Effect of sand erosion of glass surface on performances of photovoltaic module

○Kotaro Tagawa, Akifumi Kutani, and Piao Qinglin

***Abstract*— Recently, photovoltaic (PV) systems are installed in the arid land region of the world. The degradation of performance of PV system is caused by sand dust accumulation and sand erosion on the glass surface of the PV modules. It is necessary for maintain and life cycle of PV module to prevent the degradation of PV module in sand dust environment. In this study, the effects of sand erosion on surface roughness and the transmittance of the glass sample simulated the surface of PV module were investigated. Moreover, the experiment on the degradation of performance of PV module has been performed.

***Keywords*—photovoltaic module, sand erosion, surface damage

I. Introduction

THE world population has been increasing rapidly and reached 7 billion. It is perceived that the food and water shortages will be expanded globally under the current food production system if the world population continues to increase. Furthermore, the energy consumption will increase, which will cause short of energy resources. These issues are closely related each other and are serious extremely in arid land including developing country. The installation of renewable energy plays an important role to solve these issues.

There exist abundant renewable energies, such as solar and wind energy, and vast unused land in the arid region. For example, small-scale solar and wind power generations have such characteristics that they can generate electricity at places where it is needed to be consumed, thus they can be used as independent electric source in remote areas with no electric power cable. It is very useful for electrification of farm, pumping water, supply of irrigation water, etc. Moreover, large-scale solar and wind power generations have been introduced to supply electricity to the urban area in the arid regions.

However, the sand storm and dust accumulation are common phenomena in arid land. It has been reported power output of photovoltaic (PV) system was affected by dust accumulation on the surfaces of PV modules in dusty environment. The degradation of performance of PV module is caused by sand dust accumulation and sand erosion on the glass surface of the panel. It is very important for maintain and life cycle of PV module to prevent the degradation of PV module in sand dust environment.

The previous studies have been reported about the effect of dust accumulation on the performance of PV module and solar collectors [1-5]. On the other hand, there are a few reports about the effect of sand erosion on the performance of PV module. Bouaouadja, N *et al* examined the effects of the damage of glass surface on the efficiency of solar panel by the experiments focused on sandblasting duration [6]. But, the more experimental data is required about the effect of sand erosion on the performance of PV module for several factors in order to develop the PV module technology for sand dust environment.

This study aims to estimate the damage of the glass surface by simulating the dust storm and to make clear the effects of the characteristic of glass surface damaged by sand erosion on the performance of PV module.

K. Tagawa, Department of Regional Environment, Faculty of Regional Sciences, Tottori University (corresponding author to provide phone & fax: +81-857-31-5138; e-mail: tagawa@rstu.jp).

A. Kutani, Master course, Graduate school of Regional Sciences, Tottori University

Q. Piao Master course, Graduate school of Regional Sciences, Tottori University (e-mail: piaoqinglin1984@hotmail.com).

II. Experimental Procedure

In this study, a few experiments were carried out to investigate the effects of sand erosion on the performance of photovoltaic cell. Firstly, sand erosion tests used by sandblasting were carried out to investigate the damage on the glass surface. And then, the surface roughness and transmittance of the damaged glass surface were measured. Secondary, the damaged glass was actually placed on the surface of a photovoltaic cell, and the amount of power generated by the photovoltaic cell was measured.

A schematic diagram of experimental apparatus for sand erosion tests was shown in Fig. 1. This test was carried out by using the sand blasting. The soda lime glass was used as the test sample. The glass samples with dimension (200mm x 200mm x 5mm) were placed with tilt angle θ (°) 200 mm apart from the outlet of nozzle. The sand was supplied in the blasting air by a blower and blasted to glass sample from the outlet of nozzle.

The shapes of sand particles used for the sand erosion tests were shown in Fig. 2. The sand came from the sand dune along seacoast located in the Arid Land Research Center, Tottori

University, Japan. Sand particles were irregular and their sizes were 100μm to 500μm. The velocity of blasting air was set at 35.1 m/s and the sand particles were feed at 0.74g/s. The erosion time t was set 670, 1400, 2050 and 2650s. The tilt angle θ was changed from 20° to 50°.

