American MACHINIST

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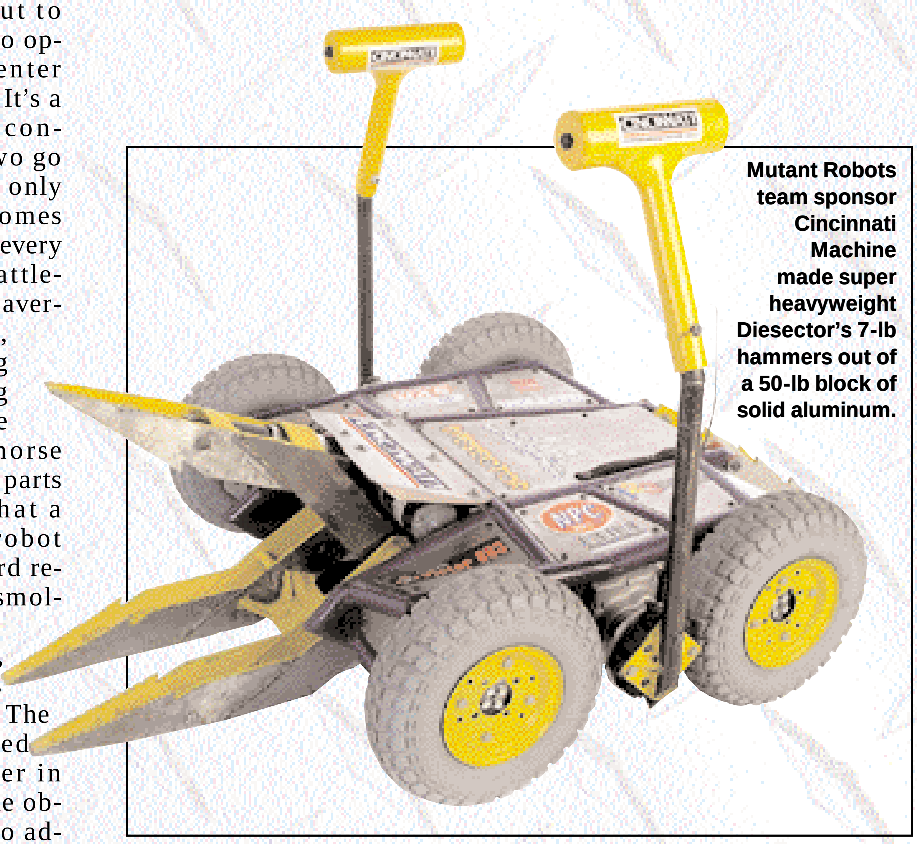
Ready to rumble

Designers, engineers, and manufacturers build the perfect fighting machines.

A deadly competition is about to begin as two opponents enter the ring. It's a simple concept: two go in and only one comes out. That's what happens every week on a show called BattleBots, where techno-geeks, average Joes, industrious kids, and even some machining folk duke it out using robots. But these aren't the average industrial workhorse robots that weld or handle parts on a machining line. What a BattleBot does is inflict robot carnage, with an eye toward reducing its opponent to a smoldering wreck of metal.

For the uninitiated, BattleBots is on cable TV's Comedy Central network. The show pits radio-controlled robots against each other in three-minute bouts, and the object of the competition is to ad-



Mutant Robots team sponsor Cincinnati Machine made super heavyweight Diesector's 7-lb hammers out of a 50-lb block of solid aluminum.

Daniel Longmire, BattleBots Inc.

