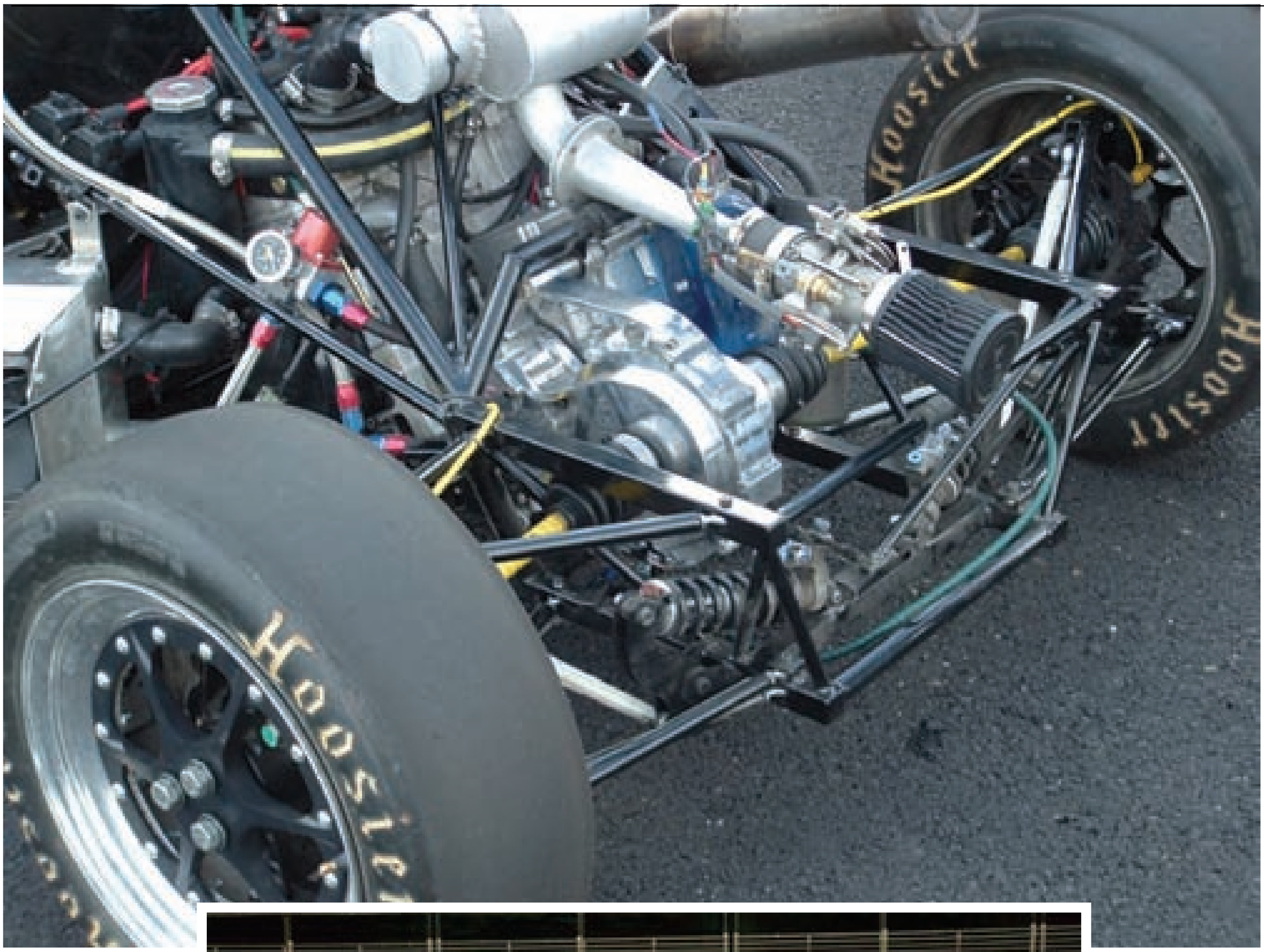
More Than Your



(Top photo): An under-the-hood look at the students' gear drive. (Bottom Photo): The 2006 Vandals Racing Team with their FSAE Car # 27.

Father's Soapbox Derby

Jack McGuinn

All aspiring design engineers covet that first hands-on opportunity to strut their stuff, and since the mid-1970s mechanical engineering students have gotten their chance at the annual Formula SAE® competition. That's where—according to the Society of Automotive Engineers website—they "conceive, design, fabricate and compete with small formula-style racing cars."

And so it was that Edwin Odom, professor of mechanical engineering at the University of Idaho (UI), and his student Vandals Racing Team, recruited primarily from the university's school of engineering, embarked on a journey of discovery that led them to the 2006 FSAE Detroit competition. The hallmarks of the nationwide and international events include an opportunity for young engineers to test their abilities, and to work over a year's time on a serious engineering challenge within a dedicated teamwork environment. Some 120 cars designed and built by students from schools around the world are judged by professionals from the worlds of engineering and competitive racing.

