



YOUR COMPANY'S GUIDE TO FRACTURE MECHANICS

Helping organizations understand and
correctly apply fracture mechanics.

ASME **L&D** LEARNING &
DEVELOPMENT

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FRACTURE MECHANICS

Fracture mechanics form an engineering discipline that engineers can leverage to solve critical design problems. It uses methods of analytical mechanics to calculate the driving force on a crack, and to characterize the material's resistance to fracture.

This is a failure theory that determines material failure by energy and strength criteria. It's a useful method of determining stress and flaw size, fracture toughness and fatigue crack growth. The strength of a product is impacted by the size of cracks or defects that occur during processing, production and handling—making fracture mechanics a crucial discipline for trained engineers.

Fracture mechanics quantifies the combination of three variables: stress, flaw size and toughness. Fractures occur when the driving force (stress and flaw size) exceeds the material resistance (toughness). The nature of fracture mechanics is such that once two quantities are known, it's possible to calculate the third.

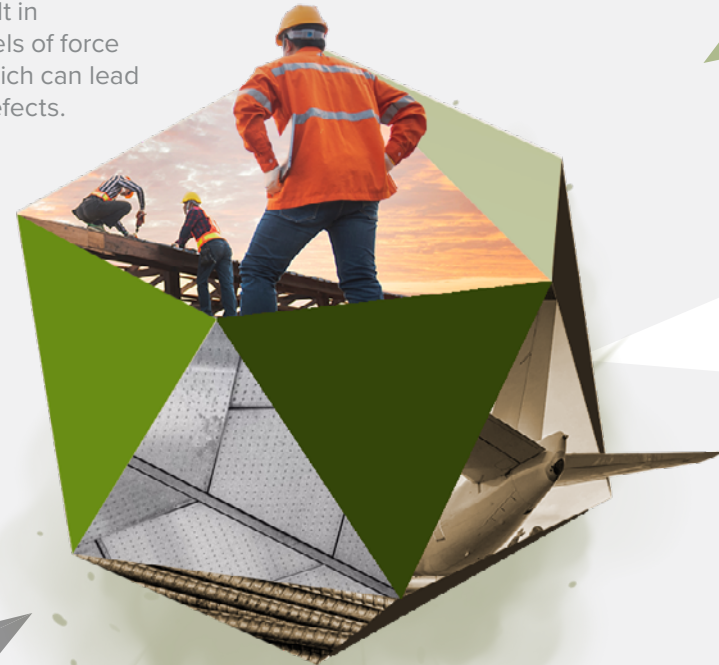
This guide explores how engineers can apply fracture mechanics to perform simple to complex calculations in the problem-solving process. Discover some common challenges for engineers, as well as the fundamentals of performing fracture mechanics calculations. Plus, learn more from our expert, who answers some of our most frequently asked questions about fracture mechanics.

FRACTURE MECHANICS IN HIGH PRESSURE INDUSTRIES

The discipline of fracture mechanics is most commonly used in the aerospace, energy and shipbuilding industries, with usage becoming more frequent in sectors such as automotive and rail transportation.

Fracture mechanics is used in designs for components like joints on airplane wings, pipelines, pressure vessels, car tire rims, car windshields and even the tempered glass on your phone screen. It can be found in everything from miniscule safety mechanisms to large structures, making it a critical discipline for copious industries and, by extension, the engineers working in those industries. It can be used in three areas of the engineering process—design; material selection and alloy development; and determining the significance of defects.

Understanding how a design will initially crack and eventually fail can allow engineers to directly improve the longevity and safety of products. Failure to properly calculate stress, toughness or flaw size can result in unacceptable levels of force being applied, which can lead to catastrophic defects.



FRACTURE MECHANICS FUNDAMENTALS

Types of fracture mechanics:

Fracture mechanics focuses on how cracks form and propagate. There are two common material assumptions in fracture mechanics that engineers need to be aware of.

Linear-elastic fracture mechanics (LEFM)

LEFM is the basic theory of fracture that deals with sharp cracks in elastic materials. The stress intensity factor and energy release rate are the most common linear elastic crack tip parameters. Fatigue crack propagation is usually analyzed with LEFM approaches. LEFM is valid as long as the zone of yielding at the crack tip (i.e., the plastic zone) is small compared to the cross section of the structure or laboratory specimen.

Elastic-plastic fracture mechanics (EPFM)

EPFM applies when fracture is preceded by plastic deformation. Fracture in elastic-plastic materials can occur by stable ductile tearing or unstable cleavage. The J-integral and crack tip opening displacement (CTOD) are the most common.

FATIGUE CRACKING AND FRACTURE MECHANICS

Many mechanical failures result from fatigue damage that occurs during cyclic loading. Fracture mechanics plays an important role in mitigating the risk of fatigue failure.

Fracture mechanics models predict the rate of growth of cracks due to cyclic loading. However, fracture mechanics does not address the formation of fatigue cracks from pre-existing imperfections or on smooth surfaces.

