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EXPERT SYSTEM TOOL BOX FOR CORROSION PROBLEMS

B VIJAYASEKARAN AND C AHMED BASHA*

Division of Pollution Control, Central Electrochemical Research Institute, Karaikudi 630 006. Tamil Nadu. INDIA

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Innumerable literature have presented the fundamentals of corrosion and its prevention and monitoring. However, very few papers mention the use of computers for understanding corrosion fundamentals, corrosion detection and its control. The intention of this paper is to develop an Expert System (ES) for corrosion problems. The developed software has two modules for the user interface Tutorial and Consultant. The tutorial mode deals with the students and the new comers who are having little knowledge about the corrosion problems. The consultant mode deals with the consultant parties who know some extent level in the corrosion problems. The system deals with corrosion rate calculation, design details and so on. In addition to this the developed ES also deals with the values of potential and pH for non-corrosive operations with the display of Pourbaix diagram for some industrially important metals. The chief advantage of the developed ES is its flexibility to update future improvements and to account the temperature effect on the Pourbaix diagram.

Keywords: Expert system

INTRODUCTION

Programs known as ES were first developed in Artificial Intelligence laboratories [1]. The use of computers in the corrosion application field dates back to the late 1970's. The first technical paper on the use of computers for data collection and storage was presented at the western region conference of the National Association of Corrosion engineers (NACE), 1964 [2]. The paper "Corrosion control evaluation and data recording by electronic computer" discussed the use of electronic computers in data collection and storage. In 1958, Creole Petroleum Corporation leased an IBM 650 data processing computer for accounting and materials control [3]. In 1965, Rochester Gas and Electric Corporation used a standard punch card computer to store data from its pipe to soil potential surveys [4]. In 1967, Texan Eastern Transmission Corporation used a computer for data processing of 650 rectifiers protecting over 10,000 miles of pipeline [5]. The computer system improved performance, efficiency and saved money.

* E-mail: cab_50@yahoo.com

ES have been utilized in a number of disciplines [6-9], including oil well drilling, mineral exploration, diesel locomotive repairs, medical analysis, organic chemical synthesis and computer system configuration. Development of specialized, limited in scope expert systems has been the cost successful, while development of more generalized all-encompassing expert system has been more difficult. Although personal computers may be limited to smaller, specialized ES, it is these ES that are often the most useful.

In an expert system, the control logic is referred to as the inference engine [10] and the problem logic as the rule base. The rule base contains the expertise. The inference engine makes logical deductions based on the expertise in the rule base. The same inference engine is usable in any number of ES, while the rule base must be developed for each different ES application.

This paper describes the essential features and solution of corrosion problems using an ES and a second part the system also gives the predominance area diagram for some industrially important metals and suggestions on corrosion prevention.

Background to computer program

The developed expert systems has two separate programs both dealing with the solution to the corrosion problems from the point of view of fundamental concepts and by the use of Pourbaix diagram aiming for non-corrosive potential and *p*H ranges. 'C' coding developed the programs [11], as it is the best highly structured language and has a very efficiency way of modularized approach, which has facility to create executable files.

ES and other forms of artificial intelligence were once considered strictly the domain of main frame computers, however, advances in both hardware and software house made it possible to run relatively small and specialized expert systems on personal computers. The ES can also built by employing ES generator software [12]. It is an "example driven" system, to enable the software system help solve problems in a specific area; one must build the system using four different files.

The program

One of the most important constituents of an expert system is the user interface [13], that is the user interacts with the system such as user asks the questions and the system answers to him in the rule-set basis of the corrosion methods. In this ES methodology different modules are used, the master module has three data files storing the information on different types of materials used for various environments, details about the metals corroded and a file listing the corrosion mechanisms detials. There are two modules developed for the user interface Tutorial and Consultant.

Tutorial mode

This mode deals with the students and new comers who do not know much about the corrosion problems. This module gives the details about i) Various types of metals to be corroded, ii) Corrosion problems at different environment, iii) Protection from the corrosion problems, iv) Corrosion rate details and is mechanism, v) Corrosion monitoring system - this shows the various metals and their environments with their corresponding corrosion mechanism details.

Consultant mode

This mode deals with the consultant parties. In this situation the users know some extent level in the corrosion problems so they don't need the grass-root details about the corrosion problems. In this reason this module deals with i) The detailed useful information about the corrosion rate for the various metals, this rate is calculated by coupon method [14]. ii) The corrosion mechanism for different metals in the different environments and its protection to the user in its environment.

Decision making

The user can take decision for corrosion problem with right protection level with minimum cost and with maximum gain using the above developed ES which gives the following information.

- System gives corrosion mechanism corresponding to the user details.
- System gives the useful information for the protection of the material from corrosion.
- From the user's detail the system gives the corrosion rate to him.
- It gives the corresponding protection suggestion details.
- If the user wants the paint coating protection the system gives the total charge for it.

