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The Impact of Motorsports Engineering on Automotive Performance

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Abstract

The application of sound-engineering design principles in the development of vehicles intended for motorsports competition has come into more frequent use during the past decade. Instead of the trial-and-error mode of development, which was prevalent in motorsports in the past, engineers are now playing a major role in the design of new cars intended for competition. This has brought about a new field of study at some institutions of higher education: the field of motorsports engineering. One of these schools is Indiana University Purdue University Indianapolis (IUPUI), where students and faculty have been working with racing teams and businesses associated with motorsports to produce designs capable of improving vehicle performance in competition. On June, 11, 2010, Cory McClenathan set a new world record for the quickest that a vehicle has ever traveled 1000 feet from a standing start. The record was the result of a unique collaboration between Don Schumacher Racing (DSR) and IUPUI and was a demonstration of how the engineering aspects of motorsports are making an impact in engineering education, as well as how motorsports engineering graduates will impact the future of the sport and automotive design.

Introduction & Background

In a world where engines produce over 8,000 horsepower and vehicles achieve over 300 miles per hour in a mere 1,000 feet of distance in just over three seconds of time, engineering analysis can be a very useful tool to achieve performance optimization. In an effort to examine vehicle behaviors in this incredible environment, Don Schumacher Racing (DSR) and Indiana University Purdue University Indianapolis (IUPUI) partnered on an educational research program. [1] DSR is one of the most successful teams in the Top Fuel category of the National Hot Rod Association's (NHRA) premier drag racing series. IUPUI is the first university in the United States to offer a bachelor's degree in motorsports engineering [2], with a curriculum specifically aimed at training the next generation of engineers for the motorsports industry. [3] The innovative motorsports engineering courses at IUPUI, with a distinct applied-engineering slant, have drawn attention for their innovation. [4] Plans of study that involve experiential learning and research activities, which focus on undergraduate student involvement, have been indicated in studies by the National Academy of Engineering [5] and numerous leaders of engineering academia [6] as the direction of the future for engineering education. IUPUI has been one of the leaders in attempting to develop innovative curriculum for undergraduates and pre-engineering STEM students, [7] with motorsports-themed activities leading the way. [8]

The relationship between DSR and IUPUI arose from the inspiration of Lee Beard, the DSR Team Manager. Race teams are always looking for competitive advantage, and Beard believed that the coupling of bright young minds from the university with experienced members of DSR's team could yield new ideas. The first project of the partnership was aimed at determining the characteristics of the chassis of a Top Fuel class car, which might have a beneficial effect on performance. Cory McClenathan was the driver of one of the DSR Top Fuel cars, shown in Figure 1.

Figure 1: Cory McClenathan's Don Schumacher Racing Top Fuel dragster was the object of a redesigned chassis based on analysis by motorsports engineering students. (Photo used with permission of DSR)

Methodology

With the tremendous levels of power being transmitted to the ground by these cars, traction is paramount. The critical focus of the study became whether the chassis could be optimized in a way that positively enhanced the car's ability to maximize traction. The first step was to construct a Finite Element Model (FEM) of the existing chassis. IUPUI students worked side by side with DSR fabricators to understand the design of the frame and develop their model as shown in Figure 2. The students had completed courses in structural modeling, statics, dynamics, and vehicle dynamics, all under the guidance of IUPUI's engineering technology and motorsports engineering faculty. The model was constructed as a tube frame using a FEM routine. Particular attention had to be paid to tube dimensions, material properties, and configuration of the tube junctions.

