

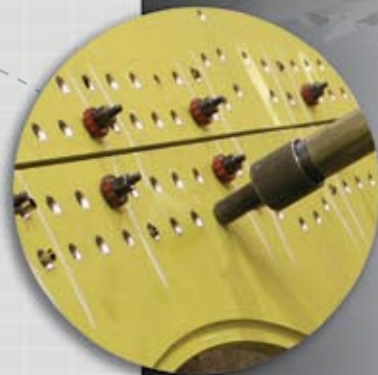
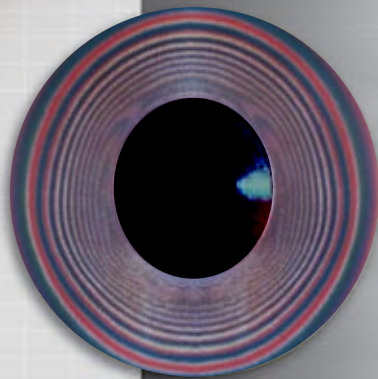
Split Sleeve Cold Expansion™

FATIGUE LIFE ENHANCEMENT OF HOLES IN METAL STRUCTURES



PROCESS BENEFITS:

- Typically improves the fatigue life of a hole by 3 to 10 times
- Arrests the growth of small cracks in holes
- Cost-effective alternative to redesign of the structure
- Does not add weight or change structural stiffness
- Simple and easy to use one-sided operation
- Works in most common aerospace metals including aluminum alloys, titanium and high-strength steels
- Applicable to rework and new production environments



**Over 40 Years
of Technology
Advancement and
Industry-Wide Use**

FTI
FATIGUE TECHNOLOGY

FATIGUE LIFE ENHANCEMENT OF HOLES IN METAL STRUCTURES

FTI's Split Sleeve Cold Expansion system is a cost effective solution to problems associated with fatigue cracks in holes in metal structures. Split Sleeve Cold Expansion is accomplished by pulling a tapered mandrel, pre-fitted with a lubricated split sleeve, through a hole in aluminum, steel, or titanium. The disposable sleeve reduces mandrel pull force, ensures uniform radial expansion of the hole, and allows one-sided processing. Cold expansion counteracts the fatigue-prone characteristics of a hole by creating a compressive residual stress field around the hole, effectively shielding the hole from the cyclic tensile stress loads that cause cracks to form and grow. Design engineers use cold expansion to reduce the stress concentration factor associated with a hole, thereby improving fatigue and damage tolerance of a structure and allowing for weight savings by designing to a higher working stress level.

- In use since 1969.
- FTI's Split Sleeve Cold Expansion is approved and used by aircraft and rotorcraft manufacturers and operators worldwide including:
 - > Boeing
 - > Airbus
 - > Bombardier
 - > Bell Helicopter
 - > Cessna
 - > Dassault
 - > General Electric
 - > Northrop Grumman
 - > Lockheed Martin
 - > Sikorsky

Cold expansion is also used to provide insurance against:

- Changes to aircraft operating loads
- Hole drilling or joint assembly induced defects
- Material inclusions
- Service environment induced degradation such as fretting or corrosion

Rework of holes in aging structures using cold expansion can provide added protection against undetected cracks.



THE INDUSTRY STANDARD

In the late 1960s, Boeing developed a process for cold working aircraft structural holes to improve fatigue and damage tolerance performance under cyclic tensile loading. Fatigue Technology (FTI) developed a manufacturing method for the split sleeves required for Boeing's new process. FTI has continued to advance the science of cold expansion and remains the world leader in this field of technology.

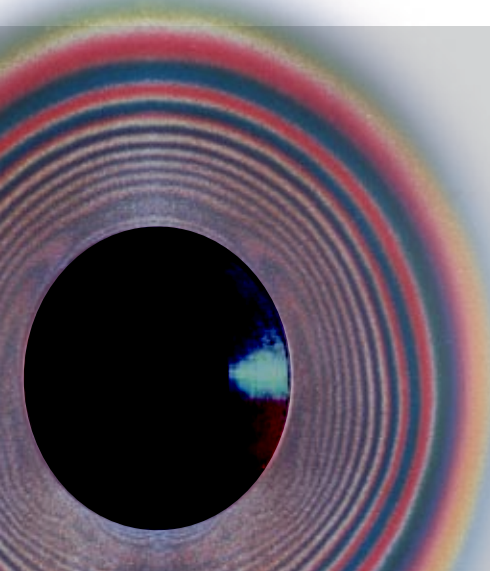
The FTI integrated system of tooling has been used to generate nearly all of the cold expansion comparative research and lifing data for the aerospace industry for the past 40 years. Furthermore, well over 80 million holes have been cold expanded using FTI's system with 100% in-service reliability.

