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Engineering & Scientific Consulting

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Professional Profile

Mr. Sire specializes in fracture, fatigue, and fitness-for-service assessment of mechanical systems. He has more than 40 years of experience assisting clients in evaluation of pipelines, ship structures, ground transportation vehicles, aerospace structures, and implantable medical devices.

Recently, Mr. Sire has managed a number of large, multidisciplinary teams supporting clients in domestic and international arbitrations and litigations involving gas and liquid petroleum transmission pipelines, process piping, and electric power generation equipment. His capabilities include deterministic and probabilistic fracture mechanics analysis, development of fracture and fatigue analysis software, finite element analysis, and integration of test data and performance history with analytical methods.

Mr. Sire's areas of professional focus include evaluation of damaged transmission pipelines, steam turbine failures, electric generator failures, stress and fatigue analysis design support for new product development, and failure analysis of welded structures. He has assisted clients developing implantable medical devices, energy storage systems, and offshore petroleum transport systems. Mr. Sire has also served on failure review panels for commercial clients related to nuclear fuel bundles and communications satellites.

Mr. Sire is a developer of the NASCRAC Software™, a general-purpose fracture mechanics analysis program developed by Exponent for the National Aeronautics and Space Administration (NASA). Mr. Sire has developed specialized fatigue analysis software for NASA based on measured strain histories for Space Shuttle Main Engine components, and he has developed probabilistic analysis modules for steam turbine rotor life evaluation software for the Electric Power Research Institute.

Academic Credentials & Professional Honors

M.S., Solid and Structural Mechanics, University of California, Los Angeles (UCLA), 1980

B.S., Mechanical Engineering, University of California, Los Angeles (UCLA), 1978

Recognized twice by the National Aeronautics and Space Administration for creative technological developments in fracture mechanics

Prior Experience

Staff Engineer, Structural Mechanics Department, Missile Systems Group, Hughes Aircraft Company, 1979-1980

Engineering Assistant, Structural Engineering Department, General Atomic Company, 1978

Professional Affiliations

American Society of Mechanical Engineers (life member)

ASTM International

- Committee E8 on Fatigue and Fracture (member)

Publications

Sire RA, Ames N, Hanson E. Crack Growth Analysis Averts Failure in Pumped-Storage Hydroelectric Generator Rotors. J Failure Analysis and Prevention 2021; 21(5): 1538-1556.

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Murray SJ, Edmonds JS, Foulds JR, Sire RA, Chi W-M. Modeling fault propagation in and electric generator stator core. Proceedings, 8th EPRI Steam Turbine-Generator Workshop and Vendor Exposition, Electric Power Research Institute, 2003.

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Moncarz PD, Caligiuri RD, McDonald BM, Sire RA, Borduin WP. Ultimate moment capacity of many steel

connections: failure in design, materials or workmanship. EUROMAT '98-Conference on Materials in Oceanic Environment, Lisbon, Portugal, July 1998.

McDonald BM, Sire RA, Caligiuri RD. Ductile initiation of cleavage fractures in welded moment frame connections. Proceedings, 12th Engineering Mechanics Conference, American Society of Civil Engineers, pp. 74-77, La Jolla, CA, May 1998.

Sire RA, Hopkins SW. Analytical modeling for life extension of aging equipment. International Journal of Fatigue 1997; 19(Sup.1):S261-S266.

Harris DO, Sire RA, Dedhia D. NASCRAC™ NASA crack analysis code, Version 3.0. User's and Theory Manuals, Failure Analysis Associates and Engineering Mechanics Technology, Inc., July 1994.

Sire RA, Kokarakis JE, Wells CH, Taylor RK. A probabilistic structural life prediction system for container ship repair and inspection. International Journal of Pressure Vessels and Piping 1992; 50(1-3):297-315.

Popelar CF, Kanninen MF, Davidson DL, Harris DO, Sire RA, Duncan LB, Kallis JM, Buechler DW, Sandkulla DC. Experimentation and analysis of fatigue crack growth in microscale components. Proceedings, Fracture Mechanics: 23rd Symposium, American Society for Testing and Materials STP 1189, Chona R (ed), 1992.

