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Customer:	Morini Competition Arm SA / CH-6930

Contents

CH-8304 Wallisellen, 02/08/2018
Testing supervised by: Natascha Portner

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1 Introduction / test assignment / details of the item tested

The item examined was a ruptured compressed air cylinder (Photos 1 to 2, Annex 1.1). According to information supplied by the customer, the material used was a high-tensile type 7075 aluminium alloy in heat treatment condition T6. The customer requested that a failure analysis examination be carried out to determine the cause of the rupture. This draft report presents the current status of our examinations as at 13 July 2018.

2 Fractographic examinations

2.1 Macroscopic examination

A conspicuous feature of the cylinder's surface was the presence of numerous corrosion scars. The area around the rupture on the container displayed a partly fissured fracture structure but with minimal deformation. There was a distinctive semi-elliptical structure which showed up as a bright shiny area. Consequently, it was possible to localise the fracture origination point to the outer side of the cylinder. The rest of the fracture area was of a uniformly grey colour (Photos 3 to 4, Annex 1.2).

2.2 Scanning electron microscope examination

Under the scanning electron microscope, a smooth intergranular structure coated with corrosion products could be seen in the area of primary cracking. Secondary cracks could be detected on the surface in the fracture origination area. The final forced fracture exhibited the characteristics of a microductile forced rupture (Photos 5 to 9, Annexes 1.3 to 1.5).

Energy dispersive X-ray identified chlorine in the corrosion products as the corrosion-inducing element (Spectrum 1, Annex 2.1).

3 Metallographic examinations

Branched crack systems emanating from the corrosion scars could be seen in the polished microsection. The etched microstructure displayed a compressed microstructure with intermetallic phases. The cracks very largely followed an intergranular path (Photos 10 to 13, Annexes 1.6 and 1.7).

4 Chemical analysis

The surface of the specimen was roughened by milling and analysed using a Type ARL 3450 Advantage spark emission spectrometer. Measurements were carried out in accordance with SOP No. ZP320. The readings are subject to measurement uncertainties and are available on request.

Nominal values according to: AW-7075 as per ISO 209-1:2007-07

Table 1: Spark (optical) emission spectrometry, mass fraction w

	Broken specimen g/100 g	**Specified values** *Nominal values* g/100 g	
		min.	max.
Si	0.10		0.400
Mn	0.18		0.300
Cr	0.19	0.180	0.280
Ti	0.03		0.200
Cu	1.36	1.200	2.000
Fe	0.18		0.500
Zn	5.97	5.100	6.100
Mg	2.34	2.100	2.900
Zr+Ti	0.07		0.250
Al	Base	Base	

< = Below detection limit; --- = No specifications

The chemical composition of the broken specimen conforms to the aluminium alloy 7075 (Perunal 215) as specified by the drawing.

5 Mechanical and technological testing

5.1 Results of the hardness measurements

The hardnesses were measured using the Vickers method in accordance with EN ISO 6507-1 (2005) and SOP No. ZP167. Experience has shown that the relative measurement uncertainty of this method is approximately ± 4% of the measured value.

Table 2: Results of the hardness measurements

	1 HV1	**2** HV1	**3** HV1	**Mean value** *Mean* HV1
Sample No. *Sample No.*				
The broken specimen	169	174	174	172

Typical standard values for the T6 condition are 160 HV. Based on its hardness, the cylinder can be said to be in accordance with the heat treatment and strength condition as specified by the drawing.

6 Summary

The item examined was a ruptured compressed air cylinder.

The findings can be summarised in key statements as follows:

- The chemical composition of the ruptured cylinder conformed to the 7075 alloy specified (Perunal 215).
- Based on its hardness values, the cylinder's heat treatment condition was as required by the drawing specification.
- The fracture origination point was identified as being on the outer side of the cylinder; it exhibited an intergranular structure.
- Under metallographic examination, various secondary crack systems emanating from corrosion scars and following an intergranular path could be seen.

7 Interpretation of the findings

Based on the findings, it can be stated that all the characteristics of stress corrosion cracking were present on the ruptured cylinder.

For stress corrosion cracking to occur, the following conditions need to obtain simultaneously:

- The material must be susceptible to stress corrosion cracking.
- A specific corrosive medium needs to be present.
- The component needs to be exposed to sufficiently high tensile stresses (internal stresses, assembly stresses, working stresses).

