Behind every great race car is a computer-aided design, engineering, and manufacturing team

DESIGN DRIVEN

BY DAVID COHN

Photo courtesy David Cohn.

America has had a long love affair with cars, especially fast cars. In fact, auto racing now ranks among our biggest spectator sports. Attendance at NASCAR (National Association of Stock Car Auto Racing) events essentially doubled during the last decade, and the Formula One-style style CART (Championship Auto Racing Teams) races are now watched by more than 60 million viewers. Race fans know that these two popular forms of racing are worlds apart in terms of automotive technology. But what's not so obvious is that both are now being driven by computer design, engineering, and manufacturing tools. Indeed, what race teams are discovering is that even the smallest engine or body enhancements made to virtual models translate into huge advantages on the track.

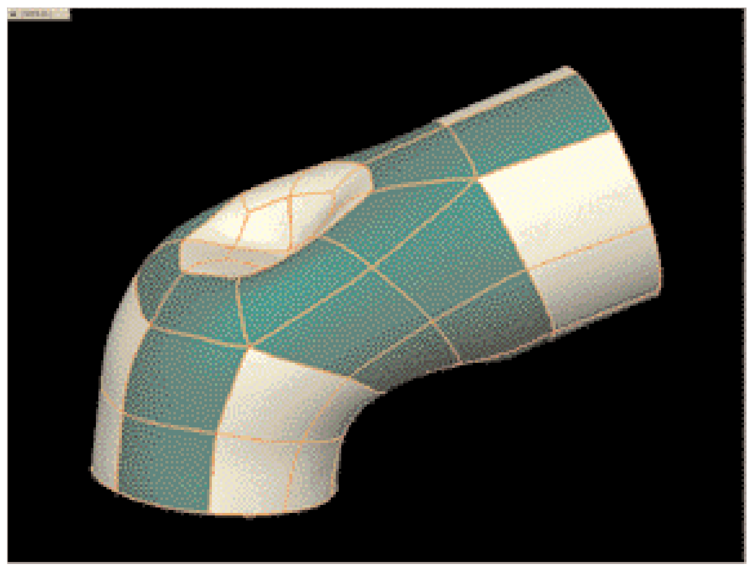
Designer Engines

NASCAR's Winston Cup Series, the most popular form of auto racing in the US, features cars that look very much like those you see on the street, from familiar companies like Chevrolet, Dodge, and Ford. In fact, in its early years—NASCAR dates back to 1948—the cars were exactly the same production models that anyone could buy. Today's cars still resemble street cars in the shape of their bodies, but they are hand-formed from sheet metal over a metal space frame and riveted together to meet NASCAR's strict aerodynamic shape specifications.

While creating stock car bodies is an art form in itself, the primary challenge in designing NASCAR vehicles is to coax as much horsepower out of the engines as possible. The "stock" V8 engines, although limited to 358 cubic inches in displacement, can be modified to produce up to 750 horsepower, enabling the cars to reach speeds of over 200 mph on the banked oval race tracks. NASCAR specifies that the cars must use four-barrel carburetors and four-speed transmissions. On some tracks, for safety purposes, NASCAR also requires the addition of a restrictor plate between the carburetor and intake manifold to reduce engine power to 420 horsepower and speeds to 200 mph. To meet these design challenges, NASCAR teams are starting to rely heavily on CAD/CAM/CAE technology.

One such team is Richard Childress Racing (RCR) in Welcome, North Carolina, home to the late Dale Earnhardt, seven-time Winston Cup champion. One area that RCR engineers concentrate on is cylinder head ports, which allow air and fuel to travel through the cylinders. Improving the efficiency of that flow delivers more of the fuel-air mixture to the cylinders and increases horsepower. "The cylinder head port is the heartbeat of the engine," says Greg Jones, design engineer at RCR. "It is pivotal to the success of the car and one of the most guarded secrets in an engine department."

