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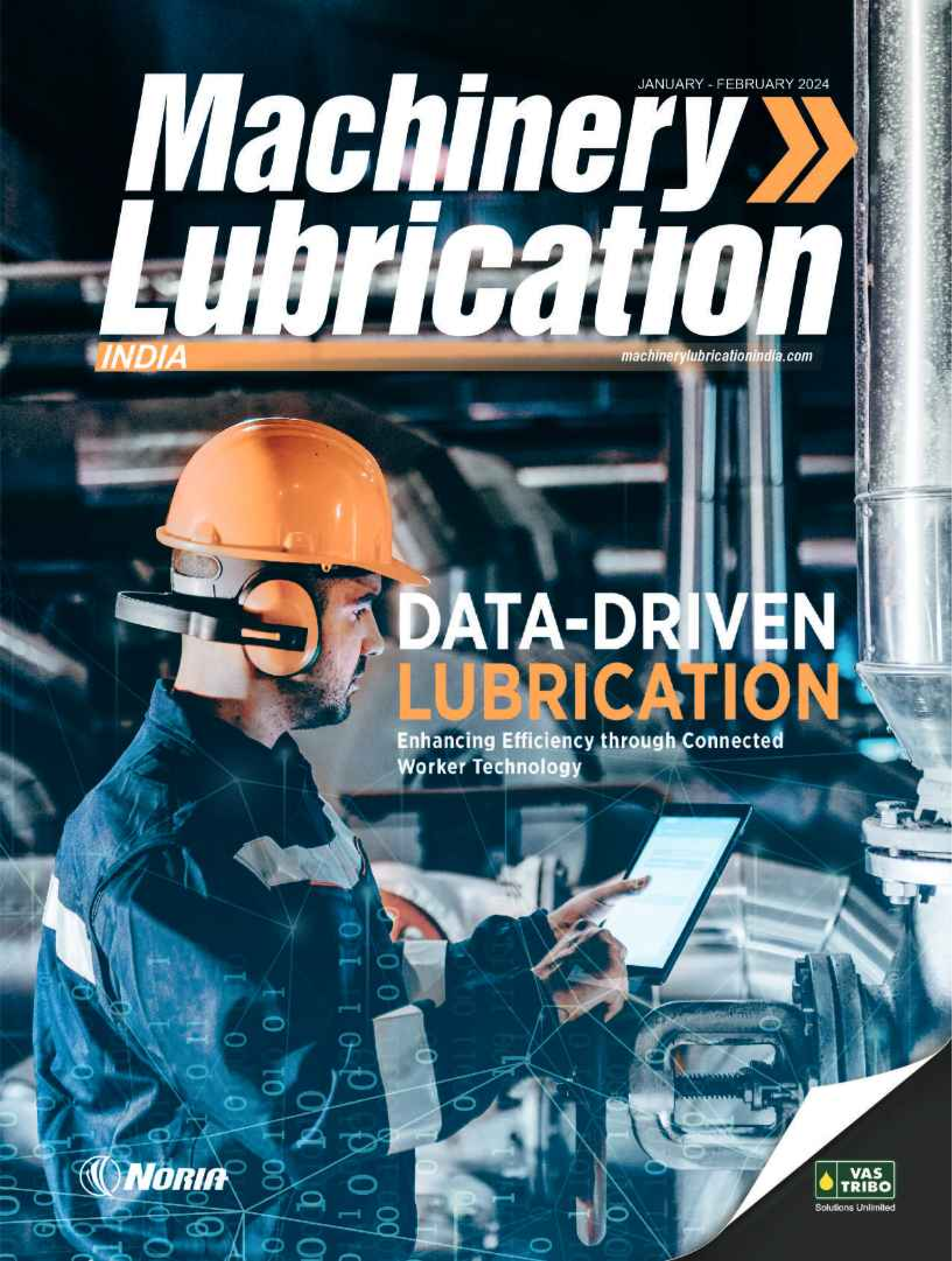

DATA-DRIVEN LUBRICATION

Enhancing Efficiency through Connected Worker Technology

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TABLE OF CONTENTS

EDITORIAL FEATURES

Publisher's Note

Sport is the biggest teacher of it all! The first lessons in one's life generally come from sports in the form of games and activities in one's childhood. The learning continues with our growth and I can say with confidence that some of our best lessons in life come from having played some sport or the other. The lubrication world is no stranger to learning from games and sports. There have been numerous equipment and reliability management lessons from sporting events, be it Cricket, Football, Chess or Badminton. 1+ billion people across the country suffered heartbreak in Nov 2023 as India fell short of winning the ODI World Cup after a terrific campaign. For 40 nights since their first win against Australia in Chennai, India strode like the invincible, but would stumble on the 41st night to a tame defeat.

The ODI World Cup match between India and Australia had its fair share of twists and turns, showcasing the importance of adaptability, grit, and strategic thinking. Failure is productive when it occurs in a new, unexplored area that produces valuable knowledge. When failure is chronic, controllable, known to management and significant in its impact, such as with lubrication-induced equipment failures, it is embarrassing and irresponsible.

Likewise knowing when a piece of equipment is going to fail (predictive maintenance) is much more difficult than making it last long (proactive maintenance). Even more complex is root cause analysis (RCA) which is performed postmortem, like an autopsy. Still, reliability professionals are increasingly stressing the importance of performing RCAs following all failures of critical machinery. As odd as it sounds, it is more productive to study failures than successes. Many have said that RCA is more art than science. Indeed, it seems to draw from a range of skills, talents, experience and knowledge. Some investigators seem to have a special knack for it while others toil through the process. But even if an RCA is unsuccessful at uncovering the root cause, the process usually brings forth new knowledge and greater awareness of reliability risk factors to the team.

Similarly lubricant users should understand the essence of world-class lubrication. They should define a clear pathway to excellence and best practice. After all, much has changed in the lubrication field over the past two decades, yet too often, the activities of lubrication have remained unchanged from more than half a century ago. As today's industries face harsh competition and razor-thin operating margins, there is real need to challenge conventional wisdom regarding how machines are lubricated.

Specific skills and tasks may vary significantly from company to company, but it will typically include measuring performance of critical assets, identifying root causes for failures, managing related data, and implementing maintenance tasks to improve reliability.

Maintenance technology is advancing at a breath-taking pace. This cover story takes a detailed look into how connected worker technology offers organizations of all sizes a real opportunity to minimize capital spend and operating costs while improving equipment availability, safety, and asset longevity. Some other topics covered in this edition includes: The era of mobile dominance, chat GPT in lubrication, maintenance and reliability root cause analysis explained, a comprehensive exploration of tribology unveiling the historical evolution, managing turbine oils in a sustainable way, what am I looking at: 3 questions in oil analysis, enhancing equipment performance: the role of oil analysis and particle counting. We look forward to your support and feedback to enable us to improve the content and layout of Machinery Lubrication India. We welcome readers to participate by sending their feedback & contributing articles. We'd like to hear from you about case studies or new products in the field of lubrication, especially methods and/or products that have been successful. We look forward to the continued patronage of the advertisers and the subscribers.

Warm regards,
Udey Dhir

THE ERA OF MOBILE DOMINANCE: Smart Phones are Overtaking Machinery Lubrication Management

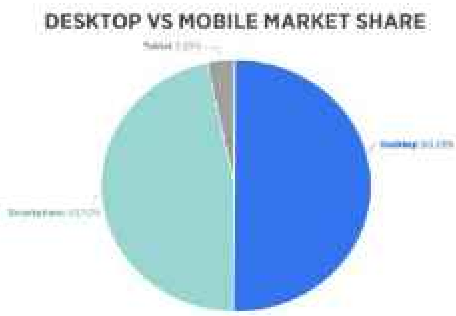
In today's digital age, mobile phones have become an indispensable tool for professionals across various industries. This is particularly true in the industrial sector, where mobile phones have revolutionized how professionals manage their tasks. Mobile phones have taken precedence over traditional computers, from communication and data analysis to condition monitoring and maintenance. In the realm of lubrication management, mobile phones have emerged as a vital component, offering unprecedented convenience and efficiency. In this article, we will explore how most professionals, especially those in the industrial sector, rely on their mobile phones rather than their computers for managing machines that require lubrication and daily lubrication tasks.

According to Zippia, "60% of all website traffic worldwide comes from mobile devices." That is the last data point in a steady increase over the previous ten years since 2012, which reported only 8.53%. The most significant increases were in the first few years, with it crossing the 50% mark in 2016. Nevertheless, mobile hardware technology continues to evolve rapidly, and the applications developed are evolving even faster. In the United States, this is still hovering around the 50% mark comparing mobile device use versus standard personal computers (PCs). This primarily refers to mobile phones and tablets that have created most of this use. Still, other wearable technologies, like smartwatches, are also becoming a factor.

If the web traffic on mobile devices versus PCs specifically represented usage types, such as personal or professional use, there would be a difference. Personal use is around 60-80% on mobile devices, and professional use is 40-60% on mobile devices. And depending on the specific profession, we could also analyze the professional use even more granular into categories such as general communication (email, texts), content creation (writings and graphics), asset management (physical assets, financial assets, people management), project management, and more.

