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Technical note

Estimation of design parameters for thermal performance evaluation of box-type solar cooker

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Abstract

The paper presents a simple test procedure for determination of design parameters to predict the thermal performance of a box-type solar cooker. A series of out-door experiments were performed on the double-glazed solar cooker of aperture area 0.245 m^2 with a fibre body to obtain two figures of merit, F_1 and F_2. The necessary design parameters—optical efficiency, $F'\eta_o$ and heat capacity, $(MC)'$ of the cooker are calculated using the linear regression analysis of experimental F_2 data for different load of water. Based on the experimental results, a correlation for F_2 as a function of quantity of water (load) is proposed. The close agreement between experimental and calculated F_2 indicates the validity of the correlation. The proposed procedure is then applied to predict the heating characteristic curves of the solar cooker for different load of water. The predicted heating characteristic curves are validated by comparing with the experimental data from a series of cooker testing experiments. The results of present study reveal that $F'\eta_o$ and $(MC)'$ are the critical design parameters required for the prediction of thermal performance of the solar cooker.

Keywords: Box-type solar cooker; F_2 tests; Optical efficiency; Heat capacity; Heating characteristic curves

1. Introduction

There has been a considerable recent interest in the design, development and testing of various types of solar cookers like box type [1–3], concentrator type [4,5] and oven type

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[6,7] around the globe. Out of these types of solar cookers, only the box type solar cookers have so far been disseminated at the mass level in India [8,9]. In the box type solar cooker, which is the simplest in terms of operation and fabrication, the temperature of around 100 °C is achieved. This range of temperature is suitable for cooking by boiling, which is prevalent in the most parts of India. However, in spite of having these desired features, such cooker may either fail to cook or take a longer time to cook full load of food. The design parameters of solar cooker are among the several other important parameters that influence its thermal performance. Therefore, the knowledge of these design parameters is essential for evaluation and comparison of different cooker designs, in addition to providing a basis for the selection of proper materials for the construction of cooker. The present work is focused on the determination of important design parameters-optical efficiency and heat capacity of the solar cooker.

The optical efficiency of any solar collector depends on several factors that include angle of incidence of solar radiation, the number of covers (glazings), material for covers, coating of cooker absorber plate, etc. The literature review reveals that a lot of work has been done to determine the optical efficiency of the flat plate/tubular solar collectors and concentrator solar cookers. In case of flat plate/tubular solar collector, it can approximately be calculated by considering multiple reflections between cover system and absorber plate [10]. Moreover, several standard test procedures based on instantaneous efficiency equation are available to determine the optical efficiency of a solar collector [11,12]. Gogna et al. [13] reported a relatively simple test procedure based on zero thermal loss from the solar collector at the steady-state condition. It involves the measurement of stagnation temperature that the absorber approaches when no heat is extracted from the collector. Mullick et al. [4] developed the thermal test procedure to determine the optical efficiency for a paraboloid concentrator solar cooker. Kumar et al. [14] compared the three experimental test procedures for determination of optical efficiency of concentrator solar cooker. Mullick et al. [15] proposed the thermal test procedure for evaluation of double-glazed box type solar cooker. In the test procedure, the need to obtain high ratio of optical efficiency to overall heat loss coefficient, as a figure of merit of the solar cooker, was emphasized. However, the procedure did not quantify these design parameters separately. The other design parameter, namely the heat capacity of cooker may be estimated by knowing the types of materials used, their dimensions and physical properties. Since the reliable and accurate data for these materials are not always available, the use of these values may lead to erroneous results.

In order to analyze the thermal performance of a box-type solar cooker in a better qualitative manner, it is therefore necessary to have the knowledge of design parameters-optical efficiency and heat capacity of the cooker. To date, to the best of author's knowledge, there is no experimental published work carried out on the determination of these parameters. Therefore, the objectives of this work are: (a) to propose a simple test procedure to determine these parameters using the experimentally obtained F_2 data for different load of water; (b) to apply the proposed procedure to predict the heating characteristic curves; and (c) to validate the proposed methodology by comparing the predicted values with those obtained experimentally.