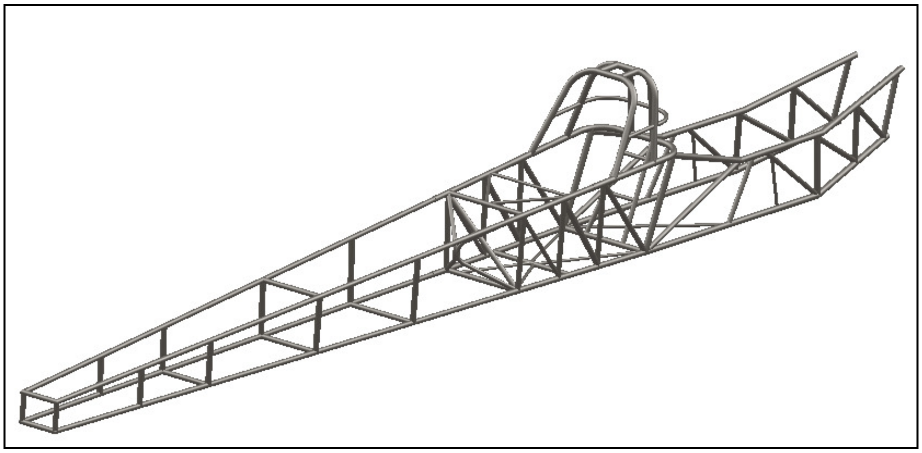

Figure 2: Finite element model of a Top Fuel dragster chassis.

The second step was to correlate the model. DSR conducted a static load test, fixing the frame at the front suspension attachment points and at the rear axle housing. A static load was applied in the center of the frame and deflections were measured along its length. The model was then constrained at the same locations and the same load was applied. Predicted and measured deflections were then compared. This step required refinement of the model, particularly in the vicinity of the rear constraint, to accurately represent the frame in its test configuration. The emphasis had originally been on the frame members and not on the axle housing. This had to be adjusted in order to match the test results.

Ultimately a good correlation was achieved, as shown in Figure 3, allowing the analysis to continue. The chassis has a different stiffness in twist, vertical bending, and horizontal bending. The next step in the process was for the experienced members of the DSR team to sit down with the IUPUI students and faculty to discuss what flexibility characteristics of the chassis they collectively believed had the greatest impact on the vehicle's ability to maximize traction and thus its ability to put the power to the ground. The IUPUI team then began parametric studies utilizing the correlated model. Over a hundred different configurations were examined in a process that indicated several trends pointing toward the selected goals. To examine the various configurations, three load cases were repeatedly applied to the model. One case examined vertical bending of the chassis, one examined lateral bending of the chassis, and the third examined torsional twist of the chassis. Deflection results of the model, as shown in Figures 4 and 5, were summarized for each configuration and were compared back against the baseline to see which configuration best achieved the goals. In addition to the performance parameters, max stresses under various load conditions were tracked to make sure that frame life would not be significantly impacted, and naturally weight was tracked since a gain in weight of the race car would offset any advantage gained from the increase in traction.

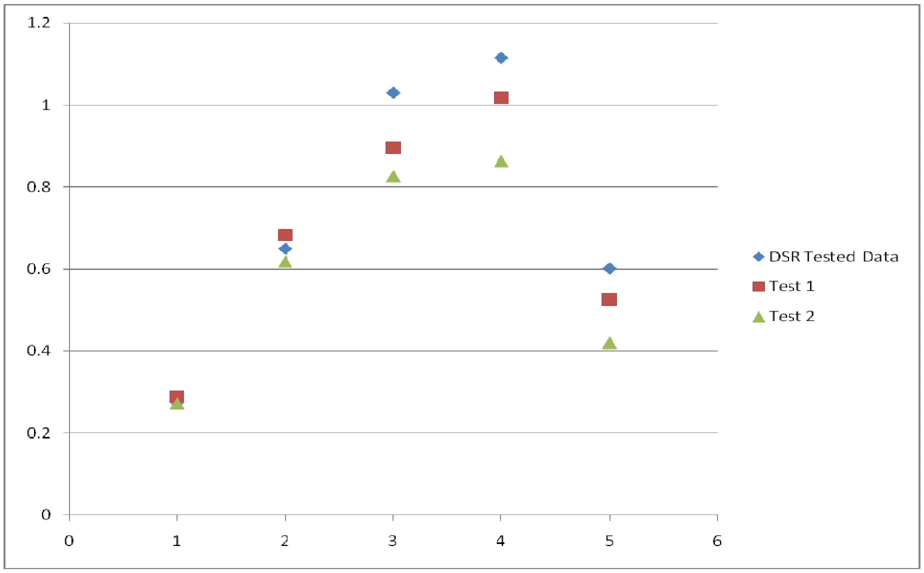

Figure 3: Correlation of chassis deflection test and analysis data.

