Engine Performance: Benchmarking Through Spark Plug Analysis

By A. R. Brenholts Jr.

From the spark plug manufacturers' perspective, the routine and conscientious examination of spark plugs removed from service can make a meaningful contribution to the diagnostic regimens used to benchmark engine performance.

A spark plug is the recorder of a power cylinder's operation throughout the service life of the spark plug in a specific power cylinder.

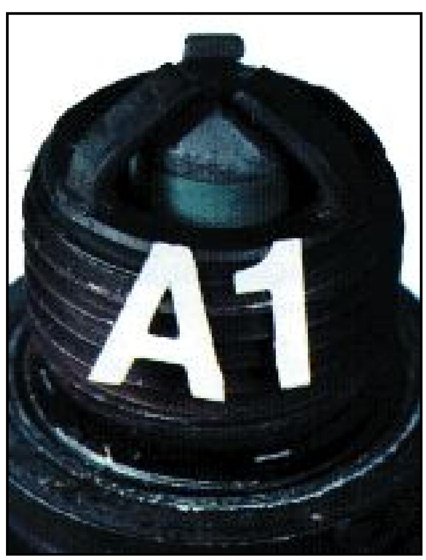
Since the spark plug is the most accessible power cylinder component, it can be the most relevant diagnostic aid available to the conscientious engine operator. Careful and informed inspection of the firing ends of all the spark plugs removed from an engine can detail conclusions regarding operating conditions. This information can assist in significantly reducing component failure, saving considerable amounts of downtime and money.

Virtually all spark plugs subjected to firing-end, deposit analysis have lube-oil derived elements in the deposit. In many instances, where the lube oil from the subject engines was being regularly analyzed, we have frequently found elements in the firing-end deposits that did not show up in the lube oil analysis.

We conclude that power cylinder component wear can be occurring excessively and that conventional lube oil analysis can miss it. The wearing material in the power cylinder above the BDC position of the bottom-most piston ring may be vaporized, the bulk of it leaving the engine in the exhaust gases. If the thermally colder spark plug should get in the way of this vaporized material, it should cause this material to condense out on the plug's firing-end, thus capturing a clue to operating conditions within the power cylinder. The examination of the operating record retained by the firing-ends of spark plugs during their service interval should be regarded as one of the most revealing methods available for monitoring an engine's operation, establishing trend-lines of possible component wear events and rates.

The following case studies illustrate the spark plug's ability to reveal wear trends of major engine components.

CASE A



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The plug in Case A is one of a set of 12 that had operated for approximately 2000 hours in a naturally aspirated, four-stroke cycle, natural gas fueled, stationary. V-angle, 12-cylinder engine driving a separable compressor at approximately 1000 rpm.

The abnormal (blue) deposit on "A1 " is rarely observed as a spark plug deposit coloration, but, in this instance, five of the 12 spark plugs exhibited this coloration.

As a rule, only the metallic element, cobalt, can cause a blue coloration that will endure the elevated temperatures of combustion. Cobalt is not a constituent of any firing-end component of this spark plug. This spark plug's deposit coloration then, is a warning that some engine component may be experiencing high temperature wear that might progress to catastrophic failure. In response to the observation of this coloration (as well as to other exceptional deposits), we would recommend a borescope examination of the involved power cylinders, and possibly the quantitative analysis of the deposit material for a clearer resolution of all the excessive wear-involved components.

A scanning electron microscope analysis conducted upon the turquoise material deposited in photo "A1 ", revealed this chemistry in approximate volume: 39% aluminum, 21% cobalt, 24% chromium, 8% iron, 1 % nickel, 5% phosphorous, and 2% calcium Excepting the phosphorous and the calcium, which are typically lube oil-derived elements, the principal constituents are metallics, probably introduced in the process of abnormal wear. The next step would be to isolate wear-subjected engine components fabricated from these elements and respond accordingly.