Considering these detail the user take correct protection action from the corrosion in the correct time.

Pourbaix diagram

The second part of the ES that is developed as separate coding deals with the display of the Pourbair diagram for some industrially important metals like iron, aluminium, zinc and others.

Possible output formats

The developed ES has provided options for the users. The menu starts with the choices of input to the master module, type of mode to be accessed and the exit choice. One can update the information in an ES at any time by choosing the input option. The type choice gives the submenu to deal with tutorial mode of consultant mode.

Tutorial mode

It gives the choices of possible corroding metals, environment opt for corrosion, corrosion type or mechanism, protection suggestion, monitoring and corrosion system as shown in Fig. 1. The first two choices give the various corroding metals such as copper and its alloys, nickel alloys, iron and steel, zirconium etc. and the environment on which it is highly corrosive like buried, marine, cooling water, organic etc. The third sub module corrosion gives the several types of corrosion and the details about a type chosen from the menu as shown in Fig. 2. The protection module gives the protection methods for corrosion prevention and more details about a method of user choice as in Fig. 3. Monitoring option gives the data needed for corrosion rate calculation and weight loss coupon method used for calculating the corrosion rate in millimeter per year, the display is as in Fig. 4. The final sub module of tutorial mode is corrosion systems, it gives the cumulative result incorporating the metal, its most corroding environment

WELCOME TO TUTORIAL MODE

1. METAL
2. ENVIRONMENT
3. CORROSION
4. PROTECTION
5. MONITORING
6. CORROSION SYSTEMS
7. EXIT

Enter your choice (1/2/3/4/5/6/7)

ES Tool box, CECRI

Fig. 1: Menu displaying the sub modules for tutorial mode

CORROSION MECHANISM

General Corrosion
Galvanic Corrosion
Localized Corrosion
Pitting Corrosion
Crevice Corrosion
Stress Corrosion
Erosion Corrosion

Press any key to continue

Enter the type of corrosion
for details ——— galvanic corrosion

Usually this type of corrosion exists between two dissimilar metals when in contact with a corrosive solution

ES Tool box, CECRI

Fig.2: Display for the sub module corrosion mechanism in tutorial mode

PROTECTION SYSTEMS

(a) Coatings

1. Painting
2. Metallic coating
3. Ceramic coating
4. Rubber or Plastic coating

(b) Cathodic protection
(c) Anodic protection
(d) Environment control inhibition

Press any key to continue

Enter your choice ——— Cathodic protection

An impressed direct curt to a sacrificial anode-zinc, magnesium, aluminium. Inspite or the higher initial cost and anode weight loading, CP systems have near maintenance free nature.

ES Tool box, CECRI

Fig. 3: Display for the sub module protection systems in tutorial mode

CORROSION MONITORING

It is a systematic masurement of cororsion rate of metals in a process industry

$$\text{Corrosion rate} = \frac{(\text{Loss of weight x } 87.6)}{(\text{Area x time x density})}$$

ES Tool box, CECRI

Fig. 4: Display for the sub module corrosion monitoring in tutorial mode

and the mechanism by which the corrosion takes place, the system is as shown in Fig. 5.

Consultant mode

In an ES, questions that prompt the user to enter assertions about the environment, materials etc., are stored in a separate rule base for use through out a consultation. This second mode of consultant displays the choices of monitoring, designing and painting calculations as shown in Fig. 6, each sub modules are illustrated as follow:

Monitoring

Corrosion monitoring is achieved by determining the bulk corrosion rates, many electrochemical techniques for determining corrosion rates have been achieved but the weight loss coupon method is both rapid and economic. By feeding the data such as weight loss, metal area, density and monitored time one can get the corrosion rate in milli meter per year. For the values of 345.678 gms of weight loss, 456.89 cm^2 of metal area 45 gms/cc density with 456.45 hours of monitoring the corrosion rate was found to be 0.002616 mm/yr.

WELCOME TO CORROSION SYSTEMS

Metal	Environment	Mechanism
Copper & its alloys	Buried	General corrosion
Nickel alloys	Marine	Galvanic corrosion
Iron & steel	Cooling water	Localized corrosion
Stainless steel	Colling water	Pitting corrosion
Titanium & alloys	Organic	Crevice corrosion
Aluminium & alloys	Vapour	Stress corrosion
Zirconium	Heat transfer	Erosion corrosion

Press any key to continue

ES Tool box, CECRI

Fig. 5: Display for the sub module corrosion systems in tutorial mode

WELCOME TO CONSULTANT MODE

1. MONITORING
2. DESIGNING
3. PAINTING CALCULATION
4. EXIT

Enter your choice (1/2/3/4/5/6/7)

ES Tool box, CECRI

Fig. 6: Menu display for consultant mode

Designing

This sub module gives the corrosion mechanism taking place and the solution to choose proper protection system that is to be designed. By providing the information about the metal and its environment this mode gives us the corrosion mechanism involved and proper coating choice. For the metal copper and its alloy in the buried environment the corrosion mechanism displayed is general corrosion and the protection coating choice suggested is metal coating using zinc or cadmium.

