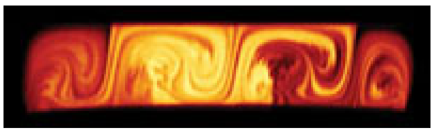
Chaos, Twist Maps and Big Business

July 26 2004



Obscure mathematical ideas developed back in the 1980s could solve current problems of **mixing fluids at the microscale, and revolutionise the technology**, reports an article in Science this week (23 July 2004).

The need to mix fluids at the microscale affects a whole range of developing technologies – from inkjet printers to DNA analysis – and finding ways to do it is becoming big business. Millions of dollars have already been poured into 'lab-on-a-chip' projects, but making miniature labs is not just a question of scaling things down.

When you pour cream into your coffee via the back of a spoon, it forms a delicious layer on the top, through which you sip your coffee. Should you want to mix the layers together, however, you simply pick up the spoon and stir, creating turbulence in the fluids that causes them to mix.

But it's a different story when the amount of fluids you are trying to mix is very, very small. Tiny volumes behave in strange ways and getting them to mix is extremely difficult. This is where a powerful mathematical idea that involves chaos theory – ‘chaotic mixing’ – becomes useful, since it provides a key mechanism for mixing at such small scales.

Professor Steve Wiggins, a mathematician at Bristol University, and his colleague Professor Julio Ottino, a chemical engineer at Northwestern University, USA, pioneered ideas of chaotic mixing back in the 1980s. Recently they stumbled on even earlier, highly abstract, ideas – the exotically named ‘linked twist maps’. These, they suddenly realised, could be applied to the problems of mixing tiny volumes.

A common design for many micromixers currently in use is a construction that has several segments, each with different geometrical characteristics. Twist maps describe the swirling motion particles undergo as they movedown the length of one segment, while ‘linked twist maps’ describe particle motion through multiple segments. As a result of their structure, Wiggins and Ottino found that linked twist maps can be designed to give exceptional mixing properties at the microscale.

This discovery has provided Wiggins and Ottino with a new method for the design of micromixers, and the potential to revolutionise the technology.

Professor Wiggins said: “Chaotic mixing is probably a long way from the thinking of those who develop new designs for mixing fluids at this scale. But this is an area where seemingly abstract mathematical work could have a direct impact on the bottom line.”

Design strategies are mainly based on a ‘trial-and-error’ procedure. This can be prohibitively expensive and negatively impact on commercial viability, due to uncertainties in the fabrication processes.

Source: [University of Bristol]