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Ant mound as an optimal shape in constructal design: Solar irradiation and circadian brood/fungi-warming sorties



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HIGHLIGHTS

- Geometry, ambient and in-dome temperature, solar radiation and illumination are measured.
- Insolation of a right cone by direct-beam, descending and ascending reflected radiation is modeled.
- “Cozy trapezium” where the insects-brood are exposed to “morning” sunbathing sessions are demarcated.
- Mound optimization criteria involve pure solar energy gained by the dome penalized by losses for locomotion.
- Optimal cone angle is explicitly expressed through the zenith angle of the Sun and meteorological constants.

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ABSTRACT

Sizes, shapes, ambient and in-dome temperature, incoming solar radiation and illumination are measured on a *Formica rufa* anthill in a mixed forest of the Volga-Kama National Reserve in Russia. These data are used in a conceptual model of insolation of a right conical surface by direct-beam, descending atmospheric and ascending ground-reflected radiation. Unlike a standard calculation of the energy flux intercepted by a solar panel, the anthill is a 3-D structure and double-integration of the cosine of the angle between the solar beams and normal to the surface is carried out for a “cozy trapezium”, where the insects expose themselves and the brood to “morning” sunbathing pulses (Jones and Oldroyd, 2007). Several constructal design problems are formulated with the criteria involving either a pure solar energy gained by the dome or this energy, as a mathematical criterion, penalized by additive terms of mechanical energy (potential and friction) lost by the ants in their diurnal forays from a “heartland” of the nest to the sun-basking zone on the surface. The unique and global optima are analytically found, with the optimal tilt angle of the cone explicitly expressed through the zenith angle of the Sun and meteorological constants for the isotropic sky model.

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“... This golden optimum of Solar radiation, which is tiding us, was, apparently, the best and most important quantitative cause, which forced an organic cell to ascend in its evolution to a human being... Solar energy is, most probably, the main factor determining evolution of plants and animals, a constant factor with respect

to the geological time and geographical position of the site”. Chizhevsky (2004).

1. Introduction

The ant hills (hereafter AH) are remarkable structures constructed by social insects (Wilson, 1971; Oster and Wilson, 1978), with several colony-protecting functions similar to dwellings of the human race. Andrews (1926) stated: “The mound is not only adobe of the adults but preeminently the incubator for the young and thus the means of securing the perpetuation of the race... one of the

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