Painting calculation

Among the protection systems available for corrosion problems, coating is the most suitable for several structures. This sub module deals with the

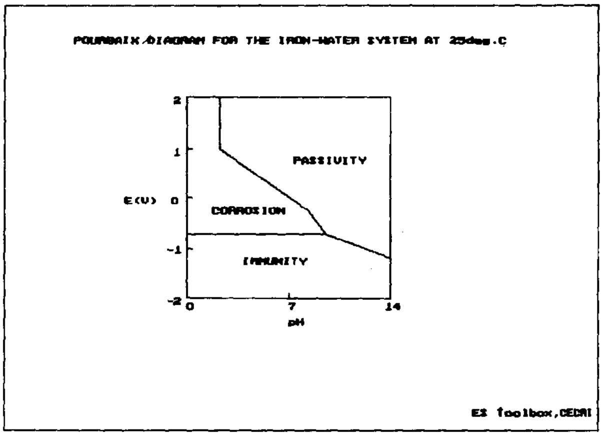

Fig. 7: Output displaying the Pourbaix diagram for iron-water system

economic aspects of coating; it gives the cost for single and double coating of specified paint provided the data such as the pain cost, metal area and labour costs. The costs for a single and double coating were calculated as Rs.13,700 and Rs.9,185 with a labor cost (surface cleaning and applying paint) of Rs.7,500 and Rs.5,000 respectively for a metal area of 30,000 ft^2 and s.75 per litre paint.

Pourbaix diagram

The second set of coding system displays the relative stabilities of solid phases and soluble ions that are produced by reaction between a metal and an aqueous environment as functions of two parameters; the electrode potential E and the *p*H of the environment (Pourbaix diagram), as shown in the Fig. 7. Such information is available for some common industrially important metals such as iron, aluminium, zinc, copper, tin and nickel water systems with the domain of stability for water superimposed. As an additional option this can be continued to a table [15] displaying the resistance for various acids, alkalis, salts and gases. Fig. 8 gives this tabulated output.

CORROSION RESISTANCE OF IRON IN VARIOUS ENVIRONMENTS

Resistance to	Non resistance to
Acid solutions	Acids except hose mentioned ot the left
H_2CrO_4	
HNO_3 concentrated	
H_2SO_4 > 70%	
HF > 70%	
Alkaline solution	
Most alkaline solutions	Hot concentrated alkalis
Salt solutions	if in stressed condition
	$KMnO_4$ < 1 gms/lit
$KMnO_4$ < 1 gms/lit	H_2O_2 > 3 gms/lit
H_2O_2 > 3 gms/lit	Oxidizing salts, e.g. $FeCl_3$, $NaNO_3$
$K_2Cr_2O_4$	
Nitrites	Hydrolysing salts, e.g. $AlCl_3$, $Al_2(SO_4)_3$, $ZnCl_3$, $MgCl_2$
Gases	Air > 723 K
Air < 773 K	Cl_2 < 473 K
Cl_2 < 473 K	F_2,
SO_2, dry < 573 K	SO_2 moist
NH_3 < 773 K	NH_3 < 773 K
H_2O < 773 K	H_2O < 773 K
H_2S < 573 K	H_2S < 573 K

Fig. 8: Output displaying the table for corrosion resistance of iron

Related programs

There are some contributions in the recent past for the use of ES for corrosion problems. A program was developed to help corrosion engineers' design cathodic protection systems [16]. It uses nonlinear and dynamic cathodic boundary conditions to simulate real polarization conditions during the formation of calcareous deposits. One potential application of numerical techniques is the modeling of localized corrosion dells using the finite element method [17].

Allegro CL [18] is the cost powerful dynamic object-oriented development system available today and is especially suited to enterprise-wide, complex application development. Powered by common Lisp, Allegro CL's true dynamic object technology allows developers to generate leading edge, mission-critical applications that are robust, extensible and easy to evolve and deploy. Inter Corr International, Inc, and others [19-21] are also lending the design, implementation and maintenance of corrosion source. Inter Corr is a novel portal site for corrosion content and development of web-based corrosion and materials services.

CONCLUSION

A corrosion ES has been developed to help solve corrosion problems in chemical process industries. The advantages of this ES include (1) The permanent documentation of the present expertise, (2) The wider accessibility to this precious expertise, (3) The easy and quick addition of new information to this body of expertise, (4) The distinct separation between the data banks and the procedures for using the data and (5) The ability to solve "Knowledge-intensive" problems when the data are incomplete or when human experts are not readily available.

The concept of corrosion ES used to solve corrosion problem remains to be tested and proven valid by the plant operators.

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