If this were taken down to the lubrication management aspects, including lubrication work execution, even a smaller percentage use a mobile device. But the point is not how low the rate might be right now but where that trend is headed ... UP. Generally speaking, lubrication technology has always been a laggard compared to technology developed for larger markets. But that presents an opportunity to see the larger market technology as a predictor of what to expect for lubrication management in the future. And the reality is already setting in; lubrication management is quickly becoming overtaken by the growing dominance of mobile devices as the standard tool. So for those who have not considered lubrication solutions like this themselves. A warning.

Source : https://www.zippia.com/advice/mobile-vs-desktop-usage-statistics/



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Lubrication Management and Mobile Devices

Maintenance and reliability professionals face the challenge of effectively monitoring and maintaining the lubrication needs of machines daily. They know how critical lubrication is to the machine's reliability; smooth operations and prolonged equipment life depend on careful lubrication and contamination control practices. Mobile phones have emerged as an indispensable technological tool for professionals in this field.

It all starts with convenience providing accessibility through this pocket tool. Mobile phones are becoming the preferred device for your machinery lubrication management needs. As a lubrication consultant working with lube techs and reliability professionals on the plant floor, I often see mobile devices used to pull up necessary data, even when the data source wasn't intended for mobile-accessibility. Yet, while convenience is the #1 benefit, mobile devices also provide levels of efficiency and enhanced capabilities that have driven their use as a clear winner to meet business objectives. The second half of this article reviews some of these benefits.

1. Mobility and Accessibility:

Mobile phones provide unparalleled mobility and accessibility, making them ideal for professionals in diverse industrial environments. Unlike computers that are typically fixed to a specific location, mobile phones can be carried effortlessly, enabling professionals to access lubrication data and perform tasks more accurately and comprehensively on the plant floor. Whether inspecting machinery, monitoring lubrication levels, or accessing lubrication schedules, mobile phones allow professionals to access critical information anytime, anywhere. This mobility ensures that lubrication tasks can be addressed promptly, minimizing costly communication hurdles and ultimately risking equipment downtime and lost productivity.

2. Real-time Monitoring and Alerts:

Mobile phones empower professionals with real-time monitoring capabilities, revolutionizing machinery lubrication management. With dedicated mobile applications and connected devices, professionals can wirelessly

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Machinery Lubrication India Volume 69 - Issue 1, January-February 2024 is published bi-monthly by VAS Tribology Solutions Pvt. Ltd. Operation Office:213, Ashiana Centre, Adityapur, Jamshedpur-831013, India.

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connect to machinery and receive instant updates on lubrication status. These apps provide real-time insights into lubrication conditions through sensor data and Internet of Things (IoT) technology, ensuring that professionals can promptly address any deviations or issues. Mobile phones can also generate alerts, notifying professionals of critical lubrication parameters, allowing them to take immediate action and prevent potential equipment failures or damage.

3. Digital Documentation and Data Analysis :

Gone are the days of manual paperwork and documentation associated with lubrication management. Mobile phones facilitate efficient digital documentation, enabling professionals to seamlessly record and track lubrication tasks. With dedicated applications, professionals can digitally capture essential information, such as lubricant type, quantity and application details. This digital documentation simplifies record-keeping, eliminates paperwork errors, and enables easy synchronization with cloud-based platforms. Moreover, mobile phones facilitate data analysis, empowering professionals to gain insights into lubrication patterns, identify trends, and make data-driven decisions to optimize lubrication practices.

4. Task Management and Scheduling :

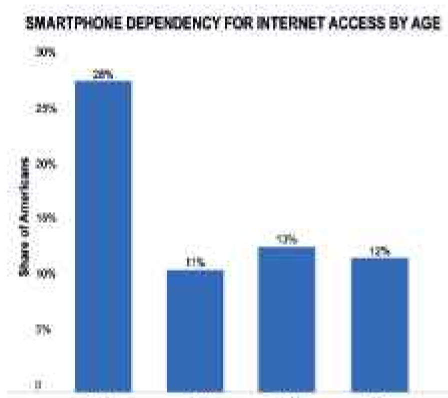
Mobile phones excel in task management and scheduling, ensuring that lubrication activities are well-organized and executed efficiently. With specialized applications, professionals can access lubrication schedules, set reminders, and track completed tasks, all from their mobile devices. These features give professionals a comprehensive overview of lubrication activities, preventing tasks from being overlooked or delayed. Mobile phones facilitate effective communication and collaboration among team members, enhancing teamwork and coordination for seamless lubrication management across multiple machines or facilities.

5. Resource Accessibility and Training :

Mobile phones are a gateway to extensive resources and training materials for machinery lubrication professionals. With a wide range of educational apps, online tutorials, and technical documentation readily available, professionals can access critical information and training materials instantly. Mobile phones enable professionals to stay updated with the latest lubrication best practices, equipment specifications, and troubleshooting techniques, ensuring they are well-equipped to handle any lubrication related challenges. This accessibility promotes continuous learning and skill development and empowers professionals to excel in their lubrication management roles.

Adopting a New Tool Takes Time

For the last ten years, I have heard countless debates about the use and benefits of mobile devices in lubrication management. The polarity on this topic sometimes has a personal preference aspect, especially with those seasoned with years of working a certain way. Lubrication work activities are particularly affected by this. But this goes hand in hand with the general trends with mobile phone use across different generation age groups. Younger generations taking more roles in these types of jobs will only strengthen the use of these technologies. In some industries, there is also a corporate-driven suppression of the technology used. Sometimes there is legitimacy to this with safety risks with electrical devices or the simple distraction it sometimes can cause. But over time, these



concerns will be overcome with more developed solutions and awareness.

Regardless of the hurdles, mobile phones are transforming the machinery lubrication management landscape by providing professionals with a versatile, portable and efficient tool. LubePM is one example of how this has taken shape with a comprehensive approach to managing lubrication, blending strengths with PC and mobile-based features to streamline and optimize the lubrication work activities. These technologies provide solutions beyond mobility, including real-time monitoring capabilities, digital documentation, task management features, and access to valuable resources. We are only taking what we all know about mobile phones, their unmatched convenience and enhanced capabilities, and extending that to the daily activities of maintenance and reliability professionals. As the industrial landscape continues to evolve, embracing mobile phones as the primary tool for machinery lubrication management ensures streamlined operations, optimized maintenance practices, and improved equipment performance, leading to increased productivity and cost savings.

About the Author

Bennett Fitch is the Chief Strategy Officer (CSO) for Noria Corporation. His years of experience at Noria includes director of development for Lubrication Program Development (LPD) services and LubePM, the lubrication program management platform. Additionally, he serves as a senior technical consultant and is an instructor for Noria's Machinery Lubrication and Oil Analysis courses with an interactive, yet relaxed approach to engage his audience. His expertise is established from years within oil analysis and machinery lubrication as the core of his career. He received his bachelor's degree in mechanical engineering from Georgia Institute of Technology with a concentration in applied tribology and a master's degree in business administration from the University of Tulsa. Bennett is also certified through the International Council for Machinery Lubrication (ICML) as a Machinery Lubrication Engineer (MLE), Machinery Lubrication Technician Level II (MLT II) and Machine Lubricant Analyst Level III (MLA III). Contact Bennett at bfitch@noria.com.

Eric Whitley | Noria Corporation

DATA-DRIVEN LUBRICATION

Enhancing Efficiency through Connected Worker Technology

It's difficult to open an industry publication and not read about the Industrial Internet of Things (IIoT), advanced analytics and connected workers. Although this technology and its potential are exciting, many companies don't have the resources for a complete digital transformation and will be using legacy equipment for years to come.

However, digitalization and connected workers don't need to be an all-or-nothing-discussion. The available technology allows companies to make minor investments while achieving tangible benefits. In this article, we'll look at ways businesses can enhance critical lubrication practices using connected workers and IIoT to increase asset longevity, reduce break downs and improve safety.

1: MONITORING LUBRICATION QUALITY

Organizations can start small with connected technology, implementing wireless networks and selecting IIoT sensors to monitor only their most critical equipment in near-real time. Seek applications requiring minimal investment, with easy implementation but strong financial returns.

Many companies offer ruggedized, miniaturized, commercial-off-the-shelf (COTS) sensors to monitor fluid levels, flow, and pressure differential. The collected data provides several benefits. Service teams can ensure that lubricant quantities are sufficient for continued equipment operation without physical inspection, and maintenance teams can monitor trends that might indicate poorly seated pressure relief valves, clogged filters or pumps in bypass. The information gathered also becomes part of the in-service record, evidencing correct lubrication practices in the event of warranty claims for equipment malfunction.

Ultrasonic sensors can be installed to warn of increased friction in rolling elements, allowing plants to schedule lubrication or maintenance intervention proactively. Ensuring optimum bearing operation reduces wear, increases asset life, and reduces energy use, all of which improve equipment availability and lower operating costs.

Connected desiccant breathers can point to the precise time a breather requires changing, ensuring you don't replace a breather too soon, which costs money, or too late, affecting lubricant quality. With many breathers in remote or difficult locations on operating equipment, connected breathers also decrease the risk of injury to technicians.

