ULTIMATE TUNING OF MECHANICAL FUEL INJECTION

by Robert Szabo

Drag racing mechanical fuel injection is a simple hydraulic system. It follows all of the scientific rules of any other hydraulic system such as the ones that are throughout manufacturing; dump trucks, tractors with hydraulic shovels, hydraulic elevators and many other applications around us. With some setup provisions, mechanical fuel injection provides a very high capacity for horsepower making. It is the standard in many injected as well as supercharged classes. It works well with gasoline, methanol, ethanol and especially nitro. Since mechanical fuel injection is not adaptive like a carburetor, it requires proper adjustment. That can be a tough obstacle to a new tuner without fuel injection experience.

FUEL INJECTION WITH EXPERIENCE

An experienced methanol fuel injection tuner will know that a 0.034 inch diameter nozzle and a 0.130 bypass will get the stacker injected Big Block in the ball park with a seven gallon a minute fuel pump. He knows the bypass is a return path for tuning the engine. It provides a route to return excess fuel to the fuel pump. He knows if he increases the bypass jet to a 0.135 inch diameter, the car will run well in warm weather. He also knows that on a cold day, he may have to run a 0.125 inch (smaller diameter) jet, necessary for the more dense air from the cold temperature.

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He has experience setting up the idle adjustments as well as where to set the launch control to stay within a fuel pressure range for good launch response.

Another tuner has experience with 0.040 inch diameter nozzles on methanol with another main bypass and fuel pump for a bigger Big Block. He or she has similar tune-up rules: larger main bypass for warm weather and a smaller main bypass for colder weather. Another has experience with 0.026 nozzles on racing gasoline and still another has experience with 0.070 nozzles on nitro.

Some fuel injection racers have found the center of the operating window for their fuel injection. They seldom change a jet or poppet pressure for any of the IHRA tracks they compete at all year. They travel to a known number of racetracks and stay within their setup range. The key for this trouble-free performance is that they found the center of an operating window.

INDUSTRIAL PROCESS

My last industrial (non-racing) contract was to develop spot welding for the GM Suburban aluminum lift gate in the rear of the vehicle. This was the first ever low-cost, aluminum assembly to go into high production. This manufacturing task had hundreds of welds per minute with many settings per weld. The engineering challenge became the determination of process windows of adjustment -- and setting each adjustment to the center of the window. To give you an idea of the success of this method, look at the smooth spot weld dimples in the sides of the lift gate of any new GM Suburban, Yukon or Tahoe. Those uniform dimples are revealed when the gate is open. The spot welding of this aluminum component was successful because of the adjustments set to the centers of the process windows. When I last saw this production about one year after the startup, the welding production remained essentially flawless.

THE RACECAR PROCESS

A racecar is nothing more than a process, just like any other production process. There are benefits from good adjustments and perils for bad ones. My racecar experience was always more difficult than my industrial experience until I realized that the process window concept with its benefits would apply equally well to racing.

FUEL INJECTION PRESSURE DETERMINATION

After that realization, the first tasks I did with my blown alcohol bracket Funny Car was to determine a fuel injection operating pressure window. I started out with a larger total jet area for the injectors and bypass jets. That results in a lower pressure. I had access to some math that determined the approximate value of that pressure. I tested the racecar and noted the engine characteristics.

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Then I reduced the total injector and bypass jet area. That produced a higher pressure. During this test, I maintained the same ratio of injector area (to the engine) as bypass jet area. That kept the same air to fuel ratio in the engine. After a series of test runs, I selected a total jet area that provided the best system pressure for response and reasonable fuel pump loading. Higher pressure provides good response. Lower pressure provides better fuel pump life. A tradeoff is necessary. With a preliminary value selected, I kept that total jet area to maintain a system pressure of about150 psi. That was done for all subsequent test and competition outings.

AIR TO FUEL RATIO DETERMINATION: RICH START

The next task was to determine my air to fuel ratio window. In a series of test outings, I started with a rich mixture and, in subsequent outings, leaned the engine in fairly equal steps. In the first outing, the engine was set up so rich that some amount of raw methanol was shooting out the exhaust pipes on the run. The engine did not heat up. After a few test passes, I took the racecar home, changed the soupy oil and prepared it for the next outing in a week or so. The oil was soupy from methanol contamination washing by the piston rings. This became my rich air to fuel ratio limit.

