Simulation of the Effect of Dust Barriers on the Reduction of Mirror Soiling in CSP Plants

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Outline

- Background – why are dust barriers needed?
- Previous dust barrier development
- Simulations performed
- Results
- Outlook

Background

- Most regions suited to CSP are typically dusty and arid

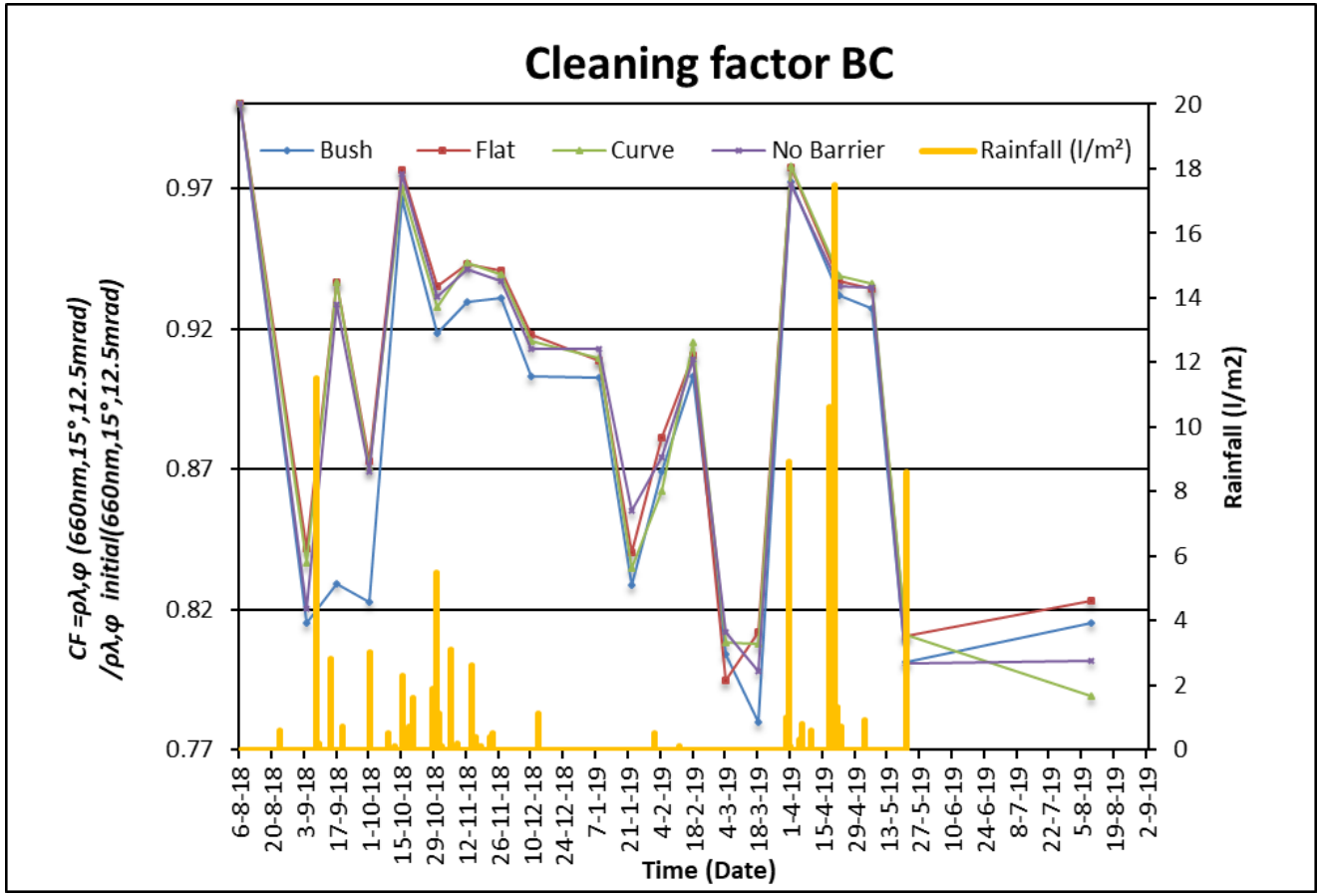
- Water is precious in such locations – need to reduce its use
- A number of solutions have been developed under WASCOP
- Now being implemented at full scale for SOLWATT/SOLWARIS