More recently, sensors are becoming available to monitor fluid cleanliness using lasers, pressure differential or image - processing technologies. While these sensors do not yet rival laboratory analysis, their data complements an oil analysis program by helping initiate timely inspections, filtration tasks or water removal processes.

2: ANALYZING LUBRICANTS CONDITION

Laboratory lubricant analysis is the gold standard for understanding the condition of lubricants and the assets they protect. Yet, such analysis takes time, is expensive and the collection process can introduce contaminants. Also, it doesn't guarantee that the sample represents the entire fluid body.

Technology has advanced sufficiently to enable real-time oil analysis using in-line sensors. While still new and requiring further testing, miniature sensors use techniques including capacitance, magnetic flux and infrared and X-ray spectroscopy to measure contamination and fluid degradation in real time, warning of imminent failure or triggering maintenance tasks and operational adjustments.

Having analyzed the lubricant, data analysis is the next step. With such an abundance of data, and as an organization's connected worker strategy becomes more sophisticated or widespread, it can use the collected data from sensors for more than operational tweaks and maintenance tasking.

Cloud-based data, analysis, and presentation can inform tactical decision-making through real-time dashboards and KPI monitoring. Making such information widely available improves communication and knowledge transfer throughout a company because everyone can view the same information.

The information about the effectiveness of maintenance strategies, the outcome of lubrication trials, increased energy use and the impact of changes in servicing regimes is available to inform connected personnel, enforce accountability, and initiate actions. The data access is device-agnostic, meaning in-factory, remote or international personnel can access information wherever they use their mobile devices.

3: STREAMLINING MAINTENANCE INTERVENTION

Knowledge and analysis are fine, but they are nothing if they don't ultimately result in data-driven decision-making and proactive intervention. A connected workplace using IIoT, machine learning (ML), and AI ensures a layered approach to maintenance interventions.

In its most basic form, connected worker technology can flag assets that diverge from an acceptable range of operating characteristics. These alerts or advisories can take many forms, from audio or visual warnings to emails or texts. Contextually relevant, they can target workers best qualified to address the issue or those currently on shift.

Automated responses can also initiate an intervention. If an ultrasonic sensor registers increased friction in a bearing, it could activate a single-point lubricator to deliver a calibrated measure of lubricant to provide optimal bearing lubrication, returning the ultrasonic signals to pre-alert levels. Such automation removes the need for human intervention, addresses the issue promptly, and avoids over or under-lubrication that is wasteful or damaging.

A sophisticated connected platform implementation uses augmented reality (AR) technology to assist service or maintenance technicians during a maintenance intervention. Smart glasses, tablets, mobiles or headsets guide workers to the component requiring attention, using data overlapping the image of the object. Current operating parameters can stream in near-real time, with checklists, maintenance data, and task information available for selection.

PARTING THOUGHTS

Companies don't need to commit to extensive digitalization investment to access the benefits of connected worker technology. Starting small and investing in sensing and monitoring for lubrication tasks on critical equipment provides an immediate benefit, with a considered implementation resulting in excellent returns on investment from increased asset life and equipment reliability.

As the technology proves its value, organizations can incrementally develop enhanced management strategies and automated equipment lubrication practices. Connected technology places equipment performance, lubrication information, manufacturer data, and potential solutions into the hands of front line workers, empowering them to take timely action.

Maintenance technology is advancing at a breathtaking pace. Connected worker technology offers organizations of all sizes a real opportunity to minimize capital spend and operating costs while improving equipment availability, safety, and asset longevity.

About the Author

Eric Whitley

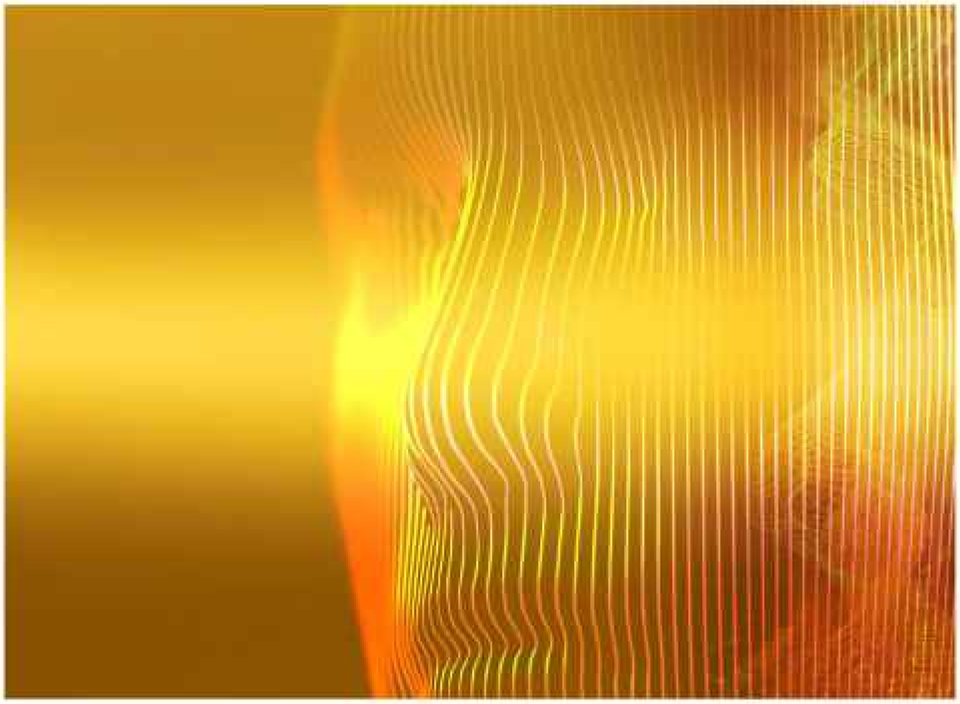
For more than 30 years, Eric Whitley has been a noteworthy leader in the manufacturing space. In addition to the many publications and articles he has written on various manufacturing topics, you may know Eric from his efforts leading the Total Productive Maintenance effort at Autoliv ASP or from his involvement in the Management Certification programs at The Ohio State University, where he served as an adjunct faculty member.

After an extensive career as a reliability and business improvement consultant, Eric joined L2L, where he currently serves as the Director of Smart Manufacturing. His role in this position is to help clients learn and implement L2L's pragmatic and simple approach to corporate digital transformation.

Eric lives with his wife of 35 years in Northern Utah, where, in his free time, he can usually be found on the water with a fishing rod in his hands.

Chat GPT in Lubrication

In what has become the most buzzworthy trend of the past decade, Artificial Intelligence (AI) is making huge waves in everything from art to essays and even diagnosing machine issues. It has started a conversation around what the confines of the technology should be and how much impact this will have on people's jobs and livelihoods.



While similar to the conversation surrounding robots taking over certain duties, the AI conversation is very interesting because the battleground isn't necessarily what physical work could be taken over but what logical or cerebral work can be accomplished by AI.

Many commercials and fun videos have shown the harmonious union between people and technology to perform all sorts of tasks. Robot dogs dancing to music and sarcastic software giving Tony Stark a hard time are examples of how culture is beginning to anthropomorphize tools that are more sophisticated than what weare used to. Robots aside, AI is continually being scrutinized as to whether it is sentient or able to display emotion, or in some cases, forcing the question of what emotions or feelings truly are.

The Impact of Artificial Intelligence

Outside of students using Chat GPT to write their homework (or consultants using it to write their articles), how useful is this technology? Let's take it a step further and ask, how will this impact industry, and specifically, how will this impacta Lubrication Technician's daily work? To best answer these questions, we must first understand the typical work of a Lube Tech.

Lubrication is a skilled trade requiring specialized training and tools to perform it correctly. Sometimes this work is shared across multiple parties, such as maintenance, reliability, and operations, and sometimes it is designated to a single team. Regardless of how it is staffed, the work has to be completed in an optimal manner to ensure that the machine operates effectively and reliably, all while extending the component's life.

Let's start by looking at the normal activities within a typical lubrication program.

Typical Lube Tech Activities Greasing of Components

This is where high demand for manpower typically exists. While it depends on the type of facility, it is not uncommon for there to be thousands of grease points that must be visited multiple times over the course of a year. The Lube Tech must apply the correct grease with the correct volume at the correct time to each of these fittings.

Oiling of Components

Like greasing, multiple components must either be periodically refilled with oil, particularly total-loss systems, or the oil must be completely changed based on interval or condition. This involves draining the fluid, refilling it with new fluid, and then disposing of the used oil. Knowing the correct fluid and performing this to get the appropriate fluid volume and minimize opportunities for contamination is key.

Inspections

Often, this activity is shared across multiple departments. Proper inspections should provide information on the equipment's external and internal conditions and operating parameters. Oil level, temperature, differential pressure, and breather condition are all examples of valuable data that should be collected and used to trigger corrective action when needed.

Some of these may result in changing a lubricant, filtering the lubricant, alerting maintenance and operations of a pending failure, or a litany of other things that might have to happen.

Change Outs

Several consumables are often attached to equipment that helps with lubrication or contamination control. Some examples would be:

- Replacing a single-point lubricator.
- Changing a filter that has hit a high differential pressure.
- Swapping out a breather that has become saturated with moisture.

