STRESS ENGINEERING SERVICES INC.

an employee-owned company

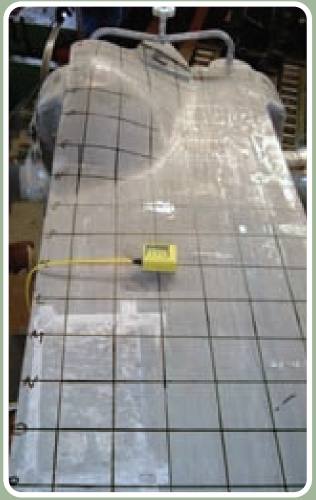
MATERIALS ENGINEERING AND METALLURGY

Failure Analysis

Failures Have Never Been More Expensive

A broken pipe, valve or bolt can be devastating to personnel safety, continued service, and operating revenue. Identifying the root cause of the failure, whether it is due to manufacturing defects, maintenance practices, operating parameters, or is design related, makes it possible to develop a deliberate plan for corrective action and avoid another failure in the future. At Stress Engineering Services, our engineers have the education, experience and tenacity to investigate the failure, find the causes and identify a solution.

A cast 8-inch sliding stem valve body showing a through wall crack after it was tested using dye penetrant.

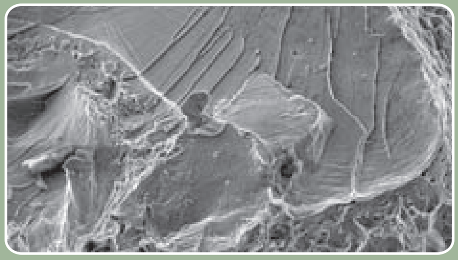


A 6-inch grid on the surface of a vessel explosion bulged aluminum plate fin heat exchanger. The grid was used to support a finite element analysis model.

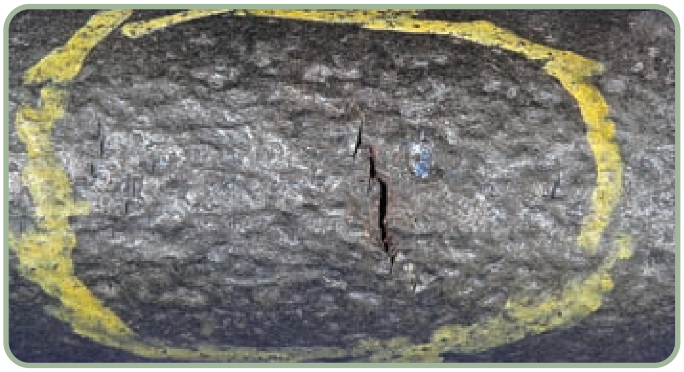
Vessel Explosion

A cross section through the bulged region of an aluminum plate fin heat exchanger showing the separation at the low and high pressure passages.

(right) A scanning electron microscope (SEM) image of a mixed mode fracture in steel showing some dimples together with cleavage facets.



Fractured Pipe Weld



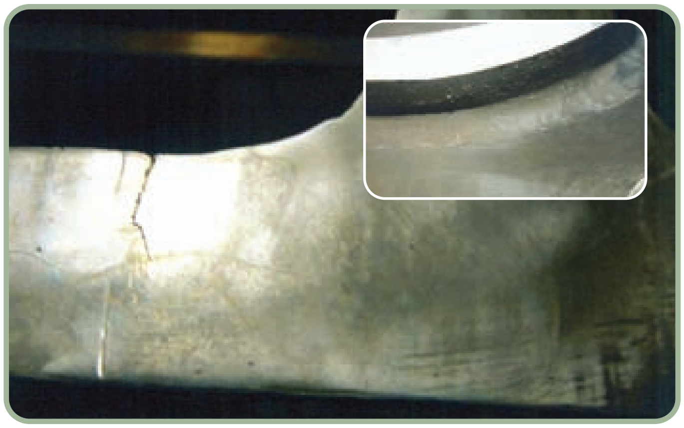
Thermal Fatigue

Non-Destructive Testing

When visual assessment is not sufficient, it may be necessary to use other nondestructive techniques to coax critical clues from the failure. These techniques include radiography, magnetic particle, dye penetrant and ultrasonic evaluation. The choice of nondestructive method is determined by the metallurgical and materials engineer based on the specific nature of the failure material, and complexity of the component.

