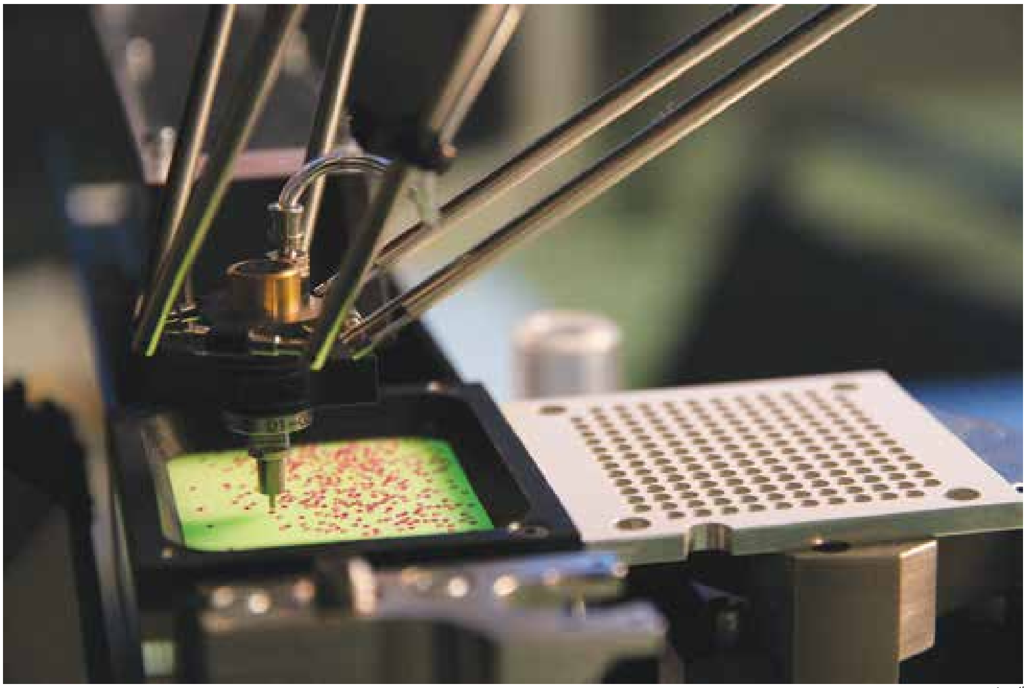
By William Leventon,
Contributing Editor

Coming to grips with sticky surface forces



Asyril

Microparts on a vibration feeder and a vacuum gripper mounted on an assembly robot.

One might think the biggest challenge in micropart handling is picking up the components. As it turns out, letting them go might be even more difficult.

Why? Because of the adhesive forces that act on the surfaces of objects. When part sizes reach about 100µm, surface forces start to win out over gravity, which weakens as part volume decreases. When gripper jaws open, tiny parts will often stick to the gripper surface rather than drop into place.

Troublesome surface forces include:

- Van der Waals force, an intermolecular attraction thought to be one of the ways a gecko can climb sheer walls. It is created by the relatively weak attraction between the electron-rich and electron-poor areas of two molecules that pass very close to each other.
- Electrostatic force, the attraction of two atoms of opposite charge.
- Surface tension, caused by cohesive forces between molecules at or near the surface of a liquid.

These three forces vary in the amount of adhesion they generate, depending on factors such as part size and material, as well as the environment in which components are handled, according to Mélanie Dafflon, R&D manager at Asyril SA, a Villaz-Saint-Pierre, Switzerland, manufacturer of equipment for feeding and packaging small parts.

A pound of prevention

The good news for part manufacturers is that there's no shortage of ideas on how to prevent surface forces from creating sticky situations in micropart-handling applications. These ideas range from the practical to the exotic.

On the practical side, manufacturers can tightly control humidity in part-handling areas, Dafflon noted. Humidity produces a thin layer of water on surfaces. If the relative humidity is 70 percent or higher, she said, surface tension caused by moisture will make manipulating small parts more difficult. On the other hand, electrostatic forces will be "very strong" if relative humidity drops below 30 percent, she added, complicating the task of finding the right humidity level for a part-handling area.

