

EFFECTS OF ATMOSPHERIC ENVIRONMENTAL CONDITIONS ON FATIGUE CRACK GROWTH RATES

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Corrosion has a significant impact on the fatigue of aging aircraft. In service, an airframe will be exposed not only to a spectrum of mechanical loading due to variations in flight profile and mission types, but also to a spectrum of environmental conditions. The detrimental influence of chlorides on fatigue performance for metallic materials has been well-documented in mechanical tests typically performed in an aqueous solution. In studying aircraft alloys, however, the environmental influence is that of a multifarious non-stationary gaseous atmosphere, making an aqueous exposure a poor predictor of in-service corrosion phenomena. Temperature, humidity, atmospheric gas composition, salt concentration, pollution, and UV light exposure all vary as a complex function of geographical location, seasonal weather patterns, diurnal cycle, and flight mission profiles. Research in accelerated corrosion testing has resulted in noteworthy advances in understanding the kinetics of atmospheric corrosion. Current test methodologies, such as the salt fog described in ASTM B117, often correlate poorly with field exposure. The addition of ozone, UV light, and control of relative humidity was shown to create corrosion in highly pure Ag samples similar to outdoor exposures due to the formation of reactive oxidizing species. AA 5083 and carbon steel samples demonstrated similar discrepancies between lab simulated and actual field exposures that were mitigated in lab testing with the addition of ozone and UV light. Chlorides in conjunction with strong oxidizers like ozone react to create species that attack the substrate material. Furthermore, the aerosols that deposit chlorides on field exposure samples can vary in size, composition and acidity. These variations have proven in recent experiments to influence corrosion morphologies and rates. When considering environmental influences on fatigue crack growth rates (FCGR), investigations have focused on a more limited set of parameters. The effects of water vapor on FCGR have been examined in tests under vacuum, partial vacuum, dry inert gas, lab air, and at climatic low temperatures by numerous investigators. At low temperatures, air has little capacity to hold water. Indeed, experiments with AA 2024-T3 and AA 7075-T6 at -75°C demonstrated FCGR much lower than that at room temperature. Similar results were obtained with AA 2024-T351 and AA 7475-T7651 at room temperature and at -54°C though the FCGR difference was clearly sensitive to stress ratio, R , and stress intensity factor range, ΔK . Further evidence for the role of water vapor was demonstrated by research exhibiting decreasing FCGR with decreasing relative humidity and tests exhibiting the same behavior with decreasing water vapor pressure, both with AA 7075-T651. Since systems to apply and control multiple environmental parameters in conjunction with mechanical loading are not readily available, such a system has been developed to apply and control relative humidity (2% to 100%), specimen temperature (-57°C to 121°C), ozone (30 ppb to 50 ppm), salt spray (NaCl, CaCO₃, NaHCO₃), background gas (CO₂ and N₂) and UV light. The chamber is designed to fit 245 kN and some larger servo-hydraulic test frames. The current test program is designed to elucidate the effects of the individual environmental parameters before moving onto combinations of parameters to enable a better understanding of the underlying mechanisms. Baseline FCGR tests are underway on center-cracked AA 7075-T651 specimens at a range of R values between -1 and 0.9. Constant amplitude sine wave decreasing ΔK , increasing ΔK tests are used to generate full FCGR curves to characterize behavior from threshold to stable tearing, but constant K -gradient test control will be investigated as a means of accelerating testing efforts. Tests at various ozone levels and chloride loading levels are to follow. The effects of ozone levels at 1-3 orders of magnitude higher (0.5 – 50 ppm) than typical ground level ozone values will be examined to determine at what combinations of ozone concentration and testing frequency an effect can be seen. Salt loading will focus primarily on the effects of relative humidity variations near the deliquescence point. There is some evidence to suggest that FCGR may decrease at relative humidity levels above the deliquescence point presumably due to significant corrosion products influencing crack closure. These effects will be of significant interest. Testing will eventually transition into the simultaneous application of a spectrum of environmental conditions with a mechanical loading spectrum. The resulting test data will ultimately be used to improve fatigue life prediction models that typically rely upon laboratory air FCGR data.