S&V OBSERVER

FSAE Competition Challenges Engineering Students

Gary Newton, Brüel & Kjær, Canton, Michigan

Rainy, cloudy, cold and unpleasant. Sounds like a weather forecast better suited for staying indoors and finishing up a term paper you have been putting off for 15 weeks than getting outside to race around in overpowered go carts. But for some, this type of weather has come to mean something a whole lot more exciting then not finishing up a term paper – Formula SAE (FSAE) time! For the past few years, the weather has not been very cooperative for the Michigan event. Yet undaunted, over 1,500 engineering students come to push not only their cars, but themselves to the extreme limit.

This annual SAE (Society of Automotive Engineers) sponsored gathering has challenged some of the worlds best engineering students to organize, design, build, test and compete in a wide range of grueling events. The events are designed to test these small Formula One style cars that the students have spent the better half of a year putting together. This is their chance to finally implement, in a practical real world application, the theory taught in the classroom. Students that participate in FSAE events gain first-hand knowledge of the problems and issues facing engineers today.

The event sponsored by SAE and co-sponsored by a consortium of the world's top automotive companies has taken place for over 27 years. The competition has grown so much over time that a second event was introduced – a 'West' competition. This gave more teams the opportunity to compete and, for some, a second chance. Over 200 teams from more then 10 different countries came to the 2006 competition which made it the largest ever.

In order for teams to qualify to run in the events, they must first pass a battery of tests designed to test the car for durability and, more importantly, safety. These initial tests include a rigorous technical inspection conducted by top examiners from SAE, SCCA (Sports Car Club of America), as well as participating auto makers and suppliers. Their goal is to be sure that the car complies with all safety requirements and mandated mechanical construction. The rules for the cars have changed over time, but some remain the same. Every car must have a working suspension, brakes on all four wheels and, at most, a 610 cc four-stroke piston engine. On top of that, more attention is paid to subsystems like fuel, exhaust, power and occupant safety. Roll cage construction has to be checked for frame thickness and welding points are double checked for integrity.

Passing the tough visual inspections is only the beginning! Once cars are cleared from the physical inspections they are sent off to the fuel station, where the vehicles are tanked up and the fuel systems double-checked for leakage and overflow. Fully fueled vehicles head over to the tilt table (see Figure 1) where the car and driver are strapped to a hoist that positions them at 45° and 60° angles to make sure nothing comes out (including the driver). The next stop for car and driver is the brake station. The purpose of this inspection is to test the cars braking systems under full power. They accelerate through a speed trap and then lock up all four tires, coming to a complete stop without killing the engine (or bystanders). This event alone has been known to buckle the knees of even the most veteran engineering student and faculty advisor.

Figure 1. Car on the tilt table at FSAE West.

But they are still not finished! One more test must be completed before a team can move to the dynamic competition portion of the event. This one test has brought tears to the eyes of some (mainly because of the exhaust smoke) and has come to be known as the dreaded noise test!

In order to truly expose students to the real world considerations of automotive engineering, SAE has placed a maximum allowable noise level on the cars. This noise limit, set at 110 dBA, has stopped some of the most experienced teams dead in their tracks. This level may seem high, but data from the past three years have shown that only about 65% of the vehicles pass on the first attempt. The average of the first round of noise tests in 2006 was 108.6 dBA, up 0.9 dBA from the 2005 event.

The tests are conducted under the watchful eye of the noise event captains and all possible considerations are taken to ensure fairness and equity from test to test. The site is run like an assembly line. Cars are pushed into the noise area, which is typically isolated from the other events to minimize the influence of background noise and other environmental factors. A difference of 20 dB is maintained between the expected car sound levels and the test site ambient level. A Brüel & Kjær 2250 sound level meter is set up at the entry to the noise event and sound levels are logged at 1 sec intervals when the car noise tests are being conducted. This provides an objective tool for assuring that a 20 dB difference is present. A check of the data will show any times when a less then 20 dB difference existed.

Figure 2. Car undergoing noise testing at FSAE in Romeo, MI.

