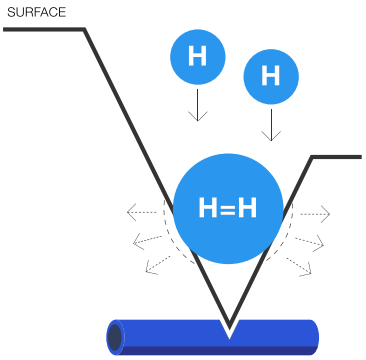
PREVENTING HYDROGEN EMBRITTLEMENT IN HIGH-CYCLE PRESSURE VESSELS

High-cycle compressors and other forms of high-pressure storage and transport of hydrogen are becoming increasingly common. A major concern for the advancement of this technology is the hydrogen embrittlement effect (HEE). HEE weakens the integrity of the vessel walls and shortens the fatigue life. Haskel has developed a new technology that creates pre-compressive stress along the pressure vessel wall, eliminating the risk of leaks or ruptures due to HEE. Haskel's technology shows great promise for the hydrogen-transport and pump industry and has led to a revision of the 2017 ASME Pressure Vessel code.

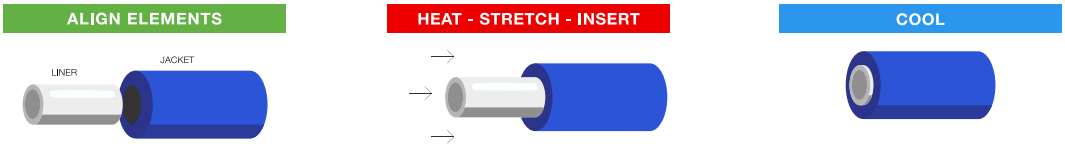
The increased use of hydrogen fuel cells as an energy source for cars and power plants has brought innovation and market expansion, but it has also caused an increase in concerns about the safety of hydrogen compression, transport, and storage. The past several years has seen regulatory agencies impose stricter rules for construction of pressure vessels and compressors in hydrogen service to mitigate the safety risks. A particular concern the is the hydrogen embrittlement effect (HEE).



What is Hydrogen Embrittlement? The effects of HEE

Hydrogen embrittlement is the process in which hydrogen introduced into a metallic component causes its structure to crack. At the metallic surface, hydrogen molecules dissociate into atomic hydrogen. Hydrogen atoms are unstable and will re-associate immediately to molecular form if they enter a void in the metallic structures. Such voids exist as material defects caused by pre-manufacturing processes. The re-associated molecular hydrogen in the cracks is more stable and occupies a larger volume. As a result, the molecule pushes against the crack walls to further open it,, making more room for subsequent hydrogen re-associations. This process increases the crack growth rate, which shortens the fatigue life of the pressure vessel.

A Solution Fit to Innovate: Shrink-Fit Liner Technology



Haskel has developed a method for mitigating HEE that involves fitting a liner within the jacket of the high-pressure vessel. The liner has an outer diameter that is slightly larger than the jacket's inner diameter. The process involves three steps:

Align elements: Place the interior liner at the opening of the vessel jacket with the center-axes aligned.
Heat-Stretch-Insert: Heat the vessel jacket, which expands its inner diameter. This allows the cold liner to fit within the jacket.
Cool: When the assembly returns to an equilibrium temperature, the jacket's inner diameter decreases. The resultant stress at the boundary of the liner and the jacket creates compression on the liner.

The compressive stress generated by the jacket upon the inner liner prevents any cracks within the vessel walls from opening and expanding further. This procedure mitigates the risk of HEE by eliminating all voids in the pressure vessel wall.

Key Results

Extensive simulation of the shrink-fit liner concept yielded four principal results:

1. **Keeping all the existing cracks closed prevented any chance of HEE.**
2. **The process successfully compensated for fatigue caused by defects created during the material-manufacturing process (e.g. annealing, heat treatment, cold drawing, etc.)**
3. **Fracture mechanics analysis demonstrated an effectively long fatigue life.**
4. **The shrink-fit process enables innovation by relaxing specifications and manufacturing costs for H_2 service vessels and compressors.**

Conclusion

The method of construction has proved valuable. Relaxing materials specifications for hydrogen service vessels and gas boosters is enabling innovation in the hydrogen fuel cell industry. The 2017 ASME Pressure Vessel code was revised to allow the use of shrink-fit liners in the design of hydrogen vessels.

NOTE: This technology is currently a pending patent by Haskel International. U.S. Patent Application Serial No. 15/809,508

About Haskel

With over 70 years of unrivaled expertise in high-pressure, liquid and gas transfer and pressurization technology, Haskel is the solution provider for applications in aviation, defense and aerospace, oil and gas and other critical industries. Haskel meets complex and critical challenges with innovative solutions that ensure safety, reliability and the highest quality. As the clear market leader in high-pressure pumps, Haskel products are made to fit customer needs and market demands. Whether working in oil and gas, automotive and defense or extracting cannabis oil in the emerging medical market, every Haskel product provides the performance that is expected from a global leader.