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This Issue's Features

Machine Design

Off-Road Industry Focus - Hydraulics Reference Guide - IFPE - CONEXPO - Kinematics - Tolerancing

FEATURES

Giving brains to off-highway brawn
GPS equipment and innovative power sources are at the top of Caterpillar's wish list.

Process Capable Tolerancing
Setting proper tolerances early in the design phase helps avoid headaches in production.

These mounts don't get the "point"
Replacing point contacts with line contacts boosts load capacity of kinematic mounts.

Predicting the life of hydraulic hose
A variety of service factors affect how long a hose assembly will last.

Servosystem deftly handles Airbus wings
With a span nearly as long as a football field at 261 ft, producing a single Airbus A380 wing involves precisely positioning a massive structure to drill, rivet, and bolt approximately 180,000 holes.

High-efficiency hydraulics quiets truck
An innovative hydraulic system lets refuse trucks operate at full power while the engine remains at idle, greatly reducing the noise associated with municipal waste-collection.

Valve separates power from control
Anew directionalcontrol solenoid valve from Eaton Hydraulics, Eden Prairie, Minn., is said to facilitate distributed control of hydraulic systems. It takes advantage of contemporary wiring practices to meet automotive-manufacturing specifications.

Sizing bolts for flexible brackets
In this last of three parts dealing with bolted joints, David Dearth, a consulting stress analyst and president of Applied Analysis & Technology, Huntington Beach, Calif., shows how flexible brackets deform when loaded.

Five secrets to avoiding workplace interruptions
If your workdays are shorter than your to-do lists, you're in good company.

Runn'in light and cool
Russia-based Ural, an off-road truck maker, recently began out fitting 4 4, 6 6, and 8 8 trucks with lightweight copper-brass radiators.

Antireflective acrylic guides the way
GPS's from Garmin International Inc., Olathe, Kans., are popular items in mapping systems for cars, boats, and aircraft.

Tin foils RFID thieves
The person sitting nearby with a laptop computer may be gathering personal info about you that would let them steal your car or buy gasoline on your credit card.

Switches and the NEC
Most wiring in buildings is installed and maintained by electricians rather than by engineers.

EDITORIAL COMMENT

Stop salting the roads
I've never forgotten a conversation I once had with a lady about winter driving.

BEHIND THE WHEEL

2005 Lincoln Navigator
Big and luxurious are the two words that come to mind when describing Lincoln's mammoth SUV. It is powered by a 5.4-liter, three-valve engine that develops 300 hp and 355 lb-ft of torque.

SOFTWARE REVIEW

Software generates top-notch surfaces and more
Icem Surf software is well suited to designing Class-A surfaces, those that consumers see and feel on products, and could influence buying decisions.

APPLICATION BRIEFS

They walk like men
Simple toys inspire researchers to devise bipedal robots that mimic the human gait.

Construction equipment and fluid power take center stage
IFPE 2005, the International Exposition for Power Transmission, is this year's premier event devoted to hydraulic,

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They walk like men

Simple toys inspire researchers to devise bipedal robots that mimic the human gait.

Researchers at Cornell University, the Massachusetts Institute of Technology (MIT), and Holland's Delft University of Technology have built robots that mimic the human gait — and the Cornell robot matches human efficiency. The researchers' inspiration: simple walking toys that fascinated children in the 19th century.

"Already our robot seems to be at least 10 times more efficient than anybody else's," says Andy Ruina, Cornell professor of theoretical and applied mechanics. The Cornell robot consumes an amount of energy per unit weight and distance comparable to a human walker. In contrast, Cornell researchers estimate the Honda Asimo uses at least 10 times as much energy as a human. The reason: Asimo is based on the mainstream control paradigm, precise joint-angle control. This scheme demands actuators with high precision and a frequency response exceeding that of human muscles. It actively controls every joint angle at all times.

The MIT and Delft robots, though not built deliberately to be energy efficient, also use much less energy than the Asimo. More important, the researchers say, is that their robots provide a more realistic model of how humans walk.

Ruina, his former student Steven Collins, MIT postdoctoral researcher Russ Tedrake, and Delft postdoctoral researcher Martijn Wisse recently described their new robots in the journal *Science* (Feb. 18, 2005) and at the annual meeting of the American Association for the Advancement of Science in Washington, D.C.

Cornell's robot rivals human efficiency, Ruina explains, because it uses energy only to push off, while other robots needlessly use energy to absorb work; for example, in moving the limbs forward more slowly than they would naturally swing under gravity power. "In other robots, the motors are fighting themselves," he says.

Researchers at each of the three universities have built walking robots, differing slightly but based on the same principle. They are an extension of several years of research into "passive-dynamic walkers" that walk down a shallow slope, very much like simple walking toys that have been around since the 1800s and developed more scientifically starting in 1988. These downhill walkers were developed further in Ruina's lab, leading to a two-legged version with articulated knees built by Wisse during a visit to Cornell.

For current robot studies, the researchers simply substituted small motors for gravity power. Ruina says the research followed the example of the Wright Brothers, who carefully researched gliders, then simply added a motor to achieve powered flight.

The robot work was done primarily to study the biomechanics of human locomotion, but it could have applications in practical robotics. Collins, now at the University of Michigan, already is applying some of what he has learned to the design of a powered prosthetic foot for amputees. "It's not exactly the same thing, but certainly the mode of thought comes from thinking about robots," he says. Information gained from studying walking robots should be of use to the rehabilitation community, he adds.

The researchers note that gravitypowered walkers have been considered irrelevant to human walking by some

From left to right: Delft, MIT, and Cornell walking robots. The Cornell biped weighs about 13 kg and dissipates roughly 11 W total. To

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because humans don't always walk downhill, but that these new machines demonstrate that there is nothing special about gravity as a power source.

and robots of different sizes, researchers used a dimensionless specific cost of transport, *ct* = (energy used)/(weight distance traveled).

Gravity-powered walking toys walk downhill by swaying from side to side, allowing first one foot and then the other to swing forward. Human beings minimize the swaying and bend their knees to allow the moving foot to clear the ground, and two of the three new robots do the same. All three robots have arms synchronized to swing with the opposite leg for balance.

The Cornell robot supplies power to the ankles to push off. When the forward foot hits the ground, a simple microchip controller tells the rear foot to push off. During the forward swing of each leg a small motor stretches a spring, which is finally released to provide the push.

The Delft robot uses a pneumatic push at the hip, and the MIT robot uses electric motors that directly move the ankle. Control programs in the Cornell and Delft robots are extremely simple, while the MIT robot uses a learning program that lets the robot teach itself to walk, which it can do in about 600 steps.

The fact these robots can walk with a humanlike gait with simple control programs "suggests that steady-state human walking might require only simple control as well," the researchers say. "The success of human mimicry demonstrated here ... strongly suggests an intimate relationship between body architecture and control in human walking."

Make Contact:
Andy Ruina's research page:
www.tam.cornell.edu/Ruina.html#research
Video and other supporting materials:
www.aaas.org/news/releases/2005/0217robot.shtml

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