FEATURE

THE STORY OF AN ENGINE CHANGE

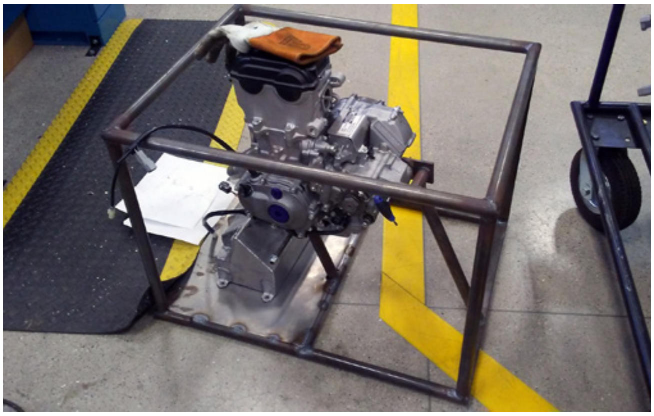
The 2019 University of Michigan-Dearborn racecar after completion of the Formula SAE Michigan competition.

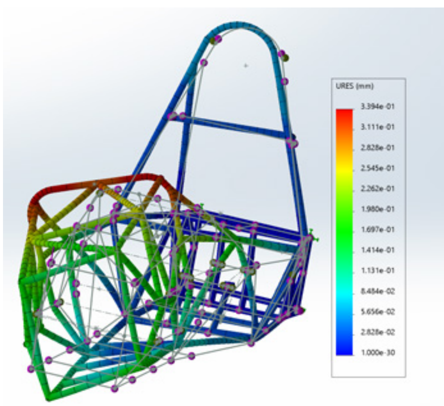
(Or how changing one component changed the whole racecar.)

2019 racecar during the Endurance run at Formula SAE Michigan. This was the last SAE competition for our Yamaha Genesis 80fi engine.

IN THE MONTHS LEADING UP TO THE 2019 FORMULA SAE COMPETITION SEASON, the University of Michigan-Dearborn team (Formula UMD Racing) knew that there would be major changes coming for the vehicle architecture in the following season. During this timeframe, we learned that Yamaha was easing support for the Genesis 80fi 2-cylinder engine, which we had been using as the heart of the powertrain system for our racecars for nearly a decade. We kept three of these engines in stock, and every year we would rebuild at least one of them for the next competition vehicle. If there were sufficient monetary and human resources available, we would sometimes rebuild a second engine for dynamometer work as well. No more support from Yamaha for the engine meant no more OEM replacement parts that we needed for our rebuilds. As a team, we had talked about switching engines for the past several competition seasons, but now our hand was being forced.

Therefore, when we sat down as a group after finishing the 2019 Formula SAE Michigan competition to start discussing design goals and vehicle architecture, the impending engine change was on everyone's mind. This was because the choice of engine to power the vehicle affects not only the powertrain system, but also the frame that has to contain and support it, and the suspension that in turn must carry the frame and respond to vehicle loading in a variety of dynamic scenarios. Furthermore, changes in the frame and suspension cascade to aerodynamics as a result of packaging considerations. In short,

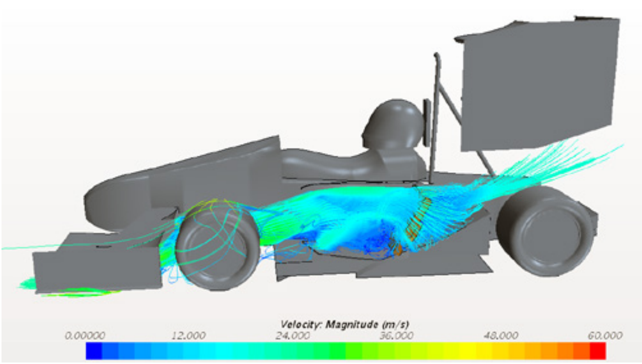




ABOVE: Our new Yamaha YZ450f engine, mounted in the portable test frame we built for it.

RIGHT: FEA analysis of the new frame design.

BELOW: CFD analysis of the new aerodynamic elements.



Frame under construction in the weld shop.

an engine change meant that, to a certain degree, we would be designing the 2020 season racecar from scratch.

SELECTING A NEW ENGINE

After defining a set of qualitative and quantitative characteristics on which to evaluate a potential new engine, we proceeded to assess a large number of newer models available on the market. In the process we considered small, high-performance options from manufacturers such as Honda, Yamaha, KTM, and Kawasaki, evaluating availability, pricing, packaging size and geometry, number of cylinders, peak power & torque, weight, and much more. In the end, we selected the KTM450 SX-F single cylinder engine with an integrated sequential transmission. With the engine known and other vehicle design goals defined, the design phase commenced. Shifting from a CVT to a sequential transmission allowed for the entire powertrain packaging space to be longitudinally compressed, resulting a slightly shorter frame with the differential mounted inside, rather than cantilevered off the back of the rear bulkhead as in previous years. The gear ratios available from the transmission also allowed us to reduce the final drive ratio from 5.1:1 to approximately 3:1.

