Artificial Soiling Setup Development and Dry Cleaning Simulation

F. Wiesinger[1], F. Sutter[1], A. Fernández-García[2], F. Wolfertstetter[1], N. Goldberg[3]
[1]German Aerospace Center (DLR), Institute of Solar Research, Paseo de Almeria 73, 2, 04001 Almería, Spain
[2]CIEMAT-PSA, Ctra. de Senés s/n (km 4), Apartado 22, 04200 Tabernas, Spain
[3]BrightSource Energy, Kiryat HaMada St 11, Jerusalem, Israel

Motivation

- Growing share of electricity market for CSP (concentrating solar power) in arid and semi-arid regions in the sun belt
- Degradation of optical surfaces due to sand storms represents a risk for investors and no reliable service lifetime prediction models are available.
- Realistic soiling simulation is important for CSP technology assessment (1).

Objectives

Observation:
- Expose state of the art material to field conditions where soiling occurs
- Collect relevant field parameters for meteorological & geological site assessment

Simulation:
- Design & Construction of a laboratory setup to perform accelerated soiling tests
- Find adequate parameters for laboratory aging to reproduce the defects observed in the field

Quality assessment:
- Use of the accelerated laboratory setup to test new materials and coating technologies.
- Use of the accelerated laboratory setup to assess various cleaning methodologies against each other where realistic soiling is a must (2).

Approach & Methods

Field campaign at the PSA

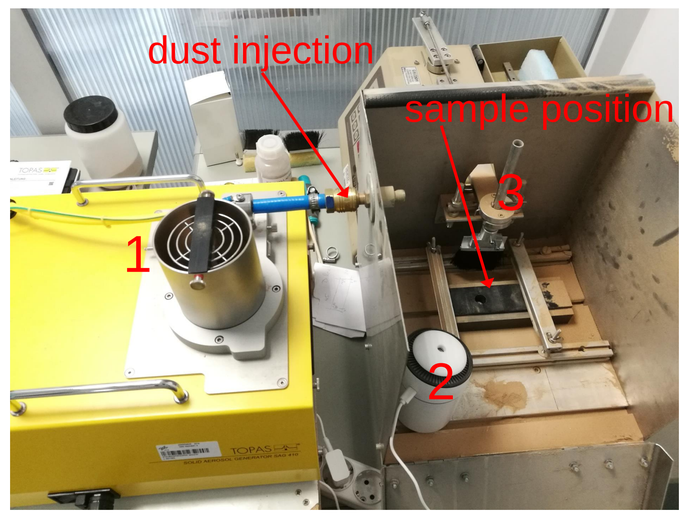
Exposure of solar mirrors and collection of field parameters at the Plataforma Solar de Almeria (owned by CIEMAT).

Exposure of state of the art reflector material in the field to accumulate natural soiling. Additionally the following meteorological and geological data were acquired in order to allow for future comparism to other sites: Irradiation, wind velocity and direction, relative humidity, aeolian dust concentration, particle size distribution (PSD) of aeolian as well as soil material, chemical composition of soil, shape of particles

Artificial soiling and brush-cleaning simulation

A prototype of the artificial soiling and cleaning setup was developed which contains the following parts:

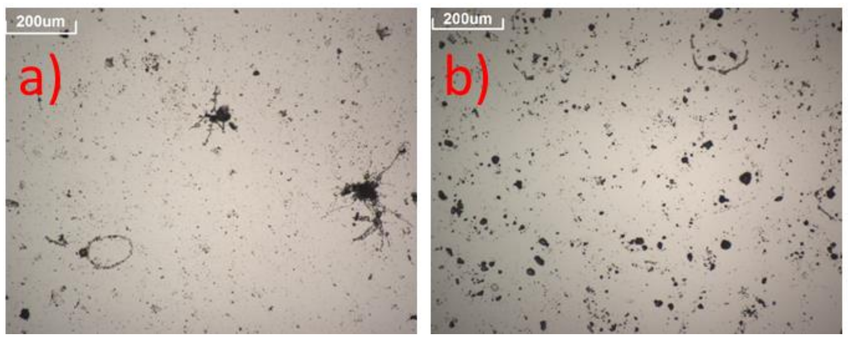
1. Aerosol generator SAG410/L from Topas GmbH which facilitates the dispersion of dry dust material. Natural dust with particle size <200µm is used.
2. Ultrasonic nebulizer produces fine water mist which simulates dew formation more realistically than water spray procedure.
3. Linear moving shaft where different brush types can be mounted to simulate dry cleaning. Brushes were supplied by Brightsource Energy Inc. who is currently testing the same materials in real plant conditions for one year (see video).



