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Notes

New configuration factor between a circle, a sphere and a differential area at random positions

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ABSTRACT

In this Note, a configuration factor between a circle and the three coordinate directions is presented. This new factor brings considerable independence and versatility to radiative transfer analysis as it allows determining the radiative energy for points lying on a plane at an arbitrary position. By virtue of the radiation vector theory, the calculation is performed whether the angles that the plane forms with the coordinate directions are known. If the said plane cuts the disk in two halves a new factor is also presented for the radiant interchange between a half disk and a differential element. Besides, by extension of the case of the circle, the view factor between a sphere and a differential element in a random position is deducted.

1. Introduction

Configuration factors that involve circular emitters and differential elements, irrespective of their relative positions in space, have posed a remarkable issue for both designers and scientists. Exact expressions derived from double integration were not accessible, and likewise it happened to those referring to a differential element in a reference system that does not coincide with the one of the emitting disk.

These configuration factors recall an interesting question about the radiative performance of circular emitters, fragments of them, like semicircles, and related volumes such as the sphere, as well as its interaction with surfaces randomly placed with respect to the source. Any figure that radiates in a three-dimensional fashion can be decomposed into circular or even spherical finite elements, and such finding will allow for unexpected possibilities of reliable and fast radiative transfer simulations. The authors have so far experimented with this possibility.

Radiative properties for the said emitters have been understood partially, mainly because available solutions for the configuration factor between an emitting disk and a differential element were limited to rather particular positions, where the element was aligned in some plane or axis with respect to the source.

We can quote in this sense, available expressions by Naragi and Chung [1,2], which give the configuration factor between an emitting disk and a differential element rotated an arbitrary angle Θ but only when the element lies on the x–z plane and is aligned with respect to the centre of the emitting circle.

In a similar fashion, Hollands [3] proposes the configuration factor between an emitting circle and a differential area, rotated an arbitrary angle to a disk bisected by the y–z plane, only when the plane that contains the element does not intersect the disk.

For any portion of the circle some approximations were made by Chung and Sumitra [9], Sparrow [10] and Minning [11]. However, the particular case of the semicircle was not properly approached.

Eventually, regarding the three dimensional extension of the circular emitter, that is, the sphere, Naraghi [12] proposed an expression for plane elements to spheres, but

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they were limited to a single plane, parallel or perpendicular to the emitter.

Complete references about the existing factors, with detailed explanation and graphical references for all the proposed expressions can be found in [4].

In this note, an approach to these unanswered questions is made by virtue of both the configuration factor and the radiance vector theory. This notion apparently originated with Mehmke in 1898, and since then Fock [13], Yamauchi [14–16], Moon [17,18] and others [6] have employed the concept of radiance vector, with several advantages, those ones referring to the calculation of view factors for inclined surfaces being the most remarkable. Thanks to them, we are provided with simpler expressions for our configuration factors, using elemental vector theory.

2. Configuration factor between a circle and a differential element, placed in a parallel and perpendicular position

According to previous researches by the authors [5–7], the configuration factor between an emitting circle and a differential element located in a perpendicular or parallel plane for the three directions of space has been deducted via analytical exact expressions, obtaining comparable results to former authors [8] when available. Thus, their three values for coordinate axes are, according to Figs. 1–3:

$$F_{d1-y}=\frac{1}{2}\left(1-\frac{x^2+y^2+z^2-r^2}{\sqrt{(r^2+y^2+z^2)^2-4r^2(x^2+z^2)}}\right) \quad (1)$$

