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ABSTRACT

A description is provided for a Corrosion and Corrosion Control course offered in the Continuing Engineering Education Program at the General Motors Institute (GMI). GMI is a small cooperative engineering school of approximately 2,000 students who alternate between six-week periods of academic study and six weeks of related work experience in their sponsoring plant. The corrosion course provides the students with an intermixing of chemistry, metallurgy, and polymer science as it applies to degradation of materials. The format of the course and sample topics are described. (MLH)

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"CORROSION ENGINEERING"

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CORROSION ENGINEERING AT G.M.I.

Corrosion and Corrosion Control, C-414, finds its origin in a Continuing Engineering Education (CEE) Program at G.M.I. The original concept was one of informing engineers with a number of years experience about new and innovative concepts in corrosion protection and control. This original course was a one week intensive program carried on in-residence by people from all over the General Motors Corporation. Because of the favorable acceptance of this course by plant personnel, it was opened to cooperative students.

As a point of background, General Motors Institute is a small cooperative engineering school of about 2,000 students. These students are predominately in the Mechanical Engineering curriculum with some industrial and electrical engineering students. These students alternate between six-week periods of academic study and six weeks of related work experience in their sponsoring plant. The group that most often takes the corrosion course is mechanical engineers in a Materials Option. The Materials Option is a sequence of seven courses at the Junior and Senior level which provide these people with a background in current materials topics.

The corrosion course provides the students with an intermixing of chemistry, metallurgy and polymer science as it applies to degradation of materials. Like the CEE course, the cooperative program course is based on practical corrosion control practices and identification. The emphasis of the course is to provide the students with a background in corrosion identification and the knowledege of control and prevention methods.

COURSE FORMAT

Corrosion and Corrosion Control is taught in two six-week segments, three hours per week. The main text is "Corrosion Engineering" by Fontana and Greene. In addition numerous supplementary texts, articles and vendor literature are used to supply the students with various viewpoints. It is the overall objective of the course to give each student a working knowledge of various corrosion phenomenon and to make him aware of the sources of corrosion information available. To this goal the following outline is followed:

Topical Outline

Basic Corrosion Chemistry
Measurement of Corrosion
Corrosion Mechanisms
Corrosion Solutions
(a) Change Material
(b) Change Environment
(c) Change Design
(d) Protect
Testing
Research Methods
Additional Related Materials

The time allocation is about three weeks on corrosion mechanisms and five weeks on corrosion solutions. The remaining time being spent on the other topics and testing.

In each six-week period there is one paper and one test. The course material emphasizes identification of corrosion mechanisms primarily in metallic materials. Besides text material each student is exposed to as much hands-on-experience as possible through slides, movies and numerous field failure samples. The objective of these experiences is to equip the student with skills which will enable him to identify field failures and to suggest possible solutions.

In the last two weeks of the first section, the emphasis shifts from identification of corrosion problems to their solutions. As a main line of discussion the concept that all corrosion problems can be solved by one of four methods: (1) Change Material, (2) Change Environment, (3) Change Design, (4) Protect the material is pursued.

Change the Material

In this area physical substitution of, as well as modification of, the metallurgical structure by alloying or heat treatment is considered. Topics included in this discussion are stainless steel, non-ferrous metals, plastics, wood, glass and ceramic.

Change the Environment

Emphasis in this area is directed toward the effects of inhibitors, velocity, concentration, temperature, pollutants, and their interaction.

Change the Design

Much emphasis in this area is directed to the general analysis of existing designs and their improvement. General guidelines are proposed regarding the physical arrangements of the metallic or non-metallic parts of the system and how this might be optimized.

Protect the Material

In this area coatings, both metallic and polymeric, are discussed as well as cathodic and anodic protection. The above areas are discussed primarily in a lecture format with guest speakers in the areas of plastic degradation and paints. These guests add variety and a broader base to the class.

In the last 1/3 of the course, laboratory and field testing, as well as electrochemical laboratory testing and other related topics, are discussed.

PAPERS

As part of the course requirement, each student must write two papers, one each during the two sections.