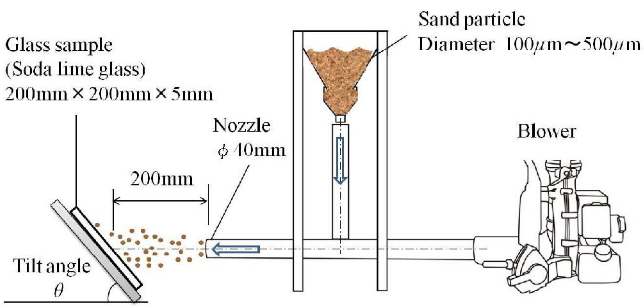


Fig.1 Schematic diagram of experimental apparatus for sand erosion tests

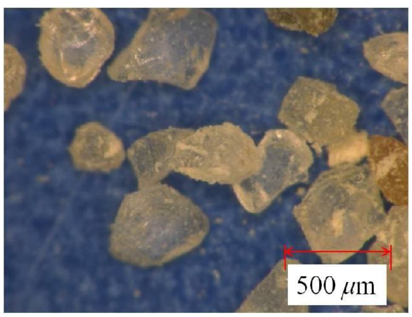


Fig.2 Shape of sand particle used for the erosion test

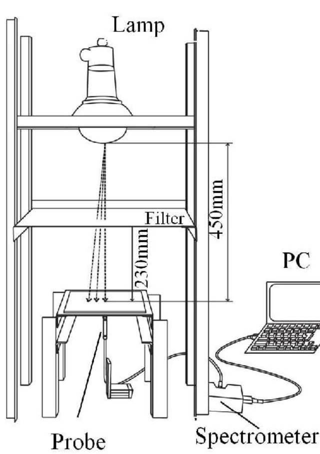


Fig.3 Experimental setup for measuring the transmittance

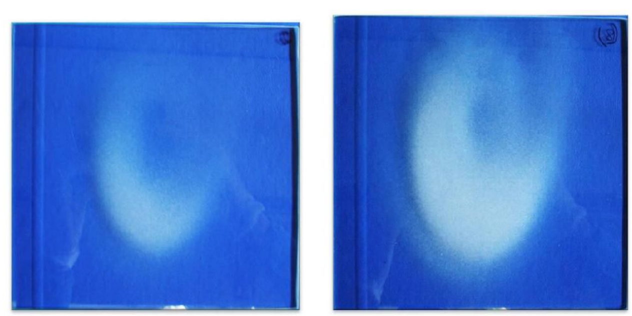
After the sand erosion tests, the surface roughness of the glass sample was measured at 15 points on the surface by the surface measuring machine (MITUTOYO Surftest SJ-400). The arithmetical mean roughness Ra was measured and the average value of 15 points was derived about each sample.

Schematic diagram of the experimental setup for measuring the transmittance was illustrated in Fig.3. A probe of spectrometer (Ocean Optics, USB2000+ Miniature Fiber Optic Spectrometer) was placed below the glass sample. The wavelength of the light from the lamp was measured and found to be about 350nm – 1050nm. The intensity of light transmitted through the glass sample was measured before and after sand erosion test. And then, transmittance of the damaged glass sample was calculated from the measured intensity of light.

Moreover, the power output of the photovoltaic cell was measured for the case of a simulated condition of the glass surface of the photovoltaic cell damaged by colliding sand particles. A glass sample with a damaged surface was placed on the photovoltaic cell. Then, the light from a lamp was irradiated and the current and voltage of the cell were measured. The intensity of the light was adjusted to 1kW/m^2 in this experiment. The surface temperature of the photovoltaic cell was 27℃±4℃.

III. Experimental results

The photographs of typical damage on the glass surface by sand erosion were shown in Fig.4. The variation of arithmetical roughness Ra with erosion time t is shown in Fig. 5. The damage expanded toward the upper of the sample widely in Fig.4. The sand particle jumped up to upper part of the glass sample after first collision with the surface because the sample was set with tilt angle and the height of nozzle outlet was positioned at the height corresponding to the lower part of the sample. The damage made clear as erosion time became longer. The arithmetical mean roughness became larger as the erosion time



Erosion time t = 670s t = 2650s

Fig. 4 Photograph of the glass sample after sand erosion (tilt angle θ = 30°)