Previous work

- What is a dust barrier?
- Fence-like structure surrounding the plant.
- 6m tall, porous mesh that deflects the air and reduces its velocity.
- Dust is either carried up and over the barriers, or stopped before reaching the mirrors.
- Developed for parabolic trough plant only (so far).
- On WASCOP: different porosities and shapes investigated with 2m tall barrier prototypes deployed for testing.

Previous work

- Results of testing –natural
- Barriers were installed at CIEMAT-PSA for 12 months
- Samples installed behind the barriers and reflectance monitored.
- Samples cleaned when reflectance dropped below threshold
- Preliminary results show a 1-2% increase in average reflectance over the test period.



Previous work

- Accelerated soiling tests:
- Four fans used to generate dust cloud using dust sieved to <250um.
- Wind approx 3-4m/s from East (behind fans), 2.5kg sand total:

	Before	After	Drop
No barrier	95.6	78.6	17
Barrier	95.6	85.9	9.7

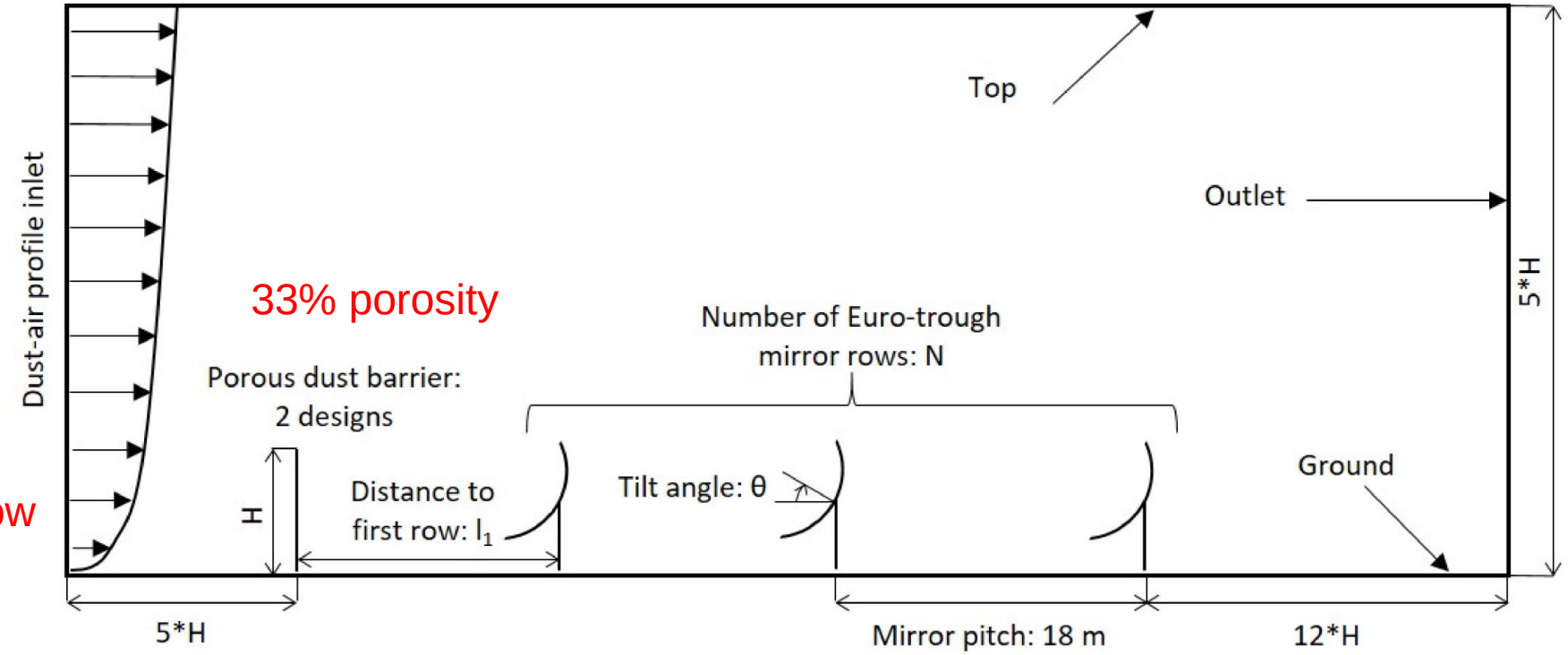
- Initial result shows a reduction of soiling of 43% when a barrier is used compared to no barrier. (Comparable to previous results and CFD.)