In its search for better performance, RCR may go through six cylinder head designs in six months. In the past, craftsmen would hand-grind each head. "It would take a total of two weeks to complete a pair of heads," Jones says, certainly not acceptable with NASCAR's extremely full racing schedule. RCR now completes the same task in 12 hours, thanks to digital duplication software from Raindrop Geomagic and NC software from PTC. RCR engineers still begin by hand grinding a cylinder head, and then put it onto a flow bench to measure its flow characteristics. But once a good design is determined, it is captured in the computer so that copies of the cylinder head can be manufactured for use on the team's cars. The engineers digitize the head using coordinate measuring machines and import the digitized data into Geomagic Studio. They then use

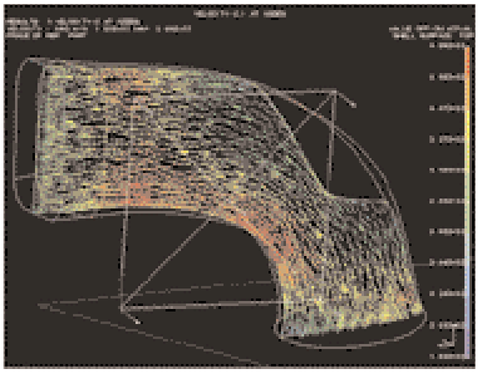


Richard Childress Racing uses software from Raindrop Geomagic to convert scan data to NURBS models, greatly accelerating the manufacture of key race engine components such as this cylinder head port.

the Geomagic software to convert the captured data into a polygonal model, then to a NURBS model, and finally export it into a watertight surface that can be manufactured to within 0.0001 inch of the original. Designers then use PTC's Pro/Engineer to complete the design process and develop a CNC program for manufacturing the cylinder heads on an Okuma CNC machine.

Another major user of computerized manufacturing technology, perhaps the biggest in the world of NASCAR racing, is Hendrick Motorsports of Harrisburg, North Carolina, home of driver Jeff Gordon. The company employs some 80 people in its engine program, which produces more than 700 engines per year. Hendrick is unusual among NASCAR teams in that in addition to its own cars, it also builds and leases engines to other teams and does developmental work for General Motors.

In the 1990s, Hendrick purchased a 5-axis machining center and seats of CADkey from CADkey Corp., SmartCAM from PointControl,



Hendrick Motorsports employs SDRC's computational fluid dynamics tools to perform flow analyses on engine intake manifold ports.

and Camand from Camax. "We were going to target some specific components that could help us from a performance and a business standpoint," says engineering group manager Jim Wall. "The primary justification for purchasing the machining center was machine work on piston tops and cylinder blocks, and porting work on cylinder heads and intake manifolds."

The SmartCAM software reduced the 17 setups and 60 hours of machining and setup time required on each cylinder block to two setups and eight hours of machining and setup time. Camand eliminated 80 percent of the production time to manufacture cylinder heads and reduced the cost from $20,000 to just $6000 per pair. The gains in consistency were so significant that current inspection technologies could not measure differences among engine components. In addition, completed engines measured within 1 percent of each other for horsepower and torque consistency.

PointControl eventually merged with Camax, which was later purchased by SDRC. Wall says he shifted to SDRC I-deas because "we needed to get more realistic physical models that would give us physical properties of parts and to be able to use analytical tools to check the integrity of a design prior to producing the component." He also needed software that would support concurrent engineering to help manage multiple revisions throughout a large design team, and to be able to design in the context of an assembly.

Today, Wall uses a complete suite of SDRC software, including Imageware, for advanced surfacing and reverse engineering. "We have 99 percent of our engine in I-deas at the component level," says Wall. "We can use their CFD tools to analyze flow and then use FEA for stress analysis and checking structural integrity," he says. "And then once we're satisfied that the design meets our criteria, we generate machine tool setups to produce the parts in-house." The machine shop now includes eight HAAS CNC machining centers, two digital coordinate measuring machines, and four dynamometer cells, which each measure more than 60 critical engine parameters. Since 1995, Hendrick engines have won a third of all NASCAR races.