First Paper

The objective of the first paper is to involve the student with the current literature and to present the state of the art on some practical corrosion problem. Typical topics for this paper are:

(a) Corrosion in Cast Iron
(b) Protective Coatings for Marine Environment
(c) Corrosion Characteristics of HSLA Steels
(d) Chloride Corrosion of Reinforced Concrete
(e) Corrosion and Cooling Water Treatments
(f) Stress Corrosion in ABS

These titles are topics of common interest from readily available periodicals and journals as well as from personal experience. Students may choose a topic from a list as provided by the instructor or he may write on a topic of his invention with the instructor's consent.

The student is required to give both oral and written reports on the subject. The written report is generally limited to ten (10) typed pages. In conjunction with his oral report, he is asked to provide each member of the class with a one page handout summarizing the important areas of his presentation. This handout not only aids the speaker during his presentation, but it also provides each student in the class with a ready source of knowledge on a specific current topic that he would not normally have available to him without extensive library work.

Second Paper

The purpose of the paper in the second six-week period is to involve each student in a hands-on experience and to evaluate that experience and report on it. This usually entails a laboratory investigation of an area of interest to the student. This hands-on experience is quite beneficial to the student since he is required to make decisions which will greatly influence the behavior of his test situation. In general, the students achieve well in this phase of the course. There is free discussion between the lead professor and the students and numerous brain storming sessions which allow free interchange of ideas between students and faculty. The problems that are investigated are, in many instances, quite pertinent to current manufacturing and design conditions. (See Appendix) These topics are of the students' choice and are often related to his plant experience or in other cases a student may choose a topic from the area of his first paper. There is usually no trouble in determining an area of investigation but rather some difficulties are encountered in narrowing the topic area to fit the time and equipment constraints. Before a student can begin a project he must meet with the lead professor and outline his investigation. When agreement is reached as to the extent of the project and what is expected of the student, he can begin.

Again each student is required to present both oral and written reports for his second paper and as before a handout sheet outlining the pertinent points of his paper.

EVALUATION OF STUDENTS

Tests

Generally two one-hour examinations are given during this course. One in each six-week period. The exam during the first section is about 1/2 theory and 1/2 diagnosis of field failures. These field failures are presented to the student in the form of actual parts with a card listing some facts about the environment. Students are asked to:

(1) List the form or forms of corrosion.

(2) Briefly describe what features led them to their decision.

(3) How can this problem be avoided.

Samples for this portion of the test are carefully chosen to minimize confusion of the student. As an example; if a dezincified part is displayed--the student would be expected to identify the form by color and by alloy and suggest replacement with a Sb or As modified brass alloy or a lower Zn brass.

The second exam is written late in the second section and deals primarily with case studies evaluation of corrosion failures. Several situations may be proposed in which a design modification or a protective system installation might be appropriate. The student would be expected to describe the new system or changes to an existing system giving specific reasons for these changes.

WRITTEN AND ORAL REPORTS

Written reports are evaluated by the lead professor after the student's oral presentation. The reports are judged on how well the original plan and the final report correlate, how carefully the data was collected, either in the literature or in the laboratory, and what conclusions were drawn. The student is judged on his ability to field questions, his presentation, his originality in attacking the problem and his technical expertise in the area. The evaluation is primarily carried out by the lead professor. There are, however, inputs from those faculty who have particular expertise in the area of the student's investigation as well as the fellow students.

COMMENTS

The corrosion course operates on a very practical level. It is not intended to produce corrosion researchers, but rather mechanical engineers with an understanding for the causes and effects of corrosion.

The heavy emphasis on skill learning in the first section of the course may be considered by some to be technical training. I believe this form of education is necessary to really penetrate the intellect and give the student a "gut feeling" for the subject. Properly grounded in a discipline, a student can more readily apply this knowledge to real situations. Consequently, an engineer with a strong sense of what is happening and with the ability to identify the problem quickly can more effectively solve or hopefully prevent potential problems.

