



METALLURGICAL CONSULTING
1146 Leroy Stevens Rd., Suite A
Mobile, AL 36695
Phone: (251) 639-3433
Fax: (251) 639-3105
email: kclarke@metalconsult.com

Metallurgical Analysis
Corrosion
Welding
SEM
Failure Analysis
Fracture Mechanics

RESUME

C. Kendall Clarke, Ph.D., P.E.

President

Metallurgical Consulting

EDUCATION:

Doctor of Philosophy, Metallurgy and Materials Science, Lehigh University, Bethlehem, Pennsylvania, 1973. "A Fractographic Study of a Low Nickel Steel"

Techniques were developed for utilizing the newly developed scanning electron microscope in critical studies of fracture surfaces. Results were compared with earlier transmission electron microscope work. Fracture mechanics and fracture testing were also involved.

Master of Science, Metallurgy and Materials Science, Lehigh University, Bethlehem, Pennsylvania, 1970. "The Kinetics of Manganese Oxide Reduction from Blast Furnace Type Slags by Carbon Saturated Iron."

Research and academic programs were conducted jointly in the Metallurgical and Chemical Engineering Departments. Thesis covered experimental and analytical studies of the rate of reaction of a molten slag-metal system.

Bachelor of Science, Metallurgical Engineering, University of Alabama, Tuscaloosa, Alabama, 1968.
Tau Beta Pi honorary.

PROFESSIONAL REGISTRATION

State of Alabama Professional Engineer #15088

State of Mississippi Professional Engineer #18136

WORK EXPERIENCE

April 1977 to Present:

President of Metallurgical Consulting, Inc. (sole proprietorship since 1999). This company provides consulting services in the areas of metallurgy and materials, corrosion, welding, fracture mechanics, and failure analysis. Clients have been in shipbuilding, paper, chemicals, power generation, aircraft, insurance, and law firms. A breakdown of the experience in each of these areas follows:

Metallurgy and Materials

Materials theory and laboratory procedures have been used to solve a wide variety of problems in many metals and in non metal systems. Metals and non metals have been evaluated for deterioration, defects, estimates of temperature exposure and property estimates. Many evaluations have been made on the extent and type of cracking. The extent of heat treatment and probable properties in steels has been determined using optical and electron microscopy. Knowledge of materials behavior has been used to evaluate process equipment for fitness for continued service, set up NDT inspection programs, and to form the basis of fatigue life predictions. Materials studied have included a wide range of steels, alloy steels, stainless steels, high temperature alloys, aluminum alloys, copper alloys, cast irons, fiber glass, graphite, PVC, and elastomers.

Corrosion Analysis

A large number of corrosion problems in metals and non metals have been investigated in high temperature processes, fluid process streams, and cooling water. Potentiodynamic corrosion tests have been used on many of the problems both in the laboratory and on sites. Several projects in process streams and cooling water have involved bacteriological evaluations. Potentiodynamic testing has been used to determine causes of failure, validate corrective actions and predict future rates of corrosion.

Welding

Metallurgical principles have been applied to a number of welding areas. Welding problems have been evaluated in both production and repair applications and in steel and aluminum alloys. NDT inspection programs have been established for production and repair welding. Weld procedures have been recommended for repair of process equipment. Welding drawings and procedures have been reviewed for conformance to codes. Numerous spot weld evaluations have been conducted.

Fracture Mechanics

Fracture mechanics has been used extensively to estimate stress levels at failure and in operation in many different components. This analysis procedure has also been used for redesign to insure that cracks can be readily detected before they become critical. Several designs have been evaluated for fatigue using crack propagation or cumulative damage techniques.

Failure Analysis

These areas of expertise have been used where appropriate to evaluate failures in a wide variety of equipment operating under differing conditions. Mechanical failures have frequently involved use of the technique of comparing stress analysis results with stress estimates based on fracture surface studies. Corrosion failure analyses have often involved confirmatory potentiodynamic corrosion testing. Full scale tests have been used to collect data on axle assemblies, doors, and brake systems. Acoustical emission tests have been run on fiberglass door systems. Equipment failures have included many small mechanical components, numerous process equipment failures, and several large industrial failures. Failure analyses have been conducted in a wide range of metals and non metals.

Large Projects

The following projects are specifically highlighted because of the scope of the work or its complexity. Most of these projects involved extensive testing or analysis or both.

