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ScienceDirect

Energy Procedia 69 (2015) 106 – 115

Energy Procedia

International Conference on Concentrating Solar Power and Chemical Energy Systems, SolarPACES 2014

Study of the surface damage of glass reflectors used in Concentrated Solar Power Plants

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Abstract

Solar mirrors are exposed, during their operation in Concentrated Solar Power plants –CSP-, to climatic stress factors that cause their degradation and therefore a decrease in the global efficiency of the plant. Sandstorms are among parameters that cause a decrease of mirrors optical performances by generating surface erosion. The intensity and the gravity of this erosion phenomenon is function of climatic, geological parameters and mirrors surface nature.

To evaluate the effect of these parameters on the optical performance degradation, two approaches were adopted, namely the natural aging tests in two different sites in Morocco, and the aging tests in controlled environment in a sandblasting chamber. The objectives are, by monitoring the stress factors in natural aging sites, to define aging tests under controlled environment that reproduce similar degradation phenomenon that those observed on mirrors exposed in natural aging sites. Degradations observed in both natural and controlled aging tests are compared and correlated to validate the methodologies and the hypotheses on the analysis of the degradation phenomenon. The aging tests in controlled environment permits the evaluation of the effect of each influencing parameter separately from the others on the mirrors surface erosion, and eventually accelerate the apparition of surface erosion on mirrors.

Under controlled environment, tests show that glass mirrors present maximum surface erosion at normal impact angle and that the loss in specular reflectivity is directly related to the wind speed. Exposed mirrors in natural aging sites present low loss in reflectivity which doesn't exceed 0.4% after 240 days of outdoor exposure. Concerning the effect of sand properties on erosion phenomenon, it was found that the sand hardness affect the roughness parameters, while the sharp forms influence on the impacts

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Peer review by the scientific conference committee of SolarPACES 2014 under responsibility of PSE AG
doi:10.1016/j.egypro.2015.03.013

properties (roughness parameters, impacts number, impacted area, impacts size diameter). By increasing the sand particle's size, the impacted area increase and the losses in relative specular reflectivity increase.

Peer review by the scientific conference committee of SolarPACES 2014 under responsibility of PSE AG

Keywords: Solar mirrors; Surface erosion; Natural aging; Outdoor aging

1. Introduction

In a Concentrated Solar Power plant -CSP-, more than 30% of the global investment is reserved for solar field that includes mirrors costs (installation, operation and maintenance, replacement of mirrors breakage…) **[1-2]**. To ensure high global yield of CSP plant, solar specular reflectance of mirrors are among the key-parameters that should be kept at its highest level during the entire service lifetime of mirrors **[3-4]**. This latter is directly related to the location of the power plant since several climatic stress factors like temperature, humidity, dew, irradiation and windstorms can cause various mirrors degradations such as surface erosion, corrosion of reflective layer, delamination, photo-degradation of polymeric protective layer, etc **[5]**.

To evaluate the effect of degradation phenomena on the mirrors optical performance, many studies are conducted on natural aging sites **[6-10]** where glass sheet or mirrors samples are tested during an exposure time. Natural aging tests are useful and necessary to observe and analyze degradation mechanisms under natural climatic conditions. However, it requires a long time before obtaining remarkable degradations and it is complex, in this case, to evaluate and understand the degradation linked to only one stress factor since samples are exposed to a mix of climatic parameters leading to several simultaneous degradation mechanisms. In fact, to accelerate the apparition of degradation phenomena and to dissociate the effect of each influencing climatic parameter, aging tests in controlled environment are often adopted **[2, 11-16]**. They permit to test, on specific chambers, the effect of some climatic parameters such as UV radiation, humidity, temperature, windstorms.

In this work, we are interested on windstorms effect on the surface erosion of mirrors. This phenomenon is directly influenced by the climatic and the geological parameters of the mirrors exposure site and their surface's nature parameters **[5, 11-12]**. The aim of the present study is to evaluate the effect of these influencing parameters on surface erosion phenomenon during natural aging and by conducting representative and accelerated tests in controlled environment. For this purpose, natural aging tests are made in two representative sites in Morocco. Conditions of representative tests in sandblasting chamber are defined based on the monitoring of influencing climatic parameters and on the geological analysis of both natural aging sites. These tests used both sand particles representatively extracted from the natural aging sites to approach the real aging conditions. To confirm our results, normalized sand particles are used in order to compare the obtained tendencies with literature.

2. Experimental procedure

Silvered mirrors of 0.95 mm thickness are used to evaluate the effect of surface erosion on the mirrors performances. In this conception, the glass substrate is coated with a silver reflective layer on the backside to create a second-surface mirror. To protect this reflective layer from any eventual degradation, mirror backing system is covered by several protective paints. For the present study, mirrors of 7 x 7 cm² are used for both natural and controlled environment tests. These mirrors are cut and supplied by the manufacturer without edge protection. In order to avoid the edge effects, samples of 20 x 20 cm² are added for the natural aging tests.