Complexity in ISFA (in-service fluid analysis): Part XLI

Holistic CM in the 21st Century: Part XIII

By Jack Poley

Continuing to fill in our expert system (EXSYS) two-phase Fe/Si rule, the macro rule (objective) is shown in Figure 1, yet again, for reference. We completed the lockstep part of the rule, where Fe/Si colors are matched and the initial conclusion, *that Si is causing Fe wear*, was fleshed out. Now we finish the rule for the remaining 12* propositions, those where coloration is not identical.

**There are actually 32 separate propositions linked by twos, because in any two-phase rule, two datum pieces are being matched up for a composite advisory—having 16 possibilities, wherein the evaluator should assess what influence each datum exerts on the other for each combination of colors (see Figure 2 on Page 134).*

Some rules development posits:

1. We have already done the stats to determine the appropriate coloration of the results based on table of boundaries (TOB) numeric or other test results—so we don't need to deal with this complexity in composing rules. We can always change the ranges of coloration to create triggers at any data points to achieve the desired urgency, based on any or all combinations of:
   a. Customer (usually the most precise point).
   b. Component type (a required feature in all EXSYS activity).
   c. Component manufacturer (MFR) and model. MFR alone also is a valid stepping stone—model adds nuance, sometimes quite significant.
   d. Application or duty cycle (usually a very important consideration).
   e. Special wild card (2) situations (e.g., ceramic components).
   f. Lubricant in use (if fully identified as to brand, not just Shell, ExxonMobil, etc.).
2. The example in Figure 1 is a generic rule that fires anytime both Fe and Si are not White (SEV 0).
   a. It operates independently of, say, Fe/Cu or Al/Si.
   b. If rules exist for Fe or Si by themselves—and they do, of course—the two-phase composite rule trumps both individual single-phase rules. Since Fe/Si add nuance when evaluated jointly, any aspect of the individual rule can be rolled up, morphed or ignored as suits the joint evaluation of Fe and Si, as would most likely occur since another data point was introduced, causing a dependency as dictated by the rule.
   c. Yes, if a three-phase rule, such as Fe/Si/Cu were created, this would trump our two-phase rule that trumped the single-phase Fe ▶▶▶

2-Phase Rule for Fe & Si Wear vs. Abrasives (?)

