



# self-help

It's the mechanical sort, not the psychological, and engineers can really use it. By James G. Skakoon

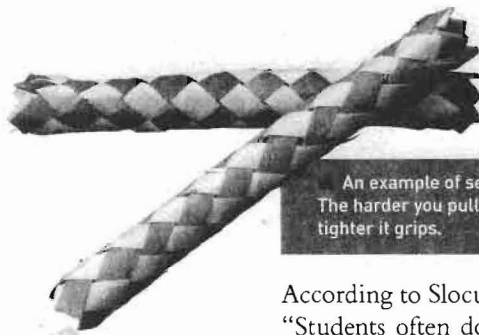
As a child you probably learned, to your astonishment, that you could carry two heavy pails of water, one on either side, more easily than one. Or you might have delighted in those Chinese finger traps that finger-cuffed you to a friend no matter how hard you pulled. These are familiar examples of the often unfamiliar design principle of self-help.

It's an odd name, self-help, for a principle of mechanical design. In popular psychology, self-help is all about solving personal problems without professional intervention. In mechanical design, it means letting the design deal with a problem from within, rather than intervening with more structure or force. Common examples that show the principle are as varied as scissors, broom holders, lift bridges, O-rings, building elevators, pressurized airliner doors, and knots.

Simply stated, self-help is using applied loads to improve performance. So adding more weight—the second water pail—eliminates the moment, and you can carry two with the same structure. And pulling alone creates the gripping force in the Chinese finger trap, so constricting it beforehand is unnecessary.

Alexander Slocum, a professor of mechanical engineering at the Massachusetts Institute of Technology and author of the text, *Precision Machine Design*, taught the principle to ME undergraduates in MIT's Manufacturing and Design I course.

According to Slocum, who led the class for fourteen years, "Students often don't believe that there is actually a real physical principle." Slocum said that self-principles, as he calls the various forms of self-help, are among the many useful guidelines to be applied right from the start in design, not at the end on some checklist.



An example of self-help. The harder you pull, the tighter it grips.

Counter-balancing with weights in lift bridges permits substantial reductions in motor power, and leaves the cable diameter unaffected, but it also increases tower load—usually a small price to pay.

“In the purest form, it’s one of Newton’s laws: action and reaction, right?” Slocum said. Nevertheless, he explained, “It’s like anything, I think, or most things, anyway. You’ve got to live it a while before you begin to appreciate how it really works.”

## How It Works

Before we live it, let me explain it some. You might be thinking, “I understand the pails, and I understand the finger trap, but I don’t connect the two.” Indeed, they work differently, but come together at a higher level: Performance can improve with action on and interaction between components, rather than remaining neutral or degrading. But how?

The forces in a structure or mechanism are used to great advantage when they:

- balance forces
- redirect forces
- create new forces
- redistribute loads.

Authors on self-help like to organize variations of the self-help principle into taxonomies. So for example, the counter-weights in lift bridges and elevators typify balancing self-help. Practically, however, categorizing is often unnecessary.

Asking the right question at the right time naturally suggests the principle of self-help, without regard for what type it is. Slocum believes that making a complicated taxonomy out of a simple, fundamental principle can often be confusing. “Academics love it, but students just glaze over,” he said. “Examples from the real world, I think, is how students really learn.”