- a) Failure analysis of paper mill continuous digester failure involved extensive metallographic analysis, stress analysis and fracture mechanics analysis. Final estimates of pressure at fracture utilized tearing instability theory.
- b) Analysis of deaerated water storage tank rupture involved metallographic, stress, and fracture mechanics analyses. Directed finite element analysis revealed a significant thermal stress role. The accident sequence was reconstructed based on the analytical work done and a review of plant records.
- c) An ammonia storage tank rupture was evaluated primarily with fractography, stress analysis and ideal plastic slip line theory. The accident sequence and failure stress was determined from this work and plant operation history.
- d) A fatigue life prediction program was developed for gray cast iron valve bodies over loaded by remotely controlled valve actuators in nuclear plants.
- e) A ship board steam line system with improper weld filler metal was analyzed for long term operational performance. Work required extrapolation of high temperature properties and knowledge of ASME code requirements. A successful case was made that the lines were safe for long term service.
- f) A ship board structural weld cracking problem was evaluated by measuring fatigue striation spacing with an electron microscope and estimating operating stress levels. A change from welded to bolted design was recommended and implemented.
- g) Fitness for continued service on an old Yankee dryer drum with low shell thickness was determined by estimating cast iron properties using hardness measurements and non destructive metallographic procedures. A finite element analysis provided the basis for rating the vessel for fatigue life.
- h) A recovery boiler found to be severely over heated was evaluated through numerous metallographic samples and short term elevated temperature tests of tube samples. A successful case was made to allow continued normal use of the boiler in light of the engineering data.
- i) Corrosion in aluminum pipe jackets at Redstone Arsenal was studied in a long term project with the Corps of Engineers. This work involved determining the corrosion mechanism utilizing a specially developed corrosion cell for potentiodynamic testing. Tests were conducted on the lines themselves to identify the moisture source and evaluate alternative jacket materials.
- j) A special inline tubular potentiodynamic corrosion cell was developed for side stream evaluation of ferric sulfate corrosion inhibitor in a once through river water heat exchanger with copper:nickel tubes. It was determined that pitting corrosion could be reduced with lower than published rates of ferric sulfate inhibitor additions. The work was published.
- k) Two cast iron water line projects have been evaluated for corrosion for the Corps of Engineers. One project in the Republic of Panama involved analysis of an existing line for corrosion damage and possible approaches to mitigation. The other involved recommendations for utilizing a non cathodic protected ductile iron pipeline in north Alabama. Concrete and plastic materials were also evaluated for performance and availability.
- l) A lot of large, high strength steel castings was rejected based on extensive metallographic and mechanical tests. The type of actual heat treatment given was deduced from the testing results.

- m) The expected service performance of heavy high strength steel castings in service on several navy ships was estimated. The work involved developing a fracture control plan with which to evaluate the materials. Probable toughness of the materials was estimated. Finite element stress analysis, cumulative damage fatigue analysis, and finite element stress intensity studies of possible defects were performed.
- n) Welding in jumbo section wide flange beams used in tension members was studied for potential problems in fabrication and erection. Weld procedures were reviewed and upgraded in places. A quality control plan was designed and implemented for welding and bolting the heavy members.
- o) Tube rolling and seal welding has been investigated in boilers and heat exchangers. The work has involved on site measurements of rolling and destructive analysis o rolled tubes and seal welds.

September 1976 to May 1977:

Associate professor in Mechanical Engineering, University of South Alabama, Mobile, Alabama. Developed and taught two materials courses. First course provided fundamentals, and the second involved industrial metallurgy. Taught one course each on manufacturing processes and fluid dynamics. Taught two-part course on strength of materials.

June 1973 to September 1976:

Boeing Wichita Division, Wichita, Kansas. Worked in the Metals and Materials Technology Unit and the Commercial Stress Unit. Primary duties were setting up and running the scanning electron microscope, development of new failure analysis techniques, and serving as an in-house consultant on failure analysis and fatigue crack growth calculations. Specific accomplishments were as follows:

1. Principal investigator on NASA contract to study crack growth phenomena. Results published in Engineering Fracture Mechanics.
2. Authored successful proposal on large crack growth study for Air Force. Proposal required a complete review of all written literature on crack growth.
3. Principal investigator on determination of crack growth rate in seawater of Navy developed titanium alloy.