BY PATRICIA L. SMITH • MANAGING EDITOR

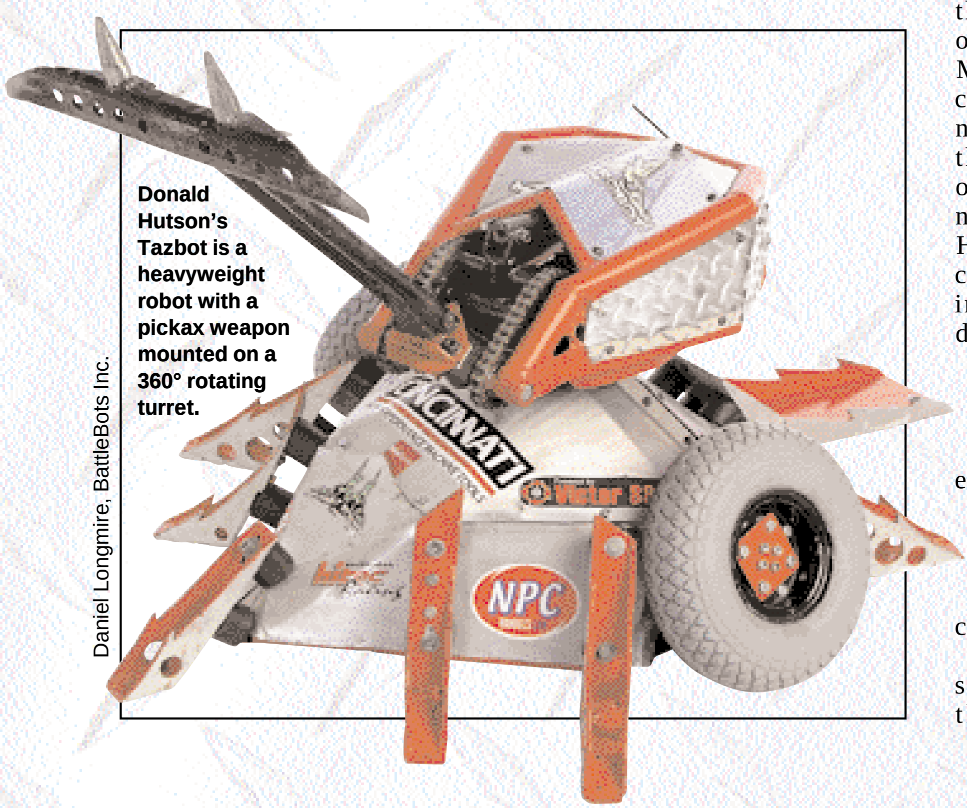
minister as much damage as possible. Robots can use weapons such as hammers, pickaxes, rotary saws, and lifting arms to beat, stab, slice and dice, or flip their opponents into submission. The robots compete in four weight categories: super heavyweight, heavyweight, middleweight, and lightweight.

All fights take place in the "BattleBox," a 48-ft^2 ring that brandishes such destructive hazards as kill saws that pop up unexpectedly from the floor and heavy hammers that pulverize any robots wimpy enough to be pushed into the corners of the ring.

The show, which has a legion of fans, has drawn in competitors from a number of disciplines and industries — the metalworking field included. Among the participants are a machine tool builder, a CAD/CAM software developer, a machine shop, and several mechanical engineers.

Team Mutant Robots: Tazbot and Diesector

Two BattleBot champions are Tazbot and Diesector, built by Donald Hutson, a mechanical engineer who works in the Machine Psychology lab for the Neurosciences Institute near San Diego. Tazbot, a heavyweight, is a wheeled robot with a pickax weapon mounted on a 360° rotating turret. It has aluminum diamond plate armor mounted to its main body by rubber shock absorbers. Diesector, a super heavyweight, is a wheeled robot that can drive on both sides, an important defense against an opponent that attacks by flipping its competitors. The robot has a chrome-alloy tubular frame that acts as an exoskeleton. Between the tubes are $^1/_8$-in.-thick Grade 5 titanium panels. Diesector's weapons are two hammers that can rotate 360° and 40-lb front jaws that can bite down on the competition.



Donald Hutson's Tazbot is a heavyweight robot with a pickax weapon mounted on a 360° rotating turret.

Daniel Longmire, BattleBots Inc.