The four other spark plugs of this engine set, which displayed a similarly blue-colored deposit, exhibited virtually identical deposit chemistries. Though we cannot establish these spark plugs in the time frame of the wear process, within the week after these spark plugs had been removed and shipped to us, the engine experienced catastrophic component failure. We suggest that a routine inspection of spark plugs being removed from service might have caught this wear trend at an earlier stage, creating the opportunity for the corrective actions to arrest the abnormal wear trends . . . or, to turn unscheduled downtime into scheduled downtime.

CASE B

This plug was returned to us as one of a set of 16 that had operated for only 200 hours in a turbocharged, four-stroke cycle, low Btu digester gas fueled, stationary, V-angle, hot water cooled, 16-cylinder engine driving a generator at 1200 rpm.

The volume of red-colored, crusty ash is extraordinarily large for such few operating hours. Virtually every spark plug from every cylinder exhibited a similar deposit volume and appearance. Because the engine is a four valve, crossflow design with a central spark plug placement, the asymmetrical concentration of deposit material indicates that it was fuelborne. The area of the spark plug firing-end with the heaviest deposit concentration is typically facing the intake valves. Unless the subject engine's lube oil consumpton has been abnormally excessive, we would find it almost impossible for this volume of deposit to occur in such a short time.

A quantitative analysis revealed the following chemistry i n approximate concentrations: 12% phosphorous, 52% calcium, 10% zinc, 19% sulfur, and 7% iron. The phosphorous, calcium, zinc, and sulfur can be identified as lube oil elements. But the deposit is comprised of a large volume of sulfur in the sulfide state, quite often indicative of hydrogen sulfide in the fuel gas. If this were the case, then the iron could be the result of hydrogen sulfide-aggravated corrosion in the fuel delivery system.

In conversations with the engine operator, it was confirmed that the fuel gas was unprocessed, unconditioned and that the possibility for high concentrations of hydrogen sulfide existed. This could not be confirmed, though, as no fuel gas analysis had been made. It was confirmed, however, that the engine was not being operated with any lube oil anything like the lube oil the deposit chemistry suggested was being introduced into the power cylinders. More to the point, the operator could not confirm any excessive rates of lube oil consumption for the engine.

The source of the operating problem was pinpointed when the operating personnel remarked that the only device consuming excessive amounts of lube oil was the compressor which was used as part of the fuel delivery system so as to boost the low Btu gas to the engines. It was eventually confirmed that the fuel delivery compressor and its excessive rate of lube oil consumption was the mechanism responsible for the large incidence of spark plug fouling.

CASE C

This plug was returned to us as one of a set of 12 that had operated for approximately 4000 hours in the fuel cells (pre-combustion chambers) of a turbocharged, four-stroke cycle, stratified charge, natural gas-fueled, stationary, V-angle, slow speed, 12-cylinder, integral compressor engine.

The operating time on these spark plugs was regarded as normal. The spark plugs were returned to us as part of an engineering evaluation control. We regard this spark plug's firing-end appearance as being typical of so many operating hours with a low ash lube oil, and include it primarily to provide a reference point for the Case A & B spark plugs.

CONCLUSION

We strongly advocate the regular examination of the spark plugs removed from service in any routine benchmarking of engine operation. At the very minimum, a careful visual examination of the spark plugs' firing-end appearances can identify power cylinders that may benefit from borescope (or other) inspection routines.

If this analysis of "used" spark plugs is to be effective, the spark plugs removed from service must be logged as to their operating hours as well as to their engine location (i.e., cylinder #2R or cylinder #2R, intake side plug, for example, if a dual spark plug cylinder). Furthermore, the full engine complement of spark plugs must be examined so that a comprehensive picture of cylinder norms can be developed, and so that exceptional appearances can be isolated based on the historical record.

These diagnostic measures are based upon our requirements for our factory-conducted diagnostic services. Our experience indicates that this type of spark plug analysis is invaluable as a diagnostic medium and can provide operators with significant information

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Originally printed in the October 1985 DIESEL PROGRESS NORTH AMERICAN EDITION

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