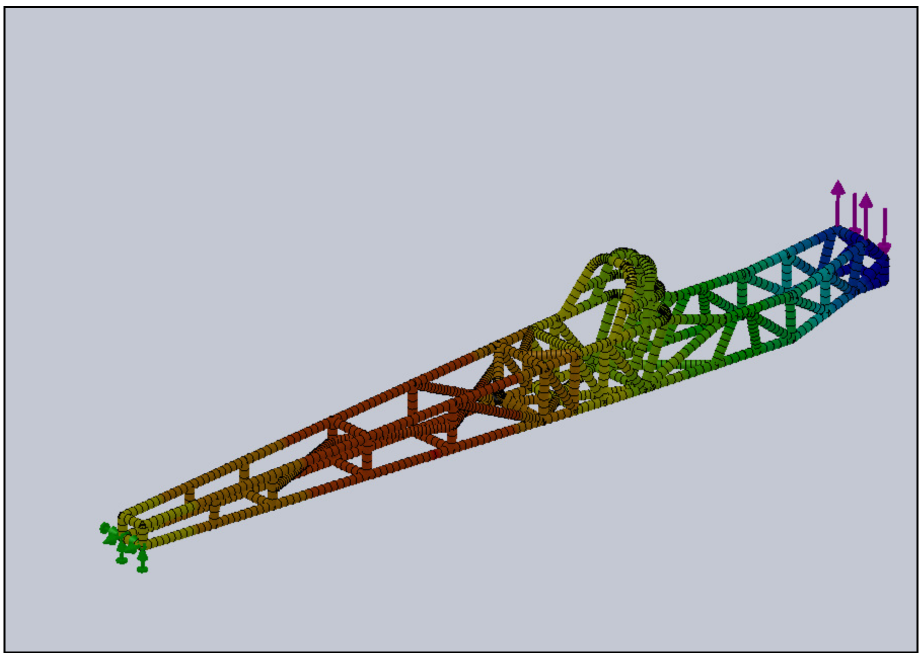

Figure 4: Predicted bending deflections shown for a load case on the Top Fuel chassis.

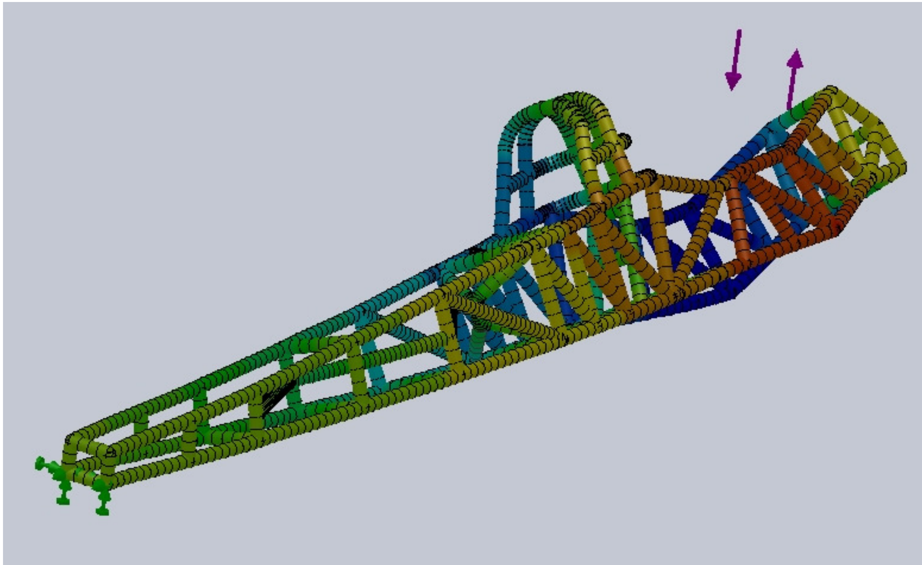

Figure 5: Predicted torsional deflections shown for a load case on the Top Fuel chassis.