The design of both robots is fairly complex. Hutson says the turret mechanism on Tazbot was challenging, while Diesector's ability to drive both right side up and upside down while having its weapons work was equally difficult. In fact, the layout of the jaws on Diesector, says Hutson, was particularly tough. Two 1,000-lb linear actuators control and support the Bot's hardened-steel jaws that open up to 43 in. and overbite themselves by 14 in. Fortunately, CAD software — in this case SolidWorks — helped in the design phase.

But however sophisticated his design tools, Hutson's machining resources were fairly primitive by most machine shop standards. He fashioned the jaws on the front of Diesector, for instance, using a bandsaw and a MIG welder. The jaws did what they needed to do, but Hutson says that his machining capabilities often limited his designs.

That recently changed, though, with the entrance of a new sponsor for his Mutant Robots team: Cincinnati Machine, Cincinnati. "It's almost scary — the possibilities that have opened up with Cincinnati's capabilities," says Hutson. "It has really changed my way of thinking, because, you tend to design based on what capabilities you have. Now, I'm starting to see where I can make some pretty neat changes and enhance the robots in many ways by having CNC-machined parts made to exact tolerances out of solid chrome alloy or titanium."

The first test of his new sponsor was a redesign of the hammer weapon on

Changing the image of manufacturing

One unforeseen benefit of the BattleBots competition is that it has raised the profile of the manufacturing and engineering professions, giving them a shot of sexy robot appeal.

Part of the reason why, says Charles Habermann, is that the competitions are a fun, but practical application of mathematics, robotics, mechanical engineering, and electrical engineering. "You have to know a lot of different disciplines to manufacture a BattleBot," he states.

Donald Hutson agrees, adding that the competition incorporates engineering skills, and actually battle-tests them, a sure hook for the mechanically minded. "I get e-mails from kids all the time," he says, "and they ask what software I'm using, what kind of titanium, and how they can machine it. They want to know how I built my robots and how they can build one themselves."

Patrick Campbell has also witnessed this excitement. "It's great, seeing 16-year-old kids interested in learning about machining, welding, and all the related things you need to know to build a BattleBot. I think it's a better way of spending your time than playing video games. You're forced to build something with your hands, and with that goes a lot of learning and appreciation for the guys that do it everyday."

The competition has even changed how some adults view machining. Just ask Hutson, who had to learn how to machine parts to build his BattleBots. "Design and manufacturing are two different entities," he comments. "You can come up with the greatest ideas in the world, but you still have to figure out how to machine those parts. And generally, engineers work on one side — where they are doing this crazy design — and then the machinists are saying 'This is impossible; you can't make this piece. Why don't you do it this way?' There's always been this battle back and forth, and I think it's great to blend the lines between the two."

Diesector. Originally, the robot had two pickaxes, but Hutson scrapped that design soon after winning the super heavyweight championship. "I barely won the final fight," he recalls. "I'm winning and all of a sudden, my weapon got stuck in the floor." If it hadn't been for his competitor's "help" — basically it cut through Diesector's arm during the fight — Diesector would not have been able to free itself.

"That's the product evolution; you come back and fix the things that are broken," says Hutson. So, when Hutson redesigned Diesector, he decided to use hammers rather than pickaxes. And this is where Cincinnati stepped in.

"Donald wanted a beefy hammer that could do some damage to his opponents," recalls Kevin V.G. Bevan, vice president and general manager of Cincinnati's Value Machine Business. The weight of the 12-in.-long hammers, however, was critical. To keep Diesector under the weight limit, they couldn't weigh more than 7 lb each. And one other complication was that Cincinnati had to produce the hammers in just a couple of weeks.

As soon as Cincinnati received the IGES file from Hutson, it had some of its applications engineers take a look at the design. One of the first recommendations they made was to hollow out the hammers to reduce their weight as solids, which was approximately 15 lb. "That was a great idea," says Hutson. Once the weight problem was solved, Cincinnati went to work.

The company machined the hammers out of a 50-lb block of solid aluminum using one of its 5-axis Arrow 1250 VMCs. "The billet was whittled down until it had the profile of the hammer," comments Bevan. "Then we took it into some manual operations where our guys bored out the center of the hammers, machined the endcaps, and welded them on. Next, they drilled and inserted the carbide-tipped inserts on the ends of the hammer."