Sire RA, Harris DO. Probabilistic fracture mechanics modeling of micro-electronic component reliability. Joint ASME/JSME Conference on Electronic Packaging, American Society of Mechanical Engineers, Advances in Electronic Packaging 1992; 2:991-997.

Davidson DL, Popelar CF, Kanninen MF, Harris DO, Sire RA, Duncan LB, Kallis JM, Buechler DW, Chen IC. Application of fracture mechanics to plated-through-hole thermal cycling fatigue. Symposium on Electronic Packaging in Harsh Environments, Electrical and Electronic Packaging Division, Winter Annual Meeting of the American Society of Mechanical Engineers, Atlanta, GA, December 1991.

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Rau CA, Eiselstein LE, Sire RA. Probabilistic assessment of crack initiation and growth in shrunk-on disks. Proceedings, Fossil Steam Turbine Disc Cracking Workshop, Charlotte, NC, October 1990; EPRI GS-7250; 9-2 to 9-7, April 1991.

Dedhia DD, Sire RA, Harris DO. Generation and use of 3-D Influence functions by use of the NASCRAC™ computer code. Advanced Earth-to-Orbit Propulsion Technology 1990, Vol. III, NASA Conference Publication 3092, Scientific and Technical Information Division, pp. 457-473, 1990.

Sire RA, Harris DO, Eason ED. Automated generation of influence functions for planar crack problems. fracture mechanics: Perspectives and directions. 20th Symposium, American Society for Testing and Materials, ASTM STP 1020, Wei RP and Gangloff RP (eds), pp. 351-365, 1989.

Harris DO, Dedhia DD, Sire RA, Woytowitz PJ, Nelson EE. NASCRACtrade;—Fracture mechanics analysis code. Advanced Earth-to-Orbit Propulsion Technology 1988, Vol. I, NASA Conference Publication 3012, Scientific and Technical Information Division, 1988.

Harris DO, Muir DW, Sire RA, Perry WC, Rau SA. Analysis of two-piece diesel engine pistons. Proceedings, American Society of Mechanical Engineers Pressure Vessels and Piping Conference 1985; 98(5); 77-88, New Orleans, LA, July 1985.

Presentations

Gupta A, Caligiuri RD, Moncarz PD, Sire RA. Fatigue damage assessment techniques for SPM anchorages. 16th International Offshore and Polar Engineering Conference, San Francisco, CA, June 1, 2006.

Sire RA, Saraf VK, Moncarz PD. Simulation of hull rupture during ship collision with dock. ASM Materials Solutions Conference, Failure Analysis and Prevention Symposium, Columbus, OH, October 2004.

Sire RA, Hopkins SW. Analytical modeling for life extension of aging equipment. Engineering Foundation International Conference on Fatigue Damage in Structural Materials, Hyannis, MA, September 1996.

Sire RA, Hopkins SW. Standardization of elements within software codes used for fatigue and fracture lifetime prediction. American Society for Testing and Materials E8.04 Workshop on Software Codes in Industry/Fatigue and Fracture, Orlando, FL, May 1996.

Sire RA, Hopkins SW. Analytical modeling using elastic-plastic fracture mechanics. ASM International Advanced Aerospace Materials/Processes Conference (AeroMat'94), Anaheim, CA, June 1994.

Sire RA. Techniques for fatigue life prediction from measured strains. Advanced Earth-to-Orbit Propulsion Technology 1986, Marshall Space Flight Center, AL, May 1986.

Project Experience

In more than 40 years of professional experience, Mr. Sire has investigated failures in hundreds of components in mechanical systems and structures, ranging in size from micro-electronic interconnects and cardiovascular implants to containerized cargo ships and aerospace vehicles. Significant commonalities in nearly all of these investigations include the relationships between the materials, geometry, and applied loads and the environment that ultimately determine the performance of the component or structure and its useful life. This work has often involved finite-element stress analyses of relevant components or systems of components. Mr. Sire has specialized expertise and experience in modeling fracture and fatigue in mechanical and electronic components for forecasting expected lifetimes of new designs or analyzing failures in existing structures. His work experience includes analysis of offshore platforms, steel-frame high-rise buildings, chemical process equipment, pipelines, pressure vessels, aircraft and spacecraft, construction equipment, trucks and automobiles, implantable medical devices, and more. He has evaluated many of these structures relative to applicable codes and industry standards, including ASME, AWS, ASTM, and API. Selected project experience is summarized below.