As soon as any one of these three conditions is eliminated, the stress corrosion mechanism does not occur. As soon as the cylinder is filled, the components are necessarily subject to mechanical stresses. Consequently, the condition relating to mechanical stresses, which is essential if stress corrosion cracking is to occur, is always a given and cannot be eliminated.

Based on the condition of the surface, it can be stated that the outer side of the component had been exposed to a corrosive atmosphere containing chloride. The condition of the surface together with the numerous secondary cracks are indications of inappropriate handling and/or storage conditions. The cylinders had, however, been given a decoratively anodised coating, providing them with protection against the usual slight amounts of corrosion. But the cylinders were not designed to withstand the aggressive conditions which appeared to pertain here. Contact with an aggressive medium, which is essential for stress corrosion cracking to occur, can be prevented by appropriate handling and storage.

Photo documentation

Annex 1.1

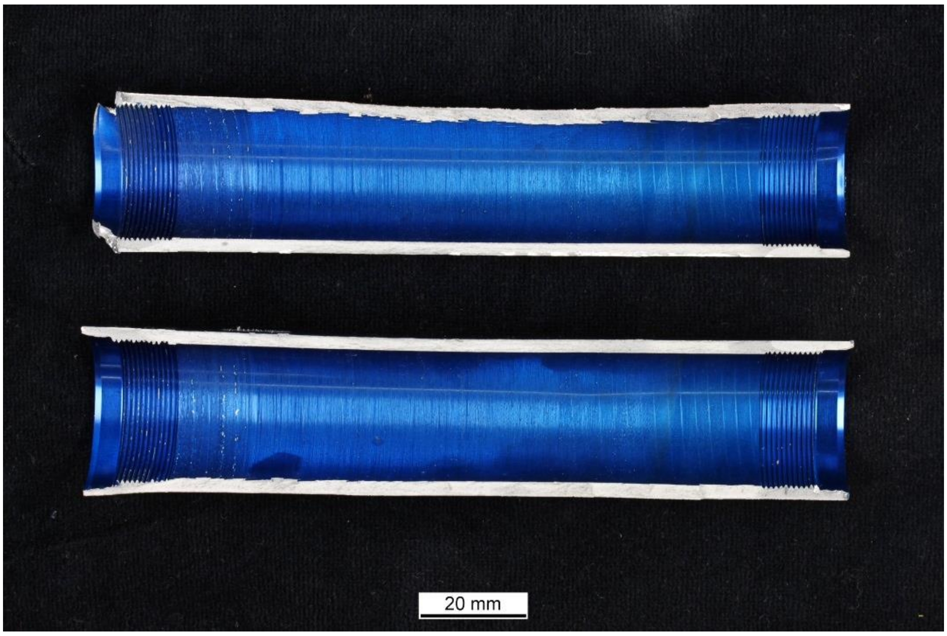


Photo 1: The broken specimen as delivered.

Photo 2: The broken specimen as delivered. The areas of corrosion attack are conspicuous (circle).