As new structural materials are introduced to meet the need for more economical aircraft, FTI's engineers and fatigue test laboratory remain hard at work to generate design data in support of numerous diverse applications and new materials. FTI authors or coauthors an average of 11 papers per year related to cold expansion and continues to receive recognition for its contribution to the industry.

THE PREFERRED COLD WORKING METHOD FOR HOLES

Split Sleeve Cold Expansion is superior to shot peening, ballizing, roller burnishing, and straight mandrelizing because it generates a more controllable distribution of compressive stress around a hole and does not damage the integrity of the hole.

Zone of compressive residual stress surrounding a cold expanded hole as seen through a polarized filter



COMPLETE SPLIT SLEEVE COLD EXPANSION PROCESS



Drill the starting hole if necessary



Ream to correct starting hole size



Verify the starting hole dimensions with the step gauge



Check the expansion portion of mandrel for wear



Slide a split sleeve onto the mandrel



Insert the mandrel and sleeve into the hole



Activate the puller unit to retract the mandrel and expand the hole



Retract the mandrel fully through the sleeve and into the puller



Remove the split sleeve from the cold expanded hole and discard



Verify correct expanded hole size with the plug gauge



Perform post-cold expansion operations if necessary

FTI's Split Sleeve:

- Provides dry film lubrication medium for the mandrel.
- Ensures the hole is radially expanded.
- Minimizes axial displacement of material.
- Allows a one-sided process.

The components of each tooling system are all coded with the same Standard Tool Diameter Number (STDN) as follows for each application:

- CB for aluminum and mild steels.
- CA for titanium and high-strength steel.
- CR for rework in aluminum and mild steels.
- KB2 for aluminum using Cold Expansion to Size System.
- KB for aluminum using the Countersink Cold Expansion System (mandrels, nose caps, and backup blocks).
- A special nose cap and mandrel are required for pre-countersunk holes.
- CBL/CB3 for low applied expansion systems for strain sensitive alloys.

A COMPLETE SYSTEM

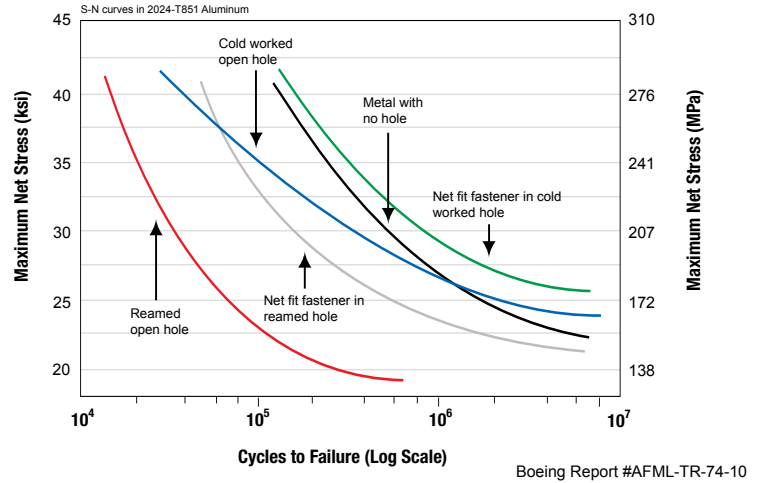
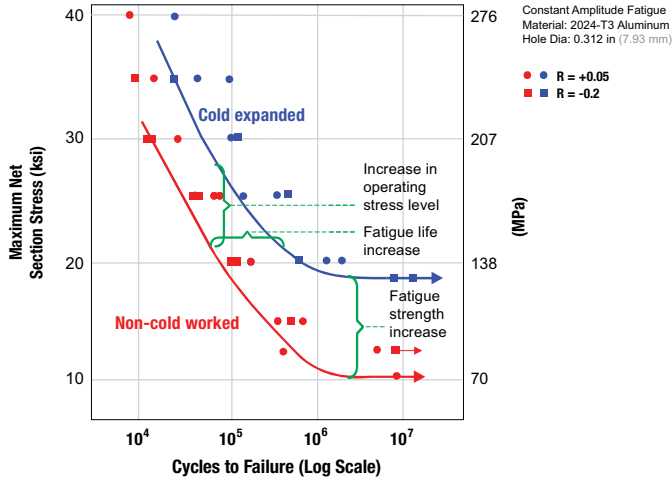
Process effectiveness is assured through use of a complete system. Split Sleeve Cold Expansion is a critical process, and as such, a completely compatible system of tooling should be used.