Another aspect of vehicle design that was examined was driver safety. Fire is always a safety concern in motorsports, especially in the Top Fuel classes where nitromethane is used as fuel. Figure 6 shows the magnitude of the fireball that can occur in a worst case scenario. Given the proximity of the driver to the engine, as shown in Figure 7, there is a possibility of flame or engine parts making their way into the driver's cockpit in such an explosion. For that reason, the DSR staff was interested in extending the protective cowling from behind the driver's head, over the top of the cockpit, to create a barrier against fire and thus further protect the driver. However, even to the casual observer, such additional bodywork would appear likely to increase the aerodynamic drag around the cockpit. In a car running over 300 miles per hour, such drag could become a real competitive disadvantage.

Therefore, another study was initiated by IUPUI and DSR, relative to the aerodynamics of the car. Using the Computational Fluid Dynamics (CFD) options of the FEM routine, the streamlines and turbulent energy distribution around the cockpit were examined as shown in Figure 8. This was done in order to ascertain whether the additional protective cowling would, as expected, create unwanted drag. When it was determined that the effect would be a performance disadvantage, further analysis was performed to determine if there existed a means to counteract this negative effect. A proposed modification to the windscreen was determined, which would subtly deflect air around the cockpit in a manner that prevented the new protective cowling from being an aero disadvantage. However, to further ensure that no detrimental effects occurred due to the changes, the flow of air around the cockpit was examined to determine if it would hinder the air flow into the engine's inlet or if it would alter the airflow over the downforce-producing rear wing. Figure 9 shows results of this portion of the analysis.

Figure 6: Fire is always a safety concern in nitromethane-fueled dragsters.
(Photo used by permission of Jeff Burk/DragRacingOnline.com)

Figure 7: The air flow around the cockpit and engine of the
Top Fuel car was an area of interest. (Andrew Borme photo)

CFD analysis is akin to conducting a wind tunnel test on a computer. It provides both a visualization tool and a calculation tool and will allow the engineer to calculate both lift (or in the case of a racecar, downforce) and drag as a function of the shape of the car. Flow energy, as well as turbulence, was studied. In the end, an appropriate combination of cockpit cowl and windscreen angle was determined, which provided the desired protection without hurting the drag, the engine inlet flow, or the downforce provided by the rear wing.

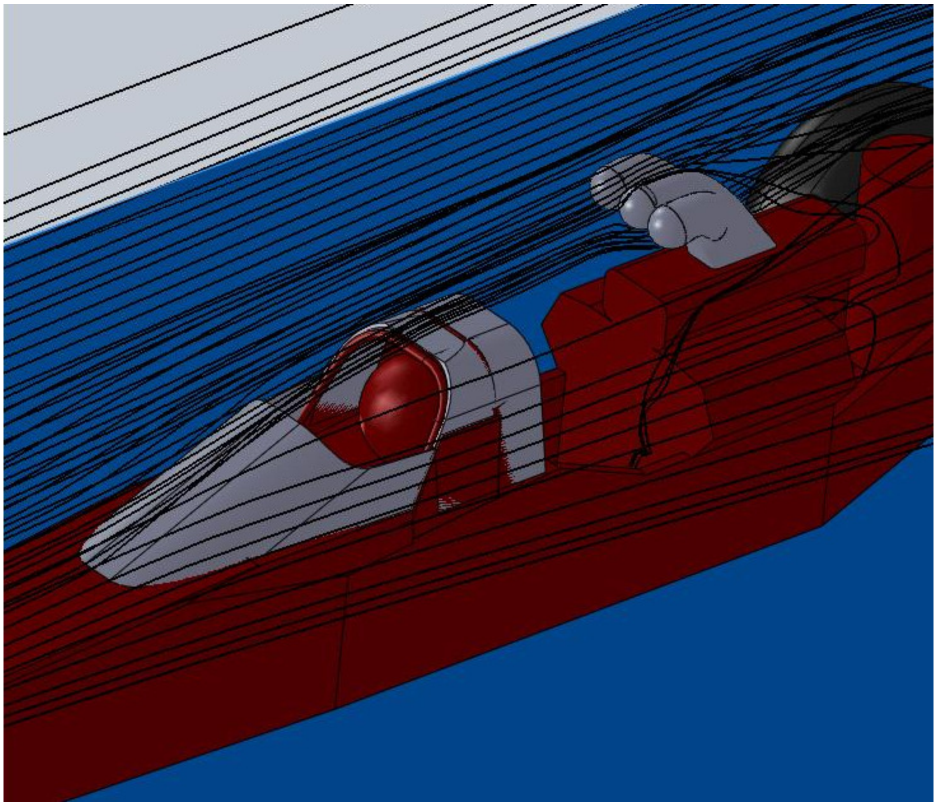

Figure 8: CFD analysis model showing airflow streamlines over and around the cockpit and engine.