Annex 1.2

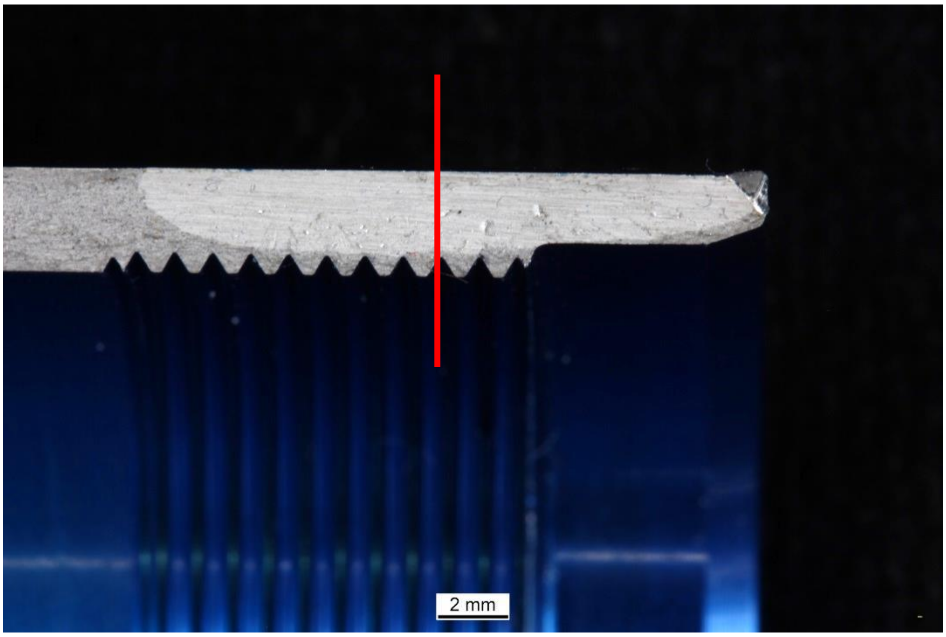


Photo 3: Close-up of the fracture area showing the bright semi-elliptical fracture origination zone. The section plane for the metallographic examination is indicated by the red line.

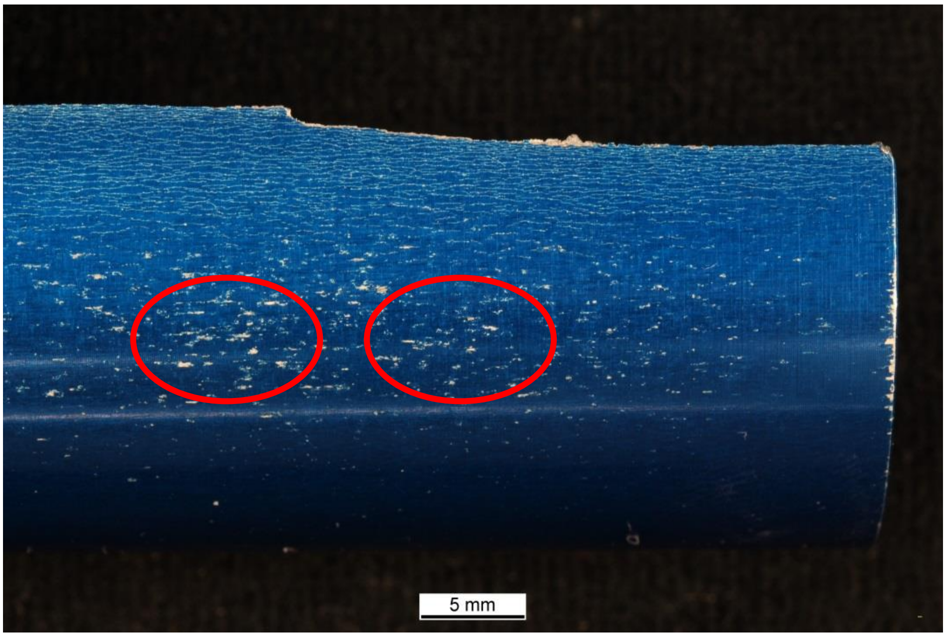


Photo 4: Side view of the cylinder with areas of corrosion attack (circles).

