A smoother engine and better economy?
Dobeck SAFR points to V-Strom rich fueling under top gear cruise load

By Cole Boehler

Dobeck Performance, out of Belgrade, Mont., a company whose principals have decades of engine fueling solutions and diagnostics under their belts, has developed a new analog air-to-fuel-ratio (AFR) gauge for the do-it-yourselfer or the commercial mechanic's shop. (See the August 2014 *NR Rider* for more details.)

We traveled to the Dobeck facility August 8 to explore an actual installation and use of the tool, called a "SAFR" for "standalone air-fuel ratio."

Our test mule was a 2003 Suzuki DL-1000 V-Strom, an early iteration of the brand's big adventure bike. It is known to suffer some drivability issues, namely rough running below 3,500 RPM where it lugs, chugs and shudders, euphemistically described by owners as "chuddering."

In fact this bike was geared down with a larger after-market final drive sprocket to run at higher RPM in all gears, allowing the rider to more readily stay at higher revs and out of that rough zone.

Often riders may be seeking improved "performance" – that is, "power." In the case of our V-Strom, it makes about 98 crankshaft ponies and that is plenty for its intended mission – an "80/20" (or maybe "90/10") bike intended for highway use and light sport-touring 80 percent of the time, and light "adventure" touring off pavement 20 percent of the time.

Seldom would more power enhance its real-world utility. Smoother engine operation, however, certainly would.

Our objectives would be to first learn and understand the bike's factory fueling characteristics by reading AFRs, then contemplate changes that would improve drivability, hopefully without a corresponding loss of fuel economy.

Simply stated, the SAFR is an analog gauge that, tapped into your bike's exhaust, will read your AFR values under a wide range of conditions and load modes such as idle, cruise, acceleration and full throttle.

The SAFR system consists of a Dobeck gauge and wideband controller, a Bosch wideband exhaust oxygen sensor, a patented Dobeck oxygen sensor chamber and exhaust probe, and various installation bits.

Unique to the Dobeck sensor chamber are reed valves that prevent any gases from reverting – flowing backward – and thus fouling accurate measurements.

The system can tap power via a cigarette lighter socket, direct to the battery, through a Battery Tender type SAE pigtail, or another power extension. The harnesses are provided.

Installation of the SAFR is straight forward and within the skills and tool range of most riders.

In essence, a hole is drilled into the exhaust header pipe (drill bit supplied) and a nut insert is pressed into the hole. The exhaust probe is mated to the nut insert and the oxygen sensor chamber threads to the probe. The probe has a "spoon" orifice that should be positioned to catch or "scoop" exhaust gases coming from the upstream exhaust ports.

Patented Dobeck Performance exhaust chamber with reed valves to prevent "reversion" is tapped into the exhaust header.

Find a spot to mount the gauge using the suction cup provided (top of fuel tank usually works), or the new handlebar mounting clip. Plug the gauge into the wideband sensor and power it up.

You can now see your AFR values under a wide range of conditions – verify what you suspect – and decide upon modifications that can improve drivability, performance or fuel efficiency, maybe some combination of the three.

Bosch wideband exhaust oxygen sensor threads in and tightens with a simple wrench.

When you're done, reverse the installation, threading the provided screw into the nut insert to seal the exhaust system.

My installation for the Suzuki went well, with coaching help from Dobeck's Dillon Binstock. Thread, tighten, plug, power up and play. Truly, any Joe Mechanic could do this at home himself.

The PAIR system should be plugged to make AFR readings most accurate. "PAIR" means "Pulsed Air Induction Reed" valve. This system, found on most modern bikes, allows additional air to be introduced into the exhaust header to help fully burn any residual fuel that may have left the combustion chamber on the exhaust stroke. Unfortunately that added air distorts true AFR exhaust gas values.

Also consider, most conventional AFR probes are merely inserted into the tailpipe. Exhaust systems produce both outward and inward pulses so a reading at the tailpipe may be distorted by additional air being drawn *into* the exhaust system – "reversion," especially likely with the short, open pipes favored by some.

Thus, it is most accurate to read the AFRs in the header pipe four to 10 inches downstream from the exhaust port.

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One of the benefits of using the SAFR, according to Dobeck, is dispensing with expensive dynamometer shop time. Instead, install a SAFR, then take your bike out on the road to observe AFRs in real-world riding conditions under varying throttle demands and loads.

The SAFR will yield AFR readings from 10:1 to 16:1, that is 10 parts of air to one part fuel (very rich), up to 16 parts air to one part fuel (very lean), based on wide-band readings of the exhaust.

Overly rich AFRs result in an engine that lacks power and wastes fuel. Too rich and spark plugs can foul and the engine may not run at all. Fuel deposits can build up in the combustion chambers and on piston crowns. Deposits on valves can lead to a loss of compression and valve damage.

Overly lean AFRs can lead to excessive combustion chamber and valve temperatures causing serious and expensive engine damage. "Detonation" or "knock," where a too-lean air-fuel charge ignites prematurely and creates tremendous cylinder shock waves, is another potentially damaging side effect.

Some, including the EPA, consider an AFR of 14.64:1 to be ideal, theoretically optimal for a well tuned, clean burning engine.

Binstock explained that many engine control units – ECUs – that run fuel injection systems via computer code "maps," actually run several maps, the choice of which is determined by what the rider demands of the system under differing circumstances: cruise, acceleration or maximum throttle.

Binstock suggested I examine AFR readings in steady cruise mode in several mid-range gears, then under moderate acceleration, then with the throttle wide open. Fortunately, there are some straight, light-traffic back roads near the Dobeck shop where testing could be conducted safely.