When Cincinnati finished the parts, it flew them out to Hutson at the BattleBots competition. "The day I was supposed to fight, I cut off the old ones and bolted on the new ones," remarks Hutson.

According to Bevan, sponsoring Hutson's team has been more than just a way to get the Cincinnati name in front of a technically based audience. "It's been good from a morale standpoint. Our employees work hard on a daily basis, but they don't see the machines other than when they leave the facility. Here, they can see the parts they've made on Comedy Central along with about 2 million other people. And with our capability, we can help Donald improve his performance in the combat arena."

Cincinnati and Hutson are already discussing other parts the builder can machine, including rims and hubs for Tazbot and the wheels and jaws for Diesector.

Frenzy

A veteran in the heavyweight category, Frenzy is a round robot made out of CNC machined 6061-T6 aircraft aluminum. It has a titanium battle ax that not only delivers a deadly blow but also rights the robot if a competitor flips it over.

Frenzy's designer is Patrick Campbell, a mechanical design engineer who works for Pace Technologies of Sun Valley, Calif. The company makes underwater camera and lighting equipment for Hollywood. His day job has him doing everything from design to manufacture, which has come in handy for building his BattleBot.

Campbell built a prototype of Frenzy in 1996, and the following year, he redesigned the robot using Surfcam CAD/CAM software from Surfware, Westlake Village, Calif. "I learned Surfcam by building Frenzy," he remembers. "I wasn't using it at work, but I was watching over the shoulder of the guy who was doing it."

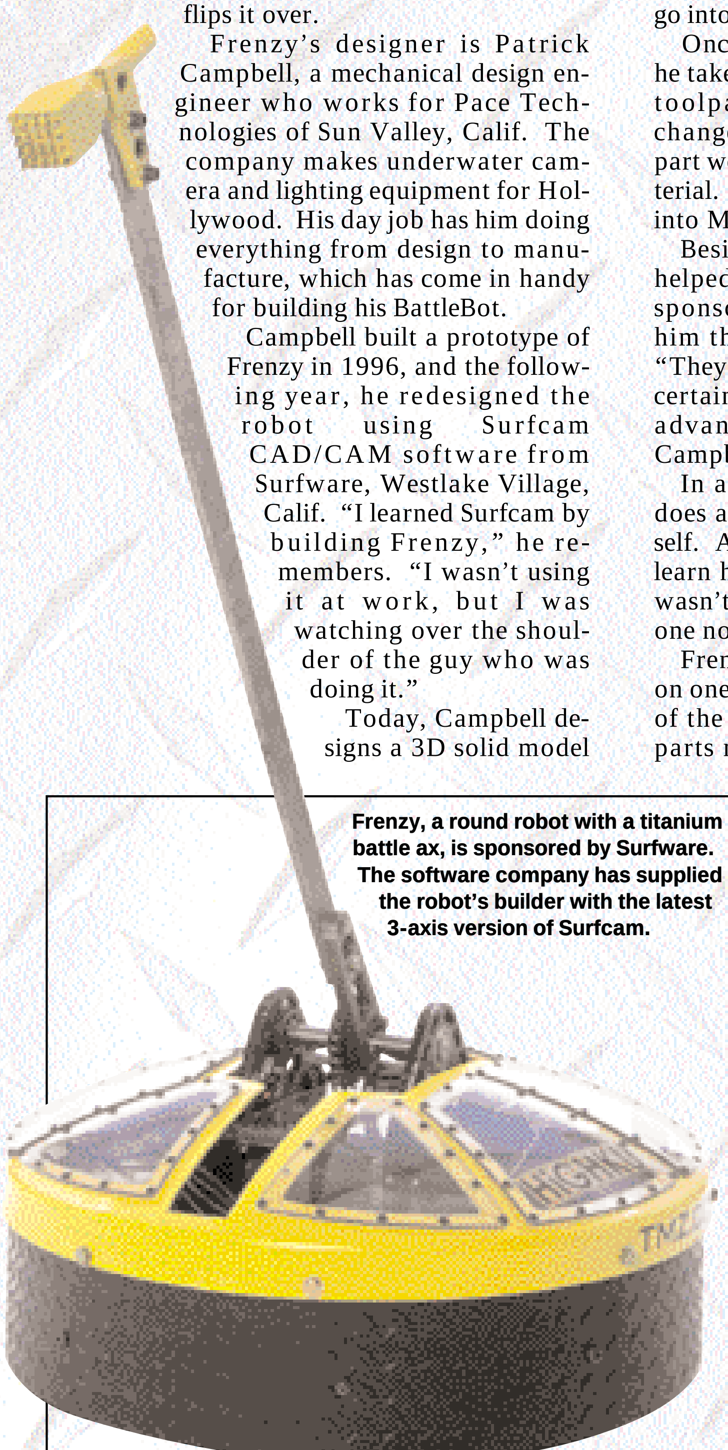
Today, Campbell designs a 3D solid model using Mechanical Desktop and processes the file with Surfcam. "Frenzy is completely modeled right now," he says. "The whole thing about building a BattleBot is that you're always changing it, always making something better or doing something different. So the neat thing is that I can go into the computer model and make changes."