Annex 1.3

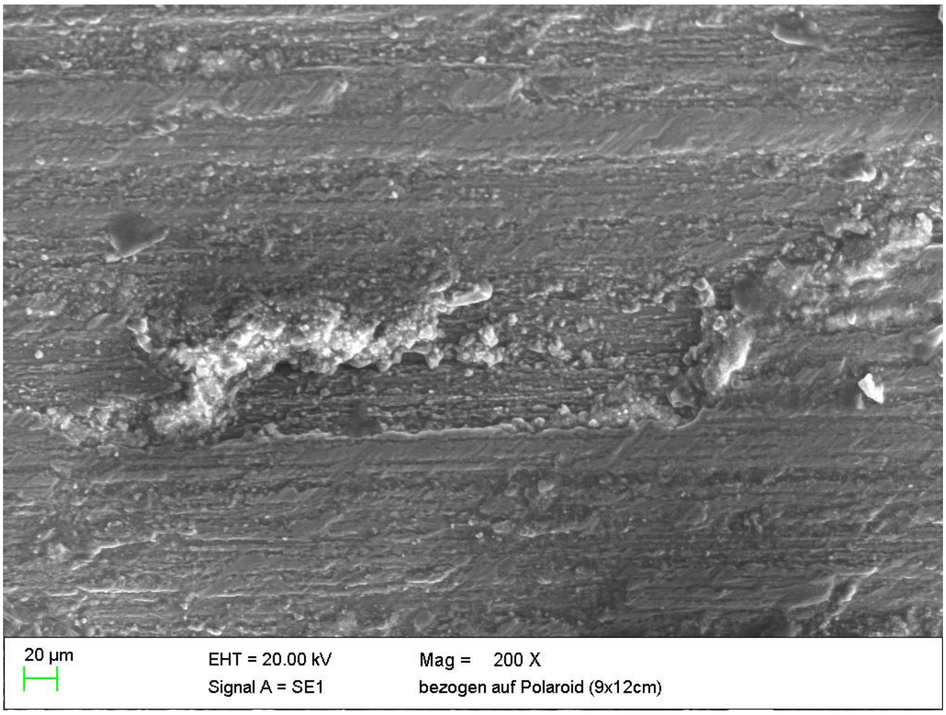


Photo 5: SEM image of the broken specimen: fracture origination point. Fracture surface partly coated with corrosion products.

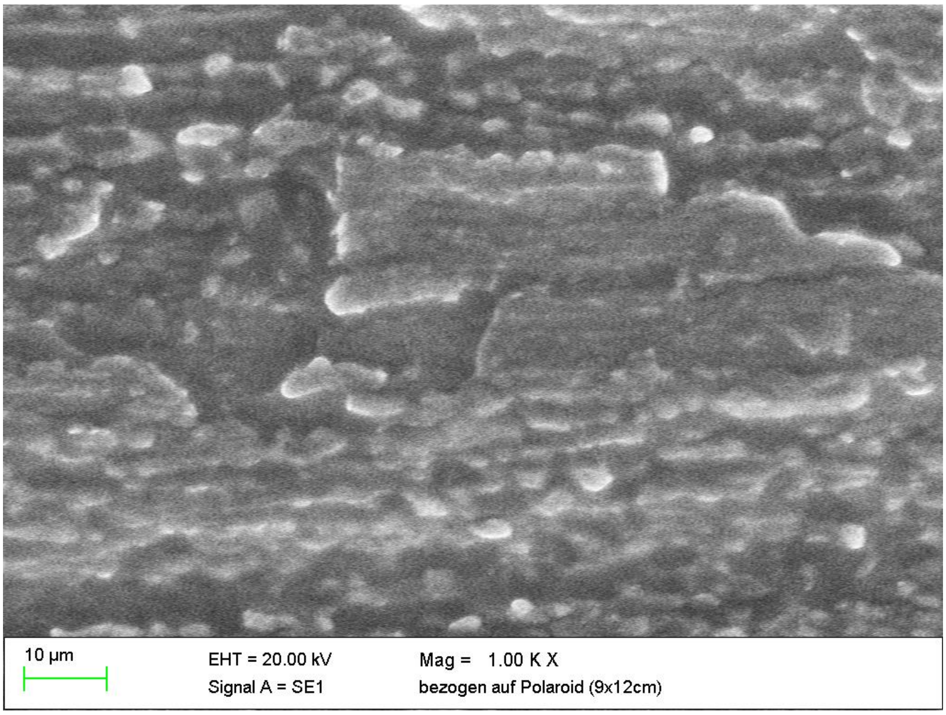


Photo 6: SEM image of the broken specimen: intergranular structure coated with corrosion products.

