TAP WATER CORROSION OF COMPOSITES WITH AA 6061 LINERS

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GLOBALLY HARMONISED DOCUMENT

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This document is adopted from the European Industrial Gases Association document IGC Document 72/06 ‘Tap water corrosion of composites with AA 6061 liners’. Acknowledgement and thanks are hereby given to EIGA for permission granted for the use of their document.

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1 Introduction

Aluminium alloy liner of composite cylinders have been in widespread use for about 25 years. A variety of alloys have been used for the liner including AA 6010, AA6351, AA5283, AA7060 and more recently AA6061.

The AA6061 became a substitute alloy for AA6351, once certain metallurgical deficiencies, notably sustained load cracking (SLC - see IGC Document 57) were observed in cylinders made from AA6351.

2 Scope and purpose

This document contains advance information known to EIGA companies of findings concerning cold-drawn hoop-wrapped (H-W) and fully wrapped (F-W) composite cylinders using liners from aluminium alloy 6061 (H-W AA6061).

3 Current Findings

Before production batches of a new cylinder design can commence, a series of mandatory prototype tests have to be performed. One such test is a cyclic fatigue test, in which selected cylinders are cycled over their test pressure range (up to the test pressure) for many thousands of cycles. The medium used to transmit the pressure cycle to the cylinder is often mineral oil or water containing a corrosion inhibitor.

However, some H-W AA6061 cylinders which had been accidentally filled and left with ordinary tap water, and subsequently cycle tested as described above (with mineral oil or water with a corrosion inhibitor), showed a substantial loss of fatigue life. The usual life of between about 18,000 - 20,000 cycles for a certain cylinder design was drastically reduced and even to less than 5,000 cycles for some cylinders.

The reduction in fatigue life was observed in cylinders which had been left with tap water for only 3 days prior to the test. After about 10 days the minimum in the fatigue life has been observed. Longer periods of exposure to tap water are being assessed. Also the reduction noted was independent of the cylinder manufacturer though a cold-formed manufacturing route was used.

Note: The reduction in fatigue life at test pressure was not observed for similarly treated non-composite cylinders of a seamless AA6061 construction.

THE CONCERNS FOR EIGA MEMBERS ARE THE EFFECTS OF ACCIDENTAL INTRODUCTION OF TAP/RAIN WATER (OR POTENTIALLY OTHER FLUIDS AS YET NOT DEFINED) ON THE OVERALL LIFE AND SAFETY OF H-W AA6061 CYLINDERS.

4 Preliminary Discussion

It is clear that a mechanism related to corrosion is in progress. Clear signs of intergranular corrosion were visible at the crack initiation sites for failed cylinders which have been metallographically examined, see Fig 1.

At this point it is well to note another feature of aluminium alloy 6061 (regardless of whether it is used for a seamless cylinder or a hoop-wrapped one). One of the mandatory requirements in National Standards, the EC Directive 84/526 and the EN 1975 and ISO 7866 standards dealing with seamless aluminium alloy cylinders, is a series of tests to check for an alloy's susceptibility to intercrystalline corrosion.

Unlike aluminium alloy cylinders manufactured from say alloys 5283, 7060 etc which are totally resistant to intercrystalline corrosion (according to testing to EN 1975) , see fig. 2, cylinders from alloy 6061 pass the test but exhibit some susceptibility to intercrystalline corrosion see fig 3.

The above would indicate that the intergranular corrosion created by the contaminants contained in the tap water introduced local stress raisers which led to premature cyclic loading failures. This intergranular corrosion promotes very high stresses during test pressure cyclic testing which effectively reduced the fatigue initiation process that usually provides the majority of the cycle life for aluminium alloys. The above can be explained by the following:-

a) Residual chemicals, notably the chloride content, in the tap water, have created some pre-existing corrosion related defects due to the alloy's susceptibility, albeit small, to intergranular corrosion.

b) The very much thinner wall thickness in a H-W composite AA6061 cylinder, compared to its seamless counterpart, means that the stress takes a lot less time to propagate the cracks to failure which have been initiated in a) above.

5 Recommendations

Manufacturers are investigating ways by which the internal surfaces of H-W AA6061 cylinders can be treated in order to overcome the reduction in their overall life. Techniques including internal coatings, sand-blasting etc are being evaluated.

It is strongly recommended that companies who use such H-W AA6061 cylinders ensure that there is no ingress of tap/ordinary water either within their factories e.g. at the time of retest or whilst in service e.g. from a customer's process through backfeed, from rainwater etc.