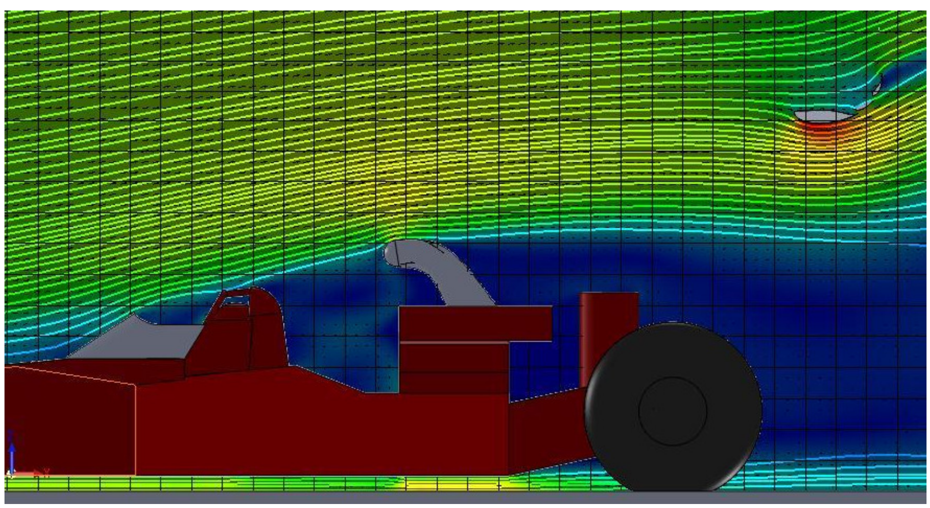

Figure 9: CFD analysis model showing airflow energy over and around the cockpit, engine, and rear wing.

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Sample Results

Motorsports of any form is, by definition, a very competitive business. For this reason, those working on the DSR/IUPUI project are not at liberty to discuss either the precise goals that were set or the exact chassis modifications that were used to achieve them. However, the results have been stunning. An initial configuration change was implemented in Cory McClenathan's frame in June 2010. The second event after the change was held at Old Bridge Township Raceway Park in Englishtown, New Jersey. The team set the fastest thousand-foot time in NHRA history at 3.752 seconds and a top speed of 324.75 miles per hour. In the post-qualifying interview, McClenathan acknowledged the work of the university, saying, "We have been working with IUPUI, and those kids are just unbelievable when it comes to aerodynamics and how the chassis should work. We have been working close with them and they were a big part of some configurations we have used. This car is basically set up the way they would like to see it go in the future." [9]

The configuration of the cowling around the cockpit was tested on two of the DSR cars during practice days for the annual U.S. Nationals race at O'Reilly Raceway Park in Indianapolis, held on Labor Day weekend, 2010. Both cars ran equivalent elapsed times and top speeds to their old configuration, while utilizing the new cowl and windscreen. Pressure data was also taken around the engine inlet, and no loss of air flow was detected. These results would indicate that the use of engineering tools and analytical skills allowed a configuration to be designed that had the desired safety provision with no detrimental performance impact. But more importantly, from a safety standpoint, when Tony Schumacher's engine exploded after the end of one of the test runs, no fire entered the cockpit, and in fact, the driver was initially unaware of the explosion. Subsequently, Schumacher, on March 27, 2011, in a race in Pomona, California, set the fastest-ever top speed for a thousand-foot run, at just over 327 miles per hour, using the new cockpit cowl. Clearly this new design offers protection without harming vehicle performance.