Annex 1.4

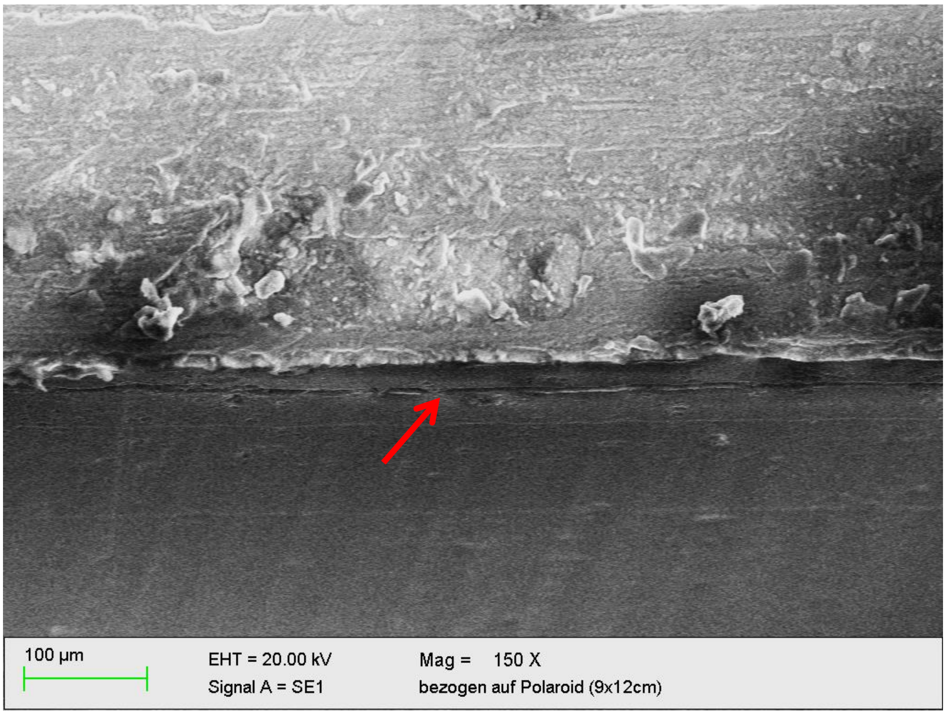


Photo 7: SEM image of the broken specimen: secondary crack (arrow) below the fracture origination point.

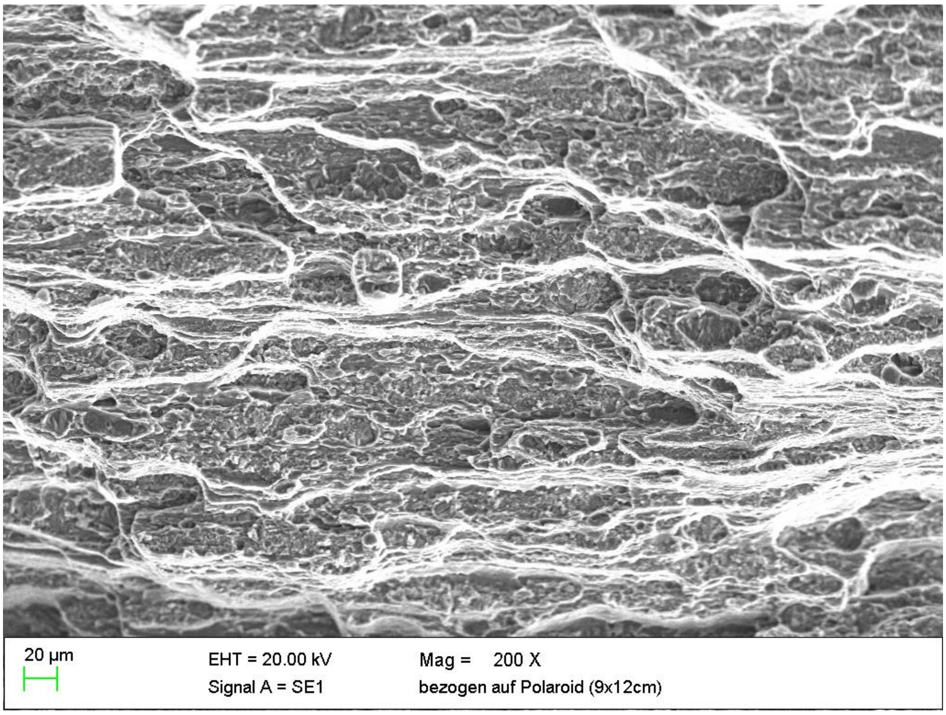


Photo 8: SEM image of the broken specimen: Final forced fracture; microductile fracture with dimples.

