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Heat transfer coefficient of window using Monte Carlo methods (Latin Hypercube Sampling)

1. ABSTRACT

Using each type of analysis depends on our intention, exactly on what we want to explore. Monte Carlo (MCA) method can be applied to the sensitivity analysis (SA) and the uncertainty analysis (UA), which is based on a random selection of a random variable generated by all the input parameters *X*. This paper discusses the realistic model of a window focused on uncertainties of the input and a sensitivity analysis of the output parameter - window heat transfer coefficient. A case study is described to evaluate a necessity of the use of uncertainty and sensitivity analysis.

2. INTRODUCTION

The input data needed in the building thermal performance calculation methods can be divided into three groups: climatic data, envelope data and building use data. Probability density functions of these data were assigned after a detailed bibliographic research. The Monte Carlo Latin Hypercube Sampling (MC-LHS) technique has been used to assess the building energy needs confidence interval and the energy performance class uncertainty. A sensitivity analysis based on the Morris method, has also been performed for the different building heat balance terms, in order to identify the most important parameter set that takes into account for the uncertainty in the model output (Corrado 2009). The above mentioned approach was applied for a case of the calculation of window heat transfer coefficient considering the uncertainty of window parameters.

3. SENSITIVITY AND UNCERTAINTY ANALYSIS TYPES

There is a wide range of sensitivity and uncertainty analysis methods. The use of particular type depends on our plan - what we want exactly to explore. MCA method can be applied to the SA and UA. The MCA is based on a random selection of a random variable generated by all of the input parameters *X*. We can get the value of a random phenomenon by using of all the random variables *X* calculated as computational mathematical model. There is selected just one set of random variables from all of the input parameters in each step of the simulation. One of the other methods based on variation of the variables is called Morris method and it is used only for the evaluation of SA. It works on the following principle: there is only random variable of selection in a calculation chosen and the other input parameters remain constant and after it the calculation is carried out and the change of *Y* is evaluated which continues until the last parameter (Campolongo, 1997; Saltelli 1997).

4. ANALYSIS METHODOLOGY

DESCRIPTION OF THE STOCHASTIC MODEL:

Stochastic model describes a system that takes into account both random and scheduled events. We assume the basic computing core of the modeled physical processes in the energy calculations in the form: $Y=F(X_i)$ (1)

Where:

F - the deterministic computational model

X_i – the input parameter of random variables

In the case where the computational model describes the physical phenomenon of the outcome variable *Y* is provided by experimental measurements.

APPROACHES TO THE UNCERTAINTY AND SENSITIVITY ANALYSES:

Methods of MC-LHS and Morris are considered to be the most suitable methods for our application.

MC-Latin Hypercube Sampling: the Monte Carlo analysis is based on repeated simulation; the outputs of interest are evaluated for each sample element x_{ij} of the sample matrix M_{nk}, where n is the input factor number and k is the sample size. Output vector $Y = [y_i]$ is then generated:

$y_i = f(x_{i1}, x_{i2}, \ldots x_{in})$ (2)

The Latin Hypercube Sampling achieves a better coverage of the sample space of the input factors. The sample space S of an input factor X_i is partitioned into h disjoint intervals $S \ldots S_h$ of equal probability $1/h$. One random input value is then selected from each interval S_i and the process is repeated k times, where k is the sample length (see Fig. 1).

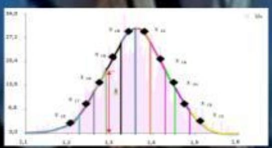

Fig.1 Illustration of the LHS method results

Morris method: The aim of the Morris method is to determine which factors can be considered to have effects, which are negligible, linear and additive, or non-linear or interactions effects. The Morris method is based on the so-called "elementary effect" of an input parameter X_i.

- Set up of the p-level grid
- Sample generation
- Finite distribution F_i

5. SETUP

This case study of a window was performed by 60 and 1000 simulations. There were six input parameters used at total: frame length, length of glazing in the *x*, length of glass in the *y*, heat transfer coefficient of glazing, heat transfer coefficient of frame, linear thermal transmittance. This includes the definition of input data and uncertainties, the random sampling (using Monte Carlo simulation), software [2]SimLab 2.2, thermal modeling (ISO 13790:2008) and the post processing analysis ([2]SimLab 2.2) (Corrado 2009). To generate the sample matrix method the MC-LHS was used.

The LHS sampling is a particular case of stratified sampling which is meant to achieve a better coverage of the sample space of the selected input parameters. There are several different techniques in SimLab available for sensitivity analysis. The chosen one for demonstrating the results is the standard regresian coefficient (SRC). The SRC provides a measure of the linear relation between any given input X and the output, cleaned of any effect due to correlation between X and any other input (Saltelli et al., 2005).

6. CASE STUDY

A case study has been analysed in order to establish the influence of input parameter uncertainties on building energy performance. The aim of this example is to find an input parameter of equation (6) which most influences the resulting heat transfer coefficient U_w of a window.

We consider the following values for the example shown in Fig. 2:

Parameter	Value
U_f Heat transfer coefficient of frame	1.1 $W/(m^2.K)$
U_g Heat transfer coefficient of glazing	1.3 $W/(m^2.K)$
A_f Area of the frame	0.465024 m^2
A_g Area of glazing	0,734976 m^2
Linear thermal transmittance	0.08 $W/(m.K)$
l_g Length of glazing perimeter in the frame	4.6 m

After the input into the form (6) is U_w values for these 6 input parameters following: U_w = 1,484 $W/(m^2.K)$

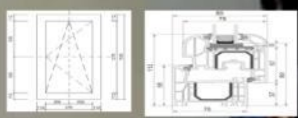

Fig. 2 Technical parameters a) scheme (plastic) window 800x1500 (mm) b) frame and wing profile

7. RESULTS OF UNCERTAINTY ANALYSIS (UA) AND SENSITIVITY ANALYSIS (SA)

Fig. 3 Density of U_w result probability, a) Probability of distribution function for 60 simulations b) Cumulative distribution function, c) Function of output distribution for 1000 simulations

Fig. 4 Graphical interpretation of SRC sensitivity coefficients

8. MORRIS METHOD

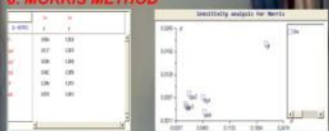

Fig. 5 Morris sensitivity of the 6 input factors

9. CONCLUSIONS

By the calculation of the heat transfer coefficient through window using the MCA (LHS) has been found that the sensitivity analysis leads to following: The sensitivity analysis shows us that the frame heat transfer coefficient is the strongest parameter that affects our value. A negative sign of the other parameters means that when we increase the parameter, value decreases. Identical analysis as it is in the Figure 5 which was secured by the values (μ) and (σ): total length of the frame, length of glass in the direction of the x- axis, length of glass in the direction of the y- axis, heat transfer coefficient of glass, heat transfer coefficient of the frame, linear thermal transmittance. However from all of these factors have the biggest influence the frame heat transfer coefficient .

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