While this was indeed a student-led exercise, Odom and his Vandals team were provided invaluable assistance by Rockford, IL-based Universal Technical Systems (UTS) gear product manager Jim Marsch. The company's design software was key to developing the gear drive the students ultimately presented at the competition.

The SAE, instituted in 1905, boasts more than 90,000 members in at least 97 countries, including "engineers, business executives, educators and students who share information and exchange ideas for advancing the engineering of mobility systems."

Following are some questions *Gear Product News* put to professor Odom regarding the competition—the challenges it presents, the students' intense desire to succeed, and the occasional need for outside-the-box thinking.

GPN: *How were decisions arrived at in determining the design for the gear drive?*
EO: It was a combination of factors. First, we had several structural failures in our early cars from the attachment of the differential to the frame. These were fixed and we moved on, but we were made aware of the importance of reliability. Second, we wanted to move the CG (center of gravity) of the car back. We always had a slightly front-heavy car, and our packaging studies indicated that using a gear drive, we could move the engine back about 5 inches, which meant we could move the driver back 5 inches. In a 60" wheel base, this is substantial. Third, it is a design competition; you are looking for a design that would differentiate your car design from others at the competition.

GPN: *How, ultimately, was the gear drive design developed?*
EO: A junior in mechanical engineering—Greg Oden—with assistance from Sam Zimmerman, a master of science graduate student, developed the first design of our gear drive. Their work was used as the basis of a class project where 70 students wrote their own gear analysis *TKSolver* program using the AGMA approach from their textbooks. Therefore, every junior student in our department had the opportunity to understand the gear analysis of the project. This design was subsequently verified and the case was designed by Scott Anderson, a master of science graduate student.

GPN: *Was there anything that set your design apart from others at the competition?*
EO: Our first priority was reliability, which we achieved. It was trouble-free and never required adjustment. It was more compact than a chain-and-sprocket design, and finally it differentiated us from other schools.

GPN: *With a limited budget, how did you get the gears manufactured?*
EO: When we were thinking about the gear drive, the question arose as to how and who to manufacture the gears. A student overheard our discussion and mentioned a high

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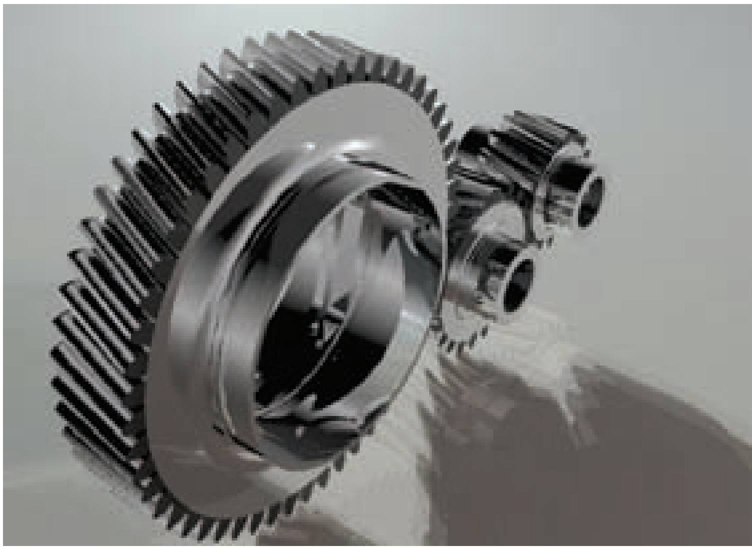
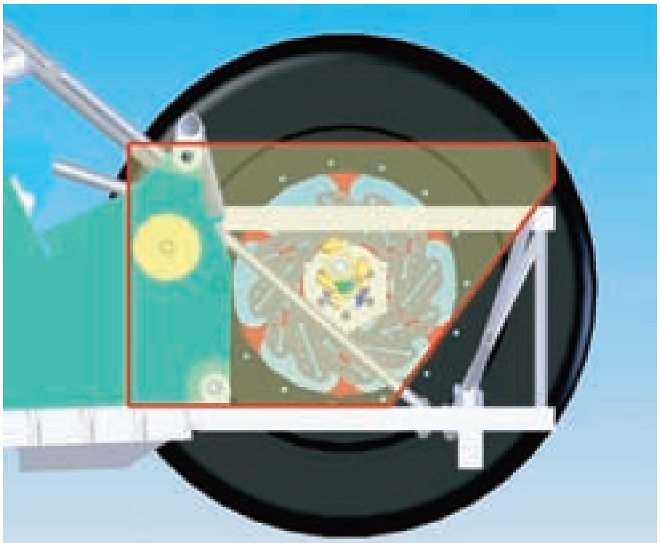
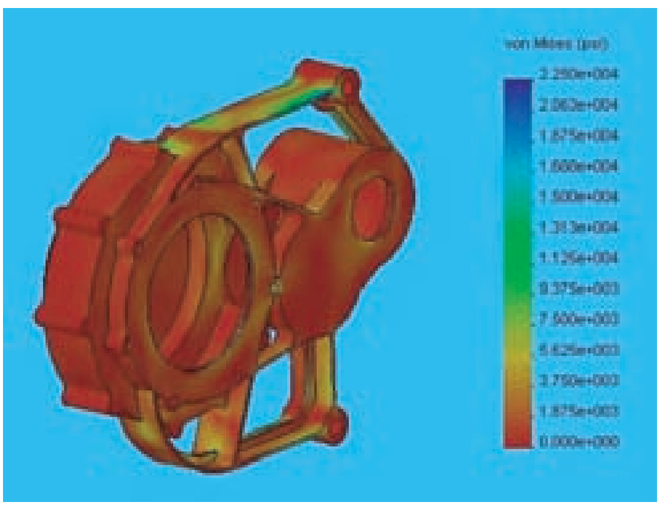


