



THE SLIP-STEP DISSOLUTION AND FILM RUPTURE MODEL - A CRITICAL REVIEW AND AN ALTERNATIVE MODELING PROPOSAL

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ABSTRACT

One of the main models which represents the electrochemical and mechanical processes of stress corrosion cracking of nickel alloys and stainless steel in high temperature pressurized water and boiler water reactors is the slip-step dissolution and film rupture model. It has been extensively built and studied for over 66 years, and some of its aspects are not completely clear. One departs from a bibliographical review of this model, to propose a theoretical alternative modeling, joining some critical issues of the review, concerning the mechanochemical effect of the slip-step process, and the formulation of the active path dissolution process.

INTRODUCTION

The stress corrosion cracking (SCC) is a very complex degradation process, and depends upon many parameters (Fontana and Greene (1978), Hertzberg (1989)), which can be classified in microstructural, mechanical and environmental (Rebak and Szklarska-Smialowska (1996)).

The microstructural factors are: (1) grain boundary chemistry and segregation; (2) thermal treatment which can cause intragranular and intergranular metallic carbide distribution; (3) grain size and cold work or plastic deformation - the two last ones fix the yield strength. The mechanical factors are: (4) applied and residual stresses: these stresses and geometry can be summarized as stress intensity (optionally, strain and strain rate which can be also described related to stresses). The environmental factors are: (5) temperature; (6) activity of $[H]^+$ or pH; (7) solution or water chemistry; (8) inhibitors or pollutants in solution; (9) electrochemical open circuit and corrosion potentials; (10) partial pressure of hydrogen which reflects on potential (Rebak and Szklarska-Smialowska (1996); Staehle (2001)).

Consequently there are many models to give to SCC a mathematic description. In this paper, one considers a SCC case in nickel superalloys (Alloys 600 and 182) and stainless steel 304, at high temperature (280°C to 360°C) water of nuclear reactors. For these cases, the main models are the slip-step dissolution and film rupture model as developed by (Andresen and Ford (1988)), the internal oxidation mechanism (Scott and Le Calvar, 1993), the coupled environment fracture model of Macdonald and Urquidi-Macdonald (Rebak and Szklarska-Smialowska (1996)), numerical models of Rebak and Szklarska-Smialowska, and others (Rebak and Szklarska-Smialowska (1996); Staehle (2001)).

In this paper, one focuses one of these main models which represents the electrochemical and mechanic processes of the stress corrosion cracking of nickel alloys and stainless steel, respectively in high temperature pressurized water (PWR) and boiler water reactors (BWR), the slip-step dissolution and film rupture model. It has been extensively built and studied for over 66 years, and some of its details are not completely clear.

This model relates the cracking (initiation and propagation) according to the slip-step and passive film rupture, with the crack tip strain rate action, which exposes bare metal surface followed by electrochemical dissolution of the alloy. After this, the passive film reforms, and after a new rupture

succeeds, reinitiating the cracking evolution. One departs from a bibliographical review suggested by Hall Jr. (2009), which reports model building and critical issues. The initial discussion which originated the model has done by Mears et. al. (1944). The experiments of Logan (1952) have confirmed Mears et al. generalized theory discussion. The model first being formed with Vermylea (1972). Parkins (1980) gave it experimental support. The main application model was obtained by Andresen and Ford (1988) in the 1980's, but it followed by critics of Macdonald (1996), Newman and Healey (2007), Gutman (2007), and Hall Jr. (2009a). These main critics are concerning the empirical approach instead of the fracture mechanics one, incomplete mechanism's observation, sensitivity of the predicted cracking, lacking of some steps in its mechanism. Peng et al. (2004) have been proposed an alternative model to the Ford and Andresen's one but it was also criticized, mainly concerning the dismissing of the creep contribution to cracking process (Hall Jr., 2008b). It had been proposed another alternative model based in his active path dissolution's concept (Hall Jr. (2009b).

In this paper a theoretical alternative modeling for the slip-step dissolution and film rupture model is proposed, joining some critical issues of the review, concerning the Gutman's mechanochemical effect of the slip-step process, and the Hall Jr.'s formulation of the active path dissolution process.