Steam Turbines and Electric Generators

Steam Turbine Blade Fracture – Investigated the cause of fracture in a last-stage blade of a low-pressure steam turbine as part of an international arbitration. Performed stress and fracture mechanics analyses and evaluated conditions related to stress corrosion cracking. Provided technical guidance and support for legal team through analysis of large amounts of data, onsite inspections, preparation of expert reports, and hearing preparation.

Steam Turbine Blade Fatigue Failure – Investigated the failure of third-stage blades in a low-pressure steam turbine at a combined-cycle power plant in the UK. Blade failures occurred by high-cycle fatigue in a blade row that did not exhibit foreign object impact damage that could have provided sites for fatigue crack initiation. Analysis indicated excitation of a blade eigenfrequency under operating conditions, which led to initiation and propagation of high-cycle fatigue crack growth.

Lamination Fault in Electric Generator – Performed detailed thermal modeling and simulations of damage to a generator stator core at an electric power generating station. Analysis involved simulation of initiation and propagation of a thermal burn-through resulting from an interlamination electrical short in the

generator stator. Modeling and simulations based on first principals matched well with observed damage.

Hydroelectric Generator Failure Prevention – Performed stress and fracture mechanics analyses of 1,200-MW hydroelectric generator rotors to evaluate the potential for fatigue cracking in pole-attachment dovetail slots. Results of the analysis indicated a relatively high likelihood of cracking given the age and operational history of the units. Recommended inspection of the pole-attachment slots revealed the presence of fatigue cracking. Further analysis of temporary repairs provided the owner confidence for limited additional operation while replacement rotors were manufactured.

Hydroelectric Generator Overspeed Event – Investigated the cause of an overspeed event on a hydroelectric generator rotor following a sudden and unexpected loss of load on the transmission line connection the power plant to the electrical grid. Inspection and laboratory analysis of a fractured pole-winding series connection on the rotor revealed that that fracture occurred due to overload during the overspeed event and subsequent to tripping of the rotor excitation.

Pressure Vessels, Process Piping, and Transmission Piping

Hypersonic Wind Tunnel Fracture Control - Performed stress and fracture mechanics analysis of very-high-pressure components in a hypervelocity wind tunnel system to evaluate fatigue crack growth life as part of a comprehensive fracture control program. Work involved stress analysis of pressure vessels and fittings with maximum operating pressures in the range of 20,000 to 40,000 psig. Stress results were used to calculate fatigue crack growth life for postulated cracks at high stress locations. Results aided the operator in repair decisions and selection of inspection intervals and nondestructive evaluation methods.

Deficient Plates Supplied for Manufacturing Subsea Pipe– Provided technical analysis and support for an international arbitration involving material problems in plates supplied for making heavy pipe for an offshore gas transmission pipeline. Work involved sampling and analysis of material from plates and pipes, metallurgical examinations, mechanical testing, environmental testing, and critical evaluation of fitness-for-service analyses purportedly performed in accordance with British Standard BS-7910.

Corrosion Damage to New Gas Transmission Pipeline – Investigated extensive corrosion pitting damage discovered on a newly installed natural gas transmission pipeline. Efforts included extensive field data collection to document and evaluate the condition of the pipeline coating and potential causes for observed pits. Evaluated soil resistivity and pipe-to-soil potentials for assessment of stray currents. Supported client responses to state regulatory agency. Provided technical input at mediation.

Corrosion Damage from Coating Failure on Offshore Platforms – Investigated corrosion damage to process piping and structural components on offshore gas production platforms as part of litigation over failure of the coating system. Involved evaluation of extensive inspection data compilations, site visits, and assessment of potential threats to worker health and safety.

