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View factor calculation using the Monte Carlo method for a 3D strip element to circular cylinder☆

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ABSTRACT

The discussion includes the application of the Monte Carlo method to determine view factor for the plate including strip elements to circular cylinder as a case in heating and cooling processes in material processing. The results involving the relationships between different discretization schemes, number of rays used for the view factor calculation, CPU time and accuracy are presented. The analysis also displays the differences between the numerical results obtained and analytical solutions for the 20, 30 and 45 element discretized figures and for (30^4), (50^4) and (70^4) rays per element. The results obtained from the Monte Carlo solution indicate that smaller elements require more effort to obtain an accurate view factor.

1. Introduction

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

For simple geometrical arrays of surfaces, many factors have been presented in the literature [2]. However, when the arrangement of surfaces and shapes is arbitrary, it is in many cases unavoidable to compute the view 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].

The Monte Carlo method is a class of numerical techniques based on the statistical characteristics of physical processes, or of analogous models that imitate physical processes. The method was developed by early workers trying to analyze the potential behavior of nuclear weapons, where experiments were difficult and the methods of analysis available at that time were not sufficient to provide accurate prediction of behavior. Directly simulating the behavior of individual neutrons and then following the history of many such neutrons allowed prediction of the average behavior of the weapon. Metropolis and Ulam (1949) provide an early clarification of the philosophy behind the approach [2].

Monte Carlo (MC) method based on random numbers and probability statistics is a kind of stochastic technique. 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 to regulation of traffic flow.

From the analysis of previous works, it is evident that Monte Carlo offers a beneficial method for finding the values of view factors as it is able to incorporate all important effects in a radiative transfer simulation without approximation [2].

MC method also has some drawbacks. One is the immense requirement for computer time; the other is the statistical fluctuation of the results. Since the results fluctuate around their true values, it may be very difficult to solve the combined-mode problems, especially when statistical error of the solution is greater than the convergence criteria for the heat transfer equation. Meantime, with the rapid development of computer technology, the first weakness mentioned above has been less concerned and the main error influencing the accuracy resulted from calculation of pseudo random numbers [3].

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 [4]. Maltby and Burns [5] investigated on performance, accuracy and convergence in a three dimensional Monte Carlo radiative heat transfer simulation with a code that included 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 view factors for an axially symmetrical geometry was developed by Miyahara and

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