HIGHLIGHTS ON BIBLIOGRAPHIC REVIEW: HISTORY OF THE MODEL

1. "A generalized theory of stress corrosion cracking" (Mears et. al. (1944)) – In this paper, main researchers as R.B.Mears, and others, from chemical and aluminium industry, emphasized that "season cracking" shall be to initiate by electrochemical action. The probable mechanisms of this current action were discussion objects on generalized theory, and the passive film rupture one was supposed.

2. "Film-rupture mechanism of stress corrosion" (Logan (1952)) – The author confirmed through the experiments reported, the general idea of the film rupture mechanism provoked by stress, and which allows corrosive action through the environment between anodic area on bare surface, and the cathodic one with the oxide passive film.

3. "A theory for the propagation of stress corrosion cracks in metals" ((Vermilyea (1972)) – Vermilyea researched the film rupture model and was predecessor of Ford and Andresen at General Electric Company, Research and Development in Schenectady, NY. The author proposed that the crack growth is sustained by film rupture induced by the deformation, which is caused by transient creep.

4. "Predictive approaches to stress corrosion cracking failure" ((Parkins (1980)) – It provided a wide view of the electrochemical process of stress corrosion. Among other important issues, one discussed the modeling of experimental data for stress corrosion cracking in C-Mn steel in environment with NO_3 , OH and $\text{CO}_3\text{-HCO}_3$ using a model based in electrochemical dissolution of the passive film.

5. Main issues of the historic review – Papers 1 to 3 belong to the historical basis of the model formulation, which was postulated, but its main mechanism had not been detailed and validated. They brought up some interesting topics which were lost with the evolution of the model and literature. In these papers, electrochemical processes studies stand out before the mechanical ones, although these had been also considered. Paper 3 is a precursor to a more accepted model according to Ford and Andresen and mechanical action to break the passive film, as well as the effect of creep, are considered. Of special interest, is paper 4, with an exceptional view of the electrochemical behavior of the stress corrosion process.

HIGHLIGHTS ON BIBLIOGRAPHIC REVIEW: THE FORD AND ANDRESEN MODEL

1. "Life prediction by mechanistic modeling and system monitoring of environmental cracking of iron and nickel alloys in aqueous systems" (Andresen and Ford (1988)) – One arrived at a main formulation of the slip-step dissolution and film rupture model, done by Ford and Andresen, researchers at General Electric, in the late 1980's. The paper shows a model which is intended for engineering, also done for use in supervisory control systems of large turbo-generators.

The mechanism of the model assumed by its authors is illustrated in Figure 1(a): the advancement of the crack is governed by the 2nd Faraday's Law applied to oxidation reactions (dissolution, repassivation and corrosion advance) occurring at the crack tip (Figure 1(b)) when the protective film is ruptured by the increasing deformation of underlying layers of base metal.

The film is ruptured by the strain rate action of increasing strain of the underlying metal. This occurs when the strain reaches the film fracture strain, due to the dissolution process: this one has a periodicity t_f which is calculated from the fracture strain of the oxide and the strain rate at the crack tip.

After each t_f period, it follows the film repassivation process. This mechanism varies in a complex manner for different environment and material conditions, and the relationship shown in Fig. 1 (a) can be put in a general differential form according to equation (1).

$$\left(\frac{da}{dt}\right)_{sc} = f(n) \left(\frac{d\varepsilon}{dt}\right)_{ct}^n \quad (1)$$

where: $(da/dt)_{sc}$ is the stress corrosion crack growth rate, $f(n)$ is a function of n , an environment and material chemistries parameter, and $(d\varepsilon/dt)_{ct}$ is the crack tip strain rate.

Equation (2) represents $f(n)$, including the Faraday law's dissolution affected by a n -dependent repassivation current density $i(n)$ (Rebak and Szklarska-Smialowska (1996), Thompson et al. (1995)).

$$f(n) = \left(\frac{M}{z\rho F}\right) i(n) dt \quad (2)$$

where: M is the metal's atomic weight, z is the valence state, ρ is density, and F is Faraday's constant. The repassivation current density $i(n)$ is supposed to follow an exponential decaying law with time t .