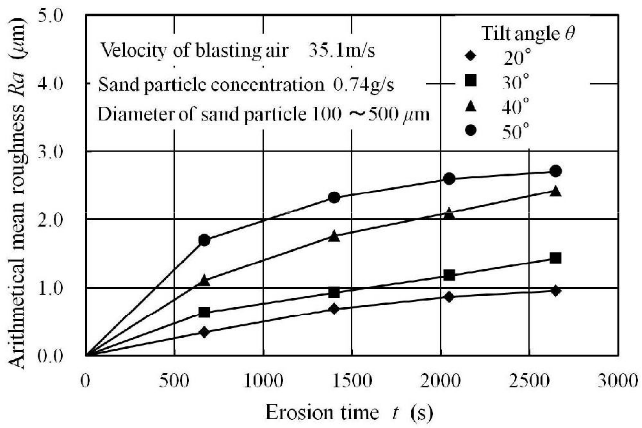


Fig. 5 Variation of arithmetic roughness *Ra* with erosion time *t*

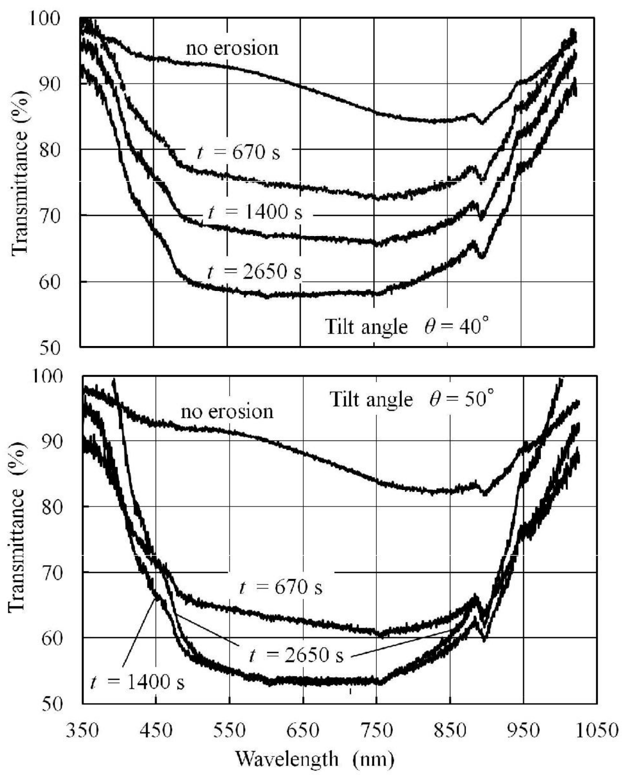


Fig. 6 Transmittance of the glass sample with or without sand erosion at each wavelength

became longer at each tilt angle in Fig.5. In case that tilt angle rose, the arithmetical mean roughness became larger because the impact of sand particles became bigger on the surface of sample which approached to the vertical plane against the blasting air.

The transmittances of light through the damaged surface at each wavelength in the case that the tilt angles of the glass sample were 40° and 50° were shown in Fig.6. The transmittance of light after sand erosion for each erosion time is also shown. From these results, it was found that the transmittance of the glass sample greatly reduced in the range of 500 to 900 nm. The reduction of transmittance in short erosion time becomes larger, when the tilt angle is bigger.

The reduction ratio of output from photovoltaic cell with damaged surface of the glass is shown in Fig.7. The output from photovoltaic cell reduces largely with increase of the tilt angle and the arithmetic mean roughness of the glass surface damaged by sand erosion.

IV. CONCLUSIONS

In this study, the effects of sand erosion on surface roughness and the transmittance of the glass sample simulated the surface of PV module were investigated. Moreover, the experiment on the degradation of performance of PV module has been performed.

From the experimental results, the damage on glass surface by sand erosion was shown by surface roughness. Also, the degradation of transmittance of the damaged glass surface and the performance of photovoltaic cell with damaged surface by sand erosion quantitatively.

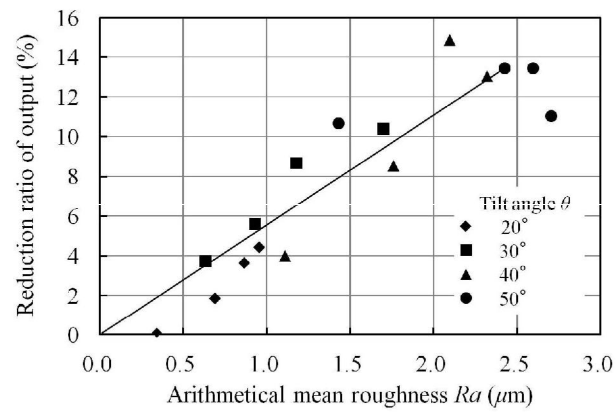


Fig.7 The reduction ratio of output from photovoltaic cell with damaged surface of the glass

REFFERENCE

[1] M. S. El-Shobokshy and F. M. Hussein, "Effect of dust with different physical properties on the performance of photovoltaic cells", Solar energy, vol. 51, No.6, (1993), pp.505-511

[2] D. Goossens and E. V. Kerschaever, "Aeolian dust deposition on photovoltaic solar cells : the effects of wind velocity and airborne dust concentration on cell performance", Solar Energy, vol. 66, No.4, (1999), pp.277-289

[3] S. Biryukov, D. Faiman, and A. Goldfeld, "An optical system for the quantitative study of particulate contamination on solar collector surfaces", Solar energy, vol. 66, No.5 (1999), pp.371-378

[4] A. M. El-Nashar, "Effect of dust deposition on the performance of a solar desalination plant operating in an arid desert area", Solar Energy, vol.75, (2003), pp.421-431

[5] H. K. Elminir, A. E. Ghitas, R. H. Hamid, F. El-Hussainy, M. M. Beheary, and K. M. Abdel-Moneim, "Effect of dust on the transparent cover of solar collectors", Energy Conversion and Management, vol. 47, (2006), pp.3192-3203

[6] N. Bouaouadja, S. Bouzid, M. Hamidouche, C. Bousbaa and M. Madjoubi, "Effects of sandblasting on the efficiencies of solar panels", *Applied Energy*, vol.65, (2000),pp.99-105