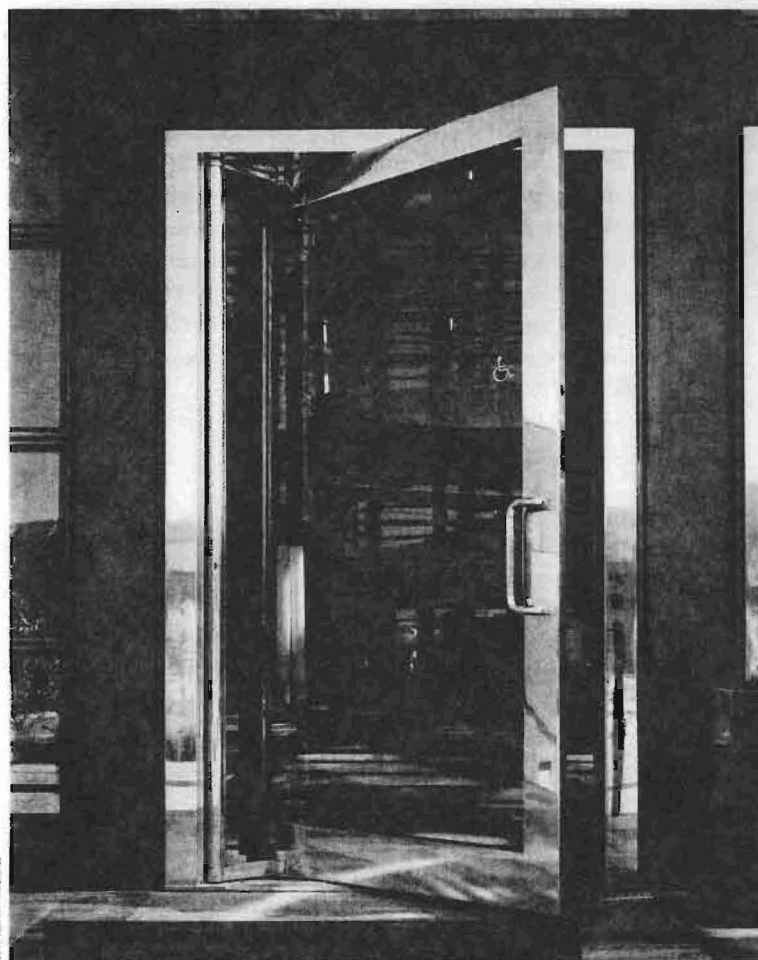
## On Balance

According to Mark Graves, vice president sales manager of Ellison Bronze Inc., his company’s founders developed an improved hinge for its doors in 1928 after seeing a woman struggle to open a door among the skyscrapers in wind-ridden Chicago. Inventor Edward H. Ellison may have thought: “Opening those big doors in a strong wind is impossible. Why can’t the wind help to open it?” He probably also noticed a strong wind blowing doors open, and holding them open as well.

“A year or so later, they came up with this hinging

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mechanism that moved the pivot point over,” Graves said. “With that pivot point moved over, roughly that portion of the door—if the wind pushes on that—is acting to help you.” Furthermore, according to Graves, “A lot of conventional doors will flutter due to the internal pressures and the wind.” Increasing the closing spring force is an obvious solution, but that also affects the effort to open it. With the balancing self-help of a balanced door, wind will neither open it nor hold it open, yet the door

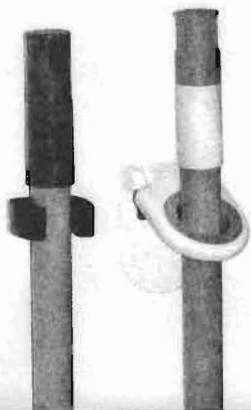


DAVID R. MOOG

Balanced doors have special, articulated hinges so wind doesn’t blow them open. Yet they open easily, and fully, when pulled or pushed.

is easily opened by pedestrians even in strong winds. “So the counterbalancing helps in both the opening and closing cycle,” Graves said. The hinge pins slide toward the jam as the door opens, opening the door fully.

Those spring clip-style broom holders work, until the broom is too heavy. An obvious solution is a stronger



Broom holders: spring-loaded (left) and self-helping.

spring, which adds the obvious problem of, well, a stronger spring. If you were designing a holder for bigger brooms, you could ask, "The broom is too heavy for a spring, so can I use the weight itself for more holding force? Then, the heavier the broom, the higher the holding force!" That thinking may have led someone to invent the jamming-style holder.

## Wind in the Sails

All modern ram-air parachutes have a device called a slider to retard deployment. Without some way to impede the opening, a ram-air's opening shock was unbearable. Ted Strong, a pioneer of the parachute industry, said, "There's been a couple of other ways of reefing a canopy—of slowing a canopy down—outside of the slider." But none worked as well, according to Strong, whose company, Strong Enterprises, has made military and civilian parachuting equipment since 1961. "However you packed it, you could jump it. The slider made that possible."

Someone probably asked, "The freefall wind opens these new parachutes too fast. Can the air flow itself



Self-help in a ram-air parachute—air speed both opens the parachute and holds it closed.