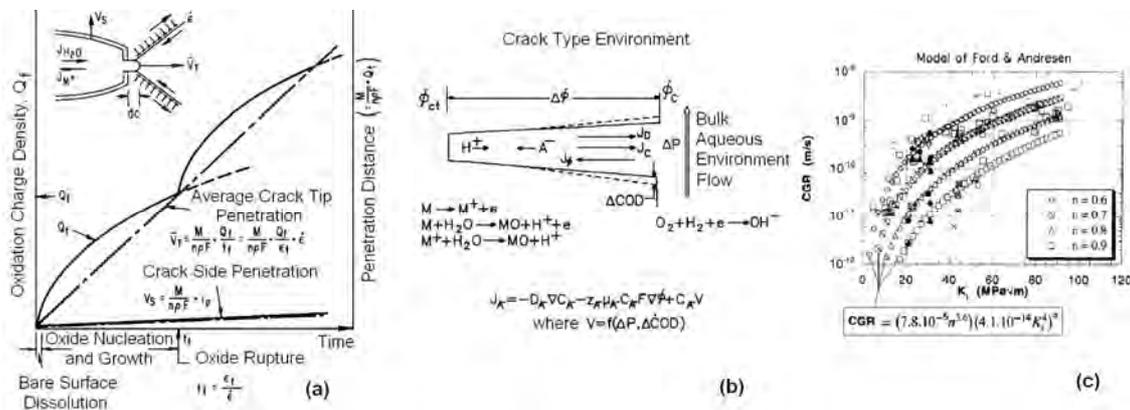


Figure 1. (a) Graphic of oxidation charge density versus time for a strained crack tip and its unstrained crack sides; (b) Graphic of the crack tip and the associated criteria of mass transport and thermodynamics, which govern the environment (Andresen and Ford (1988)); (c) Comparison between crack growth rate (CGR) values vs. stress intensity (K_I) predicted by this model and some experimental data (Rebak and Szklarska-Smialowska (1996)).

2. Main issues of the Ford and Andresen model – One showed the FA model, in its proper engineering form, with an example applied to a BWR component in equation that is represented on Figure 1(c). In this model is considered the dissolution effect by the 2nd Faraday's Law, and periodic mechanic rupture of the film caused by strain and stress followed by film repassivation.

HIGHLIGHTS ON BIBLIOGRAPHIC REVIEW: VALIDATION OF THE FORD ANDRESEN MODEL

1. “Life prediction by mechanistic modeling and system monitoring of environmental cracking of iron and nickel alloys in aqueous systems” (Andresen and Ford (1988)) – It is also presented a validation for the model, including: data upraising of oxidation rates for to characterizing SCC crack tips according to different environmental and material systems of light water reactors; integration of these bare surface oxidation current densities *versus* time relationships with the obtaining of charge densities transients; Faraday´s law application, to obtain prediction relationships between the crack propagation rate and the crack tip strain rate, and other related issues.

2. “Prediction of pure water stress corrosion cracking (PWSCC) in nickel base alloys using crack growth rate models” (Thompson et al. (1995)) – In this paper it is demonstrated that the slip-step dissolution and film rupture model allows a reasonable regression of experimental data for SCC of Alloys 600 and X-750. However, some of the specimens, as examined by transmission electron microscopy, showed no evidence of increased plasticity, neither an unique pattern of dislocations at the crack tip or along the crack to reinforce the slip-step dissolution mechanism. Thus, these slip-steps, and also voids, as well as micro-cracks hydrides showing the hydrogen effect, were not detected. Consequently the slip-step dissolution and film rupture model can be transformed in an engineering model independent of these mechanisms. The primary creep rate was considered dominant rather than the secondary creep.

3. “The mechanism of stress corrosion cracking of Alloy 600 in high temperature water” (Rebak and Szklarska-Smialowska (1996)) – In this paper one presented a validation of the model according to Figure 1(c): to lower values of “n” correspond to the increase of environmental effect, and a decrease of the threshold stress intensity value, above which stress corrosion crack initiates. The model´s prediction is well adjusted for the K_{Ic} -region equal or higher than $30 \text{ MPa}\sqrt{\text{m}}$; for the K_{Ic} -region lower than $30 \text{ MPa}\sqrt{\text{m}}$, the power law predicts higher values than the ones for the actual data. These two regions transition are not reproduced in Figure 1(c).

