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Monte Carlo method for calculating local configuration factor for the practical case in material processing☆

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ABSTRACT

The application of Monte Carlo method is discussed to determine configuration factor for the plate including strip elements to two parallel circular cylinders as a case in heating and cooling processes in material processing (e.g. transfer table in hot rolling process). The results show the relationships between different discretization schemes, number of rays used for the configuration factor calculation, and accuracy. Whereas the analytical solutions are not available for this case, Monte Carlo method with 30 and 45 element discretized figures for (100^4) and (120^4) rays per element is investigated. The results, obtained from Monte Carlo solution, indicate that smaller elements require more effort to obtain an accurate configuration factor. Additionally, it must be noted that for high accuracy results an increase in the number of rays per element requires the processing time to grow rapidly. By using the configuration factor modeling, the radiative heat transfer can be calculated in various cases for any kinds of heating and cooling processes.

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1. Introduction

Heat radiation plays a role in energy transfers at high temperatures. Even at low temperatures, heat radiation is important and it is well known that when the natural convection in air is involved, the heat transfer by convection and radiation are usually of the same order of quantity. Thus, configuration factors are essential for the evaluation of radiative heat transfer.

For simple geometrical arrays of surfaces, many factors have been presented in the literature Howell [2]. However, when the arrangement of surfaces and shapes are arbitrary, it is in many cases unavoidable to compute the configuration factors for the particular geometry and arrangement of surfaces at hand. For such cases, approximate techniques using numerical algorithms and computers must be used [1].

Monte Carlo (MC) method is a class of numerical techniques based on the statistical characteristics of physical processes, or of analogous models that imitate physical processes.

With this method, approximate solutions can be applied to a variety of mathematical problems by performing statistical sampling experiments on a computer. The method has been widely used in various other fields, ranging from economics to nuclear physics and even configuration of wind turbines in a wind farm. From the analysis of previous works, it is evident that Monte Carlo offers a beneficial method for finding the values of configuration factors as it is able to incorporate all important effects in a radiative transfer simulation without approximation [2].

The Monte Carlo method also has some drawbacks. One is the immense requirement for computer time; the other is the statistical fluctuation of the results. The method can easily simulate problems of great complexity and for the majority of problems where overall knowledge of the radiation field is desired, the method is reasonably efficient. However, if only the radiative intensity hitting a small spot and/or over a small range of solid angles is required, the method can become terribly inefficient [3]. Maltby and Burns [4] investigated performance, accuracy and convergence in a three dimensional Monte Carlo radiative heat transfer simulation with a code including capabilities mixed specular and diffuse reflection models, banded spectral material properties, transmission through external surfaces, and simulation of beam radiation.

A new numerical method for calculating the configuration factors for an axially symmetrical geometry has been developed by Miyahara and Kobayashi [5]. It was compared with the area integration and Monte Carlo methods for concentric coaxial cylinders, and was seen to be 19 times and 3 times faster than them, respectively.

A two dimensional Monte Carlo method by Qualey et al. [6] was applied to a classic radiant energy exchange problem that models the interior of an industrial furnace. The configuration involved a source as an infinite radiating plan and the heat sink as parallel rows of infinitely long tubes.

Monte Carlo simulation of radiation heat transfer in a three dimensional enclosure containing a horizontal circular cylinder was investigated by Hong and Welty [7]. A fast Monte Carlo scheme was

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