All the changeouts require having the correct replacement parts on hand and are often the result of inspections.

Lube Room Duties

The lube room is the heart of the lubrication program and, as such, must be managed in the same manner as a critical asset. The Lube Tech must beinvolved in cleaning and organizing the room, but, more importantly, they must ensure they have the appropriate volumes of lubricants and consumables on-hand. They will look at future planned activities, order these products, and work with established lead times with vendors.

Lubrication Sampling

With the desire to move to a more condition-based approach with maintenance and lubrication, sampling of equipment is beginning to be a bigger component of a Lube Tech's work. This includes extracting representative lubricant samples, sending them to a lab for analysis, interpreting results and scheduling corrective actions.

This is just a simplified listing of activities, but you can already see how involved the daily work in a lubrication program could actually be.

Lube Tech Activities with AI

Now, let's layer over where AI could be effective or help supplement the work that has to be completed.

Greasing and Oiling of Components

We are far from employing AI to lubricate equipment on a routine basis. There are some options out there that utilize condition monitoring to apply lubricants when the machine needs it. Still, those are typically reserved for specific applications, and using them on every point is not cost-effective.

AI could help in determining the proper frequency of application and the proper lubricant to use. Each application is unique and, as such, may require something slightly different from the lubricant and how often it needs to be applied. Subtle changes in additives and viscosity can yield significant improvements in reliability when matched correctly.

Inspections

There has been a great deal of buzz around the use of technologies such as robotics and drones to perform machine inspections; in some cases, this is already happening. The biggest impact AI could have is interpreting the results of inspections or identifying small changes in a machine's condition that might have otherwise gone unnoticed.

However, I do not foresee a tide change replacing the human inspector as there are too many peripheral things a person might pick up on that a machine might not where a coexistence between people and machines would be incredibly beneficial in this area.

Changeouts

Proper accessory selection is important and similar to the lubricant conversation; many variables must be weighed to ensure the proper filter, breather, sight glass, etc., is selected. Giving these variables to the AI and other information, such as pricing and availability, could remove this responsibility from the technician or manager and make it more automated. This, of course, depends on the amount of information available from the manufacturers of these types of products.

Lube Room Duties

Short of robot vacuums, there has been little in the market for automated cleaning and organization. While the Lube Techs will largely manage the daily cleanup work, the procurement of lubricants could be off loaded to the AI.

Provided it can review past usage, current volumes, and future planned maintenance activities, it could interface with the purchasing system to ensure the timely delivery of lubricants and consumables to minimize expedited deliveries and product swaps due to lead times and availability issues.

Lubricant Sampling

The biggest value in this area comes from interpreting results from the sampling. Many laboratories are already using AI in some fashion to look at larger sets of data and provide better alerts to issues that may be occurring inside the machine.

With a good set of historical data, the AI might be able to track and perceive incipient failure more easily than someone just looking at the data without understanding the full scope of trending.

Conclusion

The industry is mainly on the upsweep of the "hype curve" in relation to AI, but there will definitely be significant adoption in many facets of operations, maintenance, and reliability. What all of this will look like is yet to be fully realized.

Like any new tool or technology, this will require a cultural shift in many facilities, which can cause friction and frustration. The most successful users of this technology will find a way to imbue it with the proper data so that it can make meaningful recommendations and contributions to their work.

Regardless, this technology will be impactful in many ways, and hopefully, it can be put to work, helping drive reliability into the common practice of the industry. Meanwhile, I'll continue using it to write song lyrics and jokes about my friends and family.

About the Author

Wes Cash is the director of technical services for Noria Corporation. He serves as a senior technical consultant for Lubrication Program Development projects and as a senior instructor for Noria's Oil Analysis I and Machinery Lubrication I and II training courses. He holds a Machine Lubrication Technician (MLT) Level II certification and a Machine Lubricant Analyst (MLA) Level III certification through the International Council for Machinery Lubrication (ICML). Contact Wes at wcash@noria.com.

Root Cause Analysis Explained

What Is Root Cause Analysis?

Root cause analysis (RCA) is defined as a systematic process for identifying the root causes of problems or events and an action plan for responding to them. Many organizations tend to focus on or single out one factor when trying to identify a cause, which leads to an incomplete resolution. Root cause analysis helps avoid this tendency and looks at the event as a whole. Another common occurrence is for companies to treat the symptoms rather than the actual underlying problems contributing to the issue, leading to recurrence.

Using root cause analysis to analyze problems or events should help you tackle the primary goal of determining:

- What happened
- How it happened
- Why it happened
- Actions for preventing recurrence of the issues

In the end, root cause analysis boils down to three goals. The first goal is just as the name implies: to discover the root cause of a problem or event. The second goal is to understand how to fix, compensate for or learn from issues derived from the root cause. The third and most important goal is to apply what you learn from the analysis to prevent issues in the future.

How to Conduct a Root Cause Analysis (RCA)

Root cause analysis can be used in a variety of settings across multiple industries. Each industry might conduct the analysis in a slightly different way, but most follow the same general five-step process when investigating issues involving heavy machinery. This process was laid out by the United States Department of Energy (DOE-NE-STD-1004-92) back in 1992. Root cause analysis is commonly referred to as detective work at its finest. You'll see similarities between how a detective works to solve a case and how manufacturers can figure out the root cause of an issue in the five-step process.

Phase 1 - Data Collection

Just like how detectives preserve a crime scene and meticulously collect evidence for review, collecting data is probably the most important step in the root cause analysis process. It's best practice to collect data immediately after a failure happens or, if possible, while the failure is occurring. In addition to data, be sure to note any physical evidence of the failure as well.

Examples of data you should collect include conditions before, during and after the occurrence; employee involvement (actions taken); and any environmental factors. When machinery is involved, collect data and samples on things like lubrication systems, filters and separators, by product deposits (gums, varnish or sludge), oil analysis, and tank and sump conditions.

Phase 2 - Assessment

During the assessment phase, analyze all collected data to identify possible causal factors until one (or more) root causes are determined. According to the DOE's process, the assessment phase incorporates four steps:

1. Identify the problem.
2. Determine the significance of the problem.
3. Identify the causes (conditions or actions) immediately preceding and surrounding the problem.
4. Identify the reasons why the causes in the previous step exist, working backward to determine the root cause; the root cause being the reason(s), which if corrected, will keep these and similar failures around the facility from happening. Identifying the root cause is the stopping point in the assessment phase.

Common assessment conclusions for manufacturers include things like contaminated lubricant, using the wrong lubricant, using too much or too little lubricant, and abnormal wear debris.

Later we will discuss common root cause analysis methods and tools to help with the assessment phase of this process. Common methods include Pareto charts, determining the "5 Whys," fish bone diagrams and more.

Phase 3 - Corrective Action

Implementing corrective action once a root cause has been established lets you improve your process and make it more reliable. First, identify the corrective action for each cause. Then, ask these five questions or criteria laid out by the DOE and apply them to your corrective actions to make sure they are practical.

1. Will this corrective action prevent recurrence?
2. Is this corrective action feasible?
3. Does this corrective action prevent recurrence and still allow for the meeting of production objectives?
4. Are new risks introduced with this corrective action? Are all assumed risks clearly stated? Keep in mind that corrective action(s) should not degrade the safety of other systems.
5. Were immediate actions appropriate and effective?

Before taking corrective action, your company as a whole should discuss and weigh the pros and cons of implementing these actions. Consider the cost of carrying out these changes. The costs may include training, engineering, risk-based and operational expenses among others. Weigh the benefits of the costs associated with eliminating the failure(s) with the probability the corrective action(s) will work. In addition to cost, your team should discuss questions like:

- Will the outlined corrective actions address all causes?
- Will the corrective actions cause negative effects?
- What are the consequences of implementing the corrective actions?
- Will training be required?
- How long will it take to implement these corrective actions?
- What resources are required for implementation?
- What impact will implementing these corrective a ctions have on other departments?

Phase 4 - Inform

Communication is key. Ensure all affected parties are informed of the pending correction or implementation. In the manufacturing setting, these parties may include supervisors, managers, engineers, and operations and maintenance staff. It's also a good idea to communicate any corrective actions with suppliers, consultants and subcontractors. Many companies inform all departments of any changes so they can be aware and determine if or how the changes apply to their unique situation as it relates to the overall manufacturing process.

Phase 5 - Follow-up

The follow-up phase is where you establish if your corrective action is effective in resolving the issues.

- Track corrective actions to confirm that they were implemented properly and are working as intended.
- Periodically review the new corrective action tracking system to verify that it is being implemented effectively.
- Analyze any recurrence of the same event and determine why the corrective-action(s) were not effective. Be sure to note any new occurrences and analyze those symptoms.

