Design with Constructal Theory

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Abstract. Constructal theory is the view that the generation of "design" in nature is a phenomenon of all physics, which is covered by a law of physics (the constructal law, 1996): "For a finite-size flow system to persist in time (to live) it must evolve such that it provides greater and greater access to the currents that flow through it". This law is about direction in time: that existing configurations are replaced by easier flowing configurations.

The theory coin has two sides, both useful: (1) the prediction of natural phenomena, and (2) the strategic engineering of novel flow architectures that are derived from principle, in accordance with the constructal law, not by mimicking nature. This lecture is mainly about (2): the emergence of design features in engineered flow systems, with particular emphasis on the *vascularization revolution*: tree-shaped flow architectures that offer dramatically superior volumetric functionalities for smart materials, such as volumetric cooling, self-healing and functionally graded material properties.

One example are vasculatures consisting of trees alternating with upside down trees provide volumetric bathing with flow entering from one side and exiting through the other side. The volumetric heat generation rate is uniform. The volume fraction occupied by all the channels is fixed, as a consequence of the fact that the leading constraints on high-density design are fixed weight (solid volume) and fixed volume (solid and channel volume). Minimized are the global thermal resistance (or hot-spot temperature), the global fluid flow resistance, and the volume fraction of material with temperatures close to the hot-spot temperature. We show that there is a vascular architecture with a certain number of bifurcation levels that meets the multiple objectives. The performance of the vascular design is dramatically better than the performance of uniform-perfusion designs.

The place of the constructal law in thermodynamics will be outlined. The constructal law covers many ad-hoc and often contradictory invocations of optimality, such as maximum entropy generation, minimum entropy generation, minimum resistance, maximum resistance, minimum time, minimum weight, uniform stresses, characteristic (finite) organ sizes, etc.

Keywords: Constructal; vascular; compactness; dendritic flows; tree-shaped flows

Brief constructal bibliography:

www.constructal.org
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