Annex 1.5

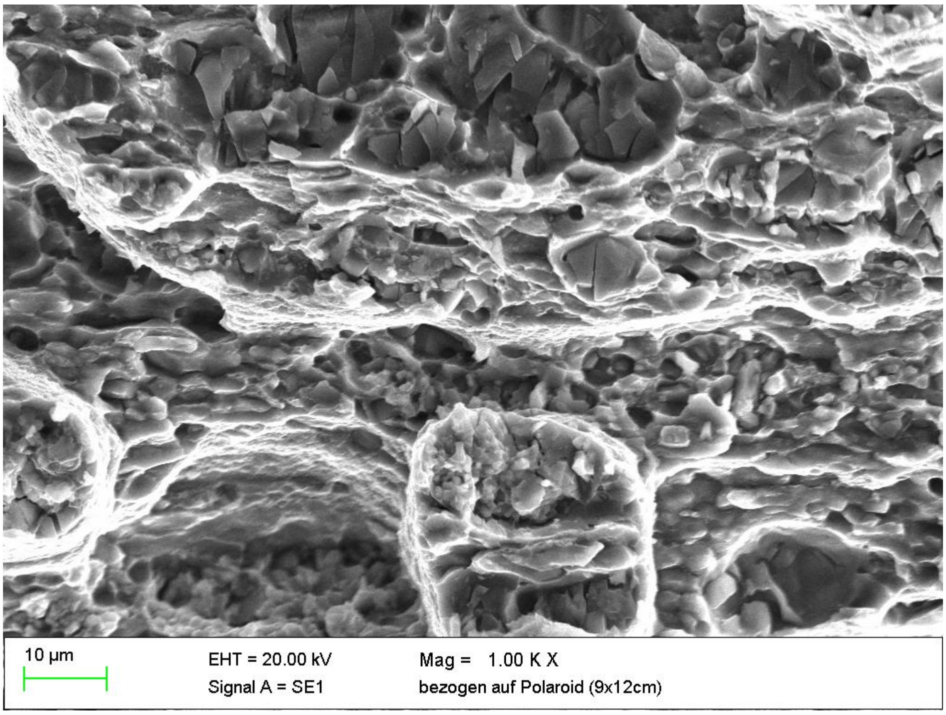


Photo 9: SEM image of the broken specimen: Final forced fracture; microductile fracture with dimples.

Annex 1.6

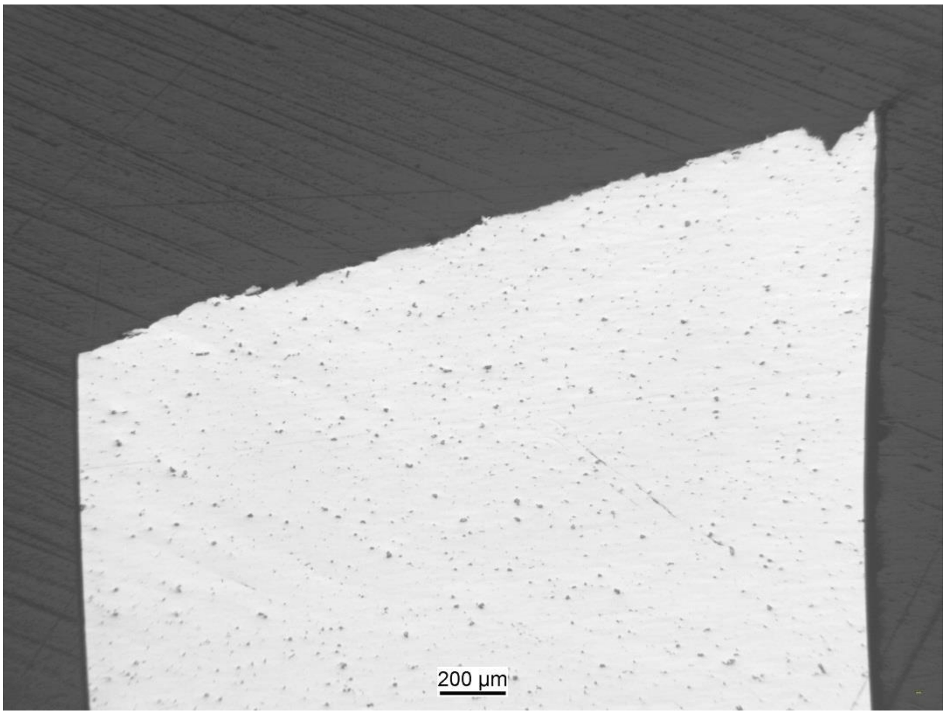


Photo 10: The broken specimen; polished microsection, side view of the fracture surface.

