# Stirling and Schumacher

**German scientists have built an engine that may just be put to work in biological systems, says** s ananthanarayanan

WHILE it may be true that small is beautiful, function does not always stay unchanged when dimensions are reduced. This is particularly true about heat engines, like the steam or petrol one. These engines work because of the force of molecules of a hot gas and the system breaks down when the moving parts are reduced to a size comparable with the movement span of the molecules. Yet a pair of researchers at the University of Stuttgart and the Max-Plank Institute for Intelligent Systems, in the same city, reports in the journal *Nature* that they have found that a heat engine of the size of microns is able to work and may show the way for energy efficient machines at these dimensions.

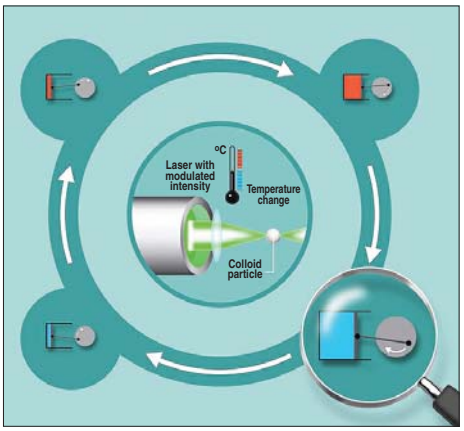
This is a device that changes heat energy into mechanical energy. The earliest instances used steam generated by boiling water to blow things, in the place of wind, and the simplest developments were mechanisms that could only pump water, not versatile methods to work different kinds of machinery. The early steam engines that could do this changed the face of industry, which could now be located away from flowing water as a source of motive power, and brought in the industrial revolution. While the steam engine uses heat from outside to heat the steam, the petrol or diesel engines are "internal combustion" ones — it is the fuel itself that pushes the pistons and makes the motor go.

But steam engines can use any kind of fuel and are also able to work at high altitudes where other engines have issues.

The principle of the heat engine is nicely described in the Sterling engine, which was developed as an air engine in 1816, as an improvement over the steam one. The Sterling engine has two cylinders – one where the gas is heated and pushes the piston to turn a flywheel, and the other which is cooled so that the piston moves back while feeding the working substance gas back into the other cylinder to be heated. The complementary motion of the two pistons works the flywheel, which can be connected to other machinery — a mill, a power loom or a locomotive wheel.

The principle is that when the first cylinder is heated the gas molecules start moving faster and push hard against the piston, which moves the flywheel. This also causes the gas to expand and then cool. In fact, it is in this cooling that the heat energy that was supplied to the gas is transferred as mechanical energy to the flywheel. The heat energy was random motion of molecules, in all directions. The rigid formation of the cylinder and the unidirectional motion of the piston convert the molecular motion of millions of molecules into the motion of the flywheel.

The system works smoothly because the number of molecules that strike the surface of the piston in a second is so exceedingly large that the piston feels a continuous thrust, not individual bumps. Reduction in the size of the engine would reduce the size of the piston, but not the size of molecules or the number that strike a given area of the piston. When the size of the piston goes down to molecular dimensions, then the numbers striking are no longer so great and the piston would actually receive sporadic impacts. In fact, at some moments it may be an atmospheric molecule that pushes the piston backwards, instead of the other way about! The result is that the smooth back and forth motion, in step with the heating-cooling cycle, is disturbed and the engine cannot work. Quite apart from the difficulty of manufacturing components at the size of microns, this nature of the heat engine has been the limitation in reduction of the engine size.




*A Stirling engine in the microworld: In a normal-sized engine, a gas expands and contracts at different temperatures and thus moves a piston in a cylinder. Diagram courtesy Fritz Höffeler/Art For Science.*

**Stuttgart experiment**

But despite this difficulty — that different laws of physics become important at small dimensions — the Stuttgart team found that the principle of the heat engine stayed unchanged. "We successfully decreased the size of the essential parts of a heat engine, such as the working gas and piston, to only a few micrometres and then assembled them to a machine," says Valentin Blickle, a member of the two-man team. In the normal Stirling engine, the piston moves back and forth and the molecules of the gas are the working substance.

The Stuttgart engine replaces the piston with a laser beam, which restrains or liberates a plastic bead, just like the piston compresses or moves to allow the gas to expand. Just as the motion of the molecules of the gas are set in motion with heat, the plastic bead gets its motion from the molecules of water, in which it floats. Thus, the water is heated and allowed to cool by an alternating laser beam, while the bead, buffeted by water molecules, moves in step with the laser that restrains or frees its motion, doing work, or transferring energy from the water to the laser field in the process.

