

A Sludge Cleaning Robot for Sulfuric Acid Tank

Tae-Gyoon Lim^{1, a}, Soon-Geul Lee^{2, b}

¹Dept. of System Solutions Research, Research Institute of Industrial Science & Technology, Korea

²Dept. of Mechanical Engineering, Kyung Hee University, Korea

^ataeglim@rist.re.kr, ^bsgelee@khu.ac.kr

Keywords: Underwater robot, Harsh environment, Acid tank, Sludge cleaning, Anti corrosion.

Abstract. This paper presents development of a cleaning robot for the sludge in sulfuric acid tank. The sulfuric acid is made during SO_x capturing process, well known as flue gas desulfurization, and it has very strong corrosion characteristics. The cloud of micro dust in the flue gas settles as sediment in the acid tank. Because the fume produced by the sulfuric acid is very toxic, the sulfate sludge must be removed not by a worker but by an underwater robot having anti-corrosion capability. For this purpose, an underwater robot is developed with anti corrosion materials for its elements such as robot body, drive shaft, wheel, waterproofing seal, power cable, slurry pumping tube, etc. A series of experiments of sludge cleaning shows that the developed robot works well in the real sulfuric acid tank.

Introduction

Because of the aspirations of well-being society and improving the quality of life, most countries are committed to prevention of air pollution, and each potential contamination source in the major industrial plants is often monitored. SO_x containing flue gas is usually issued from heavy plants when firing the sulfide seats, iron sulfides and fossil fuels, but it cannot be emitted directly to the atmosphere and is processed into the desulfurization facilities for air pollution control.

By the well known 'contact process', sulfur dioxide in the flue gas is oxidized to sulfur trioxide using oxygen in the presence of a vanadium(V) oxide catalyst. The sulfur trioxide is absorbed into 97–98 % H₂SO₄ to form oleum (H₂S₂O₇), also known as fuming sulfuric acid. The oleum is then diluted with water to form concentrated sulfuric acid.

Note that directly dissolving SO₃ in water is not practical due to the highly exothermic nature of the reaction between sulfur trioxide and water. The reaction forms a corrosive aerosol that is very difficult to separate, instead of a liquid.

Its properties are as follows.

- Molecular formula : H₂SO₄
- Molar mass : 98.079 g/mol
- Density : 1.834 g/cm³, liquid
- Melting point : 10.49 °C
- Appearance : clear, colorless, odorless liquid
- Property : hygroscopic, strongly oxidative
- Reaction with H₂O : exothermic

The sulfuric acid is used in large quantities by the iron and steel making industry to remove oxide, rust and scale from rolled sheet and billets prior to the subsequent production processing and sale to the automobile and white goods (appliances) industry.

The sludge in a sulfuric-acid tank accumulates due to the particles coming into the tank with acid. The increase of sludge causes a reduction in the capacity of the facility and at a subsequent pickling process the floating sludge will lead to product contamination or stains, therefore it should be removed periodically.

Because the sulfuric acid is oxidative and highly hygroscopic, and its fume is also very toxic, manual sulfate-sludge cleaning is very dangerous. Therefore, in this paper a sludge-cleaning underwater robot system is developed for the sulfuric acid storage tank. The developed underwater robot has the capability of corrosion resistance to the sulfuric acid, it can work sunken into the acid or alkali tank where the workers cannot reach because even the fume of the acid or alkali is very harmful to workers.



Fig. 1. Sulfuric-acid storage tank

Sulfuric Acid Storage Tank

The sulfuric acid produced during desulfurization process is collected to the storage tank shown in Fig.1, the height and the diameter of the tank are approximately 4 m. The temperature is room temperature, and the sulfuric acid is very thick since the concentration rises up to 95 to 98 %. The sediment thickness is 200 mm and the concentration is about 50 %, the amount of sludge is approximately 1.25 m³.

To clean the sludge of the sulfuric acid tank, the cleaning robot moves over the floor of the tank, the sludge is raked and pumped to the outside through a retrieval hose, and then passed through a filter with a pure sulfuric acid returning to the storage tank, and the remainder fed to a neutralization process.

Because the sulfuric acid is highly hygroscopic and highly exothermic when meeting with water, during working the eyes and nose must be protected with face protection to prevent exposure to fume of sulfuric acid and against flying of the acid.

In addition, when dealing with sulfuric acid against water, special care is needed. When water is added into the strong sulfuric acid, great heat comes out and it runs a risk of explosion and scattering of toxic sulfuric acid gas. Therefore, to have a dilute sulfuric acid, the strong sulfuric acid is added to water in small amount and repeatedly, and when priming the pump the supplement should be the sulfuric acid.