Artificial soiling and brush-cleaning setup. The lid of the metal box can be closed during the experiments.

Results

Comparison: field and laboratory soiling



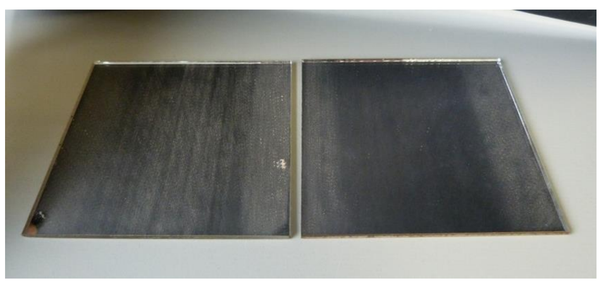
Microscope images of soiled reflectors from a) outdoor exposure and b) artificial soiling.

From the microscope images of exposed and artificially soiled samples it can be seen that:
- the adhering particle size is in the same range
- the laboratory procedure is capable of producing zones where small particles adhered and agglomerated after water droplets evaporated

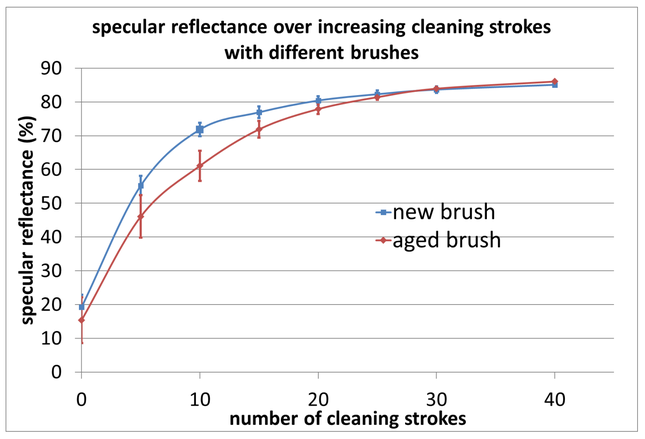
Both reflectors exhibit a monochromatic specular reflectance ρ(660nm, 15°, 12.5mrad) between 0.75 and 0.80.

Assessment of cleaning potential of brushes

The as-received brush was artificially aged by simulating 5 years of heliostat cleaning. Focus was laid on the process when the brush trespasses the edge of the heliostat, leaving or arriving at the reflector (see video). This artificially aged brush was tested against a new brush on heavily soiled reflectors (ρ ≈ 0.2) and its lower cleaning potential can be seen by naked eye **after 10 cleaning strokes**.



Soiled reflector cleaned by a)aged brush and b) new brush.



Event though the cleaning potential might be lower for aged brushes on the first sight, a reflectance analysis shows, that an increase in cleaning time (represented by the number of cleaning strokes) compensates for this disadvantage.

Summary & Outlook

- Development of artificial soiling setup prototype which is capable of reproducing outdoor observed soiling mechanisms.
- Apart from artificial soiling, the setup can be used to simulated dry cleaning processes based on linear moving brushes.
- Cleaning potential of tested brushes decreases over time of usage but can be compensated by consecutive increase of cleaning time.

References

(1) A. Heimsath, P. Nitz, Solar Energy Materials and Solar Cells, 2019. 195: p. 258-268
(2) E. Klimm, L. Ost, M. Köhl and K-A. Weiß, Energy Procedia, 2016. 91:p. 338-345.

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DLR Deutsches Zentrum für Luft- und Raumfahrt
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