There are many complications that can make fatigue analysis with fracture mechanics a challenging subject. These include:

Constant versus variable amplitude fatigue

Constant-amplitude fatigue is defined as fatigue under cyclic loading with a constant amplitude and constant mean load. Such loading is common in laboratory tests, but is not representative of most structural applications. Variable amplitude corresponds to cyclic loading with amplitudes that vary between cycles, sometimes significantly. Variable-amplitude cycling can be deterministic, random or semi random. The latter corresponds to blocks of random loading spectra that apply at different times. For example, an offshore platform subject to loading from wind and wave motion experiences different loading spectra during a hurricane compared to a calm day.

Environmental effects

Environmental factors can determine how likely it is that a crack may form and how fast it will grow. Environmental cracking requires a combination of a susceptible material and an aggressive environment. Cyclic loading in an aggressive environment can result in faster crack growth than either fatigue in air or environmental cracking under static loading.

KEY BENEFITS OF ASME TRAINING FOR FRACTURE MECHANICS



Avoid costly mistakes

Applying correct methodology enables fractures to be predicted, allowing the proper design precautions to be determined, helping to avoid equipment failures.

Uniform global approach

When engineers across the world have a common understanding of fracture mechanics, suppliers and manufacturers can be sure that fracture risk has been properly considered, ensuring mechanical designs are sound and of the same industry-grade standard.

Quality assurance

This comprehensive review of the design, construction, installation, operation, inspection, and maintenance of mechanical designs and potential fractures protect equipment from exceeding the maximum allowable pressure.

FREQUENTLY ASKED QUESTIONS

We asked our expert Dr. Ted Anderson some of our most frequently asked questions about fracture mechanics.

At what point in the design process do I begin factoring in fracture mechanics?

Fracture considerations should be included in the mechanical design/material selection stage. There are many trade-offs in design. For example, the desire to reduce weight can lead to minimizing cross sectional area and maximizing material strength, such that the reduced cross section can carry anticipated operating loads. However, there is often a

trade-off between strength and material toughness. Selecting a high-strength material with low fracture toughness may not be the best option, as it would lead to a low tolerance for cracks or crack-like flaws.

How can I be sure I've accounted for every type of fatigue my design might encounter?

At the design stage, the best predictor of future cycling is cyclic loading data for similar applications. For example, the design of a next-generation aircraft can benefit from cyclic loading data collected on existing aircraft. If, however, the new design is sufficiently different from previous generations, looking at the past is less useful. Building and testing prototypes prior to going into mass production may be necessary in such cases. In

general, it is essential to identify all potential sources of cyclic loading, even if the exact magnitude and frequency of the loading is difficult or impossible to predict. Most cyclic loads come from two sources: 1) loads that are directly attributable to the operation of the structure, and 2) loads that come from the surrounding environment. Examples of the former are internal pressure in a pipeline, the weight of an object lifted by a crane, and torsional stresses in rotating equipment. Wind loading and seismic loading are examples of the latter.

What are the benefits of ASME group training for fracture mechanics?

ASME classes provide a collaborative learning environment, where attendees learn from one another as well as from the instructor.

Ted L. Anderson, Ph.D., PE, ASME Fellow

Dr. Anderson is an internationally recognized expert in fracture mechanics and fitness-for-service methods. He is the author of a best-selling book on fracture mechanics, which has been adopted as a required text in over 150 universities throughout the world. During his career, he has held positions at a number of organizations, including TWI, Texas A&M University, Quest Integrity, and Team Inc. He founded a consulting and software company in 1995, which was acquired by Quest Integrity in 2007. He holds a Ph.D. in metallurgy from the Colorado School of Mines.

Find out more about our course [here](#).

ASME'S FRACTURE MECHANICS COURSE

Fracture Mechanics VCPD268

The course will give engineers a practical understanding of fatigue and fracture calculations using the latest methodologies.

Topics covered

- Linear elastic fracture mechanics (LEFM)
- Elastic-plastic fracture mechanics
- Introduction to fatigue crack growth
- Advanced topics in fatigue
- Environmental cracking
- LEFM applications
- Elastic-plastic applications
- Finite element analysis of components with cracks
- Fracture mechanisms in metals & alloys

You will learn to

- Explain the underlying assumptions and limitations of fracture mechanics
- Describe the process for material selection for fatigue and fracture resistance
- Explain how to perform simple to moderately complex fracture mechanics calculations
- Identify codified procedures for flaw evaluation

MORE DETAIL ABOUT OUR COURSES

ASME Learning & Development provides technical and management courses to teach codes to large groups of individuals and teams across a range of engineering disciplines.

Courses are designed for engineers of all levels from early career engineers to experienced engineers. They are essential resources for mechanical engineers, and design engineers; process engineers, and chemical engineers; reliability engineers, and maintenance engineers; inspectors, and testing engineers; as well as plant supervisors, managers and procurement personnel.

All of our courses are delivered either virtually or in-person, with the ability to tailor content to include specific use cases and pain points for corporate training customers with eight or more learners.



LET'S TALK ABOUT IT

ASME is the go-to expert in both fundamentals and applications of fracture mechanics.

Our courses are designed to help professionals remain consistent in their usage throughout the engineering process.

All ASME courses include real-world examples so that learnings can be applied to projects that your company is working on. From potentially standardizing your business processes with best practices and boosting productivity to improving engagement, we can help you maximize the potential of your workforce all while growing your organization's competitive edge. Address your unique challenges with an expert, in a private and confidential setting.

Get in touch today to inquire about ASME's corporate training for companies that operate in high powered industries.

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