At idle the SAFR indicated an AFR for the Suzuki in the range of 11.5:1-12.5:1. Binstock said idle AFR in the real world is somewhat inconsequential. Just tune it for the smoothest idle, he suggested, regardless of AFR.

The V-Strom, in stock form other than the lowered gear ratio, seems to cruise best between 4,000 and 5,000 RPM where it is most smooth and responsive.

So I checked AFRs at steady cruise throttle settings and saw in second gear at 4,000 RPM an AFR of 12.5:1 to 13:1. Cruising in third gear at 4,000 RPM, the SAFR analog gauge needle settled in the 12:1 range. It was much the same in fourth, fifth and the top sixth "overdrive" gear.

These AFRs would likely be considered on the rich side, so fueling at steady cruise throttle settings could be leaned out, potentially achieving smoother and more responsive engine operation and additional economy as well as cleaner emissions.

(Note: some ECU fuel mapping is automatically adjusted depending upon gear selection via a gear position sensor. Thus AFRs may differ under similar throttle settings and loads in different gears.)

Under moderate acceleration – perhaps half throttle – the picture changed.

When the throttle was opened, we saw the needle swing to 15:1, even 15.5:1, hang there for a second, then drift down toward 13-13.5:1 as revs came up.

This probably indicates throttle

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Then it's just plug-and-play as the SAFR is attached to the exhuast oxygen sensor and powered up.

Handlebar-mounted SAFR indicates 1,100 RPM idle AFR is at 12:1.

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butterflies opening ahead of increases in fuel flow, temporarily leaning out the mixture until increased fuel flows caught up to increased air flows. The 13-13.5:1 AFRs are quite acceptable for an acceleration condition – perhaps just a little on the rich side.

At wide open, we saw the SAFR gauge indicate an initial reading of 14-14.5:1, then settle back to 12-12.5:1, somewhat rich but what could be expected under full throttle and, again, acceptable.

We saw problematic fueling under two conditions.

First, at cruise mode in top gear, 3,000-4,000 RPM, AFR was hanging at about 12:1 – quite rich for "cruise." This could be – should be – leaned out. Fuel economy could be improved while the engine could gain some snap and smoothness.

We could also identify potential improvements when the engine was under acceleration at lower RPM ranges – under 3,500 RPM where it currently runs roughly. Here we saw AFRs ranging from 11.5:1 to 12.5:1.

The bike also exhibits some on-off "surging" at steady throttle openings in middle gears. This might be where the ECU is "switching" back and forth between maps, upsetting smooth fueling. This condition may be addressed as well.

Inherent Suzuki V-Strom engine architecture may be primarily responsible for the rough low-RPM running – big pistons hammering in big bores with a light crankshaft and flywheel producing the "chuddering"? But an overly rich AFR at low RPM could also result in air-fuel charges that are "wet" and resistant to quick ignition and a full burn.

So, instead of adding fuel, in the case of our V-Strom we would likely be focused on leaning AFRs in zones where the SAFR indicated they are too rich.

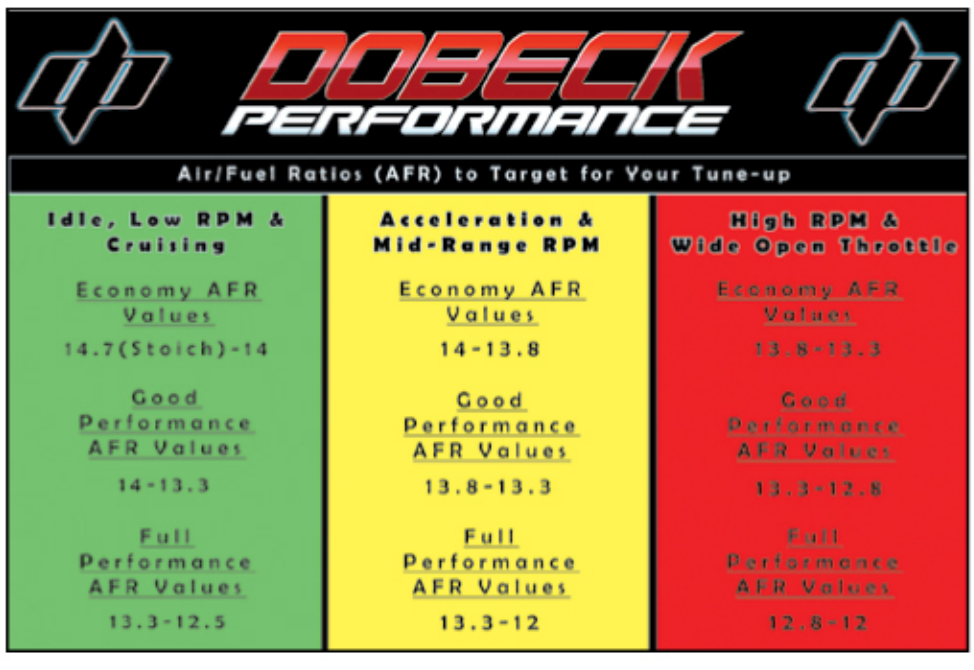
Is it possible we could achieve a smoother, more drivable engine while increasing fuel economy? We'll see.

We are planning to use the SAFR again, then attempt some AFR modifications for improved drivability. As a by-product, we may also get better economy and more power in certain conditions.

That would be an ideal outcome.

Look for our results in the October edition of *NR Rider.*

For more information on Dobeck Performance and the SAFR, check out <www.safrtool.com>.



This is a chart developed by Dobeck to illustrate what various AFRs under various load conditions can mean for engine behavior.