WATER CORROSION OF COMPOSITE CYLINDERS WITH AA6061 LINERS

Doc 72/18

Revision of Doc 72/12

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As part of a programme of harmonization of industry standards, the European Industrial Gases Association (EIGA) has issued the publication EIGA Doc 72, *Water corrosion of composite cylinders with AA 6061 liners*. This has been jointly produced by members of the International Harmonization Council.

This publication is intended as an international harmonized publication for the worldwide use and application by all members of Asia Industrial Gases Association (AIGA), Compressed Gas Association (CGA), EIGA, and Japan Industrial and Medical Gases Association (JIMGA). Regional editions have the same technical content as the EIGA edition, however, there are editorial changes primarily in formatting, units used and spelling. Also, any references to regional regulatory requirements are those that apply to European requirements.

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Amendments to 72/12

Section	Change
	Editorial to align style with IHC associations
3	Addition of publication terminology
5	Amendments to the recommendations
6	References updated

NOTE Technical changes from the previous edition are underlined

1 Introduction

Aluminium alloy liners of composite cylinders have been in widespread use for about 25 years. A variety of alloys have been used for the liner including AA6010, AA6351, AA5283, AA7060, and more recently AA6061.

The AA6061 alloy became a substitute for AA6351 once certain metallurgical deficiencies, notably sustained load cracking (SLC), were observed in cylinders made from AA6351. See EIGA Doc 57, *Recommendations for avoidance of sustained load cracking of aluminium alloy cylinders* [1][1].

2 Scope and purpose

This publication contains information on findings concerning cold-drawn hoop-wrapped and fully-wrapped composite cylinders using liners from AA6061.

The concerns for those who use these cylinders are the effects of introduction of tap or rain water on the overall life and safety of hoop wrapped and fully wrapped AA6061 cylinders.

3 Definitions

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

4 Current findings

Some national bodies require that before production batches of a new cylinder design can commence, a series of mandatory prototype tests be performed. One test is a hydraulic cyclic fatigue test, in which selected cylinders are subjected to many thousands of cycles. The fluid used to transmit the pressure cycle to the cylinder is often water containing a corrosion inhibitor.

However, some hoop wrapped AA6061 cylinders that had been filled and left with prolonged exposure to ordinary tap water, and subsequently cycle tested as previously described (with mineral oil or water with a corrosion inhibitor), showed a substantial loss of fatigue life. The usual life of approximately 18,000 to 20,000 cycles for a certain cylinder design was drastically reduced and for some cylinders, the usual life was reduced to less than 5,000 cycles.

[1] References are shown by bracketed numbers and are listed in order of appearance in the reference section.

The reduction in cycle life was observed in cylinders that had been left with tap water from only 3 to 10 days prior to the test. Also, the reduction noted can be independent of the cylinder manufacturer though a cold-formed manufacturing route was used.

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

EIGA Doc 62, *Methods to avoid and detect internal gas cylinder corrosion* lists potential sources of water that can cause corrosion [2].

5 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 that have been metallographically examined. See Figure 1.

Figure 1—Hoop-wrapped cylinders (AA6061) fatigue crack initiated from a corrosion pit (Magnification x125)

At this point, another feature of AA6061 should be noted (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, *Aluminium gas cylinders of 17 September 1984 on the approximation of the laws of the Member States relating to seamless, unalloyed aluminium and aluminium alloy gas cylinders* and ISO 7866, *Gas cylinders—Refillable seamless aluminium alloy gas cylinders—Design, construction and testing*, is a series of tests to check for an alloy's susceptibility to intergranular corrosion [3, 4].

Unlike aluminium alloy cylinders manufactured from some alloys that are totally resistant to intergranular corrosion (e.g., 5283, 7060, etc. according to testing to ISO 7866) cylinders from AA6061 pass the test but exhibit some susceptibility to intergranular corrosion [4]. See Figures 2 and 3.

This would indicate that the intergranular corrosion created by the contaminants contained in the tap water, introduced local stress raisers that 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. This can be explained by the following:

- 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; and

- The much thinner wall thickness in a hoop-wrapped or fully-wrapped composite AA6061 cylinder, compared to its seamless counterpart, means that the stress takes a lot less time to propagate the cracks to failure that have been initiated previously.

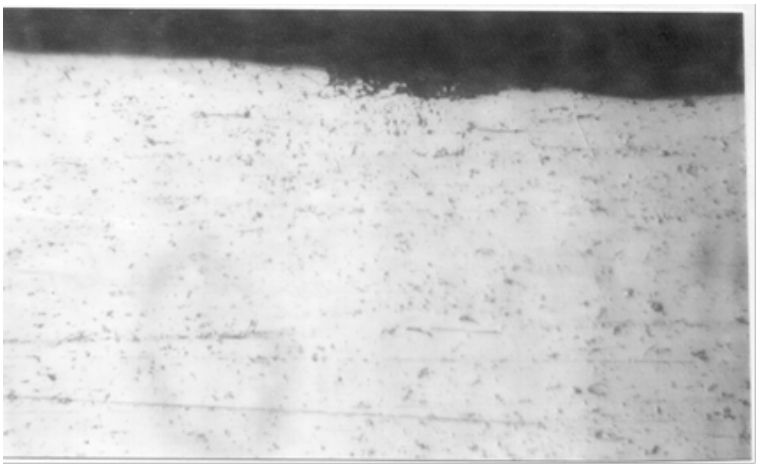

Figure 2—AA7060 Cylinder metallographic examination according to the intergranular test as per ISO 7866 (Magnification x 300)