Conclusions

1. Proper selection of racing chassis stiffness parameters has been shown to affect the ability to maximize vehicle traction.
2. Small changes in body shape can create noticeable improvements in air-flow around the race car, affecting drag, downforce, and inlet flow.
3. The use of engineering-design skills to achieve improved vehicle designs in motorsports can determine subtle changes capable of producing significant results.
4. Engineering programs focused at motorsports can develop curriculum and research projects with the ability to develop unique skill specialties applicable to motorsports, and produce students capable of making a significant impact within the industry.
5. Since developments in motorsports can lead to improvements in street cars, a program such as the one discussed here may one day influence the design of everyday vehicles.
6. Industry/academia partnerships can yield both innovative improvements and excellent learning opportunities.

References

[1] "DSR and IUPUI Share Latest Technology to Improve On-Track Performance," *Motorsports Journal,* January 16, 2010. Retrieved from http://www.motorsportsjournal.com/archives/2010/01/dsr_and_iupui_s.php.

[2] Tussing, M. "Motorsports Degree Program at IUPUI Is Off to Fast Start," *Indianapolis Star*, May 15, 2009, A23.

[3] Hylton, P. "Let's Go Racing – Constructing a Collegiate Motorsports Program," *Proceedings of the ASEE Section Conference*, Indianapolis, Indiana, March 2007.

[4] Hylton, P. "Guest Editorial: Students and Careers in Motorsports," *Manufacturing Engineering*, 141(3).

[5] National Academy of Engineering, *Educating the Engineer of 2020*. Washington, D.C.: The National Academies Press, 2005.

[6] Vest, C. (2008). "Context and Challenge for Twenty-First Century Engineering Education," *Journal of Engineering Education*, *97*(3), 235-236. Retrieved from Education Research Complete database (34435790).

[7] Hylton, P. and Otoupal, W. "Engaging Secondary-School Students in Pre-Engineering Studies to Improve Skills and Develop Interest in Engineering Careers." *The International Journal of Engineering Education,* 25(3), 119-125.

[8] Hylton, P. "Using Motorsports Design Concepts to Further STEM Education," *Journal of Technology Studies, 36*(1), 12-15.

[9] Burgess, P. "Cory Mac Makes Quickest-ever Pass to Lead SuperNationals Qualifying," *National Dragster On-line*, July 11, 2010. Retrieved from http://www.nhra.com/story/2010/6/11/2010-englishtown-friday/.

Biography

PETE HYLTON is currently an associate professor and director of motorsports engineering at Indiana University Purdue University Indianapolis. He has industry experience in both aerospace and motorsports and is responsible for the creation of the first motorsports engineering BS degree program in the United States. He is author of several books on motorsports history and is a recipient of the Sports Car Club of America's highest honor, the Woolf Barnato Award for contribution to motorsports.

ANDREW BORME is currently a lecturer in the Indiana University Purdue University Indianapolis motorsports program. He has extensive industry experience in motorsports with two Indianapolis 500 Mile Race wins as an engineer for driver Helio Castroneves and three years as the chief-aerodynamics engineer for the Toyota Formula One team.

KIRK BARBER is a motorsports engineering student at Indiana University Purdue University Indianapolis and was an integral part of the project that led to redesigning the Top Fuel dragster that was used by Don Schumacher Racing and Cory McClenathan. He is expecting to graduate with a dual BS degree in motorsports engineering and mechanical engineering in May 2013. After graduation, Kirk plans to use his education and experience to build high performance, environmentally friendly automobiles. He has experience in several different forms of motorsports and is currently the youngest championship-winning crew chief in United States Auto Club (USAC) history.

PAUL LUCAS is currently working toward a bachelor of science in motorsports engineering at Indiana University Purdue University Indianapolis. He is a member of IUPUI's Formula SAE team as a chassis team member and was an integral part of the project that led to redesigning the Top Fuel dragster that was used by Don Schumacher Racing and Cory McClenathan.

LEE BEARD has spent more than 30 years in drag racing. He has earned more than 50 wins as a crew chief in the Top Fuel and Funny Car ranks. He began his career as an owner/driver in the Top Fuel class in the early 1970s and has tuned for some highly successful drivers, including Jerry Ruth, Gary Ormsby, Pat Austin, Ed McCulloch, Cory McClenathan, Cruz Pedregon, Kenny Bernstein, Whit Bazemore, Rod Fuller, and Antron Brown. He led Ormsby to the 1989 NHRA Top Fuel championship and has won the prestigious U.S. Nationals event four times.