Destructive Testing

In the case of complex failure mechanisms, where nondestructive techniques do not provide sufficient information, metallurgical and mechanical testing is necessary to unravel the mystery and identify the cause of the failure.



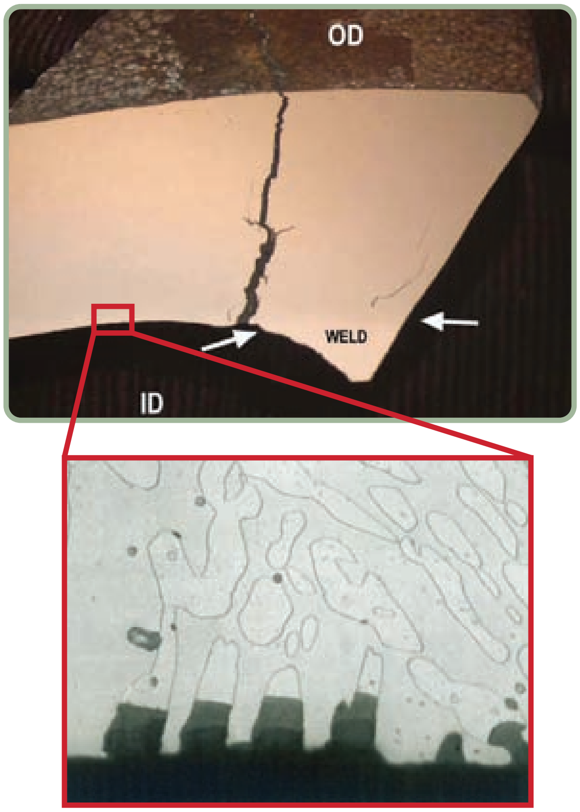
ID cracks adjacent to repair welds

Metallurgical testing requires cutting the failed section from the structure into more manageable sizes so the failure and material characteristics can be viewed directly.

Metallography

Often the first destructive test is to cut and polish a sample so the microstructure of the material can be assessed. These microstructures reveal clues about the material's original manufacturing process and provide clues of its operating conditions. The shape and extent of cracks or corrosion can help identify the cause of the failure.

ID cracks adjacent to repair welds



Selective Phase Attack

Site Inspection

Failure investigations often begin in the field. In large-scale failures, it may be necessary to capture the physical location of the equipment and debris field without disturbing the scene.

Stress Engineering uses an extensive inventory of tools and techniques including photography, three-dimensional laser survey and structured white light scanning, to extract all possible information without disturbing evidence at the scene. In addition, our engineers and technicians have specialized, portable metallurgical survey equipment to assess the material's condition.

The scene must ultimately be disturbed, and components that are suspected of being associated with the initiation of failure are extracted and moved to a laboratory environment. Stress Engineering has a state-of-the-art lab devoted to metallurgical and materials failure investigation.

(above, below) Vessel Fire Damage Assessment

The causes of a failure are buried in clues from the failed component. Once in the lab, the investigation process begins with a non-destructive visual examination and documentation and progresses, as needed, to increasingly sophisticated and rigorous testing methods.

Visual Assessment

Observation is both an art and a science, and the best failure analysts are detectives who use a variety of skills and progression of tests to solve a case. Many failures leave characteristic 'signatures' that can be observe with relatively low magnification, typically less than 100X. Stress Engineering's metallurgical and materials engineers can often determine the cause of by examining the failure surface, looking for these characteristic markings.

With the proper training, experience and equipment, visual clues may provide sufficient understanding of the materials-related cause of the failure, allowing a quick answer to the questions: What happened and how do we keep it from happening again?