4. “Measurement of the fundamental parameters for the film-rupture/oxidation mechanism” (Attanasio et al. (1999)) – The work described in this paper correlates primary water stress corrosion cracking (PWSCC) sensitivity by the combined effects of repassivation kinetics, oxide rupture strain, and crack tip strain rate, including primary and secondary creep. Normally, the chromium content increasing in nickel alloys, decreases the PWSCC susceptibility: tests were showed that the estimated crack growth rate ratio for Alloy 600 (16 % Cr) related to Alloy 690 (30 % Cr) varies between about 3.7 and 8.7 times faster for Alloy 600. Thus, the tests have been developed considering the chromium content of some nickel alloys (Alloy 600 and Alloy 690) related with these three fundamental conditions (repassivation, oxide rupture, and creep). Initially, oxide rupture tests were indicated the evidence of the slip-step dissolution and film rupture model, as shown in Figure 2 from original paper of (Attanasio et al. (1999)).

5. Main issues of the validation of the Ford and Andresen model – The model presents generally, a good regression´s agreement between experimental and predicted data, but not in all stress level ranges. Also, it seems a good engineering model which can be, in some cases, transformed in a semi-empirical model. The model has theoretical restrictions concerning the material microstructure and treatment parameters contribution, and some environmental ones like temperature, and pH. It keeps clearly the influence of the crack tip strain rate and creep in the crack growth rate, but the creep´s contribution to the crack tip strain rate is not completely understood.

HIGHLIGHTS ON BIBLIOGRAPHIC REVIEW: CRITICAL REVIEW AND IMPROVEMENT PROPOSALS OF THE FORD AND ANDRESEN MODEL

1. General critical review

1.1. “On the modeling of stress corrosion cracking of iron and nickel base alloys in high temperature aqueous environments” (Macdonald (1996)) – The author´s initial critique was about the

parameter “n” (equations (1) and (2)), which must be strictly homogeneous to satisfy Faraday’s law and it is also insufficient to represent the complete electrochemical condition of the crack; the model does not explicitly follow the charge conservation, and other failures in the electrochemical hypothesis of the system were pointed: for the author the relative good agreement between predicted and observed data is due an empirical algorithm, rather than an adequate deterministic approach.

1.2. “Response to “On the modeling of stress corrosion cracking in iron and nickel base alloys in high temperature aqueous environments” (Andresen and Ford (1996)) – The model’s authors dismissed that the model have electrochemical imperfections: for them the potential gradient *per si* is not fundamental to the crack advance process, nor the conductivity *per si*, but the different anions formed in the environment. The most important is to measure the kinetics of the repassivation on metal specimens whose composition represent the crack tip material with own’s environmental chemistry. The authors refuted that their model is empirical rather than theoretical-deterministic, simply observing its reliance on measured passivation rates.

1.3. “An inconsistency in “film rupture model” of stress corrosion cracking” (Gutman (2007)) – The author’s critique showed clearly that the slip-step dissolution and film rupture mechanism is not yet completely understood. It can happen for example, that while slip-step occurs, the film does not break up. Thus, the crack propagation can be sustained only if the film rupture process is cyclic with the fracture frequency. The description of the mechanism model was also unsatisfactory because: a) the omission of a contribution of mechanochemical effect in dissolution acceleration, like the slip-step one – Figure 2 (Wang et al. (2005)); b) it’s valid not only to stress corrosion cracking cases: for example to loadings far below the yield stress; c) one does not take into account the slip-step parameters nor the stress tensor components. In the model the anodic current seems to be insufficient to promotes the crack growth, if one considers the current parcel to form soluble products; d) mathematical deficiencies in its formulation.

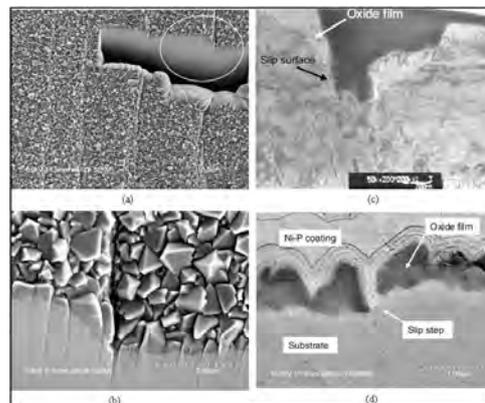


Figure 2. Slip band details on cross section of an oxide film of an austenitic stainless steel: (a) Cross sectional morphology of the surface oxide film of a specimen; (b) detail of white-circled area in (a); (c) TEM micrograph showing the oxide structure conditions. The slip band width is about 300 nm; (d) SEM micrograph showing a slip-step found in the cross section of a specimen: Wang et al. (2005).