PERSONAL

- Born April 11, 1945 in Ray, Arizona.
- Married to former Carolyn Daniels of Bay Minette, Alabama.
- Active member of Dauphin Way United Methodist Church.
- Member of Official Board Dauphin Way United Methodist Church.
- Past President of Mobile Kiwanis Club.
- Past Lt. Governor Alabama District of Kiwanis International.
- State Convention Chairman for Alabama District Kiwanis 2001 convention.
- Past member of Board of Directors Mobile Symphony and Mobile Ballet.

SOCIETIES

*Alabama and National Societies for Professional Engineers

METALLURGICAL CONSULTING

- *National Association Corrosion Engineers
- *American Society for Metals
- *Society of Automotive Engineers
- *American Society for Testing and Materials

PAPERS PRESENTED

1. "Fractography and SEM Artifacts,": ASTM Spring Meeting, Williamsburg, Virginia, 1973.
2. "Crack Tip Microfracture Processes," AIME Spring Meeting, , Pittsburgh, Pennsylvania, 1974.
3. "Basic Fracture Mechanics." ASM-SESA Seminar on Fracture Mechanics, Wichita, Kansas, 1975.
4. "Work in Crack Growth at Boeing,": SESA Seminar, Kansas City, Missouri, 1975.
5. Numerous talks on failure analysis and fracture mechanics for professional societies and Air Force Laboratories.
6. "Structural Reliability in Marine Structures,": Society of Naval Architects, Biloxi, Mississippi, September, 1978.
7. "Overview of Fatigue and Fracture in Naval Ships," Fall 1985 Meeting, The Society of Naval Architects and Engineers, Mobile, Alabama, September, 1985.

PAPERS PUBLISHED

1. "Study of Crack Tip Closure Using Electric Potential and Compliance techniques," Engineering Fracture Mechanics , 1977.
2. "Studies of Crack Tips in Steel and Aluminum," 4th International Conference on Fracture, 1977.
3. "Degradation of Germanium IR Windows," St. Louis IRIS Symposium, 1976.
4. "The Economics of Corrosion Control," AIPE 1980 Symposium, September 1980, Orlando, Florida.
5. "Analysis of a Failed Saw Arbor," C.K. Clarke, Case Histories Involving Fatigue and Fracture Mechanics, ASTM STP 918, C.M. Hudson and T.P. Rich eds., A.S.T.M., Philadelphia, 1986, pp 336-343.
6. "Role of Aerobic Bacteria and their Extra Cellular Polymers in the Facilitation of Corrosion: Use of Fourier Transforming Infrared Spectroscopy and Signature Phospholipid Fatty acid Analysis," D.C. White, D.E. Nivens, P.D. Nichols, A.T. Mikell, B.D. Kerger, J.M. Henson, G.G. Geesey, and C.K. Clarke, International Conference on Biologically Induced Corrosion, Gaithersburg, MD., June, 1985.
7. "Corrosion of Steels Induced by Aerobic Bacteria and their Exocellular Polymers," D.C. White, D.E. Geesey, and C.K. Clarke, Proceedings of Argentine/USA Conference on Biodeterioration, April, 1985.
8. "Corrosion and ground Water Pollution," C.K. Clarke, D.C. White, Environmental Health Symposium, Water and Wastewater Issues in the North Central Gulf Coast, April, 1986.
9. "Ferrous Sulfate Treatment of Once Through Water for Cu:Ni Tubing," NACE Corrosion 88, March, 1988, paper #24.
10. "Basic Requirements for Shipping FRP Equipment," F. Britt and C.K. Clarke, 12th Biennial Managing Corrosion with Plastics Sym., Baltimore, MD, 1993 pub. By NACE, vol. XI.
11. "Wheel Stud Bolt Failures," C. Kendall Clarke, Fastener Technology International, December, 1994.
12. C. Kendall Clarke: "Failure Analysis of a Pole Gin," J. Failure Analysis and Prevention, 2004, vol. 4 #2, pp 63-72
13. CK Clarke and GE Borowski: "Evaluation of a Leaf Spring Failure," J. Failure Analysis & Prevention, 2005, vol.5, #6, pp 54-63
14. CK Clarke and D Halimunanda: "Imperfections in Tree Stand Failures," Journal of Failure Analysis and Prevention, 2006, Vol 6, # 2, pp 24-30.
15. CK Clarke: "Evaluation of Fire Damaged Copper Wire," Advanced Materials and Processes, 2006, Vol 164, # 4, pp 37-39.
16. CK Clarke and D. Halimunanda: "Failure Analysis of Induction Hardened Automotive Axles", Journal of Failure Analysis and Prevention, 2008, Vol 8, #4, pp 386-396.

