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APPLICATIONS OF ENGINEERED FRACTALS IN THE SUGAR INDUSTRY (ASSBT 1999)

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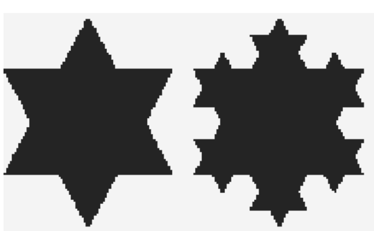
Abstract

Amalgamated Research Inc. has recently proposed the use of engineered fluid transporting fractals as functional alternatives to turbulence[1]. The purpose of these structures is to eliminate the uncontrollable geometry associated with the scaling and distribution of fluids. Because of the ubiquity of turbulence, a large number of applications are envisioned. Present applications include rapid low turbulent mixing, controlled formation of specified fluid geometry and low energy fluid distribution. Practically any fluid handling step is a candidate for the use of fractals. "Fractalization" of an overall fluid process can lead to a number of benefits. A single factory at Amalgamated Sugar LLC has so far implemented fractals for distributing fluid in the molasses chromatography process, for controlling exhaustion/regeneration in thin juice ion exchange and for providing uniform air circulation in a sugar silo.

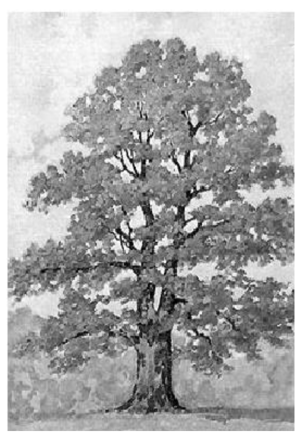
Introduction to Fractals

Fractals can be defined in a number of ways [2,3].

Definition 1**:** Fractals are self similar objects whose pieces are smaller duplications of the whole object. This is a simple qualitative definition that can be used to easily recognize such structures. Fractals can be "geometric" such that each iteration results in smaller and exact reproduction of the geometry. In a separate category, "statistical" fractals are only self similar in a statistical sense. An example is a tree (branches similar to the trunk, twigs similar to branches, etc.).



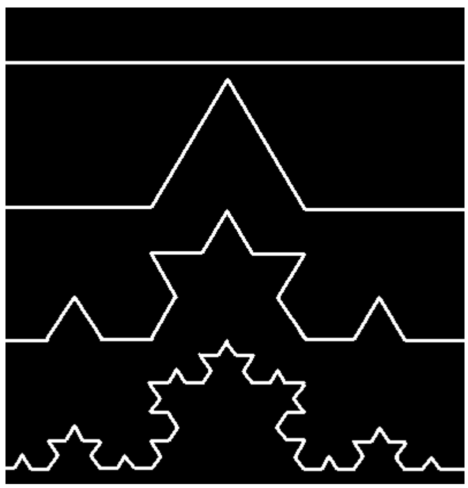
Geometric fractal



Statistical fractal

Figure 1. Fractal categories for the Koch island and for a tree

Definition 2**:** A fractal is an object in space or a process in time which has a fractal dimension greater than its topological dimension. For example, in the iterative construction of the Koch curve in Figure 2, a simple one dimensional line progressively increases in length so in the limit we have the characteristic of infinite measure of length between any two points, i.e., there is no sensible measure of length. This difficulty is practically encountered when measuring the distance along a coastline. A coastline can be measured to be any length depending upon the size of the measuring instrument. There is no characteristic scale. However, the fractal dimension can be used to quantify such an object. For example, it can provide information about how much a fractal increases in length with each iteration. A useful qualitative way of thinking about fractal dimension is to consider it as a measure of curve roughness.



perimeter:

d(topological) = 1

d(fractal) = 1.2619...

Figure 2. Koch Curve Construction

Functional Equivalence of Turbulence and Engineered Fractals

Under our proposal, fluid scaling and distribution can be regarded as a general process with an underlying range of geometric control. Turbulent processes are characterized by a progressive scaling of large to small scale motion (a turbulent jet is an example). Free turbulence is the most familiar method for obtaining deep fluid scaling. However turbulence entails very little control of the scaling geometry. At the opposite end of the control spectrum are fluid transporting fractals which also allow deep scaling but can, in addition, provide precise control of the scaling geometry. For example, fractals allow the introduction of symmetry into the fluid scaling process. Because of the ubiquity of turbulence, the opportunities for its functional substitution with a controlled geometry may be substantial.

Applications for the Sugar Industry

Sugar processing is an intensive fluid handling procedure and consequently there are many opportunities for the use of engineered fractals. Rapid formation/collection of fluid surfaces or volumes are examples. The fractal structure in Figure 3 is a distributor/ collector used in ARi's simulated moving bed chromatography systems and is equally appropriate for other adsorption processes[4,5]. The distributor has been designed to meet several criteria. These criteria include:

1. Minimal turbulence.
2. Rapid formation of a fluid surface.
3. Surface homogeneity.
4. Minimal turndown limits.
5. No disturbances caused by differential time of passage.
6. No pattern channeling.
7. No distributor-column geometry conflicts.
8. No scale-up limits.

Although fractals are most often thought of as having non-integer dimension, in this structure a fractal dimension = 2 has been approximated. This insures the formation of a surface of fluid. As bifurcations are added to the fractal pattern, turbulence is progressively reduced at fluid exit and a two dimensional surface is more closely approximated. As opposed to using turbulence as the scaling and distribution mechanism, the cascade has been designed to be extremely symmetrical. Two types of symmetry have been incorporated – between paths and between scales. These symmetries provide equivalent hydraulics to each exit point. The introduced surface is therefore completely homogeneous. Additionally, a very wide range of flowrates can be treated without any deterioration of distribution efficiency. In chromatography service, a typical configuration employs mirror image distributors and collectors. This adds a third type of symmetry beneficial to the uniform movement of the fluid through the chromatography columns.

The structure can be thought of as a kind of engineered eddy cascade. The scaling function of turbulence is present but the characteristic randomness has been eliminated.

Process Fractalization and Fractal Linking

We have found the term "fractalization" to be a convenient way of describing the progressive addition of fractals to improve performance of a fluid process. Fractalization is a logical program to consider because fluids are so often handled in an unorganized, inefficient manner. Amalgamated Sugar's Nampa, Idaho plant is presently using fluid transporting fractals in 17 ft. diameter chromatography columns, a 40 ft. diameter sugar silo (a gas application), and a thin juice softener. Although the goals in each application are somewhat different, they are all dependent upon controlling the geometry of the fluid scaling process.

A related useful concept is that of linking together fractals of different dimension. That is, a series of fractals can be used throughout a process to provide rapid fluid transitions, back and forth between surfaces, volumes or patterns of non-integer dimension.

Other Fractals for Fluid Applications

ARi is presently constructing non-integer fractal structures for study at the

University of Cambridge Department of Theoretical Physics. These wind tunnel studies are directed at developing turbulence related applications and for basic study of the phenomena of turbulence.

Conclusions

Fractals can be used to provide useful control over the general dynamics of fluids. Applications in the sugar industry, as in any other process which involves fluid handling, may be quite broad. These applications include turbulence elimination, controlled formation of fluid structure and rapid alteration of a fluid's measure of dimension.

Figure 3. An engineered fractal distributor. Comparison: A mathematically generated fractal from the cover of this paper.

References

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