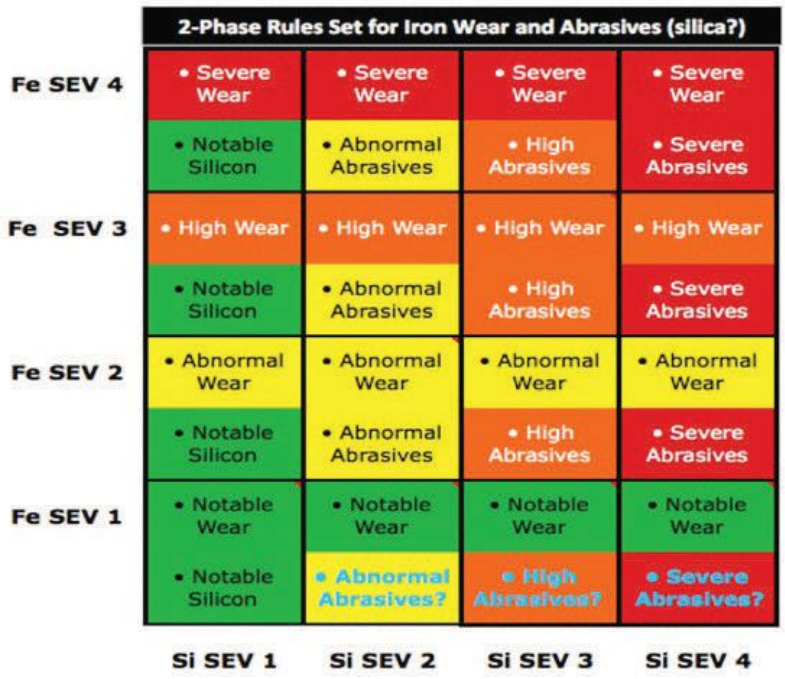

Figure 1. **Fe versus Si.**

	Comments : Advisories	Comments : Advisories	Comments : Advisories	Comments : Advisories
Fe 4	• Fe level is Severe • Perform diagnostics tests • Consider inspecting this component for abnormal wear, based on diagnostics	• Fe level is Severe • Perform diagnostics tests • Consider inspecting this component for abnormal wear, based on diagnostics	• Fe level is Severe • Perform diagnostics tests • Suggest inspecting this component for abnormal wear, based on diagnostics	• Fe level is Severe • Perform diagnostics tests • Suggest inspecting this component for abnormal wear
	• Notable Si level • Abrasives do not appear to be a significant contributor to wear; re-evaluate at next sample to note trend	• Si level is Abnormal • Abrasives may be causing Fe wear; check for ingress source • Drain lube; change filter as applicable	• Si level is High • Abrasives likely causing Fe wear: check for ingress source • Check lube storage/handling practice • Flush lube system	• Si level is Severe • Abrasives likely causing Fe wear: check for ingress source • Check lube storage/handling practice • Flush lube system
Fe 3	• Fe level is High • Perform diagnostics tests • Consider inspecting this component for abnormal wear, based on diagnostics	• Fe level is High • Perform diagnostics tests • Consider inspecting this component for abnormal wear, based on diagnostics	• Fe level is High • Perform diagnostics tests • Suggest inspecting this component for abnormal wear, based on diagnostics	• Fe level is High • Perform diagnostics tests • Suggest inspecting this component for abnormal wear
	• Notable Si level • Abrasives do not appear to be a significant contributor to wear; re-evaluate at next sample to note trend	• Si level is Abnormal • Abrasives may be causing Fe wear; check for ingress source • Drain lube; change filter as applicable	• Si level is High • Abrasives likely causing Fe wear: check for ingress source • Check lube storage/handling practice • Flush lube system	• Si level is Severe • Abrasives likely causing Fe wear: check for ingress source • Check lube storage/handling practice • Flush lube system
Fe 2	• Fe level is Abnormal • Perform non-invasive diagnostics tests; re-evaluate trend at next sample • Observe this component's operation closely	• Fe level is Abnormal • Perform non-invasive diagnostics tests; re-evaluate trend at next sample • Observe this component's operation closely	• Fe level is Abnormal • Perform non-invasive diagnostics tests; re-evaluate trend at next sample • Observe this component's operation closely	• Fe level is Abnormal • Perform non-invasive diagnostics tests; re-evaluate trend at next sample • Observe this component's operation closely
	• Notable Si level • Abrasives do not appear to be a significant contributor to wear; re-evaluate at next sample to note trend	• Si level is Abnormal • Abrasives may be causing Fe wear; check for ingress source • Drain lube; change filter as applicable	• Si level is High • Abrasives likley causing Fe wear; check for ingress source • Flush lube system	• Si level is Severe • Abrasives likley causing Fe wear; check for ingress source • Flush lube system
Fe 1	• Notable Fe - No significant wear indicated • No action recommended unless onsite observation suggests otherwise; re-evaluate at next sample	• Notable Fe - No significant wear indicated • No action recommended unless onsite observation suggests otherwise; re-evaluate at next sample	• Notable Fe - No significant wear indicated • No action recommended unless onsite observation suggests otherwise; re-evaluate at next sample	• Notable Fe - No significant wear indicated • No action recommended unless onsite observation suggests otherwise; re-evaluate at next sample
	• Notable Si level • Abrasives do not appear to be a significant contributor to wear; re-evaluate at next sample to note trend	• Si level Abnormal but not necessarily indicative of abrasives, though it is possible that an abrasives ingress event has only recently occurred; suggest diagnostics • Drain lube; change filter as applicable	• Si level High but not necessarily indicative of abrasives, though it is possible that an abrasives ingress event has only recently occurred; check • Suggest micropatch inspection • Flush lube system	• Though Si is Severe, it may not be in abrasive form, based on low Fe • Suggest micropatch inspection • Flush lube system
	Si 1	**Si 2**	**Si 3**	**Si 4**

Figure 2. **Fleshed out 16-proposition, 32-combination phase-two rule for Fe/Si.**

and Si rules. Trumping only occurs when the higher rule order (number of differentiated datum pieces, up to four-phase) contains all datum type members in the lower-order rule, thus, Fe/Si/Cu and Fe/Si/Al would co-exist but would both trump Fe/Si, and Fe/Si/Cu/Pb would only trump Fe/Si/Cu.

3. What if a rule is *good* for some customers or component types or manufacturers but not adequate or accurate for others?

