Size Does Matter

Imagine robots the size of molecules manipulating the atoms of some raw material, turning it into something entirely new, something different, something useful on our scale: new alloys that are stronger and lighter than what we have now, active materials that change and react to their environment, even whole functional parts created by microscopic machines that can repair and duplicate themselves like the living cells they rival in size. These are nanomachines, devices that are measured in billionths of a meter. Sound like science fiction, something you'd see on Star Trek or The X-Files? According to the folks at NASA, it's closer to science fact than most people realize.

Nanogears, molecule-sized gears that are made from pipes of carbon atoms with benzene atoms attached to the outside of the pipe to form the teeth, have been simulated by a NASA supercomputer at the Ames Research Center in Mountain View, CA, as part of their ongoing research into nanotechnology.

In the NASA simulations, the gears were driven by a laser that served as a motor, creating an electric field around the nanotube with a positive charge on one side and a negative charge on the other. Together, these charges rotate the gear. This generates heat, but there were also successful simulations of cooling the gears using helium and neon gases.

Cooling is very important in this case, since, according to the simulations, the gears, each about a nanometer (one-billionth of a meter) across, rotate best at around 100 billion turns per second, or six trillion rotations per minute.

According to Al Globus, a co-author of the paper describing these simulations and a computer scientist at Ames, "hope is growing that products made of thousands of tiny machines that could self-repair or adapt to the environment can ultimately be constructed."

"One practical use for nanotechnology would be to build a matter compiler," says Creon Levit, a Globus colleague at Ames. "We would give this machine, made of nanoparts, raw materials like natural gas. A computer would specify an arrangement of atoms and the matter compiler would arrange the atoms from the raw material to make a macro-scale machine or parts."

This principle is already at work today. The biotechnology industry uses peptide synthesizers that create the peptide you ask for by stringing molecules of amino acids together in the proper order. Doing the same thing with atoms requires only a change in scale.

The first step to the matter compiler is a smaller machine called the assembler/replicator. This machine could be programmed to make aerospace materials, parts and machines in atomic detail, giving these products great strength and thermal properties. Also possible are materials possessing radically improved strength to weight ratios as well as active or "smart" materials. "There is absolutely no question that active materials can be made," says Globus. "Look at your skin. It repairs itself. It sweats to cool itself. It stretches as it grows. It's an active material."

Globus strongly emphasizes that making real nanomachines may be decades away, but his computer simulations suggest the tiny machines are possible after engineers learn to build nanoparts, like gears, and to assemble nanomachines.

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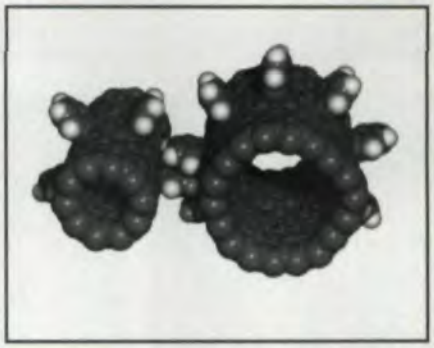
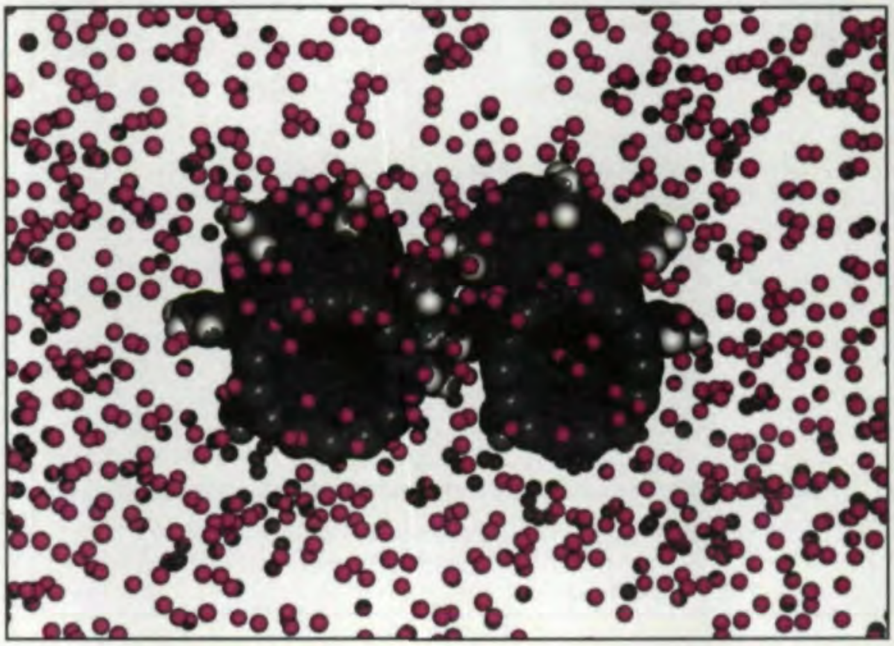
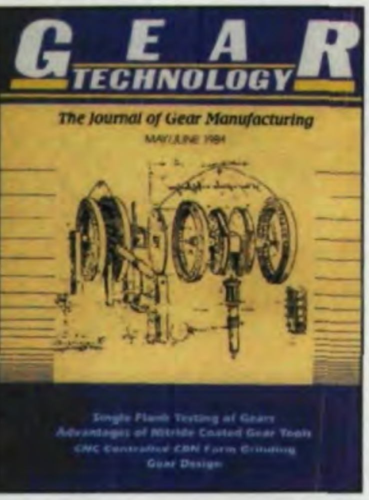