1.4. “Critique of the Ford–Andresen film rupture model for aqueous stress corrosion cracking” (Hall Jr. (2009a)) – The author’s critique was based on two issues: (a) the expression for the anodic current density is not independent of strain rate at the crack tip; (b) the instantaneous repassivation current density does not decay logarithmically, based on experimental evidence. Thus, the author used another approach, based in continuum mechanics, called as “material time derivative” (the total time strain rate differential at a material point is subdivided in two partial derivatives depending on time and geometry of the crack system), to relate crack tip strain rate to crack velocity. So, one can obtain an alternative model, based in different parameters.

2. Crack tip strain rate formulations

2.1. “Development of a fundamental crack tip strain rate equation and its application to quantitative prediction of stress corrosion cracking of stainless steels in high temperature oxygenated water” (Peng et al. (2004)) – It was proposed an alternative equation for the crack tip strain rate mathematically time-derived from the plastic crack tip strain equation of Gao and Hwang, a continuum Fracture Mechanics one. So, it’s not used a semi-empiric formulation, as in original Ford and Andresen model. The resulting model is very sensitive to a parameter (which size is on the order of several micrometers) which represents the characteristic distance away from a growing crack tip where a representative strain rate value shall be defined: consequently it’s more sensitive to overall factor influencing stress corrosion cracking in high temperature water, as load, material properties, environmental chemistry, heat and mechanical treatment of the material, as cold working.

2.2. “Stability, validity, and sensitivity to input parameters of the slip-dissolution model for stress-corrosion cracking ((Newman and Healey (2007)) – The authors have done critics to the Shoji’s version of the model (item 2.1): the derivative of the crack tip strain equation is not correct, if the characteristic parameter is dependent on stress intensity: in this case, the crack tip strain rate varies unrealistically weakly with the loading rate. An important distinction was done between the Ford Andresen model’s conception named as “continuous”, and the Vermilyea one, named as “discontinuous”: the first can explain the process through applying strain rate or load rate, the second the process through constant load. Vermilyea assumes that the increment of plastic deformation occurs only after the dissolution and repassivation stages, caused by creep: a non-continuous way.

2.3. “An alternative to the Shoji crack tip strain rate equation” ((Hall Jr. (2008a)) – It’s a critic to the Shoji’s version of the model (item 2.1): this model’s version is inconsistent, whereas the original Gao and Hwang’s strain equation was derived considering steady state, but this is not always true. The scale parameter of the strain equation is not time independent, nor there is constant applied stress intensity. So, the derived equation is mathematically incorrect. The author showed that the Shoji’s results were also inconsistent with literature (Rice, Drugan and Sham: RDS). A new strain rate equation had been proposed, including strain hardening parameter effect, in a part independent of the crack velocity, and another part proportional to crack velocity. So, the resulting crack tip strain rate also was divided in a quasi-stationary part, and in a part dependent on crack advance. The resulting equation could be able to modeling cold work, and variable stress intensity effects, but the creep effect was not considered.

2.4. “Crack tip strain rate equation with applications to crack tip embrittlement and active path dissolution models of stress corrosion cracking” ((Hall Jr. (2008b)) – It had been proposed an alternative equation for crack advance based in a crack tip strain rate equation obtained by Hui and Riedel (HR). It is valid for creep crack advance at constant velocity in a spatially homogeneous and far field stress not variable with time: this condition reproduces small crack extensions in constant load tests. The crack velocity is not a very function of the crack tip strain rate. One obtained an equation relating the creep plastic strain rate with instantaneous crack growth rate multiplied by a partial derivative of total strain rate related with the geometry of the crack advance. It had been discussed applications on two families of stress corrosion cracking models: (a) crack tip embrittlement, including the hydrogen effect; (b) active path dissolution, due to metal dissolution which may require oxide rupture. So, this case is of the best interest in this paper (item 3): it had been deduced a crack growth rate equation relating to the initial crack growth rate of the bare metal faradaic-dissolution, the crack tip fracture strain, the crack advance geometric parameter, the repassivation time inverse constant (a measure of the film repair rate in absence of the crack tip straining), the active surface area fraction generated per unit of crack tip plastic strain, and the time.