As the summer drew to a close, however, purchasing issues and administrative delays led to the two KTM450 engines we had been looking to buy becoming unavailable before we could purchase them. As a result, the powertrain group had to return to the engine benchmark analysis for other options. Well aware of design work that had already begun around the selection of the KTM450 SX-F, we knew that it would be significantly beneficial if we could choose an alternative engine of similar size and performance. Fortunately, the second-best choice on the list was the Yamaha YZ450f, another single-cylinder engine with an integrated sequential transmission, similar gear ratios, and a similar packaging geometry. We quickly decided to move forward with that engine.

REDESIGNING THE RACECAR

Two engines were soon acquired, and the powertrain team became busier than ever as engine characterization and modeling began, alongside designing peripherals such as the cooling system & components, lubrication system & components, and the intake arrangement. Furthermore, a new exhaust header and muffler configuration was required. On the control side, the powertrain and electrical groups had their work cut out for them with sensor selection, ECU (engine controller unit) work, and ETC (electronic throttle body), something the team had decided to implement for the first time alongside the new engine.

On the frame side, besides redesigning it to contain the new powertrain system while still meeting all the requirements in the SAE rulebook, new mounting points were identified for the suspension and aerodynamic components. Mounting tabs were then designed for each point – sized according the load they would be required to support. Another significant design change from the frame group was the impact attenuator type.

Historically, the UMD Racing team has always designed, fabricated, and tested our own impact attenuator. However, after considering the potential cost and time savings involved, the frame group elected to use the standard impact attenuator instead.

Meanwhile, a new suspension system was designed to accommodate the new frame. Here the student engineers opted for a simpler arrangement than we had used in the past, utilizing a double-wishbone setup for both the front and rear of the vehicle. At a high level, this served two critical functions: first, accommodating the skill level of our new suspension team and second, reducing assembly complexity significantly. The latter had been a significant sticking point of our previous multi-link suspension in the rear, especially in terms of its complex interface with the full-body diffuser.

Vehicle aerodynamics saw some major changes. Relatively early in the vehicle design period, the decision was made to switch from sprung to unsprung components. While this would reduce the maximum amount of downforce that we could generate in principle by not having the diffuser hug the pavement and the wings operating quasi-independently of the vehicle roll, the advantages were also significant. A large amount of manufacturing, mounting, and kinematic design complexity was reduced by being able to secure the aerodynamic elements directly to the frame.

MANUFACTURING

With most of the vehicle subsystem designs completed by the end of the Fall 2019 semester, the UMD Racing team was looking forward to the testing and competitions to come in the following summer. Upon returning to the University in January, we set to manufacturing with much enthusiasm. After about a month in the weld shop, our frame was complete. During the same time, the electrical group fabricated a dyno harness for our new engine, and the powertrain group manufactured test versions of all the engine peripherals. The powertrain group then began dyno testing and mapping of the new engine, validating it against the GT-Power model developed during the design phase. Meanwhile the electrical group transitioned to fabricating the full car wiring harness. At the same time, the suspension team began manufacturing their linkages for control arms. Also, the molds were built for our wing elements, diffuser, and side pods, after which the carbon-fiber layups commenced.

The UMD Racing team, just a few weeks before the campus closed.

SHUTDOWN

Then COVID-19 happened. To be fair, it had been going on elsewhere for months already. But it hit home for us in early March, when the University closed campus shortly after the students returned from spring break. All the engineering competition teams were shut down in the process. In those first few hectic weeks, we were left uncertain of what to do next. Our racecar was well on its way to completion, but that didn't matter much when we couldn't go in to work on the assembly, much less visit the machine shop to fabricate new parts. Furthermore, all of the team members were dealing with the unexpected transition of all of their coursework to a virtual format for the final six weeks of the semester. When the plans from SAE were finally released to hold a virtual-only competition later in the summer, we made the hard choice to pull registration, as the complete loss of access to our vehicle left us without information that would have been necessary to compete.

LOOKING TOWARD THE FUTURE

After a summer spent in uncertainty about the team's future, those of us who are still enrolled in the University are looking forward to the 2021 competition season ahead of us. Not that it is much less uncertain. Unfortunately, we still have no idea when the University will allow us to return in some capacity to commence with working on our vehicle, which we now plan to carry over into the new season. Nevertheless, a new semester brings with it new students interested in Formula SAE, and we look forward to introducing them to our work. Whatever the future may hold, we are proud to be the UMD Racing team; struggling, but still going strong. ■

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