Rupture of Refined Petroleum Transmission Pipeline – Provided technical analysis and litigation support related to failure of a liquid transmission pipeline due to seam-weld manufacturing flaws. Work included metallurgical analysis of rupture pipe joint, analysis of operating pressure data, comparative analysis of inline inspection results, and critical assessment of technical assertions made by opposing experts.

Main Steam Line Fitness-For-Service - Performed API 579 / ASME FFS-1 fitness-for-service analysis of a desuperheater header in a combined-cycle power plant following malfunction of an attemperator that caused thermal cracking in the line. Work included metallurgical examination, thermal-elastic finite-element stress analysis, creep and fatigue crack growth analysis, and inspection frequency recommendations.

Supercritical CO2 Wafer Cleaning Tool – Provided design analysis support for a client developing a supercritical CO2 system for cleaning PVD-processed silicon wafers. Performed design stress analyses on pressure vessels per Section VIII, Division 2, of the ASME Boiler and Pressure Vessel Code. Project included a system HAZOP analysis and assessment of leak and rupture effects on personnel and building

structures.

Upstream Oil and Gas Processing Facility – Assessed the occurrence and cause of sulfide-induced stress corrosion cracking in small-bore process-piping welds that led to releases of H2S gas to the environment.

Bellingham, Washington, Pipeline Rupture and Fire – Analyzed the failure of a 16-inch-diameter liquid petroleum line, including evaluation of external piping damage. Assessed the role that external mechanical damage may have contributed to the leak and subsequent fire.

Cast-Iron Check Valve Failure – Performed stress and fracture analyses to determine the cause of the failure of a grey cast-iron check valve installed in the ammonia-based refrigeration system at an ice cream factory. The valve failure released a large quantity of liquid ammonia, which subsequently vaporized and resulted in a large explosion and fire.

Carlsbad, New Mexico, Pipeline Rupture – Analyzed the failure of a 36-inch natural gas transmission line, including evaluation of the effects of internal corrosion. Assessed the extent to which water ingress into the transmission line from third-party producers, and the pipeline configuration, may have contributed to the observed internal corrosion.

Main Steam Throttle Valve Fitness-For-Service – Assessed the fitness-for-service of a pair of 35+-year-old main steam throttle valves at an electric generating station. Performed nonlinear elastic-plastic finite-element analysis with time-dependent creep for assessment of remaining creep and fatigue life of the valve bodies. Applied API 579 / ASME FFS-1 assessment methods.

Gasoline Pipeline Leak – Analyzed the effects of stress corrosion cracking in a gasoline transmission pipeline. Assessed the extent to which external mechanical damage to the pipeline may have contributed to the leak.

Cast Iron Natural Gas Distribution Line – Investigated the possible role of a cast iron natural gas distribution line in the cause of a fire that destroyed a house in suburban Detroit, Michigan. Efforts included evaluating the extent of graphitic corrosion of the buried pipeline.

Undersea Crude Oil Pipeline – Examined the quality of the welds in a newly constructed 24 inch-diameter liquid pipeline relative to applicable standards, and the role of the welds in the integrity of the pipeline.

PEPCON Explosion - Investigated the cause of a series of explosions that destroyed a solid rocket oxidizer plant in Henderson, Nevada. Assessed whether a 16-inch high-pressure natural gas transmission line that traversed the plant and was damaged by the explosions might have played a role in the incident.

Offshore Structures

Steel Jacket Brace Failure - Investigated the failure of a large welded tubular steel brace in the jacket of an offshore petroleum platform in the North Sea as part of an international arbitration. Evaluated fatigue fracture surface evidence, fabrication details, wave loading history, and stress analysis results to determine the cause and timeline of the failure.

Jack-up Platform – Performed stress analysis of welded tubular joints in the legs of the mobile oil drilling platform. Corner joints and K-joints were modeled three-dimensionally and analyzed for various sea-state loading conditions.