Full scale simulations

- Now moving to full scale simulations considering dust flow, mirror tracking angles and how far into the plant the dust reduction is effective.

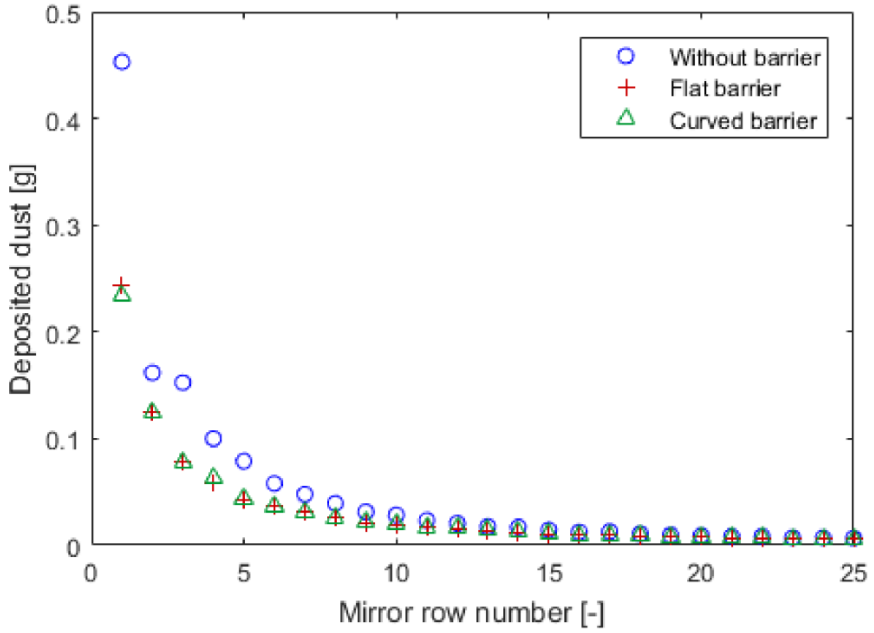
Atmospheric boundary layer 6-10ms^{-1}

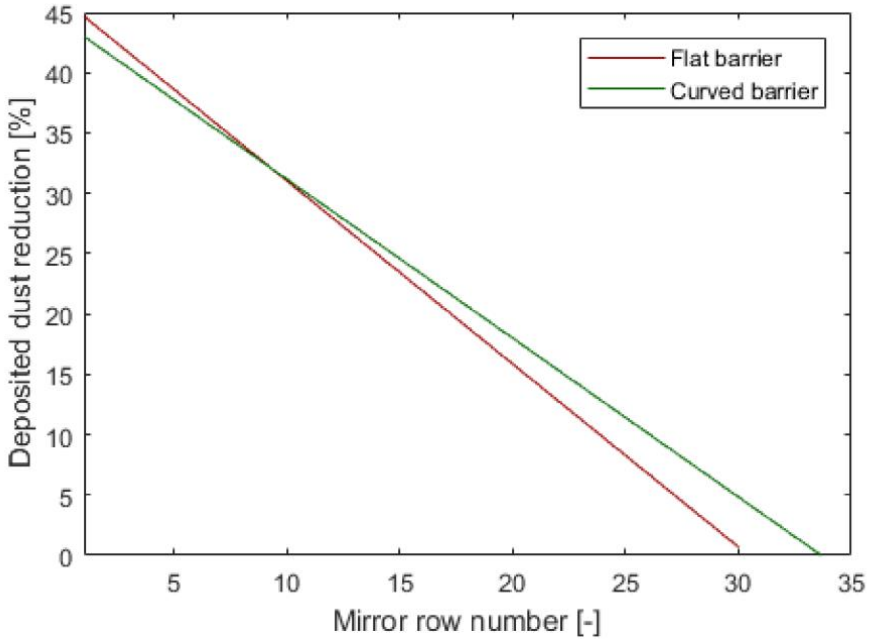
Particles <250um introduced into flow



Full scale simulations

- The majority of the dust falls on the first few rows of mirrors, with little dust falling after row 10.
- Both dust barrier types show similar behaviour though some small differences can be seen, with the flat barrier being more effective in the outer rows and the curved barrier in the inner rows.