The arrangement, with a micrometre size bead as working substance, which can be observed in a microscope, and is itself moved by molecules of water, is halfway to a heat engine that directly uses molecular motion.

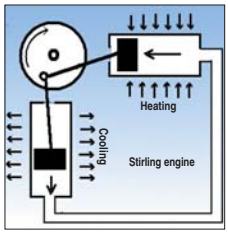
Despite the intermediary of the bead, the machine works in fits and starts, sometimes coming to a stop when the movement of the bead goes out of step. But on the average, the machine is found to work at the same efficiency in converting heat energy into mechanical energy as a normal heat engine.

"This was not necessarily to be expected, because the machine is so small that its motion is hindered by microscopic processes which are of no consequence in the macroworld," says Clemens Bechinger, professor at the University of Stuttgart and the other member of the team. Such working in fits and starts in normal life, as in the case of a "sputtering engine", would be unacceptable to the everyday motorist. But in the present case, what is being done is to show that the principle of the heat engine stays unchanged at small dimensions, despite limitations of implementation.

The normal heat engine, at any rate, is no achiever in efficiency. Even in principle, the efficiency is limited by the higher and lower temperatures involved. The higher temperature is limited by the materials available and the lower temperature cannot even come down to the ambient; it has to be not below that of condensing steam. Steam engines, or even diesel engines, are thus not more than 20-40 per cent in energy efficiency, much of the waste being in the form of "low grade heat" of the exhaust gas or condensed steam. Arrangements are thus attempted to make use of this "waste" heat so that overall efficiency improves. One method is to use the heat for domestic heating and there are ways to generate electricity from low-grade heat.

But the demand for such secondary output of the system usually cannot match the level of "waste" heat generated in large plants, where this energy has to be lost in cooling towers or in raising the temperature of adjoining water courses.

But the efficiency can be higher with a series of small heat engines and since the world became conscious of the energy crisis, there has been much work done to develop more fuel-efficient alternatives. In this context, a working, micrometer-sized engine may present very high levels of efficiency, once implemented. The Stuttgart experiment shows that the simple heat engine is workable at microscopic dimensions, which would enable all kinds of applications.




**The writer can be contacted at simplescience@gmail.com**

## UPS in the human body?

**MECHANICAL devices, like everyday machines, are rarely found in the natural world. The principle of the lever, of course, is there in the movement of limbs for grasping and all animal movement, but direct conversion of energy in the mechanical sense is not found. An only instance may be of the "helicopter seeds" of the ash tree (*Fraxinus excelsior*), which are disseminated by the wind. The seed has a screw-like wing which the slightest breeze sets spinning, giving the seed a "lift" that carries it long distances. The devices placed within the body by surgical methods are limited to "pacemakers" that deliver electrical signals or some that release a controlled dose of drugs. The creation of miniature motors or engines that can use body heat to do mechanical work could function as pumps and actually drive metabolic processes where natural mechanisms have failed.**

*The "helicoper seeds" of the ash tree have screw-like wings which the slightest breeze sets spinning, giving them a "lift" that carries them long distances.*

# The earth mother of all neolithic discoveries

john lichfield **wonders whether the 'Lady of Villers-Carbonnel' could represent the neolithic ideal of female beauty long before the coming of fashion magazines, airbrushes and Photoshop**

**FRENCH archaeologists have discovered an extremely rare example of a neolithic "earth mother" figurine on the banks of the Somme river. The 6,000-year-old statuette is eight inches high, with imposing buttocks and hips but stubby arms and a cone-like head. Similar figures have been found before in Europe but rarely so far**

**north and seldom in such a complete and well-preserved condition.**

**The "Lady of Villers-Carbonnel", as she has been named, can make two claims to being an "earth mother". She was fired from local earth or clay and closely resembles figurines with similar, stylised female bodies found around the Mediterranean. Although neolithic experts are revising their opinions, the figures have long believed to have been connected with the existence of a cult that worshipped a goddess of the hearth or of fertility.**

**The Somme "earth mother" appears to have broken into five or six parts while she was being fired between 4300 and 3600 BC. She was found in the ruins of a neolithic kiln at a French government "preventive" archaeological dig near Villers-Carbonnel on the banks of the Somme in the département of the same name.**

**The figurine may be just the beginning of a vast archaeological harvest in northern France in the next few years, stretching from palaeolithic times to the World War I. The French government's "preventive archaeology" agency, Inrap, has been given permission and the funds to explore 77 sites along the 60-mile course of the new 50-metre wide Seine-Nord Europe canal for ocean-going barges linking the Seine river to Belgium and the Rhine.**