With respect to fully-wrapped cylinders, more recent work have shown as expected that such cylinders exhibit similar, susceptibility to tap water but the reduction of life is much more important than for H-W (the reduction factor for F-W being in the range of 40 instead of 4 for H-W). Consequently it is strongly recommended to follow the above procedures also for F-W cylinders.

THIS WILL MEAN THAT EXISTING H-W and F-W AA6061 CYLINDERS WILL NEED TO BE RETESTED AT THE TIME OF PERIODIC INSPECTION USING SPECIALLY TREATED WATER, EG. USE OF INHIBITORS, REMOVAL OF CHLORIDE ETC AND USING THE SHORTEST POSSIBLE TIME OF EXPOSURE TO THIS WATER DO NOT LEAVE CYLINDERS FILLED WITH TAP WATER FOR MORE THAN 2 HOURS.

Until this problem has been fully resolved, use of a positive pressure, non-return valve with such cylinders is highly recommended, as it will considerably reduce the risks involved during service.

Figure 1 – HW Cylinders (AA 6061)
Fatigue crack initiated from a corrosion pit.
Magnification X 125

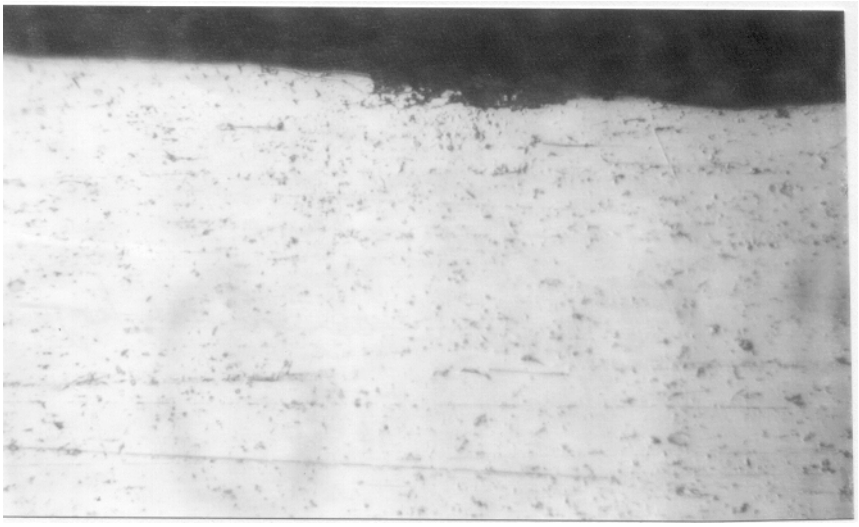

Figure 2 - AA 7060 Cylinder
Metallographic examination according to the intercrystalline test as per EN 1975.
Magnification X 300

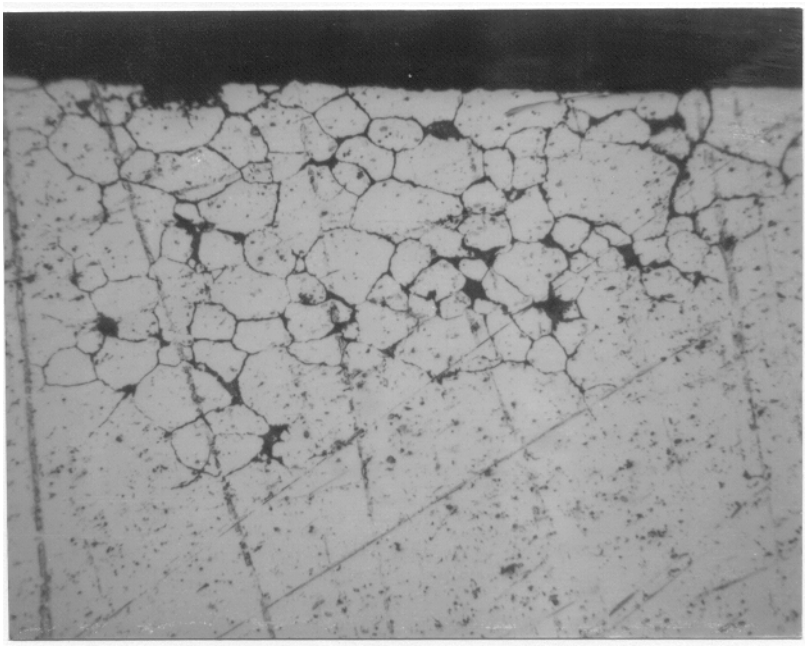

Figure 3 - HW AA 6061 Cylinder
Metallographic examination according to the intercrystalline test as per EN 1975.
Magnification X 300