Bodies in Motion

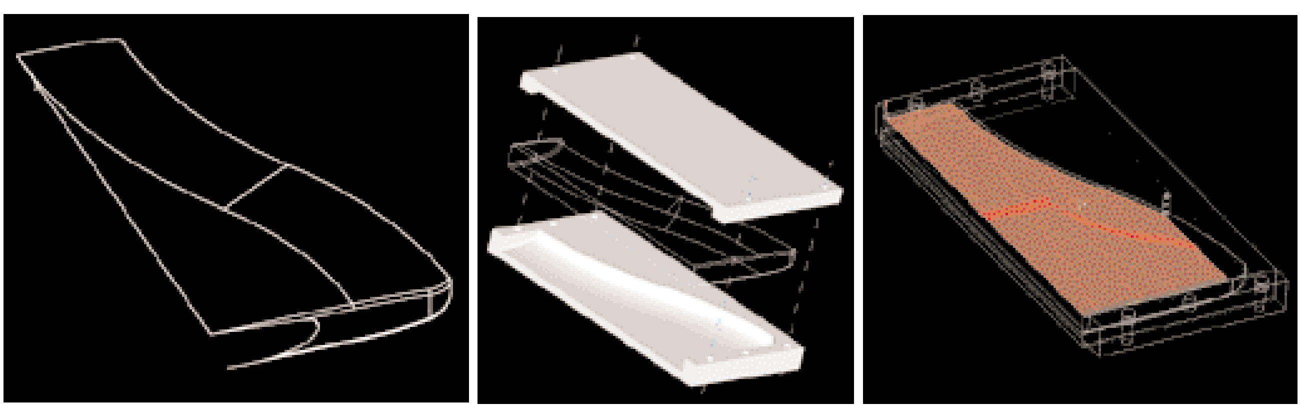
A CART race car bears more resemblance to a jet plane than to an automobile, which isn't surprising, considering that at race speeds of up to 245 mph, proper aerodynamic design is essential just to keep a car on the track. Constructed of honeycomb composite carbon fiber, the cars measure 199 inches long, 36 inches high, and 78.5 inches wide, with a 124-inch wheelbase. Each car weighs only 1550 pounds (compared to more than 3000 pounds for a typical passenger car), carries 35 gallons of methanol, gets 1.85 miles per gallon, and costs around $500,000 (not including the engine). The engines, 2.65-liter turbo-charged V-8s, rev to about 15,000 rpm and produce approximately 900 horsepower. Each of the 18 CART race teams purchase finished chassis from Lola or Reynard and lease engines from Ford-Cosworth, Honda, or Toyota. While the chassis as delivered is theoretically ready to race, it's really just a starting point.

Team Rahal, based in Hilliard, Ohio, makes about 200 changes to its stock Lola chassis each year. The company's engineers use a suite of products from PTC, including Pro/Engineer for design, Pro/Mechanica for optimization, and Pro/Manufacturing for manufacturing key race car components. Most of the bodywork comprises complex surfaces. In the past, creating the necessary molds was a four-step process, requiring designers to first create a prototype part. Then they finish the part, lay-up a mold based on it, and perform finishing processes on the mold. With PTC software, that process has been reduced to two steps: designing the mold and manufacturing it.

Bryan Holzinger, design engineer for Team Rahal, estimates that PTC's suite of products allows his team to save half the time required to design and manufacture molds for the cars' front wing end plates. It also enables them to make the molds more accurately using the NC code generated by Pro/Manufacturing. "PTC's software helps our team get more components designed, optimized, and manufactured quicker," says Holzinger. "This allows us to test more items and gain more of an advantage on the track."

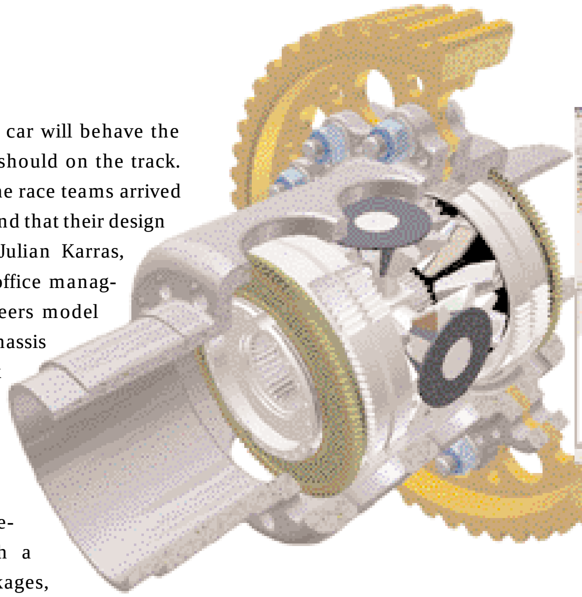
At PacWest in Indianapolis, engineers rely on Autodesk Inventor to give the team more

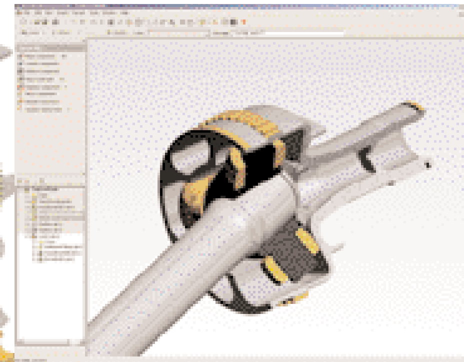
Engineers at Team Rahal use PTC's Pro/Manufacturing software to generate NC machine code to create molds for the complex aerodynamic surfaces of their CART race cars' front and rear wing assemblies.



confidence that the car will behave the way they believe it should on the track. "It used to be that the race teams arrived at the track only to find that their design didn't work," said Julian Karras, PacWest's drawing office manager. The firm's engineers model the entire Reynard chassis in Inventor, a task that pays dividends when changes are required.