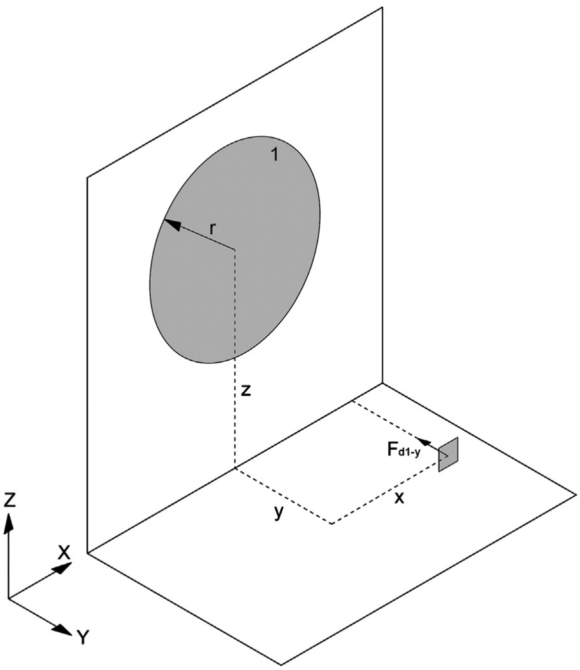

Fig. 1. Calculations parameters for F_{1d-y}.

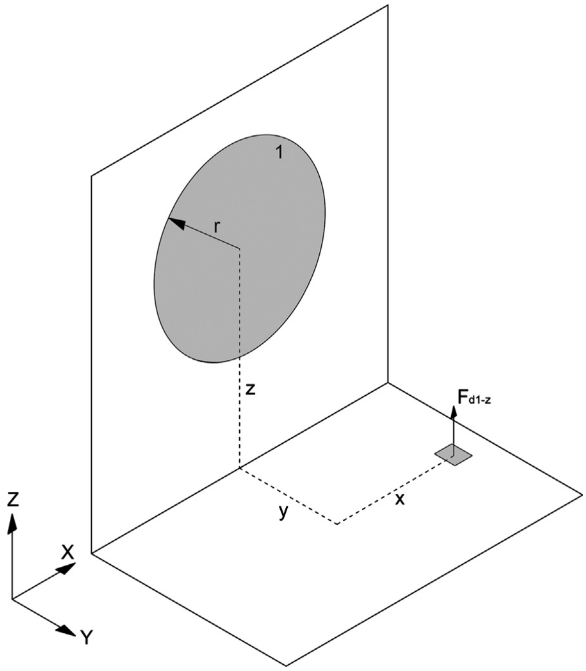

Fig. 2. Calculations parameters for F_{1d-z}.

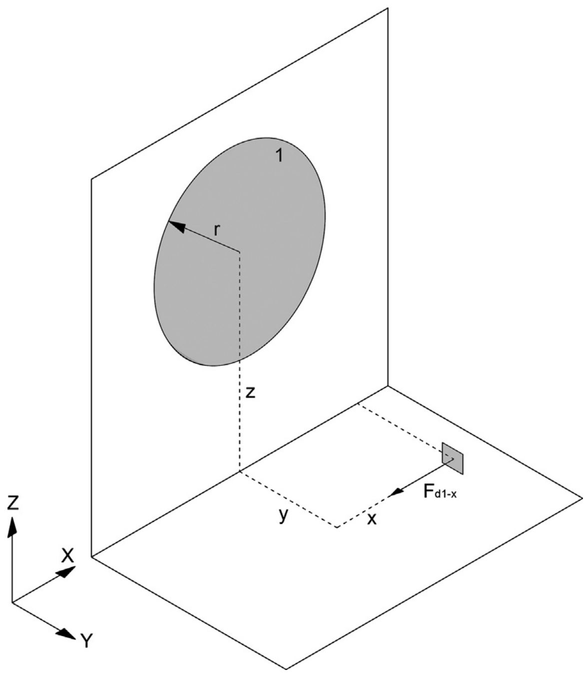

Fig. 3. Calculations parameters for F_{1d-x}.

In the *y* direction.

$$F_{d1-z}=\frac{yz}{2(x^2+z^2)}\left[\frac{r^2+x^2+y^2+z^2}{\sqrt{(r^2+x^2+y^2+z^2)^2-4r^2(x^2+z^2)}}-1\right] \quad (2)$$