Once Campbell has a design he's happy with, he takes it into Surfcam and starts programming toolpaths. Occasionally, he makes design changes in the program, things like reducing part weight by adding cutouts and removing material. He then takes the Surfcam drawing back into Mechanical Desktop and updates his files.

Besides improving his robot, Surfcam also helped him in another way. Surfware is now sponsoring Campbell's robots and has given him the latest 3-axis version of its software. "They've also offered to get me up to speed on certain things, and I definitely plan on taking advantage of some programming lessons," Campbell says.

In addition to designing Frenzy, Campbell does almost all the machining on the Bot himself. And just as he learned Surfcam, he had to learn how to use a vertical milling machine. "I wasn't a machinist before," he says, "but I am one now."

Frenzy is comprised of components straight on one edge and contoured to follow the outside of the robot on the other. These complicated parts make it difficult to chuck and reference when adding new features.



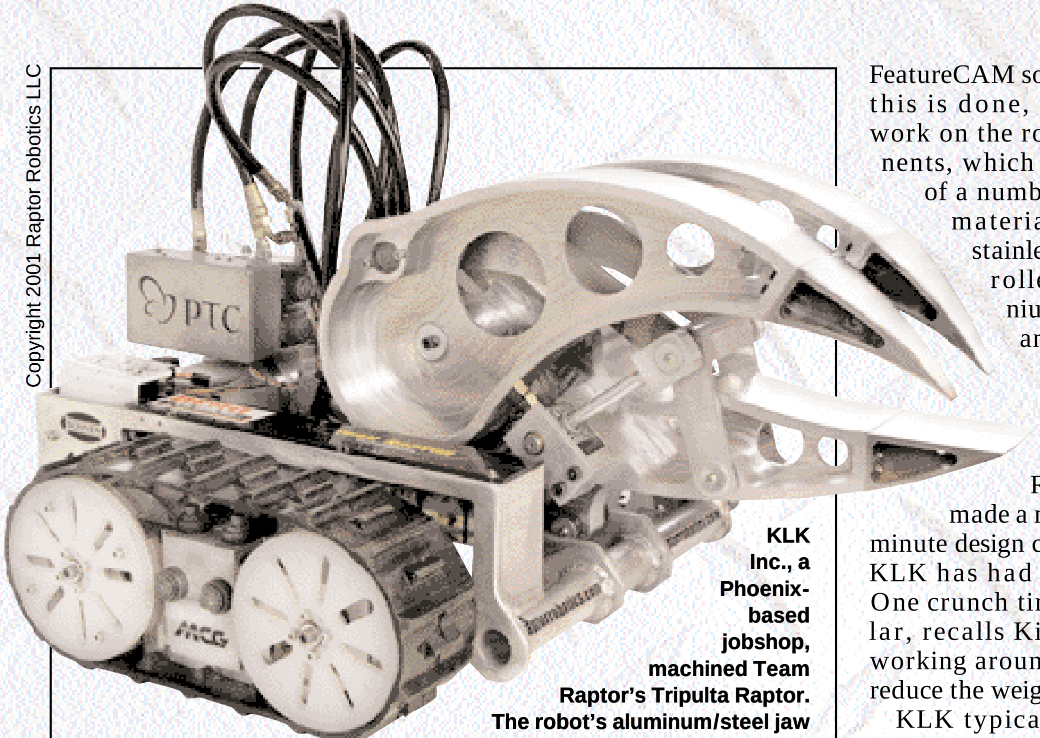
Frenzy, a round robot with a titanium battle ax, is sponsored by Surfware. The software company has supplied the robot's builder with the latest 3-axis version of Surfcam.