Karras also notes that Inventor is widely compatible with a range of FEA packages, which PacWest uses to trim excess weight from the race car and ensure that the lighter parts won't fail. After making modifications to the Inventor model, designers reanalyze the part in their FEA software. "Removing one-fourth of a pound can mean the difference between a win or a loss," says Karras. "Shaving 10 pounds is worth one-tenth of a second around an average road course. That amount of lead would cover the top five spots in any qualifying grid. So you can imagine the gains that we can potentially make in terms of using the software to reduce weight." Karras also sees great benefit to using Inventor's on-screen constraint-driven animation capabilities. Observing the mechanical actions enable the engineers to check for performance and part compatibilities as well as provide assembly instructions for the team's mechanics.



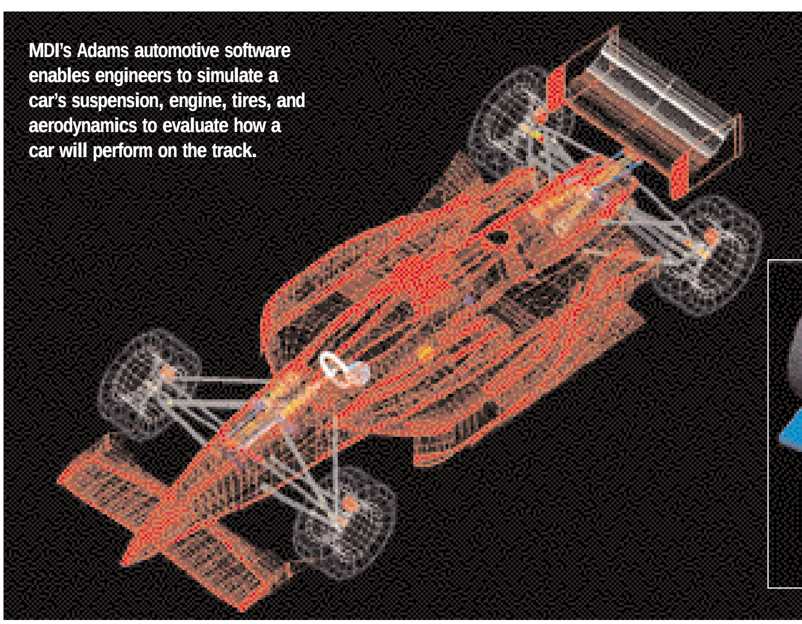


Designers at PacWest use Autodesk Inventor to model all components in their CART cars, including this differential gear assembly. The software helps the team reduce the weight of the parts without adversely affecting their performance.

Being able to predict the performance of the race car is even more crucial this year. A new CART rule for the 2002 season bans all in-season on-track testing. The only way to test cars now that the four-month off-season test period is over is to use simulation software.

Newman/Haas Racing of Lincolnshire, Illinois, uses Adams virtual prototyping software from Mechanical Dynamics to test every element of its cars. Traditionally in racing, car designs have been changed as a result of trial and error or educated guesses, says Skip Essma, Newman/Haas vehicle dynamics engineer. "But as competition grows more intense, we have to rely more on our simulation programs to complement our experience. When we get to the track, we're not making educated guesses."

Newman/Haas uses Adams/Car Motorsport, a customized automotive simulation toolkit, to evaluate subsystems such as suspension, engine, tires, and aerodynamics.



MDI's Adams automotive software enables engineers to simulate a car's suspension, engine, tires, and aerodynamics to evaluate how a car will perform on the track.

The team also uses Adams/Solver for numerical processing, Adams/Tire for modeling how tires grip the road, and Adams/Driver for examining how individual driving styles affect vehicle performance. "Adams can accurately simulate performance on a specific track with conditions selected by the race engineers," says Essma. "We can change the suspension, front and rear wing settings, or virtually any element of the entire car and send it through a series of maneuvers and see exactly how the car will perform."

While it's the drivers that get the glory, it's the technology that helps them compete week after week and enables their complex machines to withstand grueling race conditions. Whether on the high banked ovals of Daytona or in the famed Corkscrew turn at Laguna Seca in Monterey, CAD/CAM/CAE technology has improved the consistency, predictability, and performance when it counts—on race day.

***David Cohn** is a race fan and technical writer based in Bellingham, Washington. He can be reached at david@dscohn.com.*