3. Proposals for model’s improvement

3.1. “Quantification of the effects of crack tip plasticity on environmentally-assisted crack growth rates in LWR environments” (Shoji et al. (2008)) – The new model proposed was already resumed in the

item 2.1. It had been extended the evaluation of the new model, applied to austenitic stainless steel (BWR applications), and nickel alloys 182 and 600 (PWR applications). The strain distribution around a growing crack's collected data was pre-evaluated by a finite element simulation code. Departing from experimental crack growth rate *versus* stress intensity, crack tip strain rate were calculated using a model's equation. The results together with the simulation showed that there was necessity to correct the strain distribution due to the plasticity effect, by a different value attribution on a model parameter.

3.2. "Film rupture model for aqueous stress corrosion cracking under constant and variable stress intensity factor" ((Hall Jr. (2009b)) – Based on his new crack tip strain rate equation (items 2.3 and 2.4), it had been showed the complete development of an alternative model. One departed from 2nd Faraday's law general dissolution equation where the instantaneous crack growth rate is expressed by a constant multiplied by instantaneous anodic current density. After, it was introduced the local conception, of an active surface area where only active metal sites contribute to anodic current density. The fundamental differential equation (3) for the crack surface activation rate was obtained.

$$\frac{dA^*}{dt} = -k^* A^* + (1 - A^*) \gamma \frac{d\varepsilon_{ct}}{dt} \quad (3)$$

where: A^* is the active surface area fraction, t is time, k^* is the reference bare metal passivation rate constant, γ is the active area fraction generated per strain unit, and $d\varepsilon_{ct}/dt$ is the crack tip strain rate.

The author discussed some approximated solutions for constant and variable stress intensity, qualitative and quantitative prediction capacity of his model, and concluded very interesting issues about the film rupture model: (a) creep is necessary to sustain crack growth, and its rate restrains crack velocity for constant and depending on crack length stress intensities; (b) crack tip strain rate due crack advance is consequence, not a cause of the crack growth; (c) the crack tip strain gradient increases and sustains the crack tip stress with the crack advancement: consequently creep can operates and keeps crack growth; (d) the model allows to understand positive and negative stress intensity effects on the crack growth.

4. Main issues on critical review and improvement proposals of the Ford and Andresen model

4.1. General critical review – Incomplete description of the crack tip environmental electrochemistry; doubts about which physical-chemistry parameters are really important; the film rupture mechanism is not well completely understood; unpredictable cases due to microstructural parameters uncertainties; omission of the mechanochemical effects on dissolution; mathematical deficiencies on existing equations; the expression for the anodic current density is not independent of strain rate at the crack tip; the instantaneous repassivation current density does not decay logarithmically.

4.2. Crack tip strain rate formulations – Due to the functional relationship between crack tip strain rate and crack advance velocity, and about the not well understood contribution of the creep on the crack tip strain rate, some formulations had been proposed for this issue. Ford and Andresen have proposed a semi-empiric relationship, but the tendency of the new proposals is based on Fracture Mechanics theory: (a) an alternative equation for the crack tip strain rate mathematically time-derived from the plastic crack tip strain equation proposed by Gao and Hwang, generated a new formulation which had been also criticized; (b) thus it was proposed an alternative equation for crack advance based in a crack tip strain rate equation obtained by Hui and Riedel's crack tip strain rate equation and Kocks and Mecking's creep model.

4.3. Proposals for model's improvement – Two fair alternative models were described: (a) the "Ford-Andresen modified by Shoji" one, which aims to describe the complete crack advance performance with stress intensity, but which was criticized in various points; (b) the Hall's model based on his new crack tip strain rate equation, and in the assumption of an active surface area modifying the 2nd Faraday's law general dissolution equation.

