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Test Results for Camera-based Measurement of Reflection from a Multi-Cavity Receiver

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Reflection and thermal emission, collectively named radiosity, are inherent to the operation of solar thermal receivers. In experimental conditions including on-sun testing, the total losses are normally obtained by subtracting the enthalpy increment of the working fluid from the total incident energy. These losses include spillage, reflections, thermal emissions and convective losses. Obtaining an accurate breakdown of the losses allows design efforts to be dedicated to mitigating the worst component. Generally, in operating conditions, convective losses are very difficult to measure. Monte Carlo ray tracing, cone optics or view-factor-based simulations allow estimation the optical and thermal radiative losses, but additional data, such as mirror reflectivity, optical errors of the concentrator(s), the receiver surface absorptivity and emissivity, temperature distributions are required. Uncertainties accumulate greatly. For these reasons, a method that directly measuring radiative losses is of great interest.

Camera-based measurements offer a way to directly observe receiver radiosity, which also has advantages over traditional point-sensing radiometric measurements when applied to solar receivers. Cameras are portable and convenient for on-site operations. No additional sensors are required. In addition, spatial flux distributions can be obtained. The PHLUX method (Ho and Khalsa, 2011) was developed for this purpose. However, methods reported in the literature have not been demonstrated for measurements used for cavity or complex-shape receivers, such as the bladed receiver concept (Wang et. al., 2016; Pye et. al., 2018), in which blocking, shading and light trapping effects as non-uniform reflection and emission of radiation are observed. A method that reconstructs the directional and spatial energy loss distributions around complex-shape receivers based on the recorded 2D images was presented in the APSRC 2018 conference (Wang et. al., 2018). The testing results from a bladed receiver under high-flux irradiation (800 kW/m^2) on-sun tests are provided in this work.

Figure 1 demonstrates images with different exposures (shutter speeds) of the bladed receiver under the high flux irradiation. The photo with a high exposure that clearly shows the details of the supporting frame of the receiver is for 3D reconstruction; the photo with a low exposure without saturation on the receiver surface allows extracting of the directional radiosity (radiance).

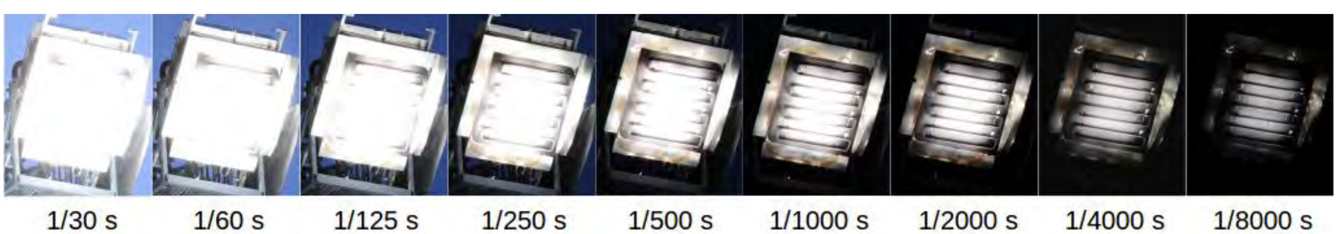
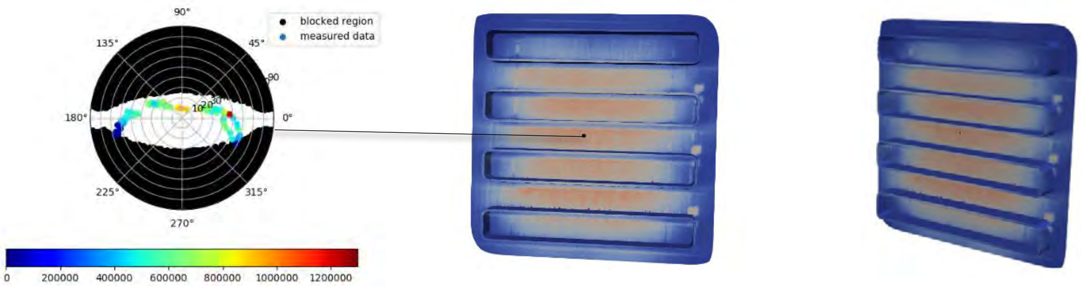


Figure 1. Demonstration of images with different exposures (shutter speeds) of the bladed receiver under high flux irradiation.

The radiance of each mesh element can be obtained by calibrating the pixel value in the unsaturated images with an image of the sun and the measured DNI (Ho and Khalsa, 2011). The directional distribution is obtained by image-derived 3D reconstruction. The spatial distribution over the whole receiver surface can be established by mapping image data to a 3D mesh of the receiver. A hemispherical integration can be performed to establish the radiosity distribution on the receiver surface. Figure 2 shows the integration results in the 3D plot. It should be noted that not all mesh elements can be seen in any given image. Figure 2(a) highlights the directions of the measured radiance of a mesh element marked in Figure 2(b), and all the possible visible domain of this mesh element. The specific procedure and analysis of results will be presented in detail.



(a) (b) (c)

Figure 2. (a) the visible domain and the directions of the measured radiance of the mesh element (the colorbar shows the radiance, W/m^{2}sr); (b) one view of the 3D plot of the hemispherical integrated radiosity, and (c) another view.

References

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