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An evaluation and model of the Chinese Kang system to improve indoor thermal comfort in northeast rural China – Part-2: Result analysis

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ABSTRACT

The part-2 provides the calibration and validation of the model backbone against the field experimental data. The paper evaluates the simulation results from a myriad of scenarios on their technical ability to increase domestic comfort. Additionally, input from local communities was used to assess rural residents' heating needs and their acceptability of possible solutions. An economic analysis was further used to evaluate the long term feasibility of possible optimized improvements. It was determined that the addition of a room radiator system, consisting of a heat exchanger, water tank, thermostat controls and a panel radiator, delivered the most economical solution in regards to the increasing the resident's comfort per dollar invested.

1. Base model calibrations and validations

To determine the accuracy of the modeling techniques discussed in the part-1 paper, the calculated values must be compared to measured data. A set of temperature measurements for the smoke, Kang, room air and outdoor air were conducted for several days (11/23/2008, 11/24/2008, 12/2/2008, and 2/19/2009) for a representative stove-Kang system in a traditional house in northeast rural China [1]. Since the data sets for the study day 2/19/2009 were the most comprehensive, this day was used to initially calibrate the model and the calibrated model was then used to predict the other three experimental days as the validation. The primary variables that were adjusted during the calibration are listed in Table 1. The comparisons of the predicted and measured temperatures for room air and Kang surface for 2/19/2009 (the calibration day when the model variables can be adjusted) and 11/24/2008 (the validation day when the model variables are fixed) are presented in Figs. 1 and 2, respectively. Discrepancies between the measured and modeled data sets are present for each study day. For example, the room temperature during the morning of February 19th remains too low during the firing period and for several hours after; on the day of November 24th the predicted Kang temperature during the first firing is too low. Despite the discrepancies between study days, the model is able to match the overall trends of the measured data.

2. Base model sensitivity analysis

It is important to understand which variables most greatly affect the model's output so the most sensitive inputs can be more accurately assessed. A sensitivity analysis was performed to ascertain which variables have the greatest influence over the models behavior. Each variable in Table 1 was altered with respective variables 20% less than the base case values and the resulting room and Kang temperatures were compared to the room and Kang temperatures of the calibrated model. Table 2 displays the associated changes in the Kang and air temperature profiles due to the change in value of the listed variables.

It is clear that the model is most sensitive to changes in the building load coefficient (BLC) and air change rate per hour (ACH). The BLC was obtained from the field measurement for this study, while the ACH was estimated based on the observation of room conditions and outdoor wind speeds. In practical applications, it is strongly encouraged to perform a blower door test to acquire an accurate ACH value that may vary significantly from house to house. Weber [2] proposed a method to calculate the amount of

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Table 1
Calibrated model variables.

Variable	Calibrated Value
$h_{Kang\ Chamber}$ (W/m^{2}K): overall heat transfer coefficient between smoke and Kang interior surface	24
$h_{Kang\ Surface}$ (W/m^{2}K): overall heat transfer coefficient between room air and Kang exterior surface	16
Additional Thermal Mass (J/K): lump-sum thermal mass to account for building envelope thermal mass influence	2,500,000
Air Change Rate per Hour (ACH): for room infiltration	0.9
BLC Interior (W/K): building load coefficient for envelopes exposed to adjacent rooms	75
BLC Exterior (W/K): building load coefficient for envelopes exposed to the outdoor	18.5

infiltration loss based on climatic data. While the method is generally too complex for the simplified model, it could be implemented if higher accuracy of the infiltration loss is desired.

3. Comparison and analysis of different improvement scenarios

A set of possible scenarios with different improvements were tested using the validated simulation program, as summarized in Table 3. Since the primary goal of the model optimization is to increase the comfort of the inhabitants inside their domicile, the room air temperature and the Kang surface temperature are the two crucial indices for performance comparison. Therefore it is important to assess the change in temperature of both the indoor air and surface of the Kang. Using the model output that is created with the default values as a base case scenario, the percentage change in air temperature and Kang temperature can be used to evaluate the effectiveness of each improvement. Three consecutive days were modeled but only the third day was compared as prior to this period the model has not achieved dynamic equilibrium. Table 3 presents the summary of performance improvement percentage for both room air and Kang surface temperatures.

There are several general observations from the resulting data. The radiator and heat exchanger system can provide added comfort

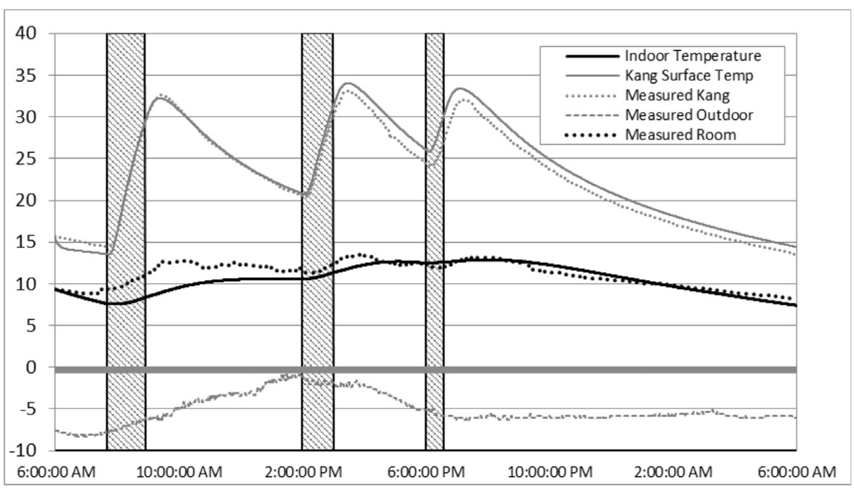

Fig. 1. Predicted and measured temperature profile on 2/19/2009.

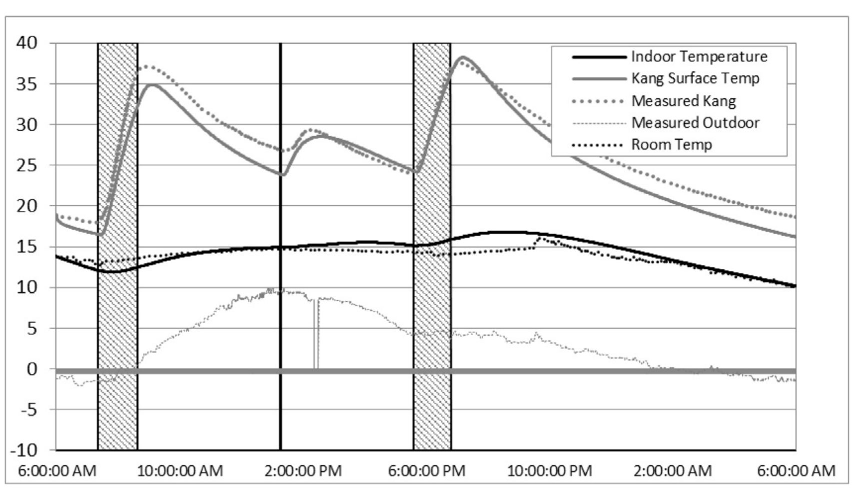

Fig. 2. Predicted and measured temperature profile on 11/24/2008.