FTI Cold Expansion Equipment



FATIGUE LIFE IMPROVEMENT

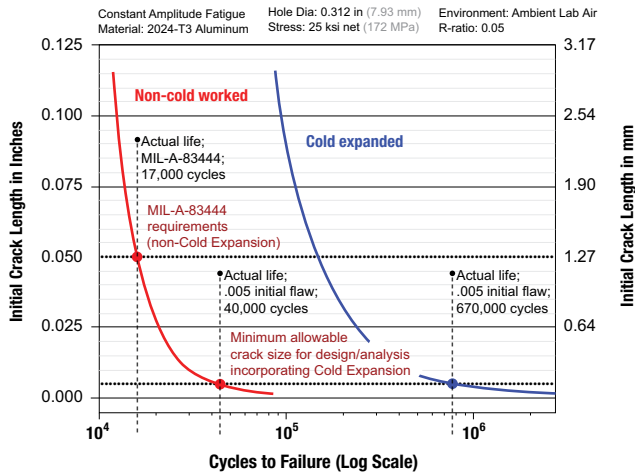
Optimal fatigue performance is achieved when the hole is expanded by at least 3 percent for aluminum and 4.5 percent for titanium and high strength steels in typical aircraft structures. Fatigue strength at low stress levels virtually doubles. The resulting combination of increased fatigue life and the ability to operate at a higher stress level allows for reduction of structural thickness and weight. Beneficial effects are typically increased even further with the installation of an interference fit fastener.



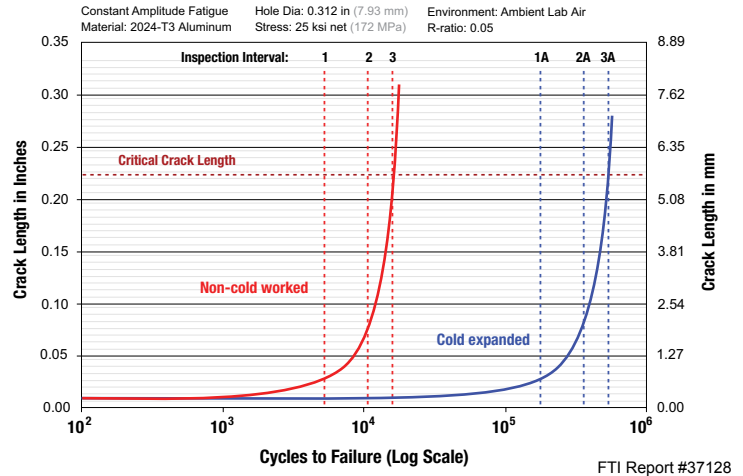
INCREASE DAMAGE TOLERANCE AND EXTEND INSPECTION INTERVALS

Airworthiness inspection thresholds are established assuming a manufacturing or initial flaw (0.050-inch) exists at critical holes. When hole cold expansion is used, authorities approve simulation of a smaller, 0.005-inch radius corner flaw to determine the residual crack growth life (A). This is a very conservative approach because cold expansion is far more effective in retarding crack growth from pre-cracked holes compared to non-cold expanded holes with a 0.005-inch initial flaw. The effect is that damage tolerance life and corresponding structural inspection intervals are greatly extended (B). In many cases, use of cold expansion will result in a terminating repair action with no further inspection required.

