Overview: Sections 1 and 2

The symposium on hydrogen embrittlement began with an overview session which provided the backdrop for topics related to the processing of steel and titanium, service environment, manufacturing and processing, prevention and control, and research in progress.

Louis Raymond, in his paper, writes about the current status and future projections related to hydrogen embrittlement test methods. He points out that many test methods are employed for the prevention and control of hydrogen embrittlement; however, only a few have been standardized, notably ASTM Standard F 519-77, Method for Mechanical Hydrogen Embrittlement Testing of Plating Processes and Aircraft Maintenance Chemicals. He then discusses proposed ASTM hydrogen embrittlement test standards falling into three categories: (1) hydrogen introduced while making steel; (2) hydrogen introduced during manufacturing and processing of hardware; and (3) hydrogen introduced during service or environmental exposure. When the source of hydrogen cannot be eliminated, you must measure the relative susceptibility of a candidate material as a function of that environment. Standards being proposed are related to the disk pressure test for high-pressure gases, the slow strain rate tension test for aggressive hydrogen sulfide, and the rising step load test with potentiostatic control in an aqueous environment to measure relative susceptibility as a function of melting practice, alloy additions, and processing. A summary is given on three general approaches used to evaluate the potential problem of hydrogen embrittlement in finished hardware. These approaches center on sustained load testing, the Barnacle electrode, and acoustic emission. Raymond concludes by emphasizing that future research and development efforts for standard test methods should concentrate on quantitative analysis using fracture mechanics and accelerated small specimen tests.

John J. DeLuccia's paper on electrochemical aspects of hydrogen in metals contains a review of the electrode kinetics of the hydrogen evolution reaction and the entry of electrolytic hydrogen into metals as it affects hydrogen embrittlement. The paper starts with a historic perspective, citing the findings of Cailletet in 1864 and Bodenstein in 1922 and moves quickly to recent work on the mechanisms and kinetics of hydrogen embrittlement. An excellent review of elementary electrochemistry follows, describing exchange current density, polarization (and mechanisms of), hydrogen in crack tips, the mathematics of hydrogen permeation techniques, and deviations from simple diffusion behavior. Summarizing, the author points out that the electrochemical discharge of hydrogen ions at a metallic surface occurring during electroplating, electromachining, pickling and cleaning, and corrosion can provide the hydrogen source for embrittlement. Polarization of the electrochemical discharge and recombination reactions will increase the probability of hydrogen embrittlement. In addition, the presence of innocuous electrolytes in surface crevices can act as potent sources of hydrogen. The paper contains 50 references.

Edward T. Clegg's paper is divided into two main topics: (1) a complete explanation of the Department of Defense (DOD) specifications and standards program; and (2) a summary of DOD standardization documents related to hydrogen embrittlement. He describes the DOD standardization organizational structure starting with the Secretary of Defense and culminating with each service and a defense logistics agency departmental standardization office, DEPSO. The DEPSO in turn delegates program responsibility to standardization offices located at military installations having the necessary expertise. A description of hydrogen embrittlement, cause and effect, is given. This is followed by specifics related to government standardization documents on post heat treatments, surface preparation, sampling procedures, specimen and parts selection, and inspection techniques. Clegg concludes by listing practical steps to minimize hydrogen embrittlement. An appendix to his paper contains a list of related government specifications, standards, and handbooks.

Allen W. Grobin, Jr. gives a liason report from ASTM Committee B08 on Metallic and Inorganic Coatings to ASTM Committee F07.04 on Hydrogen Embrittlement. Two B08 subcommittees are involved with hydrogen embrittlement: (1) B08.02 on substrate preparation to avoid embrittlement in metallic coating processes and shot peening; and (2) B08.10 on test methods for embrittlement in plated parts and for the evaluation of plating solutions. Committee B08 also prepares standards on low embrittlement processes (that is, mechanical plating, vacuum, and ion vapor deposited coatings) and administrates the U.S. Technical Advisory Group for the International Standards Organization Technical Committee (ISO/TC 107) on Metallic and Nonorganic Coatings. ISO/TC 107 is preparing draft proposals to avoid/test for hydrogen embrittlement. In addition, Committee B08 works closely with Committee F16 on test methods and product specifications to detect fastener embrittlement. Grobin gives a balloting summary of proposed methods to prevent and detect embrittlement related to steel heat treatments prior to and after surface coatings and inclined wedge and notched spring tests.

The paper by David J. Coates examines some of the techniques and test methods for monitoring and control of hydrogen-induced failure of materials developed by the Society of Automotive Engineers/Aerospace Material Specifications (SAE/AMS), Industrial Fasteners Institute (IFI), American Welding Society (AWS), and National Association of Corrosion Engineers (NACE). He cites specific examples, such as SAE ARP-1525 providing test methods for determining hydrogen embrittlement effects in metals resulting from aircraft maintenance chemicals; IFI-113 having hydrogen embrittlement test procedures for quality control in the manufacture of steel self-tapping screws; AWS A4-3 having standard procedures to determine the amount of diffusible hydrogen in martensitic, bainitic, and ferritic weld metal produced by arc welding; and NACE TM-01-77 test method to determine a metals resistance to sulfide stress cracking. Coates' concluding remarks stress the importance of having a basic understanding of the applicability of test method results to "in-service" situations and the limitations of any given test method. He sees a need for increased intersociety agreement on existing specifications and test methods related to hydrogen embrittlement.

Robert Dreher addresses the importance of accelerated testing to meet production schedules. The standard 200-h sustained load tests are too long, creating as much as a 2-month delay before being scheduled for testing by a commercial laboratory. If one of the three samples ruptures before 200 h, the test must be repeated, further extending the delay to where production hardware is often installed before the testing is completed. Therefore, not only must the test time be accelerated, but the acceptance criteria revised to resolve any disputes within a much shorter time.

W. J. Pollock addresses Dreher's concerns by proposing a modification to ASTM Method for Mechanical Hydrogen Embrittlement Testing of Plating Processes and Aircraft Maintenance Chemicals (F 519) that accelerates the test by using the type 1a specimen, but in a slow strain rate (displacement controlled) notched tension test. Pollock supplies an abundance of data, evaluating a large number of platings and coatings in order to substantiate his position.

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