   The same differentiators that are used for TOBs, in order to rate data, can be used for rules, and even advisory content, wherein a different comment is created for certain situations (e.g., a specific entity's component type and manufacturer, even though the same rule was fired). This allows nearly unlimited granularity to creating rules and the advisories that follow, based on unique constraints. This is a typical hierarchy info drill down—other orders can readily be created:

Reasoning
There should always be grave concern for the machine's health at SEV 4 Fe • *This is a generic comment about Fe Severity (SEV), applicable to any Component* • *If this were a reciprocating internal combustion engine, then, e.g., "Cylinder or Valve Train Region" would be noted; if a gearset, "Gears, Shafts, Bearings" would be noted* • *"Consider" is replaced with "Suggest", a stronger, more committed Advisory, when SEV 4 levels, especially multiples thereof, are reached (One could have a 'super' SEV)*
• IF the Component Type is known, specific machine areas will be noted, e.g., "*Air Intake System*" for diesels, or "*Vents/Breathers*" for gearsets, etc. • Abrasives likely causing Fe wear; note subtle tone for abrasives, using "may" at SEV 2, but "likely" at SEV 3 or 4 Si • Check for source: IF the component is known, specific problem areas will be noted • Flush lube system (note tone for urgency: "drain" vs "flush")
• Droping the phrase, "… *based on diagnostics*" from the inspection Advisory adds a subtle added urgency to the evaluation - everything points to a serious wear problem, even at 'only' SEV 3 Fe, likely from Si-based abrasives
• Again, usage of "*may*" and "*likely*" to present the right tone and urgency, as to the possibility of *abrasives*
• Beginning at SEV 2 wear metals (Fe solo here), where action possibilities may/should be condsidered, one will be well served to demur through the notion of 'observing' or waiting until next sample before making any firm decisions as to machine stoppage of any serious length, inspections in this mix, for sure, but even the notion of lengthy diagnostics types, however labeled, may be burdensome on production - the bigger picture. Evaluators have always leaned toward deferral in these instances, subject to Customer Aggressiveness
• Deferral in contamination assessment also occurs at SEV 2 (and 1 as evaluators may judge) • There is no particularly good reason to leave SEV 2-4 Si in the system unless one is performing a research project with the Customner's blessing. That Fe is SEV 1-2 (or more) definitely puts abrasives into play - one cannot know when the Si got to SEV 2 if it was less than that at previous sample. Could have been months, or minutes, within the last test
• There is no evidence of significant wear in the sample, likewise there is no justification for a mechanical inspection, and really not for basic diagnostics, *unless something visible or audible is or has been observed by the machine operator or the maintenance team* • It is possible that trending from White (SEV 0) to Green (SEV 1) might warrant basic diagnostics; this aspect should be factored into the Advisory dependent on Customer's maintenance aggressiveness preferences
• One cannot know if possible Si ingress was recent or developmental, unless trending is in place (multiple consecurive samples), where change from SEV 0 to SEV 1 may be alertable, based on Customer's maintenance aggressiveness practices/preferences • *Micropatch testing can be brought into play to possibly reveal the nature of the SEV 3 or 4 Si, but with seemingly no appreciable wear. Filter analysis may also be appropriate*

a. Customer
b. Component type
c. Manufacturer (MFR)
   - Model
d. Application
   - e.g., off highway or mining
e. Wild cards (2).

Each drill down trumps the preceding by way of adding another attribute as a means of best definition of the lube sample's source; however, a field gap, followed by a field fill in the attribute hierarchy, creates a lower (best definable) drill down, trumping the lesser content in terms of perceived importance, provided all the trumped list's attributes also are accounted for. Thus:

a. Customer
b. Component type
c. Manufacturer
   - Model

trumps

a. Customer
b. Component type
c. Manufacturer

that trumps

a. Customer
b. Component type
c. (Manufacturer null)
d. Application
e. Wild card 1
f. Wild card 2.

Once the highest contiguous hierarchy order is breached by a void/null, additional fills after the breach still inform the comparison, enabling further drill down to complete the rule (or TOB) selection.

Once the hierarchy assigns a *best fit* rule, the comments forming the advisory can be selected using a different hierarchy constraint as preferred.

What makes an EXSYS ultimately better than an unarmed evaluator is that *advisories (remember the purpose of ISFA) are absolutely consistent*. And when those things need correction, or upgrading, the EXSYS only improves, sometimes geometrically so. It only gets better at being an absolutely consistent evaluator. Adding a collaborative capability allows expertise to be injected from any qualified source.

With all the (sudden) attention given over the last couple years to AI, IIoT, Industry 4.0 (I doubt I need to translate these), one can see that it's inevitable that all condition monitoring data will be increasingly monitored and amalgamated into the most informed machine status determination. More on this next article.

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