Engineering Failure Analysis 60 (2016) 117–136

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Failure analysis of a leaching reactor made of glass-fiber reinforced plastic

Mari Lindgren [a,*], Gunnar Bergman [b], Markus Kakkonen [c], Markus Lehtonen [d], Jarno Jokinen [e], Markus Wallin [e], Olli Saarela [e], Jyrki Vuorinen [c]

[a] *Outotec Research Center, P.O. Box 69, 28101 Pori, Finland*
[b] *Bergman Polymer Corrosion AB, Kragstalundsv, 96, SE-18654 Vallentuna, Sweden*
[c] *Department of Materials Science, Tampere University of Technology, P.O. Box 589, 33101 Tampere, Finland*
[d] *Outotec (Finland) Oy, Rauhalanpuisto 9-13, 02230 Espoo, Finland*
[e] *Department of Applied Mechanics, Aalto University, PO Box 14300, FI-00076 Aalto, Finland*

ARTICLE INFO

Article history:
Received 5 July 2015
Accepted 16 November 2015
Available online 17 November 2015

Keywords:
Failure analysis
Composites
Process-plant failures
Tank
Environmental interaction

ABSTRACT

This paper reports a failure analysis of a leaching reactor in a zinc plant that suffered from a catastrophic failure after less than two years of operation. During normal operation the bottom of the reactor fell out suddenly, releasing the contents, a high-temperature acidic solution, into the surroundings in an uncontrollable manner. The reactor was made of glass-fiber reinforced plastic. Microscopy, thermal analysis, mechanical testing and finite element analyses were employed to investigate the causes of the failure. There were several contributing factors but the root cause was poor adhesion between the bottom and the joint laminate, which was caused by insufficient grinding during the surface preparation stage of the joint.

1. Introduction

In the case of hydrometallurgical processing, zinc can be converted from a solid material to soluble form either first roasting it and secondly leaching the calcine, or by direct leaching of zinc concentrate [1]. The direct leaching can be carried out at atmospheric conditions. The leaching stage is followed by various solution purification and metal recovery stages. If the leach residue contains silver, it can be recovered by a separate process stage involving strong acid leaching and super-strong acid leaching.

Leaching is carried out in stirred reactors [2,3]. The conditions are aggressive: the solution in the super-strong acid leaching contains up to 15% sulfuric acid, the temperature is close to 100 °C, and the solution may contain chlorides and oxidizing ions, e.g. ferric iron. There are two main options for the construction materials of the reactors: high-alloyed stainless steels and glass-fiber reinforced plastics.

Glass-fiber reinforced plastics consist of reinforcing fibers bound together by a resin, usually a thermoset resin [4]. Vinyl-ester based resins provide high chemical resistance with good fabrication properties and, consequently, they are used in the mining and metallurgical industry as construction materials [5]. The production technique of a laminate has a major influence on the product properties. Therefore, the properties of a composite are dependent on the chemical constituents, i.e., on the type of resin and the fibers but in addition, on the production technique and the lay-up of the reinforcing fibers.

* Corresponding author.
E-mail addresses: mari.lindgren@outotec.com (M. Lindgren), gunnar@polymercorrosion.se (G. Bergman), markus.kakkonen@tut.fi (M. Kakkonen), markus.lehtonen@outotec.com (M. Lehtonen), jarno.jokinen@aalto.fi (J. Jokinen), markus.wallin@aalto.fi (M. Wallin), olli.saarela@aalto.fi (O. Saarela), jyrki.vuorinen@tut.fi (J. Vuorinen).

http://dx.doi.org/10.1016/j.engfailanal.2015.11.026
1350-6307/

This paper deals with the failure investigation of a damaged leaching reactor. A wide range of experimental techniques including microscopy, thermal analysis, mechanical testing, and finite element (FE) analyses were utilized to find out the causes of the failure and to ensure the safe operation of the remaining similar reactors.

2. Description of the failure case

2.1. The incident

The strong acid leaching reactor, VHR3, made of fiber reinforced plastic (FRP) failed catastrophically in July 2014. After slightly less than two years of service, the bottom of VHR3 fell out during normal operation without any warning signs (see Fig. 1). This incident released the contents (370 m^3) of the reactor into the surroundings in an uncontrollable manner. No human casualties occurred and the effect on the environment was minimal thanks to the safety system of the plant. There were no eyewitnesses to the incident but a loud noise was generated as the failure occurred.

The failed reactor was the second newest of six identical reactors performing a similar duty. The other five reactors were not damaged during the incident but they were immediately taken out of operation, emptied and inspected, and the root cause analysis of the failed reactor was initiated.

2.2. The structure

The reactor was approximately 9.2 m high and had a diameter of 8.0 m. A coordinate system was established to identify locations around the reactor circumference. A zero point was fixed to the location of the manhole and positions were marked as meters from that location in the counterclock-wise direction (see Fig. 1). In the height direction, the zero level was fixed to the butt joint between the bottom and the shell and the positive direction was facing downwards.

Fig. 1. Overview of the failed reactor.