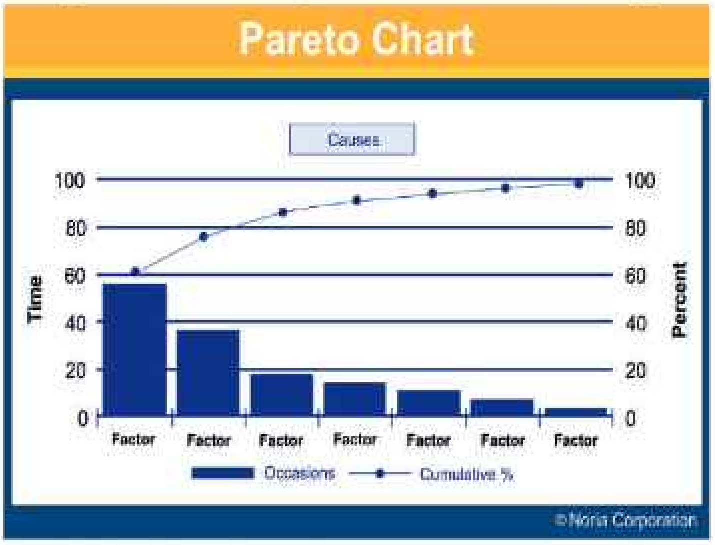
Following up regularly lets you see how well your corrective actions are working and helps you identify new issues that could lead to future failures. For a more detailed look at how to conduct root cause analysis specifically for lubrication professionals and manufacturers, check out "Root Cause Analysis Techniques-for the Lubrication Professional."

Root Cause Analysis (RCA) Tools and Methods.

As discussed earlier, the data collection and assessment phases in the RCA process are perhaps the two most important aspects when it comes to properly determining the root cause of a particular failure. There are many root cause analysis tools to choose from when you're assessing data. Each one can be used to evaluate different information or provide another way to look at similar data. Below are eight common root cause analysis tools and methods:

1.Pareto Charts:

A Pareto chart combines both bar and line graphs, with bars representing individual values (lengths or costs) shown in descending order



and lines used to illustrate the cumulative total. In quality control, a Pareto chart can highlight the most common sources of defects or the type of defect that occurs most frequently. When should you use a Pareto chart for root cause analysis?

When looking at data on how often problems occur or the causes in aprocess

- When you want to weed out other problems and focus on the most significant
- When looking at broad or general causes by analyzing their specific components
- As a good communicative tool

2. 5 Whys:

You can think of the 5 Whys method like a curious child continuously asking "why" until he or she receives a satisfactory answer. Each time you ask "why," the answer produces another "why" question. It is a simple tool, so you shouldn't use it to determine complex problems. However, it can be useful to help dive into the results from other method slike a Pareto chart. An example of using the 5 Whys might look like the following:

- Why did Machine A stop working? The circuit overloaded causing a fuse to blow.
- Why is the circuit overloaded? The bearings locked up due to insufficient lubrication.
- Why was there insufficient lubrication on the bearings? Machine A's oil pump isn't circulating enough oil.
- Why is the pump not circulating enough oil? The pump's intake is clogged with particulate.
- Why is the in take clogged? There is no filter on the pump.

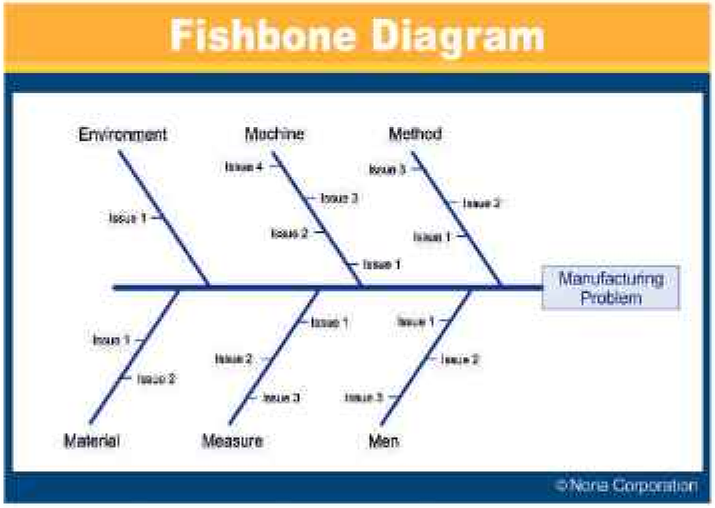
You may need more or less than five questions to get to the root of your problem, but as long as your questions keep peeling away issues on the surface, the more likely you are to uncover your root cause.

3. Fishbone Diagrams:

Sometimes called a cause-and-effect diagram, a fishbone diagram is helpful for sorting possible causes into multiple categories which all branch off from the original problem. The main categories addressed in this diagram are the six "Ms" — man, material, method, machine, measurement and Mother Nature (environment). A fishbone diagram can also have numerous sub-causes originating from eachmain category. When should you use a fishbone diagram?

- To identify possible causes for an issue.
- When your team's thinking and brainstorming tends to get stuck or stagnate.

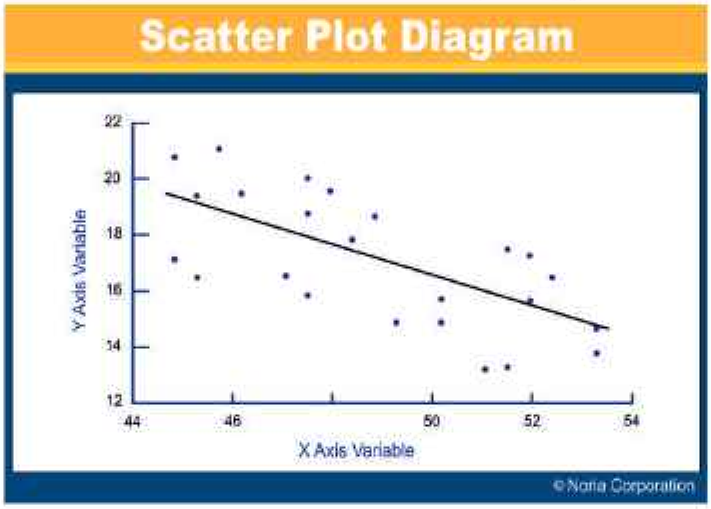
Work the diagram right to left, having your team brain storm possible causes of the problem and placing each idea in the appropriate category. Once the team is done brainstorming, rate the potential causes by level of importance and likelihood of contributing to the problem. From here, select which causes to investigate further.



In the example above, the fishbone diagram includes a main problem, six factors contributing to the main problem and potential causes of those factors branching off.

4. Scatter Plot Diagrams:

A scatter plot diagram is used to show the relationships between two variables by using pairs of data points. One variable is placed on the x-axis and another on the y-axis. Once you plot your data points, if the variables are correlated, the points will form a curve or a line. The closer the data points are, the better the correlation. As a quantitative method for determining correlation, these diagrams can be used with other methods, such as to test potential causes identified in your fishbone diagram. When should you use a scatter plot diagram?



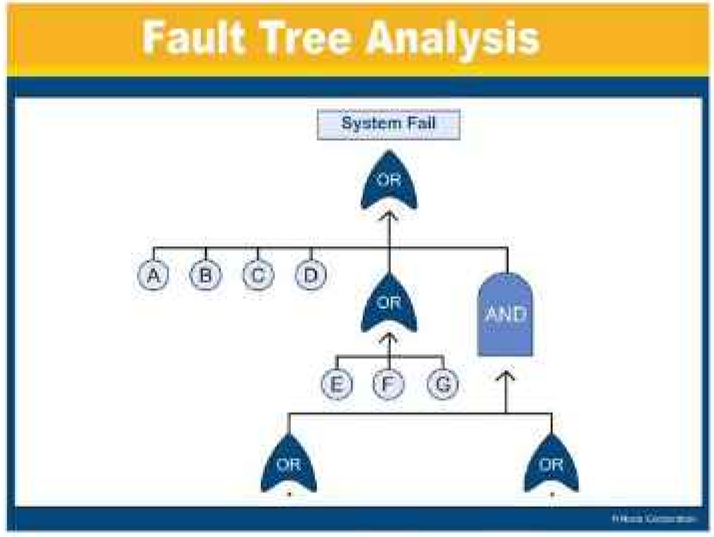
- When you have paired numerical data.
- When trying to verify whether two variables are related.
- When attempting to determine if two related effects are from the same cause.
- After brainstorming with a fishbone diagram.

5.Failure Mode and Effects Analysis (FMEA):
FMEA is used to analyze and determine potential risks, failures and causes. The process looks at ways in which failures such as errors or defects might occur and then studies or analyzes those failures. When should you use FMEA?

- During the design or redesign of a process, product or service.
- When applying an existing process, product or service in a new way.
- Before coming up with control plans for a new or modified process.
- When planning improvement goals for existing processes.
- When looking into failures of an existing process.

You can think of FMEA as more of a proactive tool rather than a reactive tool.

6. Fault Tree Analysis:
Similar to FMEA, fault tree analysis helps identify potential risks in a system or process before they happen. Sometimes calleda "top-down approach," this deductive process starts with a general conclusion and attempts to figure out the causes of the conclusion by making a logic diagram called a fault tree. The diagram utilizes shapes called "gates" to denote various interactions among contributing failure events. The two most common gates are the "and" and "or" gates. When using these gates, consider two events: input events, which can lead to another event, referred to as an output event. If either of the input events causes the output event to occur, connect these events with an



"or" gate. If both input events must happen for the output event to occur, connect the musing an "and" gate, as shown below.