Tripulta Raptor

Tripulta Raptor is one of the robots in Team Raptor's stable of BattleBots. The robot, designed by Robert Pitzer, is a wheeled robot with an aluminum chassis and a hydraulic "squishing" aluminum/steel jaw and raptor-like claw.

All component machining is done by Team Raptor's sponsor, KLK Inc., a Phoenix-based jobshop serving the computer and electronics industries. The company has a reputation for completing difficult jobs in tight timeframes and is skilled in working with a range of materials, including stainless steel, aluminum, and high-tech plastics.

KLK has about 13 different CNC machining centers and another half dozen turning centers.



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KLK Inc., a Phoenix-based jobshop, machined Team Raptor's Tripulta Raptor. The robot's aluminum/steel jaw was the most difficult machining challenge, according to KLK Vice President and General Manager Kim Wilkinson.

The company also has a plastic-fabrication department, a sheetmetal area, and a welding department. And because it serves the electronics industry, it also has a Class 100 cleanroom for full turnkey assemblies and packaging.

The shop got involved with BattleBots through a relationship between Pitzer and KLK's father-and-son team of Kim and James Wilkinson. Kim is KLK's vice president and general manager, and James is the shop foreman.

When Pitzer approached KLK about building his robots, the Wilkinsons saw the opportunity as both an engineering challenge and just a fun way of using their machining expertise.

Pitzer brings KLK a Pro/Engineering CAD file, which the shop changes into a .dxf file for transfer into its computer system. It then creates toolpaths for its milling and turning centers with Engineering Geometry Systems' FeatureCAM software. When this is done, KLK goes to work on the robotic components, which are made out of a number of different materials, including stainless steels, cold-rolled steel, titanium, aluminum, and plastics.

Just as with the other robotic teams, Team Raptor has made a number of last-minute design changes, which KLK has had to deal with. One crunch time in particular, recalls Kim, had them working around the clock to reduce the weight on a robot.

KLK typically computes the weight of each robotic component with Pro/E software. "But, with this robot, what we didn't have was the weight of the batteries and the hydraulic lines," says Kim. About 4 a.m., they finished assembling the robot, weighed it, and found it was 16 lb too heavy to make the weight class.

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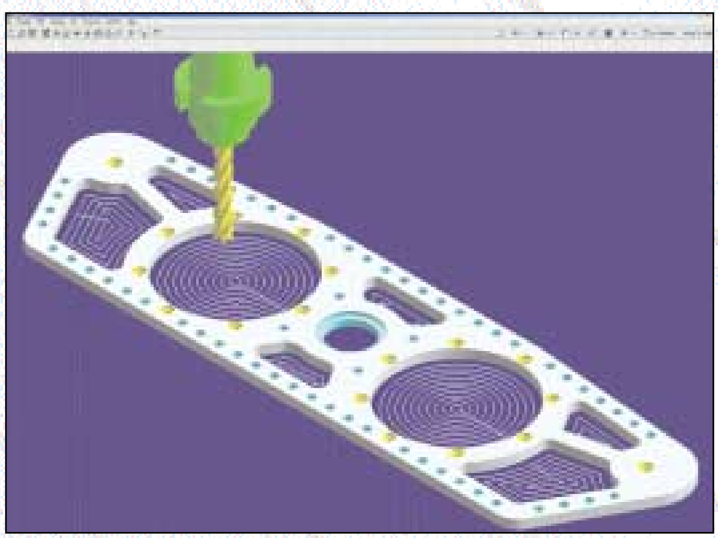

