A NEW HIGH-FLUX SOLAR FURNACE AT CIE-UNAM IN TEMIXCO, MEXICO. FIRST STAGE

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Abstract

A new high flux solar furnace facility has been developed in Mexico. It is located in Temixco, Morelos, Mexico and in its first phase of development consists of a heliostat of 36 square meters (6 m by 6 m), a shutter made of stainless steel blades 6.2 m by 6.2 m, and a multifaceted concentrator of 211 spherical mirrors with an equivalent focal length of 3.64 m. In order to set the HFSF in operation, all the mirrors were aligned, the control system was developed and tested, the heliostat was aligned and its tracking movement tested. The purpose of this paper is to present the new facility and its first results in the evaluation of its capacities. The results show that the optical error is less to 3 mrad and the calculations indicates that the average flux could be higher than 5,000 suns and the facility can reach temperatures as high as 3406 ^{o}C.

Keywords: Solar furnace, high solar flux, solar concentration, solar chemistry.

1. Introduction

In the framework of the National Laboratory of Solar Concentrating Systems and Solar Chemistry in Mexico, three research facilities were built: a solar furnace of high radiative flux (HFSF) [1], an experimental photocatalytic water treatment plant and a heliostat test field [2]. In particular, the HFSF is located at the Center for Energy Research of UNAM (18°52′30″N, 99°12′59″W), in the City of Temixco, State of Morelos, 65 Km south from Mexico City, see figure 1. The purpose of the HFSF is to serve as an experimental installation for the research and development of solar concentration technology at very high fluxes and temperatures, in particular, the development of receivers/reactors for the production of solar fuels and the study of physical properties of materials at high temperatures and high solar fluxes. The optical design of the concentrator of the HFSF was carried out through ray tracing simulations [1]. The design considers an intercepted power of approximate 30

Fig. 1. Left: Picture of the HRFSF showing heliostat, shutter and concentrator. Right: picture of the concentrator with its 211 facets.

kW, with a target peak concentration of approximately 10,000 Suns. A global standard deviation of the optical errors less or equal to 4 mrad was choosed in order to reach such a goal. The optical design of the whole HFSF consists of a heliostat of 81 m^2 (9 m by 9 m), a shutter and a multifaceted concentrator of 409 spherical mirrors. The first stage of this installation was finished and started up in December 2011. Currently, the solar furnace has a heliostat of 36 square meters (6 m by 6 m), a shutter made of stainless steel blades 6.2 m by 6.2 m, and a concentrator of 199 spherical mirrors with hexagonal contour mounted on a spherical frame and an equivalent focal length of 3.68 m, see figure 1. In order to set the HFSF in operation, all the mirrors were aligned [3], the control system was developed and tested, the heliostat was aligned and its tracking movement tested [4]. This installation was official inaugurated on March 18th of 2011. The purpose of this paper is to present the new facility and its first results in the evaluation of its capacities.

2. Implemented Tests

The operation of the HRFSF has been initiated with the implementation of two tests: the acquisition of images on a Lambertian target and the melting of metals. The schematic arrangement of the experimental setup for the tests is shown in figure 2.

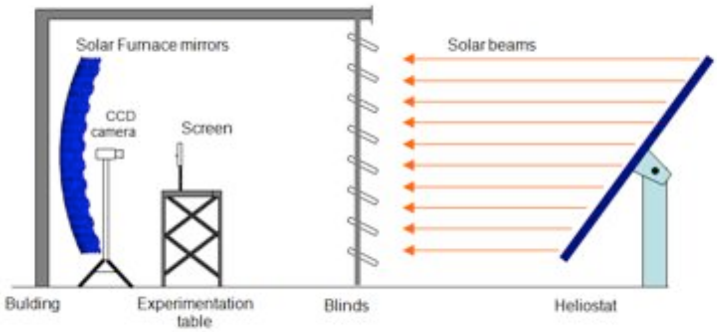

Fig. 2. Schematic arrangement of the experimental setup.

