Mechanical and Industrial Engineering -College of Engineering-Sultan Qaboos University

Analysis of Clad Failure in Aluminum Smelters

Aadil Said Al Niyadi

Abstract

Most of the aluminum smelters around the world follow the Hall–Héroult process to produce pure aluminum. The anode plant follows the Söderberg method to produce anodes for the reduction line. A critical part in the anode is the Clad, also known as the Electric Transition Joint (ETJ). This Clad is used to join the upper part of the stem (made of aluminum) to the bottom part known as bracket (made of steel). The middle part of the Clad consists of titanium which is explosion welded on one side and MIG welded on the other, to provide a connection between the upper and lower parts. Some regional smelting plants have reported repeated metal failure in the anode Clad. The defect of the Clad is characterized as elongation or bending, and could be due to uneven stress distribution, high heat, and high current. This Clad failure causes a tilt of more than 16º in the stem, leading to the failure of the smelting process. In one of the regional smelting plants, there has been a rapid increase of Clad failure in recent years (not reported in earlier years). This thesis work attempts to analyze the Clad failure problem in aluminum smelters, identify the major causes, and suggest suitable remedial action. A thorough review of the aluminum smelting process and affiliated problems was conducted. Different techniques were identified and used to investigate the Clad failure problem, such as visual inspection, X-ray inspection, chemical composition test, welding strength test, tensile test, shear test, and finite element analysis (FEA). The Clad upper portion (from external supplier) was found to be of good quality. Tensile tests and chemical composition tests of the aluminum alloy yielded values that were well within the required range. The major causes of clad failure were found to be lack of fusion, lack of penetration, and porosity in the welded joints (from both visual inspections and X-ray inspections of sectioned samples). FEA of different portions of the Clad with the welding layer (under mechanical, thermal, and electrical loads) shows that in the case of good quality welding, the assembly can safely withstand all applied loads without any failure. To mitigate this problem in the future, it is strongly recommended that the welders should have superior welding skills (proper licensing and experience of MIG welding), all welding parameters (current, welding speed, inert shielding gas, etc) need to be strictly controlled, and environmental influences need to be minimized (dust, humidity, etc).