Container Ship Deck Cracking – Investigated cracking in container ship main deck from welded stiffeners installed as part of “jumbo-izing,” in which the hull was lengthened by cutting it amidships and inserting a new section of hull. Developed a custom probabilistic fracture mechanics simulation program to evaluate the effects of various design and welding parameters on the expected fatigue performance of the ship structure. Involved evaluation of dynamic hull response to sea states, stress analysis, metallurgical analysis, and numerical simulations. Recommended optimized inspection program for enhanced reliability

and cost control.

Container Ship Bulkhead Cracking – Investigated longitudinal bulkhead cracking in a fleet of container ships used in the Gulf of Alaska. Performed finite-element stress analysis using loads obtained during actual ship voyages as part of a testing phase of the project. Strain data, meteorological records, and wave height data recorded aboard ship during voyages between Tacoma, Washington, and Anchorage, Alaska, were correlated and used to develop a long-term loading spectrum for fatigue crack growth analysis. Recommendations were made for structural modifications to improve fatigue reliability.

Single-buoy Mooring Anchorage Failure – Analyzed the cause of the failure of an offshore single-buoy mooring system during the off-loading of a very large tanker. Evaluated the relative roles of fatigue and overload in the failure of the structural welds in the rocker beam assemblies, including estimating the potential fatigue loading spectra under various tidal conditions.

Floating Hose Breakaway Couplings – Investigated multiple incidents involving unexpected separation of marine breakaway couplings used in floating petroleum hose strings for an offshore tanker terminal. Performed stress and fracture analyses, conducted metallurgical evaluations, made and implemented design change recommendations, and recommended and implemented modified assembly procedures for improved reliability. Project included development of custom load-sensing studs and procedures for preloading the coupling flanges. Interfaced with coupling manufacture in England to improve design and preloading technique.

Buildings and Structures

Construction Crane Failure – Evaluated the collapse of a tower crane at a building construction site in Seattle, Washington. The project included non-linear stress analysis of the crane base for various movements of the crane, and crack growth simulation for evaluation of the fatigue cracking that led to the collapse.

Steel Moment Frame Weldment Failures – Investigated the causes of failed welds found in steel moment frame buildings after the Northridge Earthquake in Los Angeles. Project involved ultrasonic and visual inspection of weldments in buildings, metallurgical examinations of failed welds removed from buildings, finite-element analyses of moment frame connections, and fracture mechanics analysis of weld cracks.

Nuclear Reactor Nozzle Leak – Investigated damage to a nuclear reactor vessel head caused by leakage of coolant through a stress corrosion crack in an upper head nozzle. Project involved stress and fracture mechanics analysis of the head and nozzle, simulation of thermo-hydraulic conditions from the leaking crack, and assessment of flow- and corrosion-induced head damage.

Underground Natural Gas Storage Facility Casing Failure – Assessed the potential role of failures at seal-welded threaded connections in the casing string in a massive loss of natural gas from a salt-dome storage cavern. Reviewed the specifications and welding procedures relevant to the fabrication and welding of the casing, including the effect of preheat. Performed finite-element stress analyses of the threaded and seal-welded connections.

Stress Corrosion Cracking in Nuclear Steam Generators – Investigated stress corrosion cracking and leakage of primary coolant from Inconel 600 steam generator tubes in U.S. pressurized water reactors. Conducted extensive literature reviews and analysis of operational experience and test data on behalf of the steam generator manufacturer.

Paper Mill Superheater Tie-Weld Failures – Investigated the cause of cracking in welds used to tie together serpentine tubes in a paper mill recovery boiler. Project included in-service examination of tie welds, metallurgical examination of failed tie welds, finite-element stress analysis of welded connections, and fracture mechanics analysis.

Aerospace

On-orbit Failure of Satellite Batteries – Investigated premature failure of battery cells on orbiting communications satellite. Analyses involved assessment of potential failure mechanisms in welds and brazes due to charge/discharge cycling. Evaluated potential impacts of manufacturing and pre-flight testing regimes on remaining life expectancy of cells.

