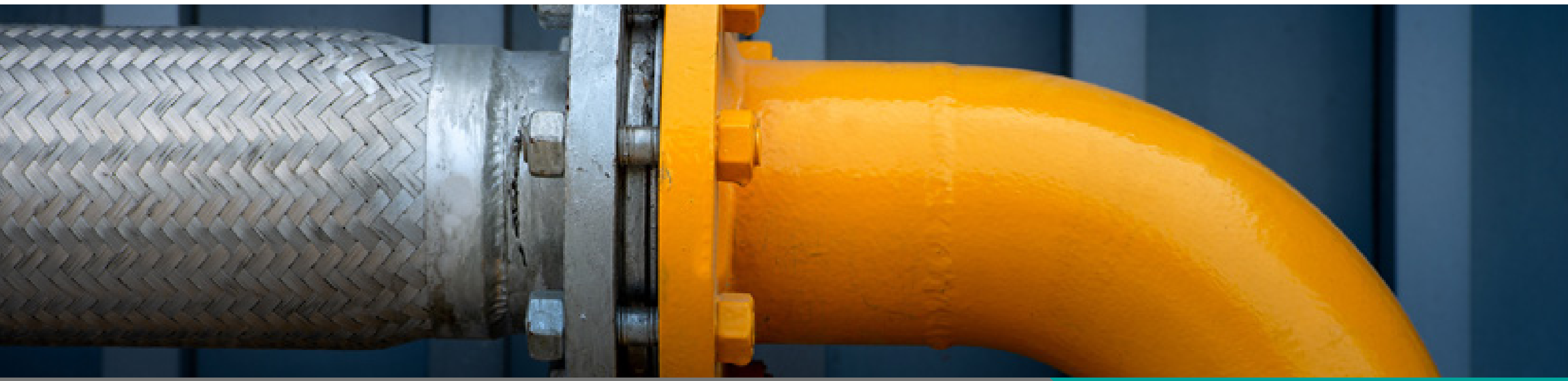
HENRY ROYCE INSTITUTE

ADVANCED MATERIALS RESEARCH & INNOVATION

MATERIALS CHALLENGES TO ENABLE HYDROGEN DEPLOYMENT AT SCALE BY 2050

Challenge: Detailed understanding of materials degradation pathways for high volume compressors to enable large scale hydrogen distribution through the UK gas grid.



CONTEXT

Transport of hydrogen in the gas grid will require the use of gas grid compressors, to take hydrogen to the pressures required for transmission (up to 94 bar) and distribution (16 bar). The small size and light weight of hydrogen molecules, along with their ability to degrade materials through mechanisms such as hydrogen embrittlement and high temperature hydrogen attack, makes the design of hydrogen compressors particularly challenging.

Reciprocating and diaphragm compressors (positive displacement type) are most commonly used to compress hydrogen in industry and for transport purposes. Centrifugal compressors often have mechanical design and efficiency advantages over positive displacement compressors in high flow rate, <100 bar outlet pressure applications found in gas transmission networks. Reciprocating and diaphragm compressors are currently used at hydrogen refuelling stations to compress hydrogen from electrolysers (10s of bar) or tube trailers (250 – 500 bar), to refuelling pressures up to 700 bar. Centrifugal hydrogen compressors are comparatively less mature, as work is currently ongoing to design and build prototypes compatible with high flow rate applications.

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MATERIALS RESEARCH CHALLENGE

For centrifugal compressors, the low weight of hydrogen molecules means the impeller blades tips operate at speeds around three times faster than for other gases, in order to achieve the same pressure differential. This leads to large amounts of heat dissipation and a need for materials that can withstand high temperatures and mechanical stresses in a hydrogen-rich environment.

Previous studies on the design of centrifugal hydrogen compressors indicate that commercially available high-strength steel and titanium alloy materials have the yield and fatigue strength properties to be used as impellers in centrifugal hydrogen compressors. These studies recommended a coating be used on compressor materials to prevent hydrogen embrittlement and other degradation mechanisms while critically not impacting the material properties of the base material. Several coatings candidates have been proposed, but greater understanding of materials degradation in real-world environments over the long term is required.

The poor understanding of compressor materials degradation in real-world environments leads to challenges with materials selection and inspection protocols. There is a need to develop standardised materials inspection protocols and understand hydrogen degradation mechanisms.

Understanding degradation mechanisms for hydrogen compressors is key to determining whether existing gas grid compressors may be used when hydrogen is injected into the gas grid, or whether new compressors will be required. New compressors will incur significant additional costs and impact the timescales for hydrogen transport in the gas grid.

In the longer term, compressors based on materials capable of storing hydrogen and releasing it at increased pressure under a thermal cycling mechanism, such as adsorbent or metal hydride materials compressors, may be able to provide solutions. While this mechanism is significantly less efficient than traditional positive displacement or centrifugal compressors, it benefits from using a heat energy input, and therefore could be exploited at industrial sites where large quantities of low-grade waste heat is generated.

UK CREDENTIALS AND WAY FORWARD

Given the number of UK projects examining the potential to blend hydrogen into the gas grid (Hy4Heat, HyNet, FutureGrid, and H21) and the need for the UK to develop material testing capability and expertise on hydrogen degradation mechanisms, this represents a key area.

A cross industry/academic group is currently developing a more detailed proposal outlining the research challenges, resources and capabilities required to achieve a breakthrough in this area to enable widescale hydrogen deployment by 2050. This proposal will be available by the end of July for consideration for inclusion in the November spending review.

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