Simulations of nanometer sized hydrogen-benzene gears. Below, the nanogears in a cooling helium atmosphere.





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This issue marks the 15th anniversary of *Gear Technology*. In the first 15 years, we've published more than 400 technical articles and more than 4,500 pages in 90 issues of the magazine.

Those of you who have read (and saved) our pages from the beginning know that the complete library of *Gear Technology* magazines occupies approximately 1 foot of shelf space.

Early issues of *Gear Technology* featured gear sketches by Leonardo da Vinci. There were 30 Leonardo covers in all, including a self-portrait of the man himself. The last Leonardo cover was published on our July/August 1990 issue.

We'd like your input on how we should shape *Gear Technology* for the **next** 15 years. Please give us a call at (847) 437-6604, fax your suggestions to (847) 437-6618 or e-mail ***people@geartechnology.com***.

Digital Supersleuth

Theodore M. Clarke's job is to find out why gears, shafts and bearings fail. That job is now getting easier and faster through the use of digital imaging.

Clarke is a senior technical specialist in metallurgical failure analysis and tribology with Case Corp., the off-road equipment manufacturer located in Burr Ridge, IL. He's written several articles in *The Microscope* and *Microscopy Today*, as well as a section on the photography of fractured parts in volume 12 of the ASM International Metals Handbook. Clarke has found that digital photomacrography takes advantage of the latest high tech gadgets to provide substantial cost and time savings over traditional film-based photographic methods.

"The industry standard is still the 4x5 instant print," Clarke says. "That gives you a high-quality photographic image. We've obtained a camera that maintains the same image quality as 4x5 instant film."

Clarke uses a Kodak MegaPlus 1.6i/AB digital camera and a bellows system modified in his home machine shop to yield digital image files with magnifications ranging from 1X to 50X in 4x5-inch prints. The camera is cabled to a PC and produces images that are immediately viewable on a 1024 x 1280-pixel monitor. This link between camera and computer makes it much faster and easier to establish proper illumination, focus and depth of field while viewing camera output on the monitor.

"It's difficult to photograph the damage or the contact pattern on a gear tooth," Clarke says. Often the operator will have to adjust lighting, positioning or camera settings to obtain a clear image.

Using traditional methods, it's not uncommon for the photographer to expose three or four sheets of instant film to get a single usable picture. With the digital setup, Clarke and others at the lab can make adjustments on the fly and see the changes in real time.

But the immediate time savings and convenience are only part of the advantage, Clarke says. "The big thing is that the images are stored on a server."

The images, along with the metallurgists' full report, are stored on Case Corp.'s token ring local area network, where they are accessible to any authorized employee. The digital file format also makes it easy to e-mail the metallurgical reports to Case Corp. offices around the world.

"When you have a problem with a part, the quicker you can get the response to the supplier or the plant, the more cost-effective the solution will be," Clarke says. "The faster the lab can determine the source of the problem, the faster the company can solve it."

Other companies have tried digital photography in their metallurgical labs with varying levels of success. "I've seen some pretty poor examples of digital images," Clarke says. The problem is often knowing what constitutes a high-quality image. "With film imaging, it was not a problem. Film has ample resolution. I see a terrible amount of confusion with digital technology."

Theodore M. Clarke of Case Corp. using digital photomacrography equipment.

Part of this confusion results from a lack of standards for digital photomacrography, Clarke says. He hopes that will be one of the issues addressed at ASM's upcoming Imaging Tech 99, to be held August 17–19 at Arlington Park, IL, because more and more companies will begin trying digital imaging as the technology becomes more widespread and less expensive.

Case Corp.'s success in digital photomacrography has made them a benchmark of sorts. Recently, a major bearing manufacturer visited Clarke's office to study his setup. They ended up buying two of the Kodak Megaplus cameras and developing a similar setup of their own, Clarke says.

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