A) INITIAL DAMAGE TOLERANCE



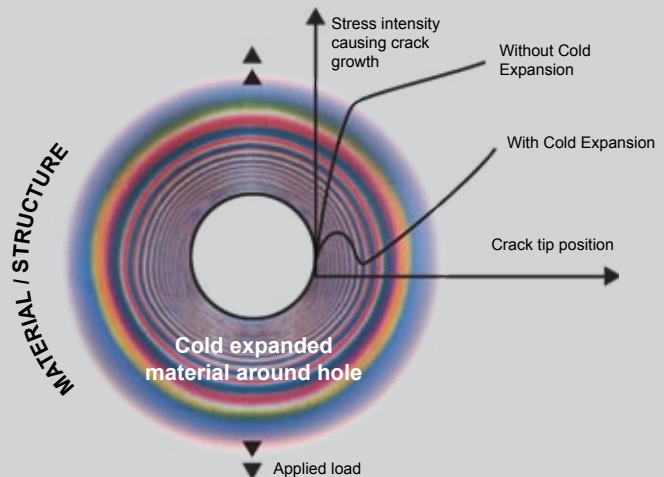
B) INSPECTION INTERVALS



EFFECT OF COLD EXPANSION ON CRACK TIP STRESS INTENSITY

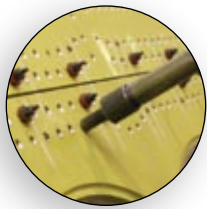
Permanent compressive stresses surrounding the hole mitigate crack growth and improve the damage tolerance of the structure.

- Crack opening displacement is minimized
- Stress intensity factor is reduced
- Critical crack length is often increased



APPLICATIONS

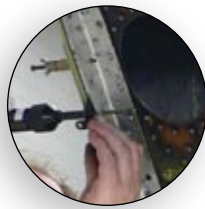
Cold expansion can be used in any metal structure in which holes and potential fatigue enhancing opportunities are present. The Split Sleeve Cold Expansion process is approved and used by most leading aircraft manufacturers, commercial airlines and military operators.



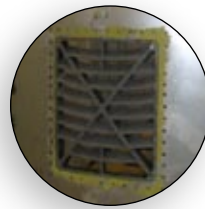
FUSELAGE



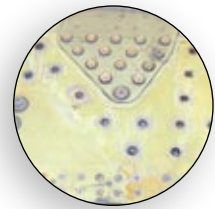
INTERNAL STRUCTURE



ATTACHMENTS



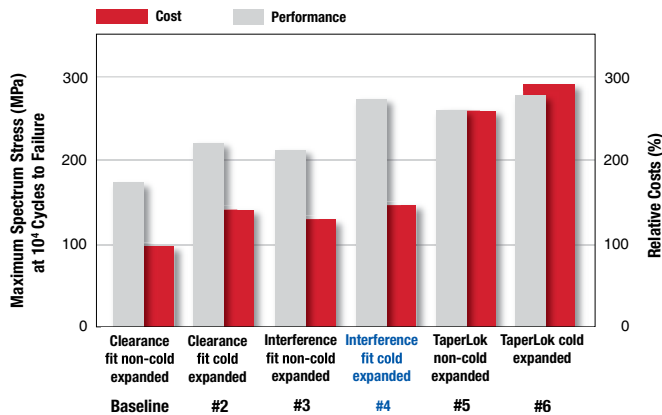
ACCESS PANELS



WING SKINS

Relative Costs of Different Fastener Hole Methods

Split Sleeve Cold Expansion offers cost savings compared to competing interference fit fastener options.



"Considering all aspects (fatigue performance, fabrication and costs), Method C (#4) is recommended for practical use."

-Dr. L. Schwarmann, International Journal of Fatigue, Volume 5, No. 2 1983

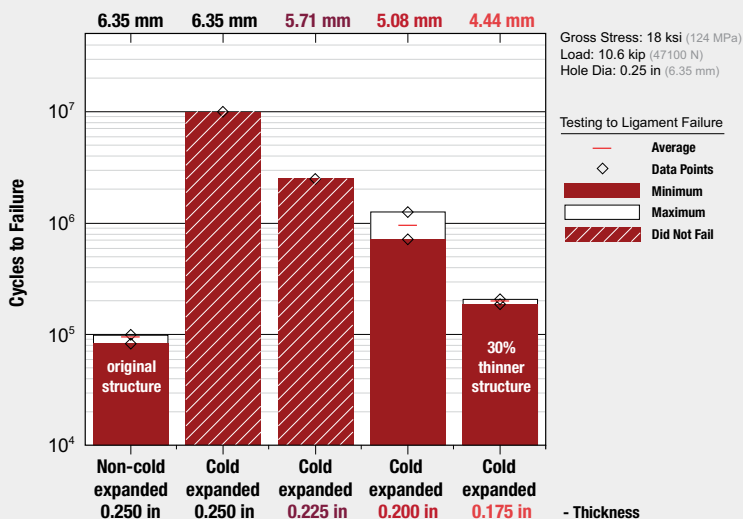
Special Considerations*

- > Free edge proximity (edge margin e/D)
- > Adjacent hole proximity
- > Surface upset at flaying surface
- > Large diameter holes
- > Diameter of hole relative to material thickness
- > Material stack-up
- > Effect of sleeve ridge and orientation
- > Effect of re-cold expanding a hole
- > Partial depth cold expansion
- > Final hole reaming allowance
- > Elevated temperature applications