**The archaeologist in charge of the Villers-Carbonnel dig, Françoise Bostyn, said, "The statuette is very beautiful and remarkably preserved. We sometimes find fragments of such statuettes but rarely the whole figure."**

**She said the stylised figure, with inflated buttocks and thighs and rudimentary head and arms, closely resembled similar figures from the period found as far away as West Asia. Could the "Lady of Villers-Carbonnel" represent the neolithic ideal of female beauty, long before the coming of fashion magazines, airbrushes and Photoshop?**

**The Independent, London**

# Journey into uncharted voids

**Voyager 1 is about to become the first man-made object to leave the Solar System, says** steve connor

AFTER a voyage lasting more than 34 years, a spacecraft that has travelled further than any man-made object is on the verge of leaving the Solar System and entering the mysterious region of interstellar space where nothing terrestrial has gone before.

Scientists at the National Aeronautics and Space Administration said the Voyager 1 space probe, which has travelled about 11 billion miles since its launch in 1977, has entered the cosmic equivalent of the doldrums, where high-speed solar winds die down at the very edge of the Solar System.

Voyager 1, launched within weeks of its twin probe, oyager 2, was originally designed to explore Jupiter and Saturn. After making a string of important observations, such as active volcanoes on Jupiter' moon Io and the intricacies of Saturn's rings, the mission was extended. Voyager 2 went on to explore the faraway planets of Uranus and Neptune.

However, long after the official planetary missions ended, both spacecraft continued to plough through the farthest regions of the Solar System, while maintaining radio contact with mission control through its Deep Space Network.

Nasa expects that within the next few months — or, possibly, years if margins of error are taken into account — Voyager 1 will finally leave the Solar System for good and begin its journey through the vast void of interstellar space that comprises most of the Milky Way galaxy. Voyager 2 — travelling not far behind — will follow suit. Nasa scientists said that over the past year Voyager 1 had entered a kind of "cosmic purgatory" where the wind of electrically charged particles streaming from the sun had calmed.

Both spacecraft are now in a region known as the "heliosheath", the outermost layer of the Solar System where the solar wind, which can travel 16 miles per second, is being slowed down by the rising pressure of interstellar gas. Nasa scientists believe this indicates the imminent entry of Voyager 1 into the interstellar region, which is dominated by another kind of magnetic wind coming from a different direction of deep space.

"Voyager tells us now that we're in a stagnation region in the outermost layer of the 'bubble' around our Solar System. Voyager is showing that what is outside is pushing back. We shouldn't have long to wait to find out what the space between the stars is really like," said Ed Stone, Voyager project scientist at the California Institute of Technology in Pasadena.

Nasa changed the orientation of Voyager 1 four times this year to see whether the solar wind and magnetic field lines had switched direction. Data released at the American Geophysical Union meeting in San Francisco shows the magnetic field lines have not changed, indicating that Voyager 1 is still just within the "heliosphere", the magnetic bubble of charged particles created by the sun.

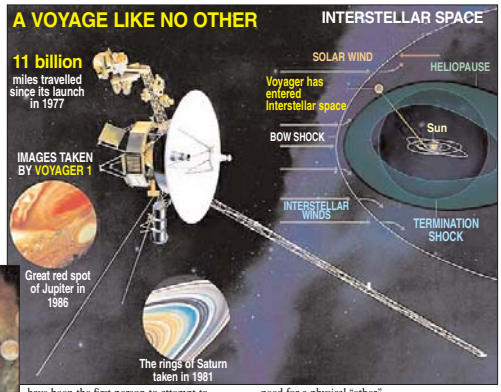
"We have seen the same east-west direction of the magnetic field since we launched. That's the solar magnetic field. Once we leave the heliosphere we will enter the magnetic field of the galaxy and all the data to date suggests that this field is orientated more north-south," Dr Stone told the meeting.

**Final frontier: between the stars**

■ English philosopher Francis Bacon appears to have been the first person to attempt to describe the space between stars when he wrote in 1626 about the "interstellar skie".

■ In the 19th century, scientists postulated an invisible luminiferous ether between the stars that allowed the transport of light. It is now known that electromagnetic waves, whether cosmic rays or light in visible wavelengths, can travel through interstellar space without the need for a physical "ether".

■ Astronomers today talk about an interstellar medium that fills the void between stars. Rather than a complete vacuum, it consists of about 99 per cent dust and one per cent charged particles or ions, but in incredibly low densities. Cosmic rays from deep space fill the void.




**The Independent, London**