- This result shows that there is a significant reduction of 40-45% in the dust deposited on the first mirror row and that an effect can be seen as far as 30-35 rows into the plant.





Full scale simulations

- The results shown so far have been averaged for the different tracking angles.
- Table 1 shows the results of the soiling reduction when considering these different tracking angles.
- As expected, there is more protection when the mirrors are at a low angle pointing towards the barrier, though the difference is small.

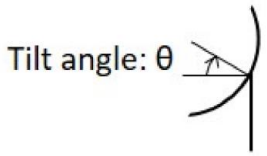
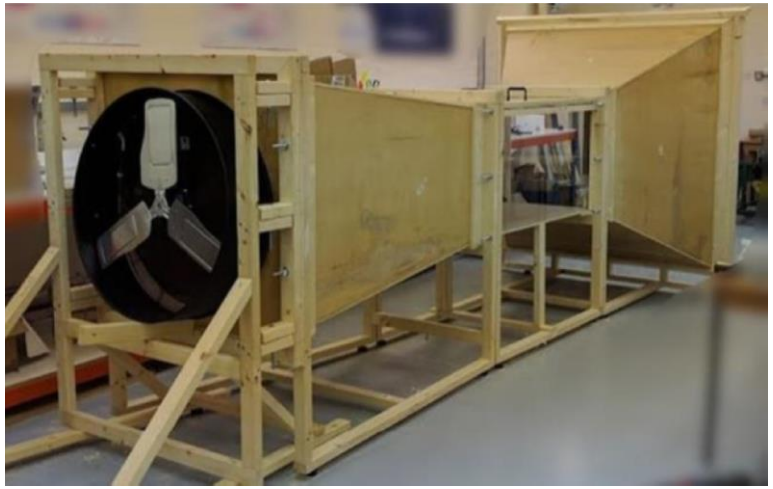


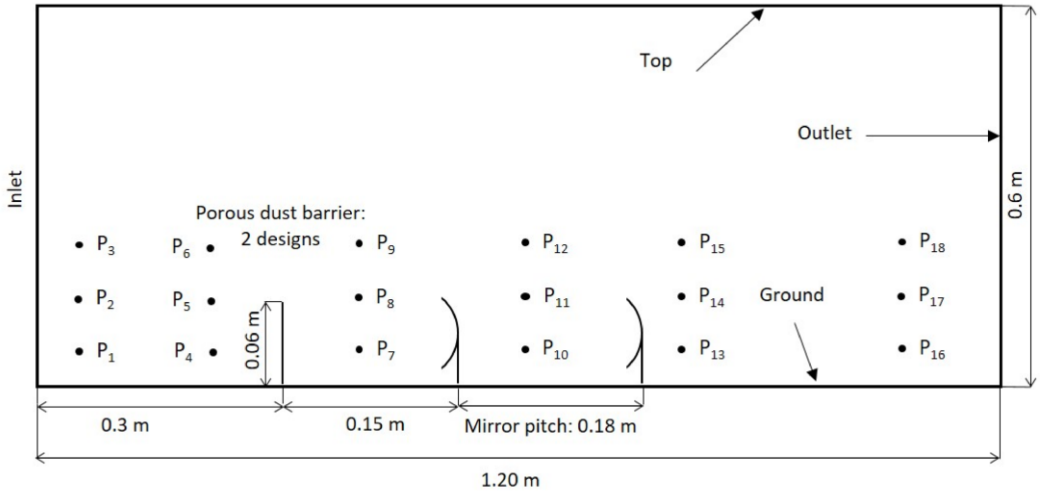
Table 1: Reduction in soiling compared to no barrier