*In all cases, please contact FTI for help with unique situations

SAVING WEIGHT BY REDUCING STRUCTURAL THICKNESS

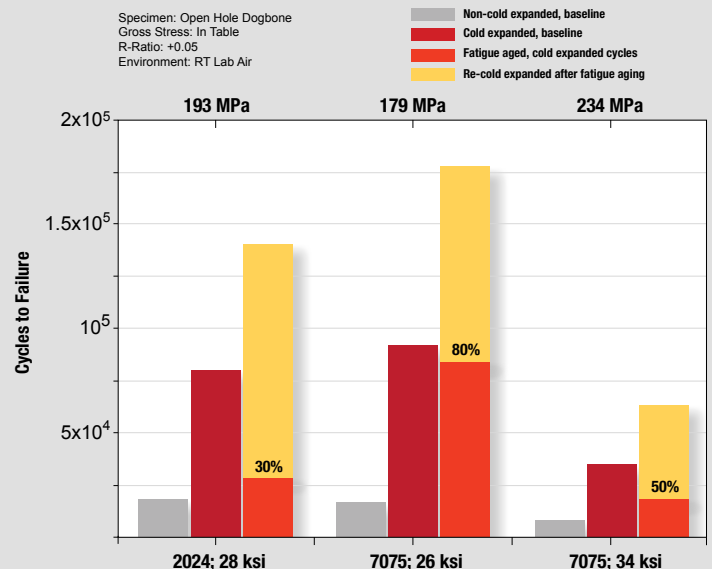
Testing data shows that fatigue life can be significantly extended using cold expansion, to the point where structural thickness can be reduced by 30%, yet the fatigue life of the original structure is maintained.



FTI Report #37584

REWORKING PREVIOUSLY COLD EXPANDED HOLES

Additional cold expansion during the structure life cycle can further extend fatigue life. Independent testing of up to five times re-cold expansion has shown progressive improvement.



FTI Report #37584

FTI designs and manufactures a full range of cold expansion products for the aerospace industry. These products are specifically engineered to achieve aircraft production and cost initiatives; meet design goals, production rates and aircraft performance objectives; and provide life-cycle cost savings.

Here are some of FTI's other innovative products:



ForceMate®

Bushing Installation System

- Reduces labor time and installation costs
- Consistent interference fit damage tolerance of holes
- Resists migration and rotational forces
- Improves fatigue life and damage tolerance of parent structure
- Superior installation reliability



ForceTec®

Rivetless Nut Plate

- Fast, consistent installation
- Meets or exceeds NASM25027
- Easily replaceable nut element – sealed or non-sealed
- Resists lightning strike damage in composite structures



TukLoc®

Blind Fastening System

- Easy hole preparation
- No additional sealants required
- Rapid installation
- Highly reliable process



Flexmate®

Expanded Fitting System

- Fatigue life improvement
- Simple one-piece design
- Minimum envelope
- Minimum weight
- Excellent sealing and electrical conductivity



FTI's corporate headquarters and manufacturing plant is located just 5 minutes from the Sea-Tac International Airport and 10 minutes from downtown Seattle, Washington.



FTI SERVICES

Fatigue Technology is the world leader in cold expansion technology. We have pioneered this science since 1969 and have advanced the cold expansion process to develop cost savings ideas for production simplification, manufacturing and maintenance time-saving, and improved aircraft structural performance. We offer our customers a full range of services to support their applications.

THESE SERVICES INCLUDE:

- On-site product support
- Technical training
- Engineering/design support
- Product and materials testing
- Research and development services
- Field repairs and upgrades

(Please contact us to discuss your current application.)

CORPORATE HEADQUARTERS

401 Andover Park East
Seattle, WA 98188-7605 USA

Phone: 206.246.2010

Fax: 206.244.9886

Email: sales@fatiguetechnology.com

www.fatiguetechnology.com

OFFICES:

Atlanta, GA
Dallas, TX
Los Angeles, CA
Oklahoma City, OK
Salt Lake City, UT
Washington, DC
Broughton, United Kingdom
Hamburg, Germany
Toulouse, France

REPRESENTATIVES:

Australia
China
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