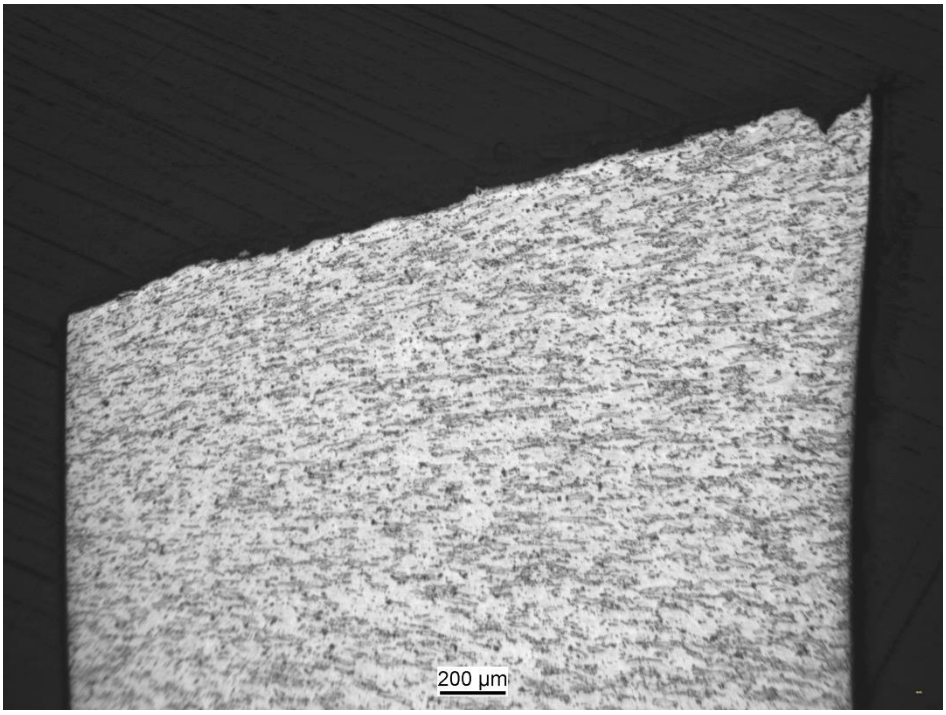


Photo 11: The broken specimen; etched microsection, side view of the fracture surface. A compressed microstructure can be seen.

Annex 1.7

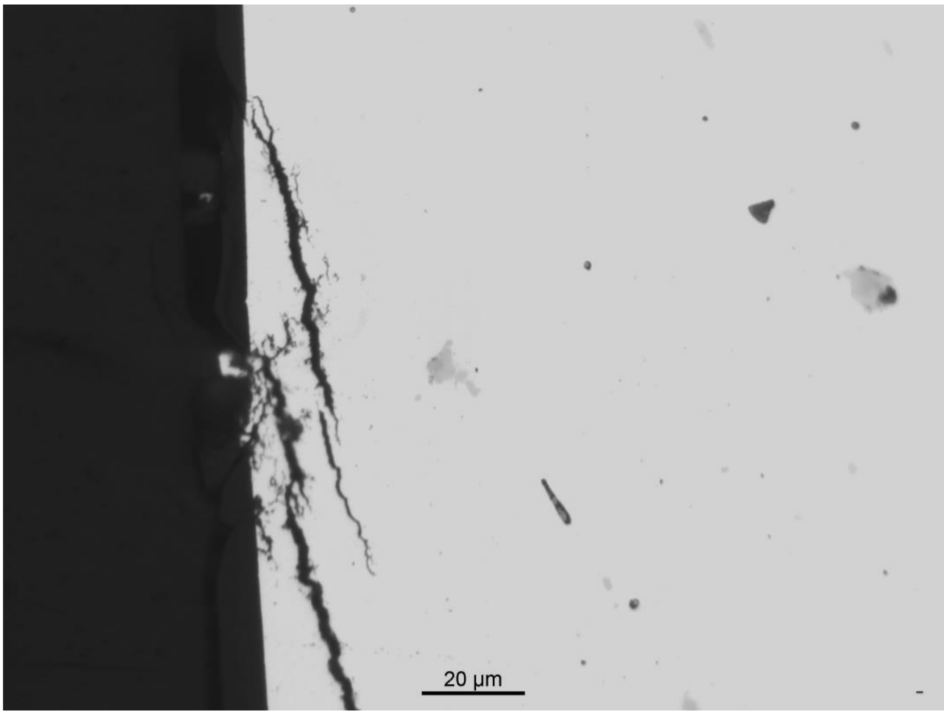


Photo 12: The broken specimen; polished microsection, illustrating a branched secondary crack emanating from a corrosion scar.