CVW/ms

APPENDIX A

TITLES OF RESEARCH PAPERS

1) Galvanic Corrosion Study Between SAE 409 Stainless Steel and SAE 950 HSLA Steel.
2) Corrosion Effects of Nitric Oxide (NO) and Sulfur Dioxide (SO_2) on 1008 Cold Rolled Steel.
3) Cutting Fluid Corrosion.
4) Solidification Tests on Inconel 718 and Inconel 625.
5) Engine Cooling System Corrosive Inhibitor.
6) Electrochemical Measurement and Anodic Polarization of Stainless Steel.
7) A Study of Corrosion Measurement by Changes in Electrical Resistance Using Aluminum and Copper.
8) Corrosion of 440C Stainless Steel.
9) Corrosion of Metals in the Food Processing Industry.
10) Underground Corrosion-A Study of Anode Position.

APPENDIX B

Samples of Handouts Prepared By Students For Their Oral Reports

BACTERIOLOGICAL CORROSION

Actually , bacteriological corrosion is corrosion of a material by the by-products of the life processes of bacteria.

Two major kinds of bacteria that are necessarily harmful to steel are :

1. AEROBIC strains which oxidize sulfur.
2. ANAEROBIC strains which reduce sulfates.

Sulfur containing compounds can be found in soluble oils or in machined chips of steel.

AEROBIC REACTION : $2S + 3O_2 + 2H_2O \rightarrow 2H_2SO_4$

ANAEROBIC REACTION : $SO_4^{-2} + 4H_2 \rightarrow S^{-2} + H_2O$

*** Low concentrations of H_2SO_4 are highly corrosive to steel.

The combination of machining chips , dirt , and soluble oil spray became a supportive medium for aerobic bacteria strains which were discovered by the pH indicator, and the pitting corrosion on a 1008 steel sample. The conditions were accelerated. Temperature was 115 F. and 100% humidity.

A possible solution to the steel hydraulic line corrosion problem would be to introduce a bactericide into the soluble oil.

Stress Corrosion Cracking of 300 Series Stainless Steels

Summary:

Stress corrosion cracking is that cracking caused by the simultaneous presence of a tensile stress and a specific corrosive medium. The danger of stress corrosion cracking is that it can cause failures well within the typical design stress range. Damage proceeds most rapidly near failure, and failure occurs by mechanical fracture.

Variables:

stress - The higher the stress, the less time it takes to cause failure. A threshold stress level exists for each set of conditions below which cracking will not occur.

temperature - Increasing temperature accelerates cracking. A temperature threshold also exists - usually below 100° C.

environment - 300 series stainless steels are sensitive mainly to chloride solutions and caustics; and the presence of oxidizers speeds the cracking process. A wet-dry-wet-dry cycle is commonly more damaging than constant immersion, and a material must be reevaluated for each change in environmental conditions.

Various alloying constituents change the resistance to stress corrosion cracking. In general, 300 series stainless steels fall into three groups of cracking resistance.

low	304	medium	305	good	310
	304-L		309		314
			316		
			347		
			347-L		

Stress corrosion cracking can be prevented or reduced by:

1. Lowering the stress levels and the temperatures
2. Reducing the reactiveness of the critical environment
3. Change to a more resistant alloy
4. Cathodically protect the part

Concrete as a Material in Corrosion Service

I. Concrete consist of three materials

A. Mixing water - almost any water will do except for minerial water
- ties up the binding agents

B. Aggregate
1. Stone, sand, [illegible]l,etc.
2. only harsh e[illegible]onments have any corrosion effect

C. Cement.
1. Four major componnd
a. $3CaO\ SiO_2$
b. $2CaO\ SiO_2$
c. $4CaO\ Al_2O_3\ Fe_2O_3$
d. $3CaO\ Al$[illegible]

II. Concrete corrosion - conerete protection

A. Leaching of free lime
1. Causes
a. Sotf water on external surfaces
b. Water seeping through struture under pressure
2. protection
a. Increase $Ca(OH)_2$ccontent
b. Isolate concrete from attacking environment

B. Exchange corrosioh of readily soluable compounds
I. Causes
a. Ion attack in a fluid media
b. washing away of corrosion product
2. Protection
a. Isolate concrete from aggresive fluid
b. Pour denser concrete
c. Find a cement more suitable to environment

C. Corrosion by expansion
1. Causes - same as "B" except corrosion product is not carried away
2. Protection - same as "B"

The best methods of protection are the simplest and least costly. Meaning during mixing and pouring of the concrete not after it is in use.