2.1 Test of images acquisition

In taking images on a Lambertian target, a flat plate of 40 cm on diameter with refrigeration on the back was built [6] and set up as shown in figure 3. The refrigeration system allows the device not damage the Lambertian target. A CCD camera was also install that allows taking pictures of the target.

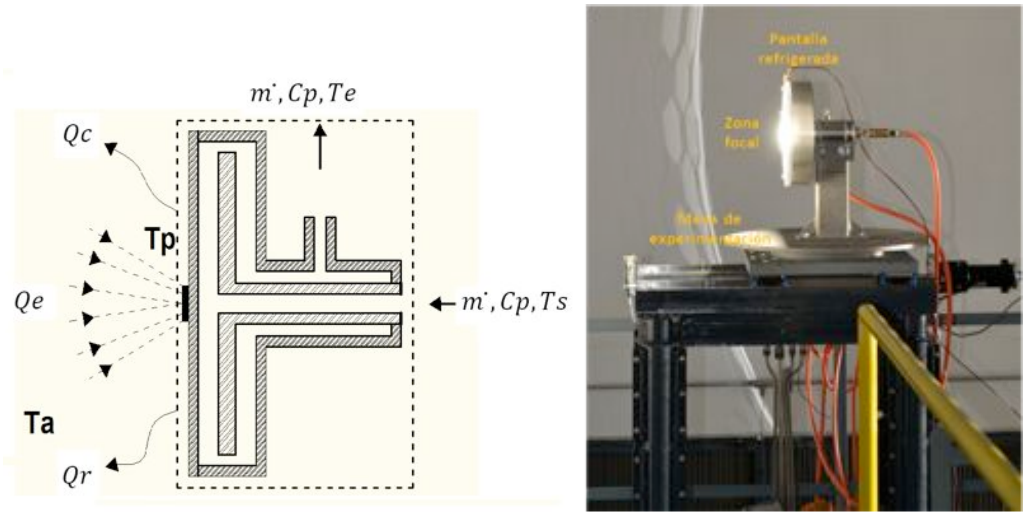

Fig. 3. Left: Cross section of the cooled flat plate target showing the energy balance. Right: Experimental set up with the cooled flat plate target at the focal zone of the HFSF.

An experimental campaign was conducted in order to take images of the concentrated sun light formed at the focal zone of the HFSF. Images like the one shown in figure 4 were obteined. With these images and a ray-trace analysis is posible to determine the optical error of the HFSF. A full discusion on this is presented in [5]. The results obteined show that the global optical error is lower to 3 mrad. The results suggest that the optical error could be improved in new experimental campaign with the complete groups of mirrors and the new heliostat of 81 m^2. With these results we can anticipate a flux peak higher than 12,000 suns and average irradiance at receiver above 5000 suns.

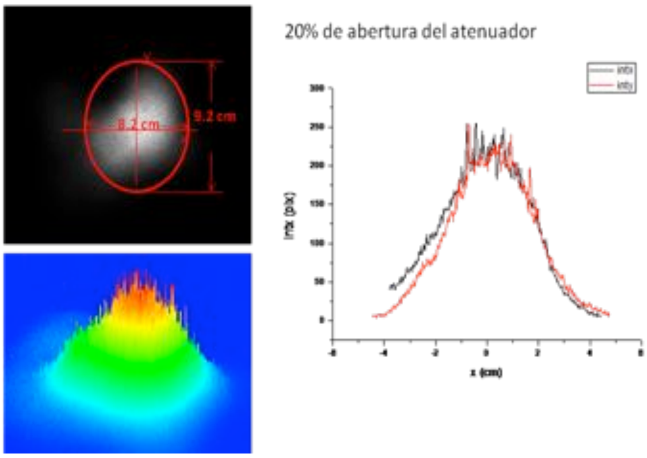

Fig. 4. Image taken with the CCD camera and the flux distribution profiles.

2.2 Tests of metals melting

Two tests of metals melting were conducted; one with a carbon steel plate and another with a set of tungsten rods.