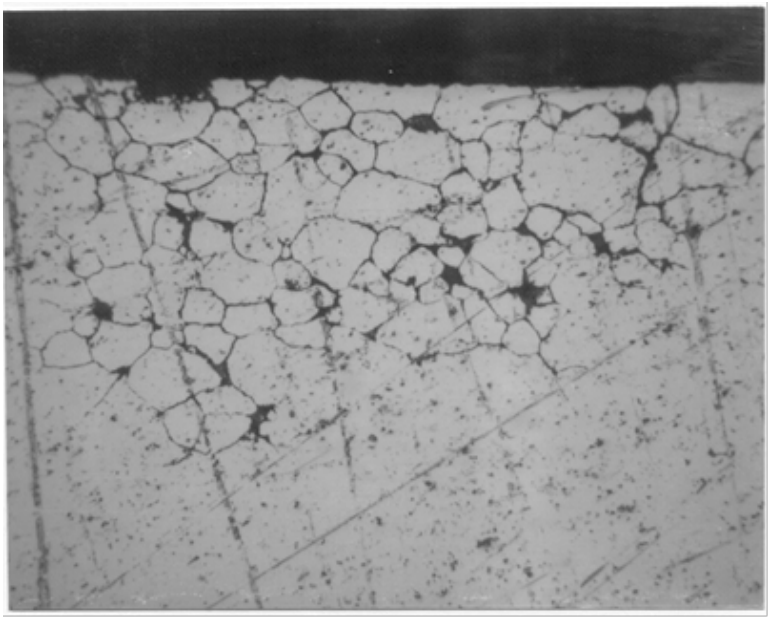

Figure 3—Hoop-wrapped AA6061 cylinder metallographic examination according to the intergranular test as per ISO 7866 (Magnification x 300)

6 Recommendations

The following recommendations include those requirements, standards, and practices that avoid water contamination during use and storage, and offer suggestions to reduce the risk of adverse effects of water used for the hydrostatic test.

Some cylinder manufacturers may use or apply a coating to the internal surface of the liner to reduce the risk of corrosion and possible reduction in their service life. Care needs to be taken when removing a protective coating that could already be on the inner surface. The inner surface present from the manufacturing process could be better than a coating added after manufacturing or at requalification. Before treating the surface, verify with the manufacturer if a coating is already present

and whether the modification or application of a coating compromises the integrity or safe performance of the cylinder.

NOTE Media blasting and other processes to remove surface coatings and the application of coatings shall only be performed by experts, preferably with the recommendation of the cylinder manufacturer.

For fully-wrapped and hoop-wrapped AA6061 cylinders, the time of exposure to the water during the hydrotest at the time of requalification should be minimized.

As found in industry requirements, standards, and practices for hydrostatically testing cylinders (e.g., ISO 11623, *Gas cylinders—Composite construction—Periodic inspection and testing*), the cylinder shall be clean and dry after the test [5]. After this process, it is recommended to either immediately fit the valve, or take measures to prevent the ingress of contaminants from the environment. It is recommended that the total time for water exposure should not exceed 5 hours. Companies that use fully wrapped and hoop wrapped AA6061 cylinders should ensure that there is no ingress of water into the cylinders from sources such as backflow or other contamination. One possible method of reducing the risk of exposure to the ingress of moisture into cylinders is the use of positive pressure, non-return (check) cylinder valves.

For cylinders that are suspected of having in-service contamination or the residence time of water in the cylinder during retest extends beyond the maximum, for example 5 hours, a risk assessment should be performed. This risk assessment should consider the number of filling cycles for the application as well as the consequence of a leak resulting from cracking of the liner. The cylinder manufacturer should be consulted when performing this risk assessment.

7 References

Unless otherwise specified, the latest edition shall apply

[1] EIGA Doc 57, *Recommendations for avoidance of sustained load cracking of aluminium alloy cylinders*, European Industrial Gases Association. www.eiga.eu

[2] EIGA Doc 62, *Methods to avoid and detect internal gas cylinder corrosion*, European Industrial Gases Association. www.eiga.eu

NOTE This publication is part of an international harmonization program for industry standards. The technical content of each regional document is identical, except for regional regulatory requirements. See the referenced document preface for a list of harmonized regional references.

[3] Directive 84/526/EEC, *Aluminium gas cylinders of 17 September 1984 on the approximation of the laws of the Member States relating to seamless, unalloyed aluminium and aluminium alloy gas cylinders* www.europa.eu

[4] ISO 7866, *Gas cylinders—Refillable seamless aluminium alloy gas cylinders—Design, construction and testing,* International Organization for Standardization. www.iso.org

[5] ISO 11623, *Gas cylinders—Composite construction—Periodic inspection and testing,* International Organization for Standardization. www.iso.org