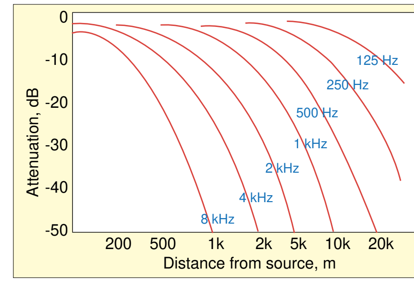

Figure 3. Attenuation of sound as a function of distance

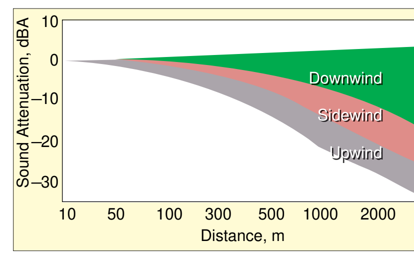

Figure 4. Attenuation of sound as a function of wind speed and noise source location.

Once in the noise test area, teams are asked to start the car with the driver fully strapped in. Then they are asked to rev the car to 3/4 of the maximum RPM for their specific engine (see Figure 2). A digital tachometer is used to assure that all teams are on a level playing field. Teams with rev-limiters are asked to set them higher or disconnect them to allow the engine to be tested normally. The test RPMs are calculated right from the teams own engine data. Taking 2× the stroke in mm and dividing it into 914.4×1000, gives an exact 3/4 throttle setting for that specific engine. From there it is rounded to the nearest 500 RPM and the test conducted.

Once that work is done, the test itself is rather simplistic. It is conducted in accordance with Formula SAE rule 3.5.5.3. First, the 2250 sound level meter is placed at 0.5 m from the exhaust outlet in the horizontal plane, carefully positioned 45° out of the flow where the reading is then taken. For cars with dual exhaust systems, each exhaust is tested and the highest measured sound level used for judging.

The test is conducted this way because it has been determined that the typical vehicle exhaust system is a point source. A point source is one where the sound radiates out spherically, so the sound pressure level is the same for all points at the same distance from the source. This puts all the teams on a level playing field.

One question that has often been raised by the students is "how come you do not use a windscreen?" Atmospheric attenuation of sound is a complex subject. The reduction of noise as it passes through the air is dependent on many factors including: distance from the source, frequency content, temperature, humidity and atmospheric pressure. The first two are the most influential. Figure 3 illustrates that lower frequencies are not significantly attenuated by distance. A typical 1/3-octave band spectrum from one of the cars would show that most of the noise components are less then 1 kHz in frequency. Another important environmental factor is wind attenuation. At short distances (less than 50 m) the wind has a minor influence on the measured sound level. The effect of the wind becomes more appreciable as the measuring location moves away from the source. For the competition we are dealing with a maximum distance of 0.5 m from the source. Figure 4 shows attenuation of sound as a function of wind direction and measuring distance from the car. Since the event captain has a 0.5 dBA judgement leeway, these factors are not really taken into account during the measurements.

The obvious method for reducing noise used by some of the teams is to alter the noise path. This might be done by placing the exhaust in the vehicle housing or by using the tires as a barrier. Lower frequencies are very hard to attenuate with barriers. Nonetheless, the rules do specify that all teams must remove any housing and obstructions between the exhaust and the sound level meter. To prevent teams from "tuning the exhaust," a rule was recently added that allowed the event captain to fail a team at any speed less then the 3/4 RPM if the exhaust has been tuned. Such a modification is not in keeping with the spirit of the competition. The rules also allow for ±0.5 dBA uncertainty. The Brüel & Kjær 2250 sound level meter is a Type 1 unit, which inherently has less than 0.2 dBA uncertainty. When field calibrated, the 2250 has a deviation of only 0.1 to 0.3 dBA from the laboratory-measured calibration.

If the team's maximum noise level is above 110 dBA, a real engineering challenge lays before them. The team now needs to take into account the delicate balance between performance, horsepower and noise and put their knowledge of engine diagnostics and performance into practice.

Some fixes are simple and quick: adding or subtracting restrictor plates; or 'packing' the muffler with glass fiber or other material in order to damp the noise. But just as in real life, simple fixes can have very bad results as one team learned the hard way. During the vehicle rev up to the required 3/4 RPM, the muffler blew out from the back pressure built up by not being able to vent properly. Other teams tighten the muffler to the body of the vehicle in order to 'add' mass to the muffler, thus reducing the effects of resonance in the system. Some teams even went as far as changing out the whole muffler on the vehicle and then resetting the performance criteria to modify the fuel intake. While some of these field fixes may or may not work, the more successful teams have taken the time back at the lab to seriously consider this specific requirement.