Patrick Campbell not only uses Surfcam CAD/CAM software in the design phase, but he also uses it to program toolpaths on individual components.

Image courtesy of Team Minus Zero (tmz.com)

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"So we're tearing it down, thinning out walls, webbing things, and drilling holes through it just to knock the weight out of it," laughs Kim. "It had to be on the road about 9 a.m., and, amazingly, it was."

One of the more challenging parts KLK has tackled was the three front claws on the Tripulta Raptor. These aluminum claws are approximately 4-in. thick and have hardened steel tips.

According to James, each claw was done in two setups on a 3-axis machining center. "We did one half, and then flipped it over and did the backside," he explains. And because of weight limitations, KLK had to pocket out an enormous amount of material. "We started with a 125-lb block and finished with a 10-lb part," says Kim. "That's a lot of chips."

Daniel Longmire, BattleBots Inc.

Snipe is a lightweight robot made out of mostly composite material. Creator Charles Habermann cut many of Snipe's parts on a 5-axis, 55,000-psi waterjet cutting system.

Snipe

Rookie robot Snipe was built by Charles Habermann, CAD/CAM/CAE specialist at PaR Systems Inc., Shoreview, Minn., a company that manufactures 5-axis robotic gantry systems for the aerospace, marine, and nuclear industries. The BattleBot, Habermann's first, competes in the 59-lb lightweight category.

"There are four different weight classifications in BattleBots, and as a designer, you have to choose which weight category you want to compete in," he comments. "Assuming you have read the regulations, the rules are pretty simple: build what you want, make weight, and bludgeon your opponent to death — as safely as possible."

His first step in building Snipe was selecting a motor and battery. "I used a 12-V motor that weighed 13 lb and a nickel-metal-hydride battery that was 19 lb." That, however, didn't leave him much weight for the chassis, weapon, drive system, and controller.

To overcome this difficulty, he constructed the robot out of mostly composite material, more specifically Hexcel aircraft flooring. He used some aluminum in critical areas, such as the drive train and motor mounts, and to make the robot's weapon, an 8-lb arm that rotates at 1,500 rpm.

Although Snipe didn't do too well in its first fight — it flipped itself over after only 2 min in the ring — Habermann hasn't given up on the competition or the methods he used to design and build the BattleBot. "I had an inherent flaw in my design, which was a high center of gravity and a narrow track width for the significant rotational inertia," he says. "And I'm certain I'll have another flaw in my new design, Tempest. That's just the trials and tribulations of building a BattleBot. But that doesn't change the fact that we used some pretty remarkable tools to manufacture Snipe."

Habermann designed Snipe with Surfcam's 5-axis toolpath generator and surface modeler. Once he had a design he liked, he built a model out of 1/2-in. OSB. "This let me check fit and finish rather than use exstensive aircraft flooring, which can be expensive," he says.

After he was satisfied with the design, he cut individual components out of the aircraft flooring with one of his company's 55,000-psi waterjet systems — a PaR-built 5-axis waterjet with an Ingersoll-Rand intensifier. Cutting the parts involved some tricky work for Habermann. "In the waterjet process, there are issues in regard to the kerf, taper, and taildrag," he explains. These issues were magnified because the composite he was using had fiberglass skin on the top and bottom that sandwiched a 0.400-in. Nomex core. "The jet wants to fan out in between the two outside layers. This presents a design challenge because the entry is clean, but the exit is not. In fact, it's sort of serrated. You have to take that into consideration when you're designing your components." AM

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