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LEANING IT DOWN

In the next outing, I leaned down the air to fuel mixture about 5%. This was done with some simple math calculations for a known change. Little if any raw fuel shot out the exhaust on the run. I made several test runs and returned home. The engine oil was less soupy from methanol contamination. In a series of several more outings, I leaned the engine in fairly equal ratio points of about 5% increments for each outing. Again, some simple math was used to determine reliable and uniform lean out steps.

LEAN LIMIT

After an outing with an air to fuel ratio several steps leaner than where I started, I checked spark plugs to see if any heat was building on the threads. One of the techniques used by many racers is to run plated spark plugs. Then after a run, the spark plugs are removed. The threads are examined to see if any were discolored. A certain number of threads with plating discolorations are a tuning indicator. That indicates a certain level of heat build up in the engine. Subsequent tuning to that same number of thread discolorations maintains a tuning baseline. After this outing, one thread was discolored in spark plugs from most of the cylinders. That would indicate still a rich mixture with little heat build up.

After I returned home, I disassembled the engine and found two melted piston domes. The piston domes were sunken in the middle from overheating from excess lean running. I was surprised that the spark plugs did not reveal the heat that caused this damage (that peculiarity is under analysis for my next book on methanol). However, I had just found my lean limit. This lean limit was about 30% away from the rich limit where I started from several weeks earlier. I replaced the pistons to restore the engine, and that was the last engine damage that I encountered with this high-powered bracket racing combination.

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MIDDLE GROUND

I chose an air to fuel ratio in the middle. It was about 15% rich or 15% lean depending on how you look at it. I set up the math to calculate the air to fuel ratio for differing conditions and spent the next few years having fun bracket racing with absolutely no burned pistons, blown head gaskets, banged blower, backfire, misfire, or any other peril from my fuel injection tune-up.

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HAVING FUN WITH NO TUNING BURDEN

Over that time period, blower overdrive ratios were changed for power output selections from 1,200 up to 1,700 horsepower. I ran at air densities from as low as 90% to as high as 103%. I always readjusted jetting in my fuel injection for the different air densities and blower overdrives. The adjustments were done to maintain that central mixture point, remembering that it was 15% away from either the rich or the lean extreme. I never did try to run without jetting readjustment as a few successful, normally aspirated methanol racers do. I am not aware of any supercharged racers who run without jetting readjustment for air density changes.

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I confirmed the math and kept corroborating the jetting changes. Near the end, I could choose a setup to run a specific quarter mile elapse time anywhere between 8 seconds down to 6.6 seconds. In one test outing, I set up a 6.70 and ran it. Then in the next test outing, I set up a 7.50 and ran it.

From hundreds of runs, I kept records of the math and procedures for how to tune mechanical fuel injection. From that, I found that mechanical fuel injection is an exact science and not an art. Once the system pressure and air to fuel ratio is controlled, the engine starts the same, warms up the same, has the same response, and opens the high speed the same. The engine makes the same power for the same air density, wherever that may be. It also makes a predictable change in power for the same change in air density.

From then on, racing has been a blast. In a typical local racetrack condition, qualifying is in early afternoon at 95+ deg. F temperature. Competition continues into the evening with temperatures down to 65 deg. F. That temperature change would require a jetting change in my engine.

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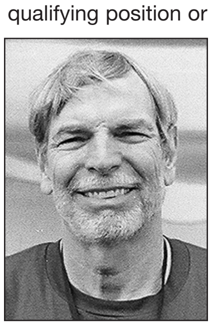
The day before an event, I predetermine my jetting for the event temperatures. With Internet information about the hourly weather predictions for the next day, I set up my jetting decisions for the different temperatures according to the time of day. When that time occurs during the next day of competition, I change jets according to my predetermined plan. I do not have to think about jetting decisions during race day. That was a major relief since there always seemed to be something else that needed full attention such as the qualifying position or the competitors' performance levels.•



Bob Szabo is writer and owner / driver of a blown alcohol drag racecar. The methods referenced in this article are presented in his technical book: "Fuel Injection Racing Secrets." The next level of tuning, specific to methanol, is to accurately change the air to fuel ratios for injection or for carburetors. Those changes would be for different engine speeds, rates of acceleration, and possibly different air densities. That information is part of the content in the author's next book on methanol racing fuel that is a few months away. Check the DRM Yellow Pages for Szabo Publishing or look on the Internet at http://www.racecarbook.com or call (707) 446 2917. If you have any comments about this article or any previous articles by the author, feel free to E-mail directly to the author at bob@racecarbook.com or to the DRM staff: pjm@livenation.com or mperry@livenation.com