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Book review

Discussion on Shape and Structure from Engineering to Nature
by Adrian Bejan, Cambridge University Press, 2000

The latest book by Adrian Bejan is devoted to the presentation of constructal theory, which he has been developing over the last few years, after the seminal paper on the cooling of a heat generating volume, published in 1996 [1].

Why constructal differs from fractal

If we refer to B. Mandelbrot, who created *fractal geometry* [2], we notice that fractals originate as a new appraisal of the geometry of nature; this geometry differs from the previous ones because it takes into account chance and chaotic behaviour (nonregular or non continuous curves: interrupted curves through an iterative procedure). It uses "invariance" of geometry by iteration, from generally macroscopic scale to small scale (ad infinitum). This leads to "fuzzy" interfaces, which have been recognized useful by engineers to describe interactions through rough and dispersed interfaces.

In short fractals appear as a mathematical (geometrical) description, with a cascade from high scale to small scale; this mathematical approach has been successfully applied more recently in various fields of engineering [3].

The way the constructal theory proceeds differs by the point of view of the author, starting from engineering consideration to go to nature. Constructal principle first consists in considering the smallest volume (surface) scale, and subsequently applies the same geometric optimization at a larger scale: an optimized volume (surface assembly) results. So this deterministic method differs from the fractal approach, by the expansion of scales, and also by the finite iterative procedure associated to the fact the considered volume (surface) remains finite.

The main idea appears to be: "shape and structure are construction processes of growth, and for a system the whole differs from the sum of parts, with a primacy of the whole over the parts". This appears to be completely new. The main example could be for living systems, the evolution from virus, to bacteria and complex system.

Optimization of functioning systems or evolving systems

The optimization principle appears as a natural law. It works in optics as a minimal length principle, or a least possible transit time (Fermat). Maupertuis and Hamilton developed the principle of least action relative to motion and mechanical change. A. Bejan considers particularly, thermodynamics and irreversibility through entropy generation minimization, with given constraints. These constraints are generally related to geometry, size, and also materials.

The most convenient developments are related to heat exchangers where the competition between mechanical and thermal transfers leads to an optimum geometry. The same holds for electronic packages: optimal package architecture is such that hot spot is minimal and widespread over the structure.

Modern thermodynamics and extension to natural and living systems

Strong interrelation with modern thermodynamics and irreversibility analysis emerges from the approach; for instance the last example seems completely related to "equipartition theorem".

The second law too inspires the author, considering the evolution of natural or living systems, with energy and mass flows, subject to geometric and size constraints.

The main problem is to minimize the overall resistance between a generating volume and a sink point. The author applies with success to many tree networks that may be found in nature: plants, leaves, river drainage basins, dendritic crystals clusters.

The same holds between slow and fast mechanisms: slow mechanisms operate at the smallest scale.

As a conclusion, a constrained open system could survive if it evolves and organizes in such a way that it provides easier access to imposed fluxes that flow through it. Constraints are external causes required when the knowledge of the whole context is incomplete (currently initial and boundary conditions).

Conclusions, perspectives

The tree of knowledge appears also as a gradually expanding construction of conditional truth, with constant reference to nature, and test for validation on engineering

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machines and processes: engineering is also an iterative procedure with trial and error leading to material creation. The same appears to hold for artistic activities, for living systems.

In this book A. Bejan proposes a new step, in the tree of knowledge, that appears attractive due to the multidisciplinary approach. It is of major interest for physicists and engineers; applications of this theory could also be developed in the fields of Economy and Architecture for example

References

[1] A. Bejan, Constructal theory network of conducting paths for cooling a heat generating volume, Internat. J. Heat Mass Transfer 40 (1997) 799–816 (published November 1996).
[2] B. Mandelbrot, Les Objets Fractals, 2ème ed., in: Nouvelle Bibliothèque Science, Flammarion, 1984.
[3] A. Le Mehaute, Les Géométries Fractales, Hermès, 1990.

Michel Feidt
LEMTA – ENSEM,
2, avenue de la Forêt de Haye, B.P. 160,
54504 Vandoeuvre les Nancy, France
E-mail address: michel.feidt@ensem.inpl-nancy.fr (M. Feidt)

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