History of SCC Research: A Record of Progress

Sergei A. SHIPILOV[1]

[1] *Materials Science and Technology Division, Oak Ridge National Laboratory, United States of America*

Among the earliest indications that the study of SCC had practical application is a report that came out of India in the last half of the 19th century concerning cracks ("season cracking") that occurred in brass cartridge cases belonging to the British army. William H. Johnson of Manchester was the first to report the detrimental influence of aqueous environment on the ductility of iron and steel exposed to strong hydrochloric acid or dilute sulphuric acid. In his first short, half-page account that was published on January 7, 1873, Johnson wrote that, "If after immersion for say ten minutes in either of these acids a piece of iron or steel be tested, its tensile strength and resistance to torsion will be found to have diminished." This apparently was the earliest experimental report of SCC in metals. In 1874, Reynolds of the University of Manchester associated the loss of ductility of iron immersed in acid with the presence of occluded hydrogen and observed the reversible character of hydrogen charging of iron. For years after these initial discoveries, only fractional experimental work was carried out on SCC and interest in this subject took a theoretical, rather than a practical, turn. However, by the beginning of the 20th century this had changed; a change prompted when SCC was detected in brass condenser tubes in the rapidly growing electric power industry. The earlier studies of embrittlement of iron and mild steels by caustic solutions, to which the term "caustic embrittlement" has been applied, were conducted between 1910 and 1914. The first published account of laboratory experiments on corrosion fatigue was given by Haigh in 1917. In 1918, the first ever SCC symposium—a Topical Discussion on Season and Corrosion Cracking of Brass—was arranged in Atlantic City, NJ. The symposium was confined entirely to the season cracking of brass cartridge cases, a problem in war time. Further historical aspects and trends in the study of SCC developed as indicated below:

- In the mid-1930s, the first structural failures due to SCC of austenitic stainless steels were observed. They were clearly distinguished from intergranular corrosion and identified as SCC caused by the presence of chlorides in 1939.
- The 1940s and 1950s were a time when the seriousness of the SCC problem, the need to identify materials sensitive to SCC and environments that facilitate material failure, and the urgency of defining a research agenda became evident. In the early 1940s, it was reported that the resistance of Fe-Cr-Ni alloys to SCC increased with Ni content. Also, in the early 1940s, the electrochemical nature of SCC was first recognized. In 1944, the first major symposium—Symposium on Stress-Corrosion Cracking of Metals—was held in Philadelphia, PA. Twenty nine papers were presented in this symposium. Although by that time SCC was recognized as a serious industrial problem, the second major symposium occurred only in 1954. These two symposia discussed a wide range of materials. However, their proceedings contain experimental data pertinent to a number of different areas and hence do not readily provide useful information about advances in SCC. The approach to research was very limited and did not draw on scientific methodologies available at the time as SCC researchers do today. In 1957 and 1961, the first component failures due to SCC arose in pressurized and boiling water nuclear reactors, respectively. Since then, SCC and stress-induced localized corrosion in various components of water-cooled reactors have come to represent a major generic problem in the nuclear industry.
- By the 1960s, fracture mechanics had become a serious consideration for studying SCC and corrosion fatigue crack growth (FCG) in high-strength steels and light alloys. The slow strain rate test (SSRT) method was developed and first applied for SCC evaluation in 1966. It was shown that titanium alloys earlier thought to be immune to SCC on the basis of conventional smooth specimen tests were, in fact, highly susceptible to SCC when evaluations made use of precracked specimens. In 1969, the first measurements of the pH and electrochemical potential within a growing stress-corrosion crack were conducted.
- In the 1970s, significant effort was exerted to identify the mechanism(s) of SCC and corrosion FCG. The search for mechanisms led to some interesting ideas and theories and fuelled interest in the International Conference on Mechanisms of Environment Sensitive Cracking of Materials in 1977. In the 1980s, a major achievement was the accurate modelling and measurement of crevice and crack chemistry and its consequences for crack propagation under static, dynamic, and cyclic loading. One of the major distinctions in research carried out in 1990s was the widespread and purposeful use of new techniques including in situ, high-resolution analytical methods and computational

methods for studying SCC and corrosion fatigue.