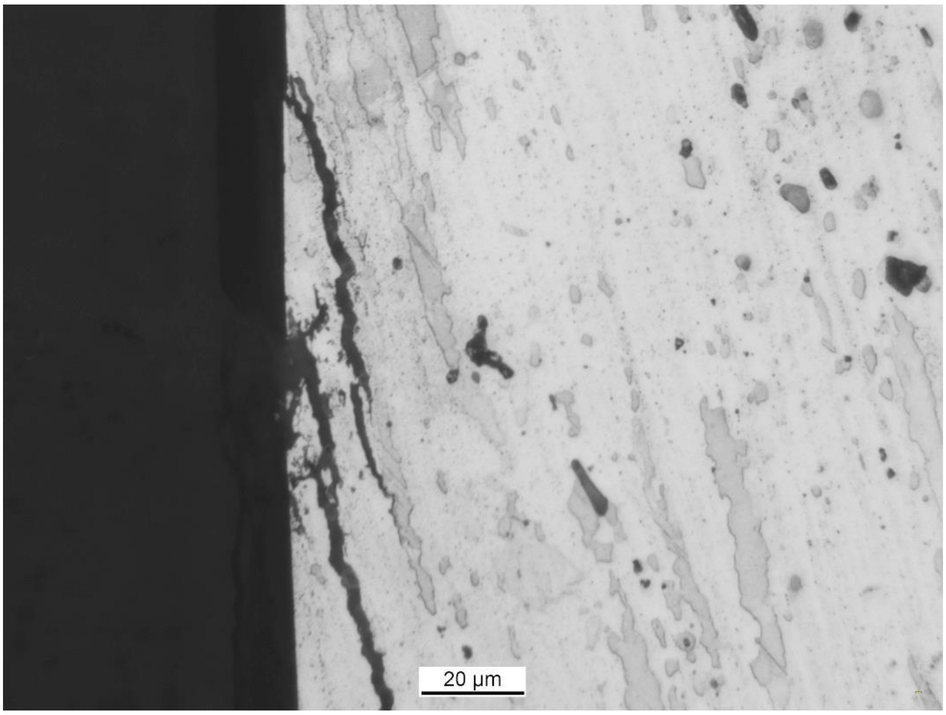
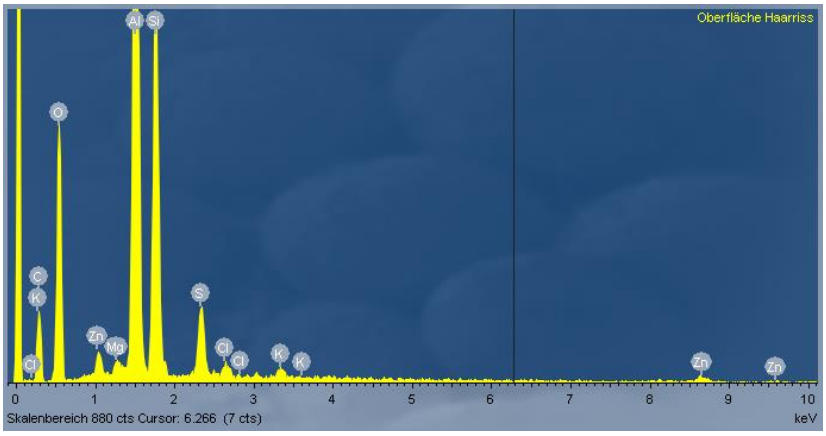


Photo 13: The broken specimen; etched microsection; intergranular crack pattern.

EDX spectra

Annex 2.1



Spectrum 1: Chloride as the corrosive substance on the surface of the aluminium cylinder.