Application of Fracture Mechanics to Micro-Scale Electronics – Participated in a joint research investigation with Hughes Aircraft for the US Air Force Wright Laboratory to evaluate the applicability of fracture mechanics analysis techniques to micro-scale electronic components, including fatigue of ultrasonically bonded, 0.001-inch-diameter interconnect wires in chip packages, and copper-plated through-hole connections in printed circuit boards. Project aimed at improving reliability of aircraft avionics systems.

NASA Strain History Life Evaluation – Developed a specialized software system for NASA to analyze strain history data from testing of Space Shuttle engine components and compute fatigue life. Project involved reduction of variable-amplitude strain-time histories to representative fatigue histograms and modeling of fatigue damage for life forecasting.

Probabilistic Retirement-For-Cause – Developed probabilistic fracture-mechanics-based simulation software for analysis of military aircraft combustion turbine components. Applied fracture mechanics analysis techniques for assessment of remaining life of flaws at cooling holes and bolt holes in turbine disks.

Ground Transportation

Metropolitan Subway Cars – Investigated the failure of current-collector components that provide the critical power connection between the electrified third rail and the rail car. Analyzed stress, fatigue, and fracture of the steel and composite components of the current collector. Developed detailed loading spectra based on analysis of field test data, and correlated analysis results with field failure experience.

Farm Vehicle Rollover Investigation – Investigated whether or not the drive shafts of a four-wheel farm utility vehicle failed while the vehicle was traversing a steep slope at a ranch in California, causing it to roll down the hill. Work included metallurgical examination of the failed drive-shaft components, stress analysis, and testing of exemplar drive shafts.

Semi-Trailer Axle Cracking – Investigated cracking failures in semi-trailer axles for a major trailer manufacturer. Project involved developing and deploying an automated data collection system for recording road load inputs to an axle set that was instrumented with strain gages and accelerometers. Recorded data were reduced to representative fatigue spectra and used for analysis of fatigue crack growth life using fracture mechanics techniques.

Container Trailer Frame Cracking – Examined the cause of cracking in trailers used to transport intermodal shipping containers. Evaluated the role of fatigue and overload on the failure of the welded frames, including metallurgical examinations, finite-element stress analyses, and fatigue crack growth simulations. Project included instrumentation of trailer frames with strain gages and testing of the frames over various road conditions.

Medical Devices

Stress and Fatigue Analysis of Implantable Medical Devices – Performed numerous nonlinear stress and fatigue analyses of various implantable medical devices, including cardiovascular stents, a TIPS device, abdominal aortic stent grafts, heart valves, a septal defect closure device, peripheral stents, and active fiducial markers for radiation treatment of lung tumors. Performed high-cycle fatigue testing of implants in simulated physiological conditions. Stress analyses have included estimating physiological loading conditions from biomechanical and medical literature reviews and modeling device and tissue interactions with finite-element analysis (FEA). Simulations have included elastic-plastic response of stainless steels

and super-elastic nickel-titanium (Nitinol) alloys. Calculated stresses or strains are used to assess fatigue life and correlate with data generated by accelerated life testing.

Mitral Valve Annuloplasty Device – Investigated in-vivo loading on a device for treatment of mitral valve regurgitation. Project included instrumentation of the device with small strain gages and subsequent collection and analysis of real-time cyclic loading data recorded during animal open-heart surgery.

General Fracture and Fatigue

NASA, Fracture Mechanics Life Technology – Researched and summarized the state of the art in fracture mechanics technology related to lifetime prediction for the National Aeronautics and Space Administration. Involved critical review of current and developing technologies. Published as a NASA report.

Probabilistic Evaluation of Rotor Lifetime (PERL) – Developed a probabilistic fracture mechanics analysis module for the Electric Power Research Institute as part of their SAFER rotor analysis software. Module applied fracture mechanics and statistical analysis techniques for simulation of flaw growth and criticality in steam turbine rotors.

NASCRAC™ Software – Developed a general-purpose fracture mechanics analysis tool for the Marshall Space Flight Center of NASA, to be used by contractors developing space-flight hardware for the Space Shuttle Program. Enhanced and commercialized the NASCRAC Software as a tool for linear and nonlinear fracture mechanics analysis, including simulation of crack propagation life and crack criticality.

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