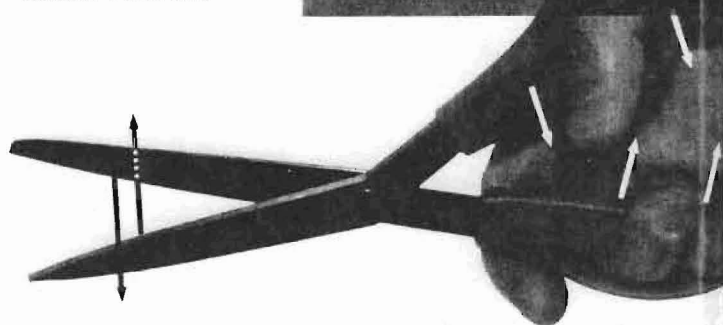
STRONG ENTERPRISES

retard the deployment?" The self-help answer is the wind-inflated slider, which rides on the suspension lines. At high speed, air flow inflates the slider and forces it to the base of the parachute, holding the parachute partially closed. The slider travels down the lines as the velocity and wind pressure decrease, until the parachute is fully open.

## Cut to the Chase

A left-handed colleague once educated me about self-help in scissors. I (right-handed) assumed left-handed scissors exist to fit the left hand. Not so. With hand action, a component vector normal to the blades forces the cutting edges together. Using wrong-handed scissors forces the edges apart, and the scissors won't cut.

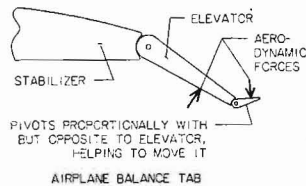
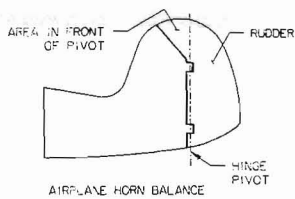
Normal action forces the cutting edges of a pair of scissors together—but only if it's correct-handed.



A design engineer noticing how the blades separate for some users might tighten the hinge play or curve the blades inward. But a good design engineer would also ask, "Is there a way that hand action can always force the blades' edges together?" From there one might conceive of left- and right-handed scissors, or even an improved pair of scissors that accentuates that action due to the grips' forms.

The examples so far balance, create, or redirect forces. A stacked leaf spring on a motor vehicle is self-help that redistributes forces. Downward deflection of the suspension brings more of the leaves into play, which stiffens the suspension for further deflection. When confronted with an overstressed single leaf spring, an inventor might have asked, "Can the load be distributed over more leaves with high loads, yet remain on fewer leaves with light loads?" Stiffness and strength can often improve rather than worsen with deflection, if you just give it some thought. Or think, for example, of Hertzian contact, which recruits ever more surface area with increasing load.

Self-help is an important feature of the control surfaces—rudders and elevators—on many airplanes. Balance weights on the opposite side of the pivot reduce the pilot's control column forces and eliminate flutter by changing the center of mass. But aerodynamic balances, such as a horn balance, counter the aerodynamic force on control surfaces and reduce control column force as well.



Aerodynamic balances on aircraft assist the pilot with control surface forces. The balance tab's long moment arm to the elevator hinge makes it effective.

One solution for pilots fatigued by high forces on the controls is the hydraulic or electrical assist in large modern aircraft, but an early aeronautical design engineer might have asked, "Why can't the air pressure itself assist the pilot?" It can, if the airflow hits surfaces on either side of the hinge, as in the horn balance. But that question could also lead to the balance tab, which is not nearly as obvious.