Another issue the teams have to wrangle with is exhaust venting and positioning. As was mentioned above, the venting of the exhaust is really not a factor since it is determined we are dealing with a point source. The only issue left is where to position the exhaust. Some teams place exhausts higher on the vehicle in an effort to radiate without reflection, while some lower exhausts to the ground in an effort to gain an advantage thinking some sort of absorption will take place.

The effect of the ground on sound attenuation is based on the type of surface material (e.g. concrete, grass, etc.). Ground attenuation is often calculated in frequency bands to take into account the spectral content of the noise source and type of ground between the source and the receiver. Figure 5 shows that the FSAE noise test is conducted on what is considered a hard surface (concrete). Teams that mount their exhaust outlet lower to the ground may be at a disadvantage due to a 3 dB sound pressure level increase they will experience across most octave bands. This is important since the most significant noise components from the cars are in the lower end of the frequency spectrum.

Once all the teams have passed the noise test, it is time to see who has the quietest car. Brüel & Kjær sponsors a special award that all teams are eligible for on their first attempt only. The Brüel & Kjær Quiet Car Cup (BKQCC) recognizes the team (or teams in the case of a tie) that truly take the noise test into consideration. Teams that score the lowest sound level reading on their first attempt get a $250 check for that school's FSAE team. In 2006, the winners were the University of New Hampshire (East) and the University of Alberta (West). Congratulations to both teams.

The University of Alberta team (Figure 6), who won the BKQCC at the 2006 'West' event, did significant work in advance to make sure that noise was not a problem. With a sound level of 101 dBA at almost 8,000 RPM in their first attempt they really took noise seriously.

University of Alberta's power plant was a Kawasaki EX500 with 500 cc displacement and a turbocharger, which was fitted with a Yoshimura RS-3 muffler. The turbo charger removed much of the pulse energy generated by the exhaust blow down and this effectively controlled the noise. They also did not let the waste gate open during the noise test, as the engine is not under load and all the exhaust must pass through the turbocharger. This had a significant noise reduction effect. They also took advantage of the engine's relatively large cylinder dimensions (compared to 4-cylinder engines) to push the noise emissions toward the lower end of the spectrum, where the A-weighting network provides more attenuation. Lastly, they approached the design of the intake placement. Internal combustion engine intakes can be quite loud and can be isolated from the noise test by placing them forward of the engine. This is particularly convenient with a turbocharger as the exhaust outlet faces the rear of the vehicle and the intake inlet faces the front.

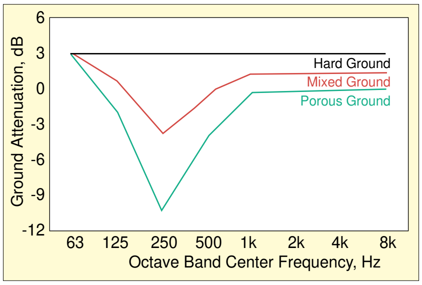

Figure 5. Attenuation of sound as a function of ground surface.

Figure 6. University of Alberta team at FSAE West.

Figure 7. University of New Hampshire team at FSAE East.

The University of New Hampshire team, who won the Michigan FSAE event (Figure 7) did some serious work up front to prepare for the noise test. First they developed a custom exhaust header and collectors, which ran into a stock Suzuki GSX-R muffler. The manifold was made from 1.25 in. stainless steel tubing . Some work was done comparing the previous years engine and headers versus the newly designed ones. The noise reduction was significant.

Brüel & Kjær has been very proud to be a member of the organizing committee and a Gold sponsor of this event. The 2250 sound level meters along with the time from Brüel & Kjær application and sales engineers are donated to SAE for this competition to assure everything runs smoothly. For the past 6 years we have done our part to help make the competition just a little bit quieter.

Please visit www.bkhome.com for more information on the 2250 Sound Level Meter and other Brüel & Kjær products.

The author may be reached at: gary.newton@bksv.com.