C. Kendall Clarke, Ph.D., P.E. Trial Appearances 1989 - Present

Jessie Neil Eaton v. Carl Joseph Bronald, et al
Mobile County Circuit Court
Case # CV-92-2415
Trial and deposition

Douglas Schultz v. Bakmac d/ba Honda Suzuki Kawasaki
5th Judicial Circuit, Florida
Case # 92-631-CA-E

Marshall Durbin Science and Technology Center v. Southwest Engineers Consulting and Testing
Madison County Circuit Court, Mississippi
Civil Action # 3955
Trial only

Donnie V. Burgess v. Clarkdale Inc. et al
US District Court, Eastern District of Louisiana
Civil Action #87-0529, Section L, Magistrate (5)
Trial

Jack Bodie et al v. Brunswick Corporation
Circuit Court of Mobile County
Civil Action #CV-87
Deposition and trial

Andrews v. Graves
Florida District Court
Trial only

Felipa T. Villalpando v. Tri C Resources
District Court of Harris City, Texas
151st Judicial District
Case # 87-39173
Trial and deposition

Mark Biletzskov v. Kelsey Hayes Company
United States District Court
Southern District of Georgia
Brunswick Division
Civil Action CV 286-241

Meridian Ship v. Armco Chili Prodein SA
United States District Court, Mobile, Alabama
CV-91-0900-B-C

Maureen Stewart v. Chevrolet Motor Co.
16th Judicial District Court
Case# 68, 649 Division "G"

Parish of Iberia, Louisiana
Trial and deposition

Anna Leonelli v. General Motors Corp.
Superior Court, Norfolk County
Commonwealth of Massachusetts
Civil Action # 89-2127
Trial and deposition

Richard Taylor v. General Motors Corp
Circuit Court Mobile County
Mobile, AL
Civil Action #CV-92-1772
Trial and deposition

Martha Campbell v. Ford Motor Co.
Jasper County Circuit Court
Civil Action # 94-0004
State of Mississippi
Trial and deposition

Royce H. Ward and Marilyn S. Ward v. Industrial Iron Works
Circuit Court, Butler County, Alabama
Civil Action # 95-76
Trial and deposition

Larsen v. Nissan Motor Company
Arizona Superior Court
Pima County
Case # 300722
Trial and deposition

Aquiniga v. Ford Motor Co.
District Court
Star County, Texas
Trial and deposition

Foster v. GM
9th Judicial District Court
Parish of Rapides
State of Louisiana
Civil Action N. 172, 576
Trial and deposition

Benson v. Huffy
Circuit Court of Lauderdale County
State of Alabama
Case # CV 93-733
Trial and deposition

Smith and Hambrick v. Emerson Power Trans Corp.
Federal Court
Jackson, MS
Civil Action # 3:96CV657BN
Trial and deposition

Tammy Snider et al v. State Farm Mutual Insurance Company
Case # 97-L-114
1st Judicial Circuit
Williamson County, Illinois
Trial and deposition

Paul Butcher v. GM
Circuit Court of Wayne County, Michigan
Case # 96-617620-NP
Trial and deposition

Appraisal / Arbitration Hearing
The Mitchell Co. vs. St Paul Insurance Co.
Mobile, AL

Mississippi Phosphates Corporation v. Furnace and Tube Services and Analytic Stress Relieving
Case No. 1:07-cv-1140-LG-RHW
The United States District Court for the Southern District of Mississippi Southern Division
Trial and Deposition

C. Kendall Clarke, Ph.D., P.E. Deposition List 1996 - Present

Foster v. GM
Ninth District Court
Parish of Rapids, Louisiana
Case # 172,676 Div "A"

Lynch v. HyTech and Star Enterprise
Delaware Superior Court and for Sussex County
Civil Action # 95C-11-016THG

Bowman v. Coleman Company, Inc.
United States District Court for the Southern District of Alabama
Southern Division
Civil Action # 96-0448-P-C

