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Impact of solar selective coating ageing on energy cost

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Abstract

In order to overcome the current energy challenges and to find new ways of producing clean energy, the solar sector is focused on improving its performance and defining the adequate technology for each application. Nowadays the concentrated solar power (CSP) technology, which uses parabolic trough collectors, is the most mature and well-established concept. The technology is based on the concentration of solar radiation using parabolic reflective surfaces (typically glass mirrors) and focusing the collected energy on a receiver tube, which is placed on the geometrical focus of the parabola.

Solar selective coatings are applied on the surface of the receiver tube surface to improve its performance in stable conditions, but these nanocoatings suffer stresses during their operating lives, which reduce their optical properties and increase the cost of the produced energy. The development of selective coatings with improved optical properties is essential to the development of CSP technology. It requires improvements in the process of layer deposition, to enhance the characterization of the coating optical properties, and to monitor the coating status during the typical 25 years of operation.

In this study it has been analyzed the impact of the ageing of selective coating in the energy gain and thermal losses and, as a consequence, the necessary evolution of CSP technology to reduce the cost of energy.

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Keywords: Absortance; Emittance; Reflectance; Selective coating; Ageing

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1. Introduction

Coatings for Parabolic Trough technology are applied on the surface of the internal metallic tube. These selective coatings are aimed at achieving a high solar absorptive rate in the visible and near-infrared spectrum (300-2500nm), while a low value of solar emittance to the environment in the IR spectrum (1-30 µm) is maintained. Fig. 1 shows the spectral reflectance of a typical solar selective coating, where the characteristic spectrum of solar radiation in the visible and near-infrared range is also shown, as well as the characteristic blackbody radiation distribution in the IR region for a body at the solar receptor working temperature. According to the relationship of the reflectance with the absortance and the emitance it can be inferred that an ideal solar selective coating should exhibit low reflectance (thus high absorbance) in the region where the solar spectrum contains more energy, and high reflectance (leading to low emittance) in the spectral range of highest blackbody radiation. Both requirements cannot be met simultaneously and a compromise solution must be sought. In the case of a coating for a working temperature of 600ºC both reference curves, the sun radiation AM 1.5 and the blackbody profile, lie closer from one another than in the case of 400ºC, so the interaction between emissivity and absortivity is even stronger.

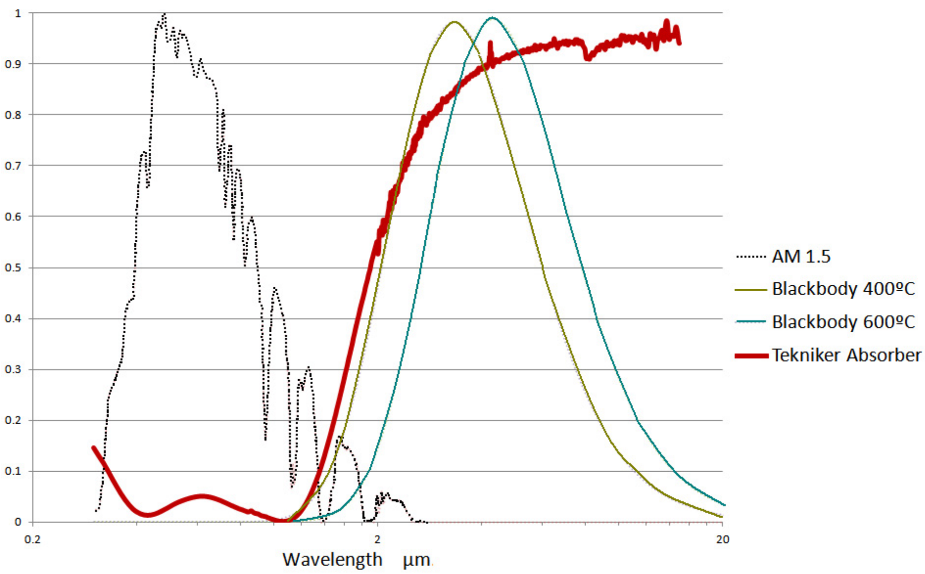

Fig. 1: Spectral reflectance of a typical solar selective coating

The coatings applied on the steel tube surface may suffer a modification of their optical properties because of the effect of working conditions in normal operation during their 25 years lifespan. Although there have been several attempts to develop testing protocols to assess these effects [1], a comprehensive procedure for the wide range of operation conditions has not been developed yet.

The ageing process mainly depends on the effect of temperature shocks, heating-cooling cycles and the presence of gases (such as oxygen and hydrogen) in the vacuum chamber where it is located (usually at pressure levels below 10^{-3} mbar). From an economical point of view, this effect results in a significant increase of the energy cost, as well as an uncertainty in the evolution of the future performance of a conventional solar plant.

2. Solar selective coatings

The stack that defines the selective coating is formed by several individual layers with different properties, providing the final required optical characteristics. The typical configuration of a solar coating is based on the combination of absorber and reflective layers, adding an antireflective layer on top in order to increase the ratio of