Another practical option for reducing

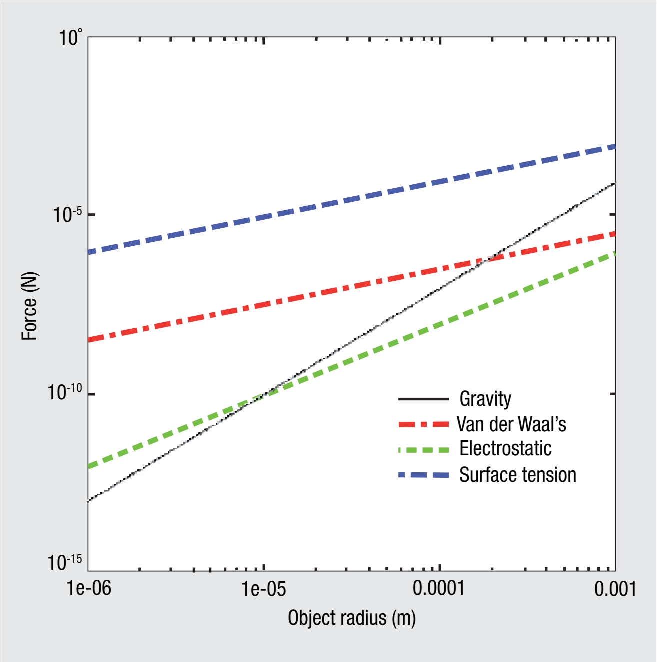
surface forces is altering the surfaces themselves. For example, some manufacturers apply zinc oxide and other antistick formulations to grippers used to manipulate very small parts, according to Dan Popa, associate professor of electrical engineering at the University of Texas at Arlington. Other helpful coating options include hydrophobic, or water-repelling, materials such as polydimethylsiloxane (PDMS), noted Popa, head of the Next Generation Systems Research Group at UT Arlington, which researches best practices in designing microscale manufacturing systems.

Popa also pointed out that sticking forces increase when two touching surfaces are very flat and smooth. Therefore, roughening the surfaces of gripper tips can effectively reduce part adhesion to grippers.

Oddly enough, manufacturers can use adhesion to their advantage when moving small parts with a gripper by placing the parts onto a sticky substrate. The idea, Popa explained, is to make sure the substrate's adhesion force is greater than the surface forces that make the parts stick to the gripper.

Vacuum and electrical charge can also be used to pull tiny parts off a gripper and onto a substrate. "You can use whatever force you want, but it has to be greater than the force on the other side of the parts," Asyril's Dafflon said.

Another option along these lines involves adding snap connectors to tiny parts. Such connectors allow the parts to be snap-fastened to an assembly substrate, said Popa, who has researched this approach. After a part is snapped to a substrate, there's more than enough force to overcome the adhesion between the part and the gripper that put it in place.



Dan Popa, UTA.

Gravitational, electric, van der Waals and surface tension forces. The graph shows the attractive force between a sphere (a spherical part, for example) and a plane (like the flat surface of a gripper).

Adhesive bonds between part and gripper can also be broken by vibration. To shake a part loose from a gripper, Dafflon explained, the acceleration applied to the part by the vibration must be high enough that the resulting shaking force is greater than the adhesive surface force.

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One part handling strategy developed by Asyril involves feeding small and micro components via vibration in three directions (X, Y and Z) to distribute and orient the parts on a surface.

No grabbing

All of the strategies discussed thus far are aimed at mitigating the effects of surface forces on pick-and-place processes. But there are other techniques that may allow users to entirely avoid the pitfalls involved in grabbing small parts.

Instead of using a gripper to move parts one by one, for example, manufacturers can move multiple parts via vibration, which "allows you to move components on a surface and guide them to the right place," Dafflon said.

Another pick-and-place alternative being scrutinized by researchers is self-assembly, where forces arrange and connect things properly without any manipulation by manufacturers. Self-assembly is constantly on display in the biological world, where "smart" materials are preprogrammed to coalesce into the proper shapes, noted Marc Madou, a professor at the University of California, Irvine.

In a manufacturing environment, a self-assembly process could theoretically be initiated using DNA strands, according to Madou, author of a three-volume work on microfabrication that includes a chapter on the problems that arise when handling tiny parts. “Suppose you have a very small part that you want to position somewhere on a substrate,” he said. “By coating this part with DNA strands, you’re basically giving it a ZIP code that will cause it to land on complementary strands placed on the substrate.”

According to Madou, one downside of this self-assembly scenario is that DNA travels via diffusion—a lengthy process. In a case like this, therefore, a better alternative might be guided assembly, another noncontact technique currently in the research stage. In a guided assembly process, a manufacturer would employ some force—such as electrical or magnetic—that guides parts to their proper destinations, Madou explained.

How could guided assembly improve on DNA-dependent self-assembly? One possibility described by Madou involves electrophoresis, the movement of charged particles in a fluid under the influence of an electric field. Electrophoresis, he said, can “get parts to the right places—and they’ll get there 10,000 times faster than they would by diffusion.” µ

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These watch components are examples of microparts affected by adhesive surface forces.

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