A fault tree can be used to build a safety program, discover what went wrong in a process or determine why employees may not be meeting company standards. For example, you can take a hypothetical incident like a lubrication spill, break down the contributing factors and see the chain of events or failures along the way. You can then choose safety procedures that help minimize these outcomes.

7. Barrier Analysis:
Barrier analysis is a tool used with other methods to understand why a failure happened and how it can be prevented. The main idea behind it is that a failure or problem can be prevented by having set barriers to control hazards. The three basic elements of barrier analysis are the target, the hazard and the barrier. The target is generally a person. The hazard is something that can cause harm to the target, such as rotating parts or electricity. Barriers can be physical, procedural or actions, and are intended to protect the target.

8. Change Analysis:
Change analysis is another tool that can be used with other methods to help define a problem. This process examines an event while considering it with and without a particular problem and then compares the two situations, taking note of the differences. It then analyzes the differences and identifies consequences of the differences. Change analysis usually is employed in tandem with another RCA method to distinguish a specific cause instead of the root cause. For example, let's say you have an abnormally good sales day and want to figure out why so you can replicate it. You'd start by considering every possible internal and external factor, such as whether a new sales training was implemented the day before or if it was the last

day of the month and people were trying to hit their goals. Next, examine each event to see if it was an unrelated factor, contributing factor, correlated factor or the probable root cause. This is where all your analysis is done and where you can loop in other methods like the 5 Whys. Finally, see how the cause can be replicated.

Root Cause Analysis FAQs

How do you decide when to conduct a root cause analysis?

You can perform root cause analysis to help solve day-to-day problems using brainstorming techniques or the 5 Whys. Employ RCA routinely as a proactive tool to analyze safety and environmental data, evaluate asset utilization, and identify trends that point to chronic losses or systematic defects. High-level RCAs are costly, so you need a process to help decide when one is appropriate. If you're considering a high-level RCA, you'll want to define triggers that determine the point at which a formal RCA should be-conducted. Below are some ideas for forming trigger criteria:

- Equipment damage or failure
- Operating performance
- Quality
- Economic performance
- Safety performance
- Regulatory compliance

How do you prepare for a root cause analysis?

It's important to spend time preparing for a root cause analysis by doing some initial investigation, identifying the appropriate personnel and anticipating problems that could arise during the RCA meeting. A common-example of preparing for an RCA is that of a puzzle builder. Even the moste xperienced puzzle builder, who may know tips and tricks for efficient puzzle-building, can't be successful if a puzzle piece is missing or there is no place to build the puzzle.

Like wise, a team can't complete a root cause analysis if it is missing important evidence, team members are absent, or the facilities are dysfunctional. So, make sure you collect evidence, identify key team members and prepare for the unexpected prior to your RCA meeting.

What is the difference between proactive and reactive root cause analysis?

In most cases, RCA is used after an event or failure has occurred. The goal with root cause analysis is to be proactive or eventually move from beingre active to proactive.

- **Proactive root cause analysis** consists of the actions, behaviors or controls implemented to prevent a failure from occurring.
- **Reactive root cause analysis** encompasses the actions, behaviors or controls implemented to mitigate or lessen the severity of a failure that has already occurred.

How long does a root cause analysis take?

The time required for a root cause analysis will depend on certain factors, such as the complexity of the incident, the availability of employees to be interviewed, whether there is regulatory interference and how far you want to dig into the causes. Most RCAs can be completed in a couple of weeks or a few months.

What are some examples of internal and external factors that could contribute to failures uncovered in a root cause analysis?

Examining internal and external factors in the weeks and months leading upto a failure event can help you obtain a snap shot of what happened. Let's say you want to find out why revenue dipped last quarter in your food-processing company. Examples of internal and external factors might include:

Severe weather reduced rice, corn and wheat production (external).

- The cost of sugar has risen (external).
- Trade restrictions have been implemented in some of your partner countries (external).
- Your processing plant experienced more frequent shutdowns (internal).
- New shift managers were hired in the processing plant (internal).

A COMPREHENSIVE EXPLORATION OF TRIBOLOGY:
Unveiling the Historical Evolution

INTRODUCTION

Tribology, the science of friction, wear, and lubrication, is a multidisciplinary field that has revolutionized the world of machinery and materials. Understanding the historical evolution of tribology provides valuable insights into the advancements that have shaped modern industries. In this comprehensive article, we delve intothe intriguing history of tribology, from its ancient origins to its contemporary applications.

ANCIENT BEGINNINGS

The roots of tribology can be traced back to ancient civilizations. Early humans recognized the need to reduce friction and wear in various applications. The Egyptians, for instance, used lubricants made from animal fats and vegetable oils to reduce friction in sledges and chariot wheels. The Greeks explored the concept of low friction by using lubricants derived from olive oil.

The word "tribology" is derived from the Greek words "tribos," meaning rubbing or sliding, and "logos," meaning study or science. However, the principles and practices of tribology existed long before the term was coined. In ancient civilizations, the need to minimize friction and wear in various applications led to the development of rudimentary tribological knowledge.

One of the earliest examples of tribological practices can be found in the ancient Egyptians' use of lubricants such as animal fat and plant oils to reduce friction in the movement of large stones during construction projects, notably the building of the pyramids. They recognized the importance of reducing friction and understood that applying a lubricant between two surfaces would ease their movement.

Similarly, the ancient Greeks and Romans contributed significantly to the early understanding of tribology. The Greek mathematician Archimedes, known for his studies in physics and mechanics, observed the concept of static and dynamic friction. He recognized that the force required to keep an object in motion is less than the force required to initiate its motion—a concept later formalized as the laws of friction.

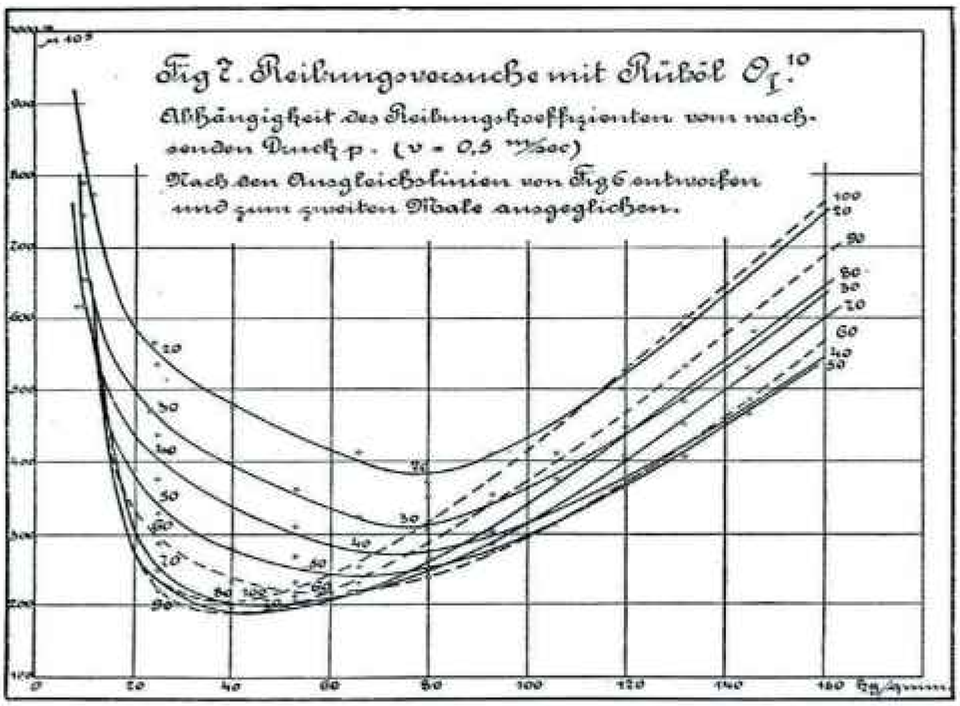
EARLY SCIENTIFIC CONTRIBUTIONS

Tribology as a scientific discipline began to take shape during the Renaissance. Leonardo da Vinci's sketches and observations on friction and lubrication laid the foundation for further exploration. Guillaume Amontons, a French physicist, conducted experiments and developed the laws of friction, providing a quantitative understanding of frictional forces.

Another notable figure in the early scientific discoveries of tribology was Charles-Augustin de Coulomb, a French physicist. In the late 18th century, Coulomb conducted experiments to understand the laws of friction. He discovered that the frictional force between two surfaces is proportional to the normal force pressing them together, regardless of the contact area. This discovery, known as Coulomb's friction law, was a ground breaking revelation that formed the basis for our understanding of friction.

In the 19th century, more advancements were made in tribology, particularly in lubrication. Sir Isaac Newton, renowned for his laws of motion, conducted experiments on the flow of liquids and developed mathematical equations to describe the behavior of viscous fluids. These equations laid the ground work for the study of fluid film lubrication, where a fluid separates and reduces the friction between two surfaces.

In the early 20th century, a significant breakthrough in tribology came with the work of Adolf Martens and his examination of steel surfaces under a microscope. Martens discovered that the surface of steel was not smooth but consisted of microscopic irregularities called asperities. These asperities played a crucial rolein determining materials' friction and wear characteristics.