A) A carbon steel plate of 19 mm (¾ inches) thickness was set up at the focal zone of the concentrator; a thermocouple type K was installed on the back and the solar radiation was allowed to hit the surface. The direct irradiance measured was de 865 W/m^2. The plate was perforated in 526 sec. The temperature meting point of the carbon steel is 1406 ºC. Figure 5 shows the melting process and the melted plate.

Fig. 5. Left: experimental set up of the carbon steel plate for the melting test. Right: picture of the melted plate.

B) A set of 40 tungsten rods 25 cm long and 4 mm in diameter were set up in a horizontal way supported by a stainless steel frame as shown in figure 6. The tungsten rods set was set up at the focal zone of the concentrator; the solar radiation was allowed to hit the surface. The direct irradiance measured was de 800 W/m^2. The tungsten rods set was perforated in 13 minutes. The temperature meting point of the tungsten is 3406 ºC. Figure 6 shows the tungsten rods melted with the formation of tungsten dioxide and tungsten trioxide (yellow dust).

Fig. 6. Left: experimental set up of the tungsten rods set. Right: picture of the melted rods.

3. Conclusions

A new high flux solar furnace facility was presented. The first test shows the capability of the facility to take maps of concentrated solar radiation at the focal zone. The results obteined show that the global optical error is lower to 3 mrad and the flux peak can be higher than 12,000 suns. The second tests show the ability of the HRFSF of reaching very high temperatures: 3406 ºC or more.

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References

[1] D. Riveros-Rosas, J. Herrera-Vázquez, C. A. Pérez-Rábago, C. A. Arancibia-Bulnes, S. Vázquez-Montiel, M. Sánchez-González, F. Granados-Agustín, O. A. Jaramillo, C. A. Estrada. Optical design of a high radiative flux solar furnace for Mexico. Solar Energy, 84 (2010) 792–800.

[2] C.A. Arancibia-Bulnes, M.I. Peña-Cruz1, D. Marroquín-García, R,E. Cabanillas, C.A. Pérez-Rábago, D. Riveros-Rosas, F. Hinojosa, C.A. Estrada. HELIOSTAT TESTING AT A NEW FACILITY IN SONORA, MEXICO. Proceedings of the SolarPACES 2011 Congress, 20-23 September, Granada, Spain.

[3] S. Vazquez-Montiel, C. A. Perez-Rabago, R. Pérez-Enciso, D. Riveros-Rosas, F. Granados-Agustin, C. A. Arancibia-Bulnes, C. A. Estrada. METHOD FOR FACETS' ALIGNMENT FOR THE HIGH-FLUX SOLAR FURNACE AT CIE-UNAM IN TEMIXCO, MEXICO. FIRST STAGE. Proceedings of the SolarPACES 2011 Congress, 20-23 September, Granada, Spain.

[4] C.A. Pérez-Rábago, R. Guzmán-Galán, N. Flores-Guzmán, E. Brito, D. Marroqui-García, R. Pérez-Enciso, C.A. Arancibia-Bulnes, D. Riveros-Rosas, C.A. Estrada. CONTROL SYSTEM FOR THE HIGH-FLUX SOLAR FURNACE OF CIE-UNAM IN TEMIXCO, MEXICO. FIRST STAGE. Proceedings of the SolarPACES 2011 Congress, 20-23 September, Granada, Spain.

[5] D. Riveros-Rosas, C.A. Perez-Rabago, C.A. Arancibia-Bulnes, R. Perez-Enciso, C.A. Estrada. CONCENTRATION IMAGE PROFILES OF THE HIGH-FLUX SOLAR FURNACE OF CIE-UNAM IN

TEMIXCO, MEXICO. FIRST STAGE. Proceedings of the SolarPACES 2011 Congress, 20-23 September, Granada, Spain.

[6] Estrada, C.A., Jaramillo, O.A., Acosta, R., Arancibia-Bulnes, C.A., 2007. Heat transfer analysis in a calorimeter for concentrated solar radiation measurements. Solar Energy 81, 1306–1313.