Casting Fracture

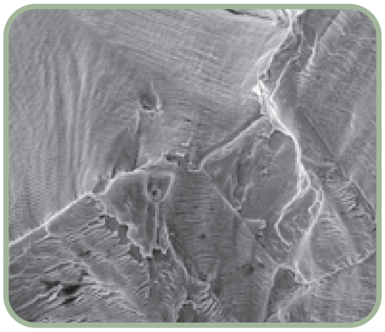
Mechanical Testing

In addition to evaluating the structure of the material, the mechanical properties may provide an important clue as to the cause of a failure. Tensile tests, fracture toughness, and Charpy impact testing can all provide information on the material processing history and it's properties up to the time of failure. This mechanical data is used in concert with other test results to help determine the cause of the component failure.

Six Million Pound Tension / Compression Test Frame

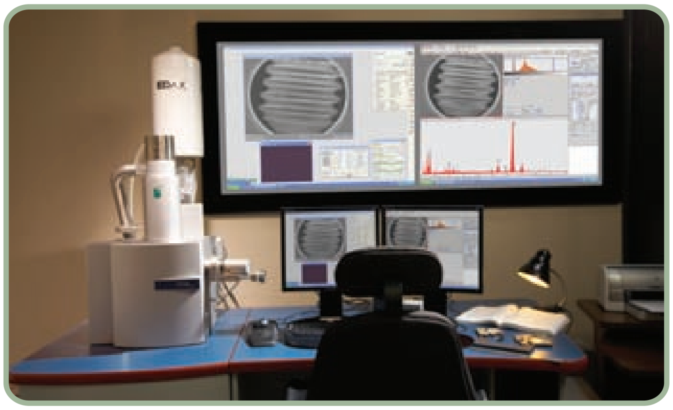
Electron Microscopy

Sometimes the complete evaluation of a failure requires more sophisticated methods to solve the mystery. Electron microscopy uses a scanning electron microscopy (SEM) to look at the topography of a fracture surface at magnifications up to 100,000X. Stress Engineering's electro microscope boasts an extra large chamber capable of imaging samples up to 7 inches in diameter, 5 inches high, and 18 pounds. Our variable pressure SEM also makes it possible to image non-conductive polymeric samples without further sample preparation. The light element energy dispersive x-ray spectrometer (EDS) allows semi-quantitative chemical analysis of the samples to determine the general composition of the material and any corrosion products associated with the failure.

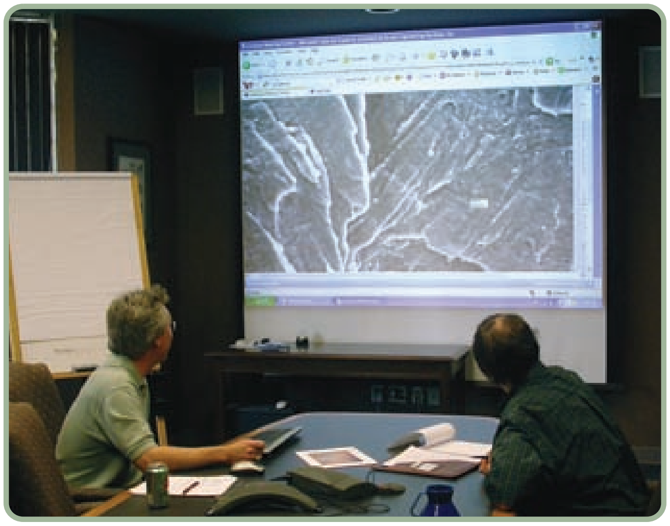


Fatigue in 725 J-Integral Test Sample

In addition, our electron microscope is equipped with an electron backscatter diffraction (EBSD) unit, allowing us to image and identify phases based on their crystal structure and orientation. The EBSD combined with EDS data provides a powerful, unique capability to identify the cause of a failure.



Scanning Electron Microscope with Integrated Chemical Analysis



Capability for long distance, real-time remote viewing of SEM results

visit us on the web at **www.stress.com**

HOUSTON
281.955.2900

CINCINNATI
513.336.6701

NEW ORLEANS
504.889.8440

BATON ROUGE
225.769.9772