The mid-20th century brought further advancements in tribology with the development of scanning electron microscopy (SEM) and atomic for cemicroscopy (AFM). These technologies allowed researchers to visualize surfaces at an unprecedented level of detail, enabling them to study the intricate interactions between asperities and understand the mechanisms of wear.

INDUSTRIAL REVOLUTION AND TECHNOLOGICAL ADVANCES

The advent of the Industrial Revolution in the 18th century marked a significant turning point for tribology. With the rise of steam engines, machinery became more prevalent, creating a demand for effective lubrication techniques. Engineers and inventors like John Harrison, John Smeaton, and James Watt made notable contributions to tribology by designing better lubrication systems and developing new materials.

The significant advancements and changes of the Industrial Revolution revolutionized various industries and technologies, leading- to challenges and opportunities in the study of tribology.

Introduction of Machinery: The Industrial Revolution marked a shift from manual labor to machinery in various industries. The widespread use of machines introduced new types of surfaces and materials, such as metal gears, shafts, and bearings. Tribologists were tasked with understanding and mitigating the friction, wear, and lubrication issues that arose from these new interactions.

Increased Industrial Production: The Industrial Revolution led to a significant increase in industrial production and the scale of manufacturing, which meant that machines were operating for longer durations, at higher speeds, and under heavier loads. Tribologists had to develop techniques to handle these increased demands, including developing more durable materials, better lubricants and improved maintenance practices.

Technological Innovations: The Industrial Revolution brought numerous technological innovations that impacted tribology. For example, the invention of the steam engine, which played a central role in the Industrial Revolution, required advancements in tribology to address issues such as steam leakage, wear, and frictional losses. Similarly, the development of rail transportation systems required understanding the tribological interactions between wheels and rails to reduce friction and wear.

Development of Lubricants: The increasing demand for machinery during the Industrial Revolution prompted the development of new lubricants to reduce friction and wear. Tribologists worked on improving lubrication techniques, including developing more effective oils and greases, which played a vital role in ensuring the smooth operation of machines and preventing damage to components.

Standardization and Precision Engineering: With the rise of industrial production, there was a need for standardization and precision engineering. This necessitated a deeper understanding of tribological principles to ensure consistent performance and minimize variations in manufacturing processes. Tribologists were crucial in establishing standards and specifications related to surface finish, tolerances and friction/wear characteristics.

Scientific Investigations: The Industrial Revolution sparked a greater scientific interest in understanding the fundamental principles of tribology. Scientists and engineers conducted extensive research to unravel the complex mechanisms of friction, lubrication, and wear. This led to new theories, models and experimental techniques, forming the foundation of modern tribology as a scientific discipline.

THE EMERGENCE OF TRIBOLOGY AS A DISCIPLINE

The 20th century witnessed the formal recognition of tribology as a distinct scientific field. In 1966, the term "tribology" was coined officially by Dr. H. PeterJost in his now-famous "Jost Report". He highlighted the economic and industrial importance of studying friction, wear and lubrication. It is worth noting that others, years earlier, began using the root "tribo" from the Greek word tribous, meaning rubbing. For instance, David Tabor at the urging of his colleague Philip Bowden, both from Cambridge University, laid the foundation for the term tribology. Tabor conceived the name "tribophysics" to describe laboratory work he was doing at-time.

Jost is considered a founder of the modern discipline of tribology, and from his report, a greater spotlight was placed on the subject. His report called for the establishment of Institutes of Tribology and the publication of a handbook on tribo-design and engineering.

In an interview conducted by Jim Fitch, founder of Noria Corporation, Jost was asked to describe tribology's conception, and he pinpointed that moment to September 1964 at the Joint Iron and Steel Institute/IMechE Lubrication and Wear Group Conference on Lubrication in Iron and Steel Works in Cardiff.

At this conference, failures were discussed, particularly in broken steel mill machinery and equipment. After this, Jost was asked to form a committee to investigate the question of lubrication education, research, and industry needs.

Shortly after the publication of the Jost Report, the Committee on Tribology was formally established on September 26, 1966, and was charged with several duties, including:

- Advising the minster of technology on measures to effect technological progress and economic savings in the sphere of tribology
- Advising government departments and other bodies on matters associated with tribology
- Examining and recommending to the industry the latest techniques in tribology
- Reporting to the minister of technology annually on its activities and on trends and developments in tribology considered to be of technological or economic significance to the nation

Tribology gained further prominence during World War II, as the need for efficient machinery and lubrication systems became paramount.

KEY MILESTONES IN TRIBOLOGY

Tribology has seen several critical milestones through out its history. Here are some notable milestones in the field of tribology:

Leonardo da Vinci's observations (1493): Leonardo da Vinci made significant observations about friction and lubrication, including the concept of reducing friction by using a layer of lubricant between moving surfaces.

Guillaume Amontons' laws of friction (1699): Guillaume Amontons formulated empirical laws of friction, known as Amontons' laws, which established the relationship between frictional force and applied load or contact area.

Invention of the ball bearing (1794): Philosopher and mathematician J.W. Land developed the concept of the ball bearing, which revolutionized machinery design by reducing friction and enabling smooth rotational motion.

Establishment of the field of tribology (1966): The term "tribology" was coined by Peter Jost in a report commissioned by the British government, highlighting the economic and industrial importance of understanding friction, wear, and lubrication.

Introduction of the Stribeck curve (1902): Richard Stribeck presented a graphical representation of the relationship between friction, lubrication regime, and lubricant properties, known as the Stribeck curve. It provided a frame work for understanding the lubrication regimes: boundary, mixed, and hydrodynamic.

Development of the ISO viscosity classification system (1921): The International Organization for Standardization (ISO) established a viscosity classification system for lubricants, which enables standardization of lubricant viscosity grades across industries.

Introduction of elastohydrodynamic lubrication (1949): Hersey and Tabor developed the theory of elastohydrodynamic lubrication (EHL), which describes the lubrication of heavily loaded contacts where elastic deformation of the surfaces plays a significant role.

Discovery of super lubricity (1996): Researchers at IBM discovered the phenomenon of super lubricity, where friction practically vanishes between atomically smooth surfaces sliding against each other under certain conditions. This finding opened up new possibilities for reducing friction and wear.

Advancements in surface engineering and coatings: The development of advanced coatings and surface treatments, such as diamond-like carbon (DLC) coatings and nanocomposite coatings, has significantly improved the tribological performance of materials, reducing friction and wear in various applications.

Progress in computational tribology: Using computer simulations and modeling techniques has expanded our understanding of tribological phenomena and allowed for more efficient design and optimization of lubricated systems, including predicting wear and friction behavior.

MODERN APPLICATIONS AND FUTURE TRENDS

Tribology has numerous modern applications and is expected to undergo exciting future trends. Here are some of the modern applications and future trends in tribology:

Energy Efficiency: Tribology is crucial in improving energy efficiency in various industries. Tribological advancements can lead to significant energy savings and reduced green house gas emissions by reducing friction and wear in machinery and engines.

Advanced Lubricants: Developing advanced lubricants is a critical area in tribology research. Modern lubricants offer enhanced performance under extreme conditions, such as high temperatures and pressures, and provide better wear protection and friction reduction.

Nanotribology: Nanotechnology has brought about significant advancements in tribology. The study of nanotribology involves understanding the behavior of materials at the nanoscale, enabling the development of nanoscale lubricants, coatings, and surface modifications to reduce friction and wear.

Biomedical Applications: Tribology is vital in the field of biomedical engineering. It contributes to designing and developing artificial joints, prosthetics, and medical devices by ensuring smooth and friction-free movement, minimizing wear, and improving longevity.

Microelectromechanical Systems(MEMS): MEMS are miniature devices with moving components, often found in sensors and actuators. Tribology is critical for ensuring these devices' reliable and precise operation, optimizing their performance, and minimizing wear-induced failures.

Tribocorrosion: Tribocorrosion is the combined effect of friction, wear, and corrosion. Understanding and controlling tribocorrosion is crucial in various automotive, aerospace, and marine industries to mitigate material degradation and enhance durability.

Computational Tribology: With the advancement of computational methods and simulations, tribology research increasingly relies on computer models and simulations to study complex phenomena, optimize designs, and predict friction and wear behavior under different operating conditions.

Sustainable Tribology: The future trend in tribology emphasizes sustainability and environmental considerations. Researchers are focusing on developing environmentally friendly lubricants, coatings, and materials that offer improved tribological performance while minimizing ecological impact.

Internet of Things (IoT) and Condition Monitoring: IoT technologies, coupled with sensors and data analytics, enable real-time monitoring of machinery and equipment. In tribology, this allows for condition monitoring, predictive maintenance, and optimization of lubrication strategies, leading to increased equipment lifespan and reduced downtime.

These applications and trends in tribology reflect the ongoing efforts to improve efficiency, durability, and sustainability across various industries, making tribology an essential field for technological advancements in the future.