AN ALTERNATIVE MODELING PROPOSAL

This one includes the main of the Hall Jr. 's proposal (item 3.2) represented by equation (4), conjugated with equation (5), which represents a modified dissolution rate equation (2) including the mechanochemical contribution of the slip-step bands action. One departed from a critical issue concerning the omission in the original Ford and Andresen model, of this contribution in dissolution acceleration (item 1.3), to propose a new crack growth rate equation (5) whose deduction is detailed in (Aly and Mattar Neto (2010)) based on this effect ((Gutman and Ke (2008)).

$$\frac{da}{dt} = \frac{da^*}{dt} \exp\left[-\left(k^* - \frac{da^*}{dt} \frac{\gamma \epsilon_r}{r_c}\right)t\right] \quad (4)$$

$$\frac{da^*}{dt} = \left[\frac{\frac{\phi M}{RT}}{\rho \left(\ln \frac{\tilde{a}_a}{a_{red}} - \frac{n \Delta \tau}{\alpha^* R' T} \right)} \right] I_{av}^* \quad (5)$$

where: da/dt is the SCC crack growth rate, da^*/dt is the bare metal dissolution rate, k^* is the reference bare metal passivation rate constant, γ is the active area fraction generated per strain unit, ϵ_r is the crack tip fracture strain (minimum strain required to fracture the crack tip volume of radius r_c), r_c is the radius of the crack tip process zone, t is time, ϕ is the electrode potential, M is the molecular weight, R is the universal gas constant, T is the absolute temperature, ρ is the density, \tilde{a}_a is the mechanochemical activity of atoms in solid metal, a_{red} is the ordinary activity of the species in reduced form, n is the number of dislocations in the pile-up, $\Delta \tau$ is the mechanical stress increase due to strain hardening, α^* is the coefficient of proportionality in the linear dependence of dislocation density on plastic strain, R' is a special constant ($R' = kN_{max}$, where k is the Boltzmann constant and N_{max} is the maximum possible dislocation density), I_{av}^* is the average bare metal dissolution current.

One shall note that the Hall Jr. 's proposal aims to correct the fault of various effects concerning the slip-bands, stacking fault, and dislocations activities, through the active area concept. The proposed alternative has the advantage of providing a more direct modeling capability, gathering the contribution of Hall Jr. (active path dissolution concept), and Gutman 's one concerning the necessity of a mechanochemical action in the slip-step dissolution: one can observe that the general solution for the Hall Jr. model, representing by equation (3) is very complex (item 3.2), and the direct slip-band mechanochemical contribution formulation, can improve the operating facility to apply the model. Naturally, there is a large work which should be done to compare results, and modeling effectiveness in both alternatives.

CONCLUSION/ FINAL REMARK

The critical review of the slip-step dissolution and film rupture model, since its first investigation, allowed the formulation of an alternative theoretical modeling proposal to improve the current used Ford and Andresen 's model version, gathering some critics of the main researchers in this field. This alternative theoretical proposal shall be tested with experimental and literature data, and compared with the original Hall Jr. 's modeling.

The critical review in this paper also allowed to perceive the following issues about this model: (a) its great importance for corrosion science and engineering in modeling stress corrosion cracking; (b) its not complete well understood its mechanism; (c) there are doubts about creep contribution for crack growth rate; (d) there is a tendency to use Fracture Mechanics, instead of semi-empirical relationships, to formulate the crack tip advance; (e) there is a lack of formulation for mechanochemical contribution; (f) there is a possible lack of understanding of complete electrochemical action in the crack tip environment; (g) there are mathematical deficiencies in its formulation.

Last but not least a remark about the scope of the slip-step dissolution and film rupture model: authors Hua and Rebak (2008) mentioned that this model is questionable to explain some cases of stress corrosion cracking like the PWR-high temperature water of Alloy 600. For them, this mechanism is not supported by experimental observations, like the independence of the chromium depletion effect over intergranular cracking, and other; notwithstanding researchers like their from KAPL ((Thompson et al. (1995), Attanasio et al. (1999)), and others (Was and Lian (1998)), seemed to have a good acceptance of this model for explain this case: so, this is a controversial point, probably derived from the not well understood mechanism, which should be better investigate. Maybe other models, like the internal oxidation one (Scott and Le Calvar (1993)), and creep models (Was and Lian (1998)), should be used depending of their applicable domains.

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