Mirror tilt angle (°)	Flat barrier (%)	Curved barrier (%)
30	40.1	42.2
60	38.9	40.3
90	37.3	35.9
120	36.9	36.8
150	38.9	38.9

Wind tunnel

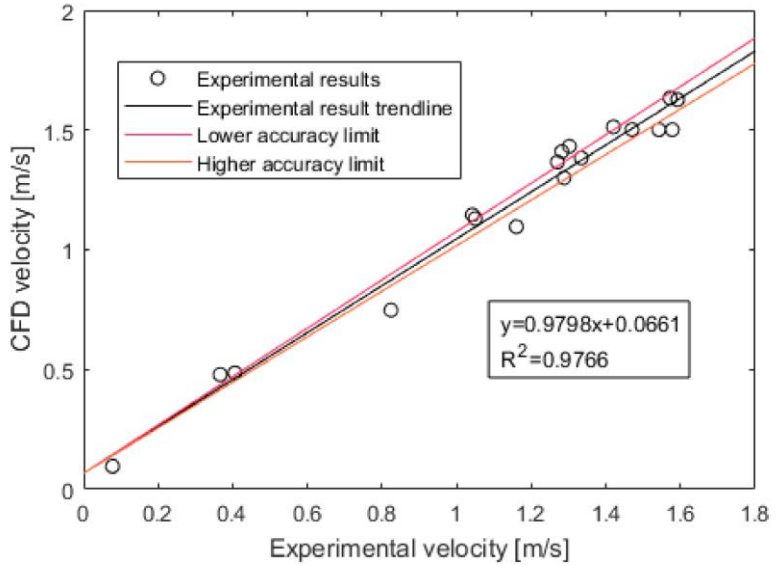
- A CFD model of the Cranfield wind tunnel was created with the same parameters as the dust barrier simulation for validation of the results.
- Wind speed measurements and flow visualisation with smoke were obtained from the wind tunnel, and compared to those obtained through CFD modelling.
- The inlet velocities were varied between 1.5 and 3 ms^{-1} and a hot wire anemometer was used to record the air velocities at the points P1 to P18.
- A smoke generator was also used to visualise the flow to verify that the behaviour was consistent between simulation and experiment.





Results

- Here it was found that the smoke behaves as predicted by the simulations and the plume follows closely with the simulated streamlines.
- The wind tunnel validation was also completed by measuring the points in the wind tunnel previously described.
- There was a strong linear correlation of greater than 95% over the 18 recorded wind speed measurements, validating the CFD simulations.



Conclusions and outlook

- Dust barriers can be an effective tool to reduce the soiling of mirrors in parabolic trough plants.
- CFD simulations have been performed considering two different barrier shapes and multiple mirror row.
- A reduction in soiling of up to 45% was seen for the outermost rows, and the effect of the barriers was seen as far as 25 rows into the plant.
- This reduction in soiling will lead to a reduction in the amount of cleaning that must be performed and so a reduction in the water used in the plant.
- The initial results show there is a small difference in performance between different dust barrier shapes, which requires further analysis.

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