Conclusion

The historical evolution of tribology showcases humanity's relentless pursuit of reducing friction and wear. Tribology has come a long way, from ancient civilizations' crude lubricants to modern scientific advancements. The contributions of notable scientists, engineers, and inventors have paved the way for significant progress in various industries. As we look to the future, ongoing research in tribology will continue to drive innovation and enable more sustainable and efficient machinery and materials. Tribology continues to evolve, striving to enhance the efficiency, reliability, and sustainability of the systems and devices that shape our modern world.

WHEN TO USE A SINGLE POINT LUBRICATOR

When it comes to the efficient and effective application of grease, a single point lubricator (SPL) can prove to be an extremely beneficial tool in our arsenal. Single point lubricators help engineers regularly and automatically deliver a small amount of grease or lubricating oil to a specific area, which:

- Extend the life of bearings
- Prevent extended downtime due to lubrication-related failures
- Eliminate the human-error element

Because of their importance, it's critical that

we understand when it's appropriate to apply this technology to capitalize on the available benefits for our teams and facilities. But often times this is easier said than done.

SPLs are not a one-size-fits-all type of technology; there are many different types and

variations available on the market that can meet a variety of greasing needs, and not all of them function the same.

So, before we start selecting SPLs at random and begin plugging them into all our bearings, there are several questions we should ask ourselves first to determine if a specific single point lubricator is justifiable for your specific application, or if you should stick with manual greasing practices.

Does the Bearing Require Frequent Lubrication?
Yes – Consider a single point lubricator.
No – Consider manual greasing.

Is the Bearing Difficult to Access?
Yes – Consider a single point lubricator.
No – Consider manual greasing.

Is the Bearing Critical to Equipment Operation?
Yes – Consider a single point lubricator.
No – Consider manual greasing.

Is the Environment Harsh or Dirty?
Yes – Consider a single point lubricator.
No – Consider manual greasing.

Does the Application Require Precise and Consistent Amounts of Lubrication?
Yes – Consider a single point lubricator.
No – Consider manual greasing.

By answering these simple questions, you can begin to determine if a single point lubricator is the best decision for your greasing needs.

When reviewing your answers, if your responses were all "no," you most likely have no need for an SPL, but if you answered "yes" to at least one of the questions, you may in fact have a case for deploying a single point lubricator.

After you understand whether or not an SPL may be an appropriate solution for your facility, you will need to identify what kind you need.

To determine this, there are several factors that will need to be evaluated. Will This Application Have High or Low Temperature Conditions?

- If so, you need to consider whether the SPL can withstand extreme temperatures.
- Positive displacement pump SPLs handle these conditions better than those driven by a chemical reaction.

Are There Routine Inspections That Must Be Done Frequently?

- Although the lubricating task may be more convenient with an SPL, it may be more beneficial to perform the greasing manually in order to encourage team members to physically visit a location and perform an inspection.

Is the Equipment Located in a Corrosive or Harsh Chemical Environment?

- Some manufacturing chemicals have the potential to eat through single point lubricators, so you need to ensure that you aren't setting yourself and your equipment up for failure.

Is There Adequate Space to Place the SPL?

- Space is not always a limiting factor, but it is something that should be considered. While the possibility exists to install a remote SPL in a tight area, we still need to look at how far we will be pushing the grease and if the chosen SPL can adequately perform the task.

Are There Multiple Maintenance Points Close by That Are All Taking the Same Lubricant and Will All Use SPLs?

- When we run into a case similar to this, we need to ask ourselves if installing a centralized greasing system would make more sense. Though these systems may have a higher cost initially, the lifecycle cost would be much lower over time for this specific application.

While it's easy to understand the appeal of defaulting to a single point lubricator when there are multiple tasks that are all a priority to complete, these units are meant to be a tool, not a crutch. We need to use informed forethought when it comes to making a decision on whether or not to utilize SPLs for our equipment– look at your reliability goals and ask yourself if they are truly helping you reach these goals. If the answer is no, don't do it.

About the Author

Jeremie Edwards is a Technical Consultant at Noria Corporation. He is one of an elite few certified by the International Council for Machinery Lubrication (ICML) as a Machinery Lubrication Engineer (MLE) and did so in order to become the best advisor for clients when it comes to their continuing education needs. Before joining Noria, Jeremie served six years in the U.S. Army as a parachute rigger and was deployed in Afghanistan, Uzbekistan, Turkey and Germany.

MANAGING TURBINE OILS IN A SUSTAINABLE WAY

Many companies utilizing rotating equipment have either initiated, or plan to initiate, decarbonization strategies. This is a process that reduces and compensates the emissions of the carbon dioxide equivalent (CO_2e) down to"Net Zero".

Lubricants are an essential component in rotating equipment, so we must determine the most optimal and sustainable ways of managing these fluids, which includes enhancing their performance.

Life Cycle Assessment (LCA) is a methodology for assessing the environmental impact associated with every stage of a product's life cycle, and it is the accepted tool to analyze a product's potential environmental impact. It is the optimal tool for measuring a lubrication program's sustainability and comparing various products and strategies.

The process of performing an LCA is defined in ISO 14040 and takes a thorough inventory of all the materials and energy required to make a product, calculatinga cumulative potential environmental impact. Part of this calculation involves assessing various midpoint indicators, such as:

- Stratospheric ozone depletion.
- Acidification.
- Eutrophication.
- Water scarcity.
- Toxicity potential.

For the purposes of this paper, we will focus

on the global warming potential measured in CO_2e.

LCA is a useful tool for a variety of purposes. For example, how do you know if an electric vehicle will lower emissions compared to an internal combustion vehicle? What if the electric vehicle gets its power from a coal-burning power plant? Doesn't mining lithium and manufacturing batteries produce a lot of emissions? There are a lot of complexities with these questions, and the answers would not be possible without performing a cradle-to-grave LCA.

Cradle-to-Gate Versus Cradle-to-Grave

When performing an LCA on a lubricant, one can look at the product's various lifestages. Cradle-to-gate represents the carbon impact of a product from its inception to the moment the product is ready for sale. This is the most common LCA performed on lubricants, as manufacturers do not have control over the use of the product once it is sold. Cradle-to-grave also covers the product's use and how it is treated at its end of life.

The image below illustrates these stages and identifies the difference between cradle-to-gate and cradle-to-grave.

The CO_2e contribution of extracting, refining, and blending the crude oil (cradle-to-gate) makes up a smaller value of green house gases compared to its end of life (cradle-to-grave).

Although antioxidants have approximately twice the carbon footprint of mineral oils, they contribute a relatively small amount to the overall total since they are used at a small percentage in the formulation. Depending on what part of the world the used oil is generated, the contribution of CO_2e at the end of life is defined by what percentage is incinerated or re-refined.

Different base oils may also contribute more CO_2e to the overall product. For example, polyalphaolefins (PAOs) have about twice the cradle-to-gate CO_2e footprint as mineral oils. However, the end of life of both products is the same, representing a larger percentage. The overall CO_2e contribution of a mineral turbine oil versus a PAO turbine oil is illustrated in Figure 2. There fore, the effort to extend the life of in-service oils will have a significant impact on lowering the total carbon footprint of a lubricant.

It is also interesting to note that transportation plays a minor role in the overall carbon footprint. This is the case as long as lubricants are not being flown around the world.

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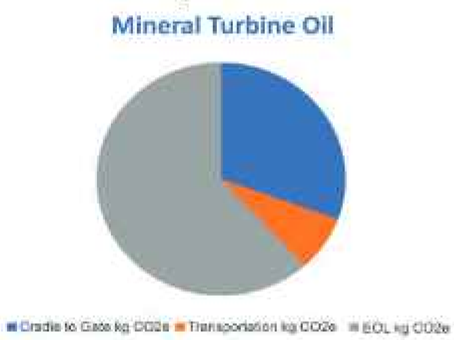
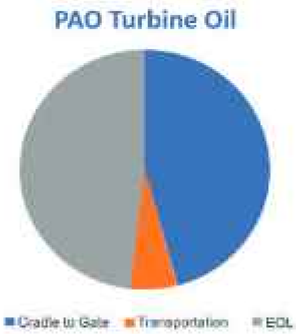




Comparing Lubricant Sustainability

There are many factors that go into measuring the sustainability of a lubricant. Figure 3 illustrates the various factors and path ways for making a lubricant more sustainable.

Using a comparison like this, it is possible to compare the sustainability of various lubricants and lubrication practices. Keep in mind that each category can be converted to kg CO_2e, except for environmental performance, which is its own category. Biodegradability performance, bioaccumulation results, and the oil's toxicity rating are important aspects of the oil's sustainability, but because they are on different scales, they must be directly compared.

Based on this spectrum, the ultimate sustainable lubricant would be one that:

- Is plant-based (oleo-sourced).
- Is made from renewable energy.
- Is readily biodegradable.
- Is non-toxic.
- Doesn't have bio accumulation.
- Provides a long service life.
- Improves the energy efficiency of the system its lubricating.
- Is re-refined or reused in other applications at the end of the fluid's life.

Also, for a sustainable lubricant to be practical, it needs to be fully compatible with the application, including materials of construction and contamination ingression. For example, an oleo-based ester may tick all the boxes but may shrink system seals and hydrolyze due to high water contamination, making it unsuitable for a specific application.

Lubricant Sustainability Case Studies

