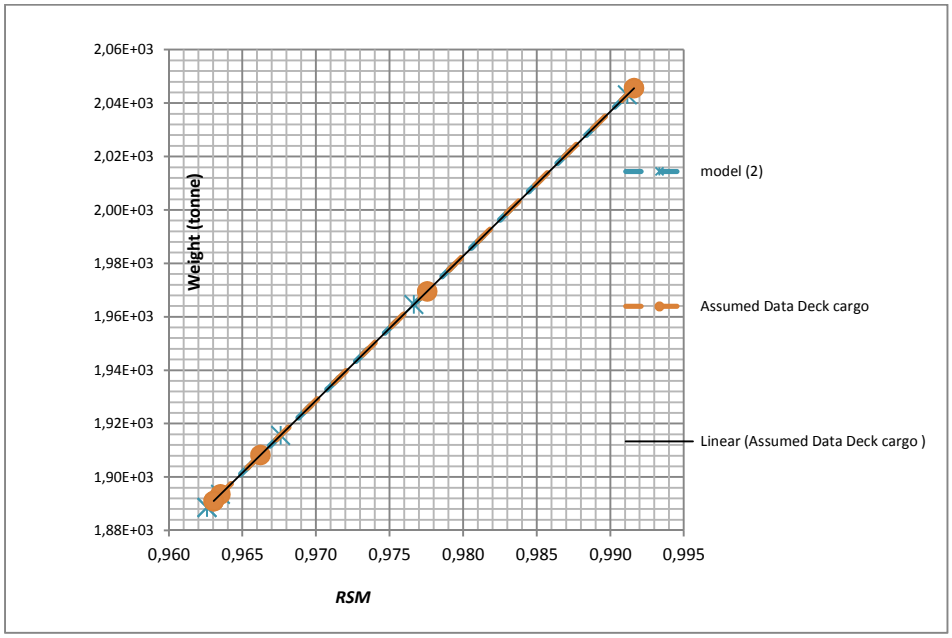

Fig. 9 - The relationship between weight and ratio section modulus of the deck tanker SHVLCC

From the Fig.9 above, the weight is linear with the ratio the section modulus of the deck touched by atmospheric corrosion. Then, we describe the model weight versus the section modulus follow the formula:

$$\text{Weight (tonne)} = 5410.9 * \text{RSM} - 3319.9 \qquad (13)$$

The analysis of the corrosion model, have large point to touch. In fact, the initial work is to define the model (2), to obtain the depth of the corrosion, comparing with the assumed data.

Using model (2) we get good prediction to assumed data. Since, we find the reduction of the section modulus and the section area follow polynomial model the order six. Finally we lost 5% the section modulus of the deck during 15 years the ship service, and for the mean section area, we lost 9.3% during 25 years. From point of view engineer, the critical area can be check by inspection is the side at draft level, where the shear forces very high at position 0.3L and 0.7L from aft part.

CONCLUSION

The initial work is to define the model (2), to describe the corrosion depth (atmospheric corrosion), comparing with the assumed data. Using model (2) there is a good prediction to assumed data. Since, it has been found that the reduction of the section modulus and the section area of the deck cargo follow polynomial model of the sixth order. Finally there is 5% lost of the section modulus of the deck cargo during 15 years of the ship service, and for the mean section area, 9.3% lost during 25 years.

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