Cline v. Jim Nelson Ford
District Court of Tulsa County, Oklahoma
Civil Action # CJ-94-03701

Larsen v. Nissan Motor Corp (USA)
Arizona Superior Court, Pima County
Cause 300722

Daniel v. Mack Truck, Inc. et al
Circuit Court of Greene County, Missouri
Division II
Case # 198CC0135

Snider v. State Farm
Circuit Court for the First Judicial Circuit
Williamson County, Illinois
Case # CV97-L-114

Broge, et al v. TSE Brakes, et al
Green County Circuit Court, Wisconsin
Case # 96-CV-150

Huynh v. Uhaul International, Inc.
Dallas County District Court, Texas
95th Judicial District
Cause # 98-6004-D

Milbrand v. DaimlerChrysler Corp.
United States District Court for the Eastern District of Texas
Texarkana Division
Civil Action # 599CV130

Schwendeman v. USAA
Superior Court of Washington for King County
Case # 99-2-06505-ISEA

Finch v. Warren & Sweat
Green County Circuit Court, Missouri
Case # 100CC900

Hargiss v. Hastings Fiberglass
Green County Circuit Court, Missouri
Case # 100CC1761

Hamm v. Murray Corp
Civil Action 2:99 CV00121
US District Court for Western District of Virginia, Big Stone
GAP Division

Rinaudo v. Fearn
Circuit Court, Baldwin County, Alabama
Civil Action # CV-99-713

Weaver v. Union Foundry Co., Sullair Co.
Circuit Court of Calhoun
Civil Action CV 97-624

Walters v. New Day Enterprises
6th Judicial District Court
Madison Parish, Louisiana
#00-273

Holmes v. Freightliner
UIS District Court
Middle District of AL
Eastern Division
Case # CV-01-F-1534-E

Dockery v. Homier Distributing
US District Court
Northeast District of Florida
Pensacola Division
Case# 3:02CV503/RV/MD

Olson v. Daimler-Benz
District Court of Bell County, TX
169th Judicial District
No. 158, 786C

Rauff v. GM
Arbitration

Stabler v. Gradall
Circuit Court of Monroe County, Alabama
CV-04-85

Brown et al v. Ford Motor Co.
United States District Court; Southern District of Mississippi; Eastern Division
Cause No. 4:05CV78TSL-AGN

McCoy v. John Deer
Circuit Court for Barbour County, Alabama Clayton Division
CV-2004-082

Brown v. Ford
US District Court
Southern District of Mississippi; Eastern Division
Cause No. 4:05CV78TSL-AGN

Kelley v. Rhett Butler Trucking
Circuit Court of Covington County, Alabama
Civil Action No. CV-04-95

McCoy v. John Deere Tractor, et al
Circuit Court of Barbour County, Alabama
CV-04-082

Mary McCarty et al vs. Savannah Oil & Gas, LLC et al
Civil Action No. 2004-35R
In the Circuit Court of Clarke County, Mississippi

Olin Corp v One Beacon American Insurance Co.
Circuit court of Washington County, Alabama
Case# CV-2005-042B

Burnice Dreding Jr. v Mobile Storage et.al.
Mobile County Circuit Court
Case# 02-CV-2006-3918

Mississippi Phosphates Corp v. Furnace And Tube Services, Inc. and Analytic Stress Relieving, Inc.
United States District Court For The Southern District of Mississippi; Southern Division
Case #1: 07CV1140LG-RHW

Gibson v. Invacare Corp
United States District Court for Southern District of Mississippi Eastern Division
Civil Action No 4: 09cv182CWR-LRA

United Fire and Casualty v Whirlpool
United States District Court for the Northern District of Florida Panama City Division
Case No. 5: 10CV199-RS-EMT

Previto v. Ryobi North America
United States District Court for Southern District of Mississippi Gulfport Division
Case No: 1: 08CV001777-HSO-JMR

International Specialty v. North Florida Shipyard
United States District Court Middle District of Florida Jacksonville Division
Case No. 3: 09CV00827-MMH-TEM

Duncan, et al v. Chevron USA, et al
United States District Court for Eastern District of Louisiana
Case No. 10-0298 c/w

Williams et al v. Clark Oil Company, Inc. et al
Circuit Court of Mobile County, Alabama
Case No. 02-CV-2008-901955.00