### A Knotty Problem

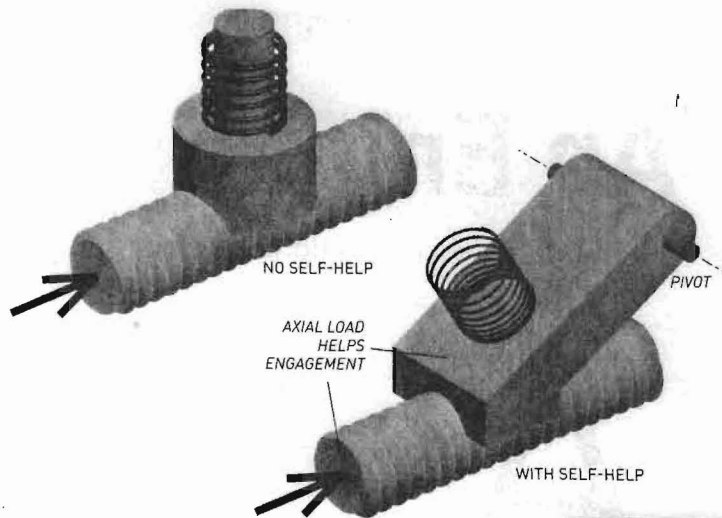
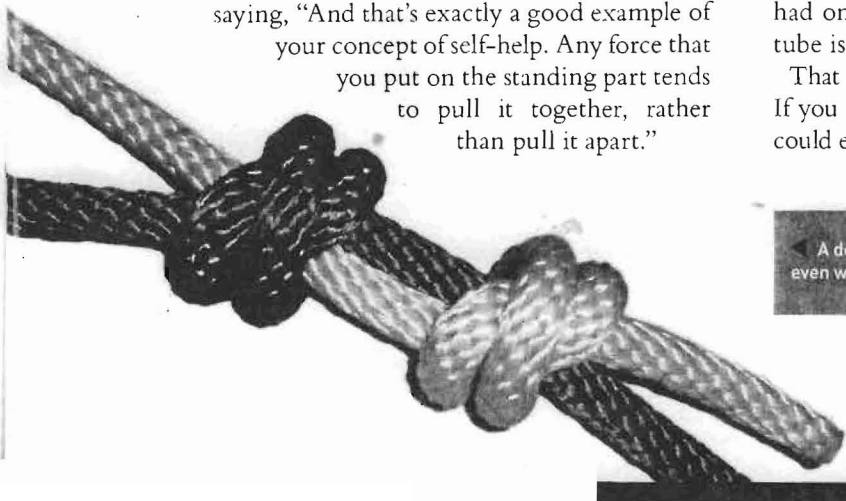
Knots in ropes hold from slipping principally because of self-help. According to the Web site AllAboutKnots.com, created by knot expert Richard Chisholm, an important effect of load on the rope is to press areas of contact together. This develops friction to resist slipping. Friction from self-help "keeps it together. Period. Doesn't 'help.' It's the only thing that does it," Chisholm said.

If you were designing a knot to tie to a post, for example, you would ask, "How can the applied loads create friction to secure the rope?" You might wrap the rope around the post multiple times for added friction, like a capstan or windlass, but you might also loop the rope over itself to clamp the wrap against the post.

But knot friction alone results only in security, or how well a knot holds with normal loads. Abnormal loads can lead to knot failure in an otherwise secure knot. This is knot stability. Pull on a bowline (or a sheet bend) the wrong way and it becomes unstable, tumbling or untying itself, and alarmingly so for a knot considered safe. Your next question should be: "Can abnormal loads tighten and stabilize the knot rather than loosen or tumble it?"

That question may have led an early angler to invent the double fisherman's knot. Chisholm writes on his Web site, "No matter how you tug at a double fisherman's knot, it does not easily deform." Chisholm, who learned about knots as a Boy Scout, Navy sailor, and ski patroller, acknowledged the self-help in this knot,

saying, "And that's exactly a good example of your concept of self-help. Any force that you put on the standing part tends to pull it together, rather than pull it apart."



▲ A half-nut for a lead screw drive can benefit from self-help.

### Getting Real

But most of today's designers don't design knots, lift bridges, airplane elevators, or scissors, and if they did, they'd already know how, right?

Right. So a real example from my experience is a half-nut for the lead screw drive of a medical syringe pump. Users decouple the half-nut from the lead-screw to quickly reset the drive. The bias spring proved too weak for the highest driven loads, and the half-nut decoupled on its own. The obvious solution was a stronger spring, but that increases decoupling effort and frictional torque, both of which are bad in a medical syringe pump.

Someone might have asked, "Can the driven load itself produce the coupling force?" That led to a jamming half-nut design with a line of action that forces the half-nut into the lead screw. This solves not only the decoupling problem, but reduces the frictional torque, now proportional to driven load, and the decoupling force, now only a return spring.

Here's another example, but in reverse, from a former colleague, Paul Lucas. He was connecting flexible tubing to the input port of an off-the-shelf PC board-mounted silicon pressure transducer. The port was a smooth metal tube, with no barb or enlargement. "Believe it or not," Lucas said, "the metal connection tube actually had a slight taper—you guessed it—in the anti-self-help direction." So even with a tubing clamp, the connection loosened with the slightest movement. If a design engineer had only asked, "Can the connection get tighter as the tube is pulled?"

That example also offers a different lesson in self-help. If you WANT something to fail, make it self-damaging. I could explain that, but by now you probably get the idea. ■

▲ A double fisherman's knot. This core-and-wrap style knot stays tied even with abnormal loads, which secure and stabilize it even more.