Sulfate Sludge Cleaning Robot

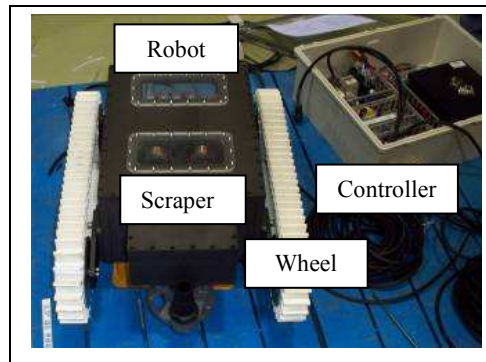


Fig. 2. Photograph of sludge cleaning robot system

Fig.2 shows the photograph of the sludge cleaning robot, composing of robot body, shafts, wheels, scrapers, and the controller. For water proof in the vicinity of shafts mechanical seals are used, and when their materials are carefully selected, they can have the superior corrosion resistance.

Transparent windows are prepared for lighting and camera mounting, and an inward check; scrapers are attached to help pumping of the sludge. To retrieve the sludge a corrosion resistant tube is connected, and the power supply line is wired for the purpose of power and withdrawal of the robot system for emergency use.



Fig. 3. Mechanical seal

The mechanical seal, shown in Fig.3 is absolutely necessary for the underwater robots to prevent leakage of the rotating shafts. The stator section is fixed to the casing and the rotor section rotates with the shaft, and the stator and rotor contact surfaces are perpendicular to the axis of rotation and parallel to each other. The two sliding-contact surfaces keep contact irrespectively of the sliding contact and sealing of rotary shaft is obtained due to the spring tension or pressure of the fluid.

The advantages of the mechanical seals are superior sealing over oil seals, no wear of the axis, all the wear only on the sliding surface, and automatic compensation of wear by the spring tension. In addition, according to the choice of the material, the application conditions (temperature, chemicals, rotational speed, pressure, etc.) may vary.

Fig.4 shows some test results of the corrosion of the materials for the sulfate sludge cleaning robot system, because the sulfuric acid is very strongly corrosive and therefore the material selection for the element parts of the robot system is the key to the system design.

Through the survey of the literature [1,2] the candidates for the materials of the element parts of the developed robot system are selected, and their material samples are sunken into the sample of the actual sulfuric acid to conduct the corrosion test, then the final selection is made according to the corrosion resistant properties. Corrosion properties of materials depend on the concentration, the temperature and the impurities of the acid.

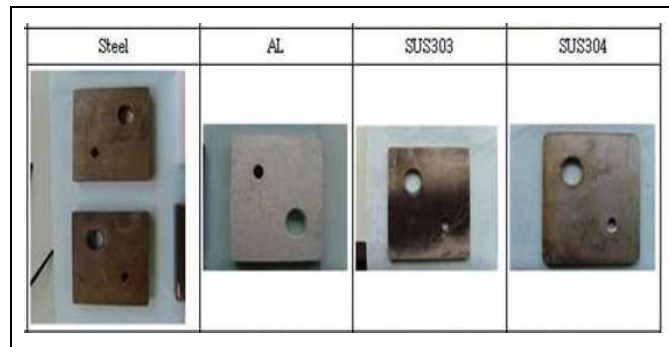


Fig. 4. Corrosion test results of the materials

Looking at Fig. 4, as candidates for organizing materials for the sulfate sludge cleaning robot, the best is STS 304 that it is not corroded, whereas iron, aluminum, STS 303 are corroded. For the wheel material, urethane is corroded and Teflon is safe.

Fig. 5 shows the actual sludge cleaning robot test in a real sulfuric acid storage tank. The robot moves into and over the acid storage tank for 3 hours and pump the sludge to the outside. As a result of the tests, the corrosion-resistance performance was verified for the robot body, wheels, tubes and power supply lines in a 98 % sulfuric acid.



Fig. 5. Sludge cleaning robot in sulfuric-acid storage tank

Summary

This paper presents development of the underwater robot to clean the sludge in the sulfuric-acid storage tank.

To this end, (1) the chemical properties of the sulfuric acid and its corrosion characteristics for the materials of the element parts were investigated, and (2) the underwater robot for cleaning the sludge was designed, and (3) some materials were selected as candidates for the elements of the robot system, and (4) corrosion tests for the above materials were conducted with the target sulfuric acid and the final materials were chosen, and (5) a sulfate sludge cleaning robot was made and the corrosion resistance performance was verified through the tests on the actual sulfuric acid storage tank.

References

- [1] Handbook of Corrosion Data, ASM International, 1995.
- [2] Uhlig's Corrosion Handbook, CANMET Materials Technology Laboratory, 2000.
- [3] Lee, Woo, and Jin, "Underwater Video Recording," PoongDeung Press, 2005.