From design to fruition; cut to students' specifications.



Cut view of car solid metal.



Stress plot of final design.

school friend was now a gear manufacturer in Coeur D'Alene (Idaho). We drove up to see him (Coeurd Morris, owner of Unidyne, Inc.); he was very friendly and willing to help. It also became apparent that our knowledge on how to give the correct specification for the manufacture of the gears was lacking. Coeurd worked through it with us and agreed to cut the gears without charge if we would buy the hob and provide him with the gear blanks mounted on an arbor ready for machining.

GPN: *What challenges were presented by design loads and space constraints?*
EO: Space constraints were a big challenge. Nearly every car at the competition was using a motorcycle engine. These engines have a very highly refined design for the geometric layout of a motorcycle. The transmission output shaft is designed for use with a sprocket, and the designers have the clutch access and shifter access points located very close to the sprocket. It's a tight fit.

Determining realistic design loads is difficult. You have the horsepower of the engine, the transmission's gear ratio and the final gear drive ratio, so you can do calculations. However, in the first two gears you are traction-limited to about 60 horsepower for excellent conditions, and then engine-limited in the third and fourth gears. But you have acceleration runs where the engine RPM is quite high and the clutch is engaged very quickly and, maybe even worse, we have downshifts that create very high unknown transient load in the reverse direction.

GPN: *Please describe the design presentation at the competition.*
EO: There are three phases to the design competition. The initial phase provides the team with about 15 minutes to present the car, and all 115 teams do this. So it takes quite considerable resources to accomplish this. The second phase is the design semifinals, and then the third phase is the finals. We did not make the semis; but we took advantage of a noontime informal design review of our car by the judges. I think we gained the insight needed to be competitive in next year's design competition.

GPN: *What was the ultimate benefit to the students in working on the gear design?*
EO: I believe the student competition will always be dependent on chain drive-based gear reduction, since the engines used are from motorcycles and you can find commercial components to support that design philosophy. Automobiles continue to be dependent on gears for their transmissions and differentials. The important academic outcome here is that a portion of the team that is interested can have the opportunity to experience the detailed design of a gear-based reduction drive.

GPN: *What motivates the students most—gear science or auto racing?*
EO: As an instructor and team advisor, there is always a tension between the lure of racing for young engineers and the need of academic outcomes for faculty. What you learn as a faculty member is to pick your battles. Insist on documentation, analysis, prototyping and testing; but accept students' interest in doing novel designs you would prefer not to do, and accept their passion for the excitement of racing.

GPN: *Please tell us about the role UTS played in the competition.*
EO: A student on the team and I attended the weekend gear school that UTS teaches before we started the design. We were able to go over the gear design with Jim Marsch, and his experience was invaluable to us. As I understand it, their software is the AGMA code with the power of their equation solver behind it. A designer can look at many different designs and do "what ifs."

I cannot over-emphasize the importance of UTS and Jim Marsch to the successful completion of this project. My guess is that I called Jim a dozen times and he was always helpful and patient. This project and its requirement to interact with a gear manufacturer, because it (the car) was really to be built, required additional information not in the textbooks to convey to the manufacturer what the design intent and manufacturing requirements were. Jim Marsch and UTS provided that added educational content to our team. Our FSAE team and I are deeply appreciative to have had access to their program and their pool of knowledge. I don't think we could have done this design without their help.

