Determination of Radiation View Factors Considering Shadow Effect

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Abstract

Shadow effect refers to the reduction in net radiative transfer between two surfaces, due to the obstruction of radiation by a third surface present inbetween them. This paper presents the details of a numerical integration technique for evaluating view factors considering shadow effect and a comparison of the results obtained with analytical results.

1 Introduction

In engineering applications where radiation is the primary mode of heat transfer, the accurate determination of net radiative transfer between surfaces is a necessity. In complicated geometries where shadow effect comes into picture, view factors can be determined in such a way that it incorporates the reduction in radiation heat transfer due to shadowing.
In the existing method of evaluating view factors, the double integration over the area of involved surfaces is converted into contour integration by applying Stokes theorem [1]. During this process the integrand becomes a function of logarithmic terms. In the present method called discretised contour and discretised surface area integration method, discretised surface area integration over the emitting surface and discretised contour integration over the receiving surface is employed [2]. The advantage claimed with the method is that the integrand is a simple function of geometrical data which results in fast and accurate computation. In the present work, view factors considering shadow effect are calculated for the following two geometries of practical interest.
(1) Rectangular receiving and intervening surfaces with radiation being emitted from an elemental area. The configuration is shown in Fig 1.
(2) A space radiator element consisting of two annular fins of rectangular cross-section mounted on a tube. This is shown in Fig 2.

Configuration 2 is a part of a space radiator array. It consists of two fins and an interconnecting tube. The shadowing effect due to the tube, as can be seen from Fig 2 is considered for study in the present work.

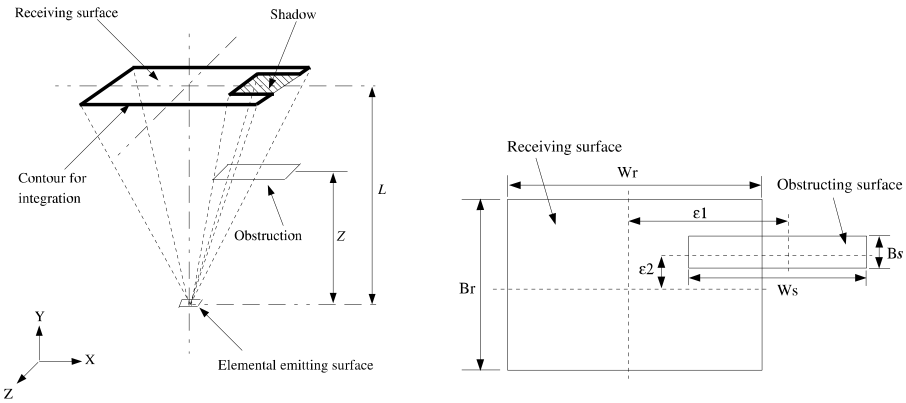

Fig. 1. Shadow cast on a rectangular area.

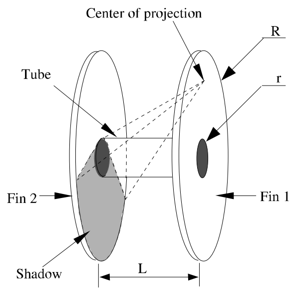

Fig. 2. Space radiator element with two fins.

2 View factor with shadow effect

A computer code is developed in Fortran language based on the present method for the computation process. The dimensions of the rectangular geometry as shown in Fig 1, taken for computation are, $Lr = 0.4$, $Wr = 0.3$, $Ls = 0.02$, $Ws = 0.005$, $L1 = 0.02$, $W1 = 0.0075$, $H1 = 0.1$ and $H2 = 0.01$. $H1$ and $H2$ are the vertical distance between the elemental emitting surface to finite receiving and obstructing surfaces respectively. The view factor F_{ij} from the program is compared with the value from the analytical expressions given in reference [3] and are shown in Table 1.

In the case of the space radiator element the emitting surface has been discretised into triangular elements and the view factor from each element to the receiving fin is determined and added up to get the total view factor between the fins. The result is then compared with the view factor obtained from the analytical expression given in the reference [4]. The comparison is shown in Fig 3. A graph, shown in Fig 4 is plotted for view factor against the ratio tube

Table 1

F_{ij}-Analytical (1)	F_{ij}-Program (2)	% error =[(2) − (1) × 100] ÷ (1)
7.677315E-1	7.68139E-1	0.053

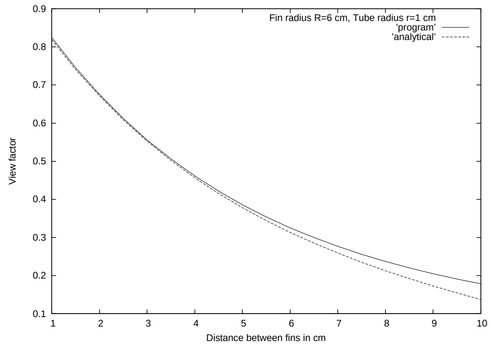

Fig. 3. Comparison of view factor for space radiator

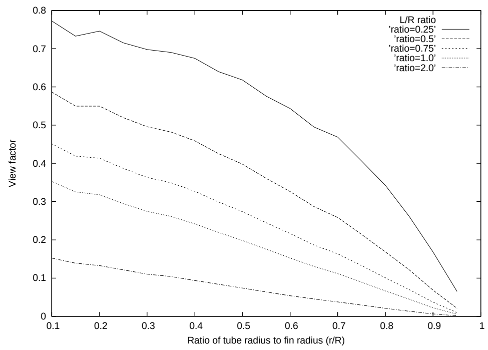

Fig. 4. View factor between two annular fins in a space radiator

radius to fin radius r/R by keeping the ratio of length of tube to radius of fin L/R constant. Each plot in the graph corresponds to a particular L/R ratio as shown at the upper right corner of the graph.

3 Conclusion

The work explains the use of a new numerical scheme for the computation of view factor considering shadow effect. In the case of rectangular geometry the result is found to vary from the analytical value by only 0.053 percentage. For the space radiator element, the comparison is done by plotting a graph and is found to be in agreement. Another graph drawn with *view factor* along Y-axis and r/R ratio along X-axis can be used to find out the view factor with shadow effect of a similar geometry with any dimensions. The present method can also be used for calculating view factor with shadowing effect created by multiple obstructions.

References

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