GPN: *Please describe the gear housing optimization.*
EO: We used Genesis software, which is a design optimization program from Vanderplaats VR&D, Inc., to design the gear housing. The design space was meshed, as well as access areas for the clutch and shifter points. The final design is shown along with the finite element analysis (FEA) results. The case was as difficult to design and manufacture as were the gears themselves.

GPN: *Please tell us, what is a "trihubdle" and how did its creation require some beyond-the-envelope thinking on the part of the students?*
EO: The trihubdle was a name a student (Greg Ogden) coined to describe our wheel spindle. Normally the rear axle has a CV joint (three bearings 120° apart) that engages into a jackshaft that has a cloverleaf-shaped female internal opening for the CV joint on one end, and a male spline on the other end. The splined end of the jackshaft then fits into the spindle that the wheel bolts to. Functionally this works well, but it required an internal spline to be cut into the spindle which we had to send out. By combining the jackshaft and spindle, we were able to eliminate both the internal spline, which we could not do, and the external spline on the jackshaft. The students thought it to be a novel idea, and named it the trihubdle because it combined the cloverleaf (three lobes)-shaped opening for the CV joint into the spindle.

GPN: *Who drove the car?*
ED: Two juniors, Kameron McKeehan and Matt Soden, and senior Mike Maughn.

GPN: *What were the ultimate lessons learned by the team?*
EO: I think the students really learned to appreciate the subtleties of detail design where you do not pick the most important item, because everything is important. The gear drive design as well as the entire car bring home the lesson that the question of what is most important on this engineering project is the wrong question, because the answer is that *everything* is important. A loose wire or hose clamp; inadequate marketing or engineering documentation; an unknown load or boundary condition; the need for teamwork and commitment—all wake me up in the middle of the night. I tell this to the students and they tell me they wake up also. I ask, 'Do you want to quit?' and the answer is 'No.'

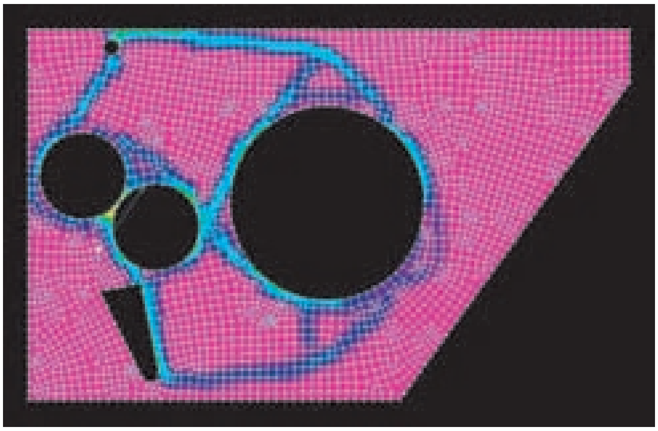
For more information:

Edwin M. Odom
Professor of mechanical engineering
University of Idaho
Moscow, Idaho 83844-0902
Phone: (208) 885-7330
Fax: (208) 885-9031
E-mail: *eodom@uidaho.edu*

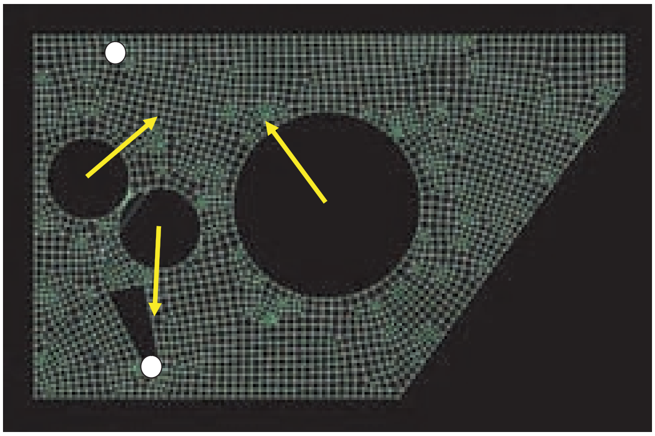
Universal Technical Systems, Inc
202 West State Street / Suite 700
Rockford, IL 61101
Phone: (815) 963-2220
Fax: (815) 963-8884
Toll Free: (800) 435-7887
E-mail: *sales@utc.com*

Unidyne, Inc.
P.O. Box 2751
Hayden, ID 83835
Phone: (208) 659-4352

Vanderplaats Research & Development, Inc.
1767 S. 8th Street / Ste. 100
Colorado Springs, CO 80906
Phone: (719) 473-4611
Fax: (719) 473-4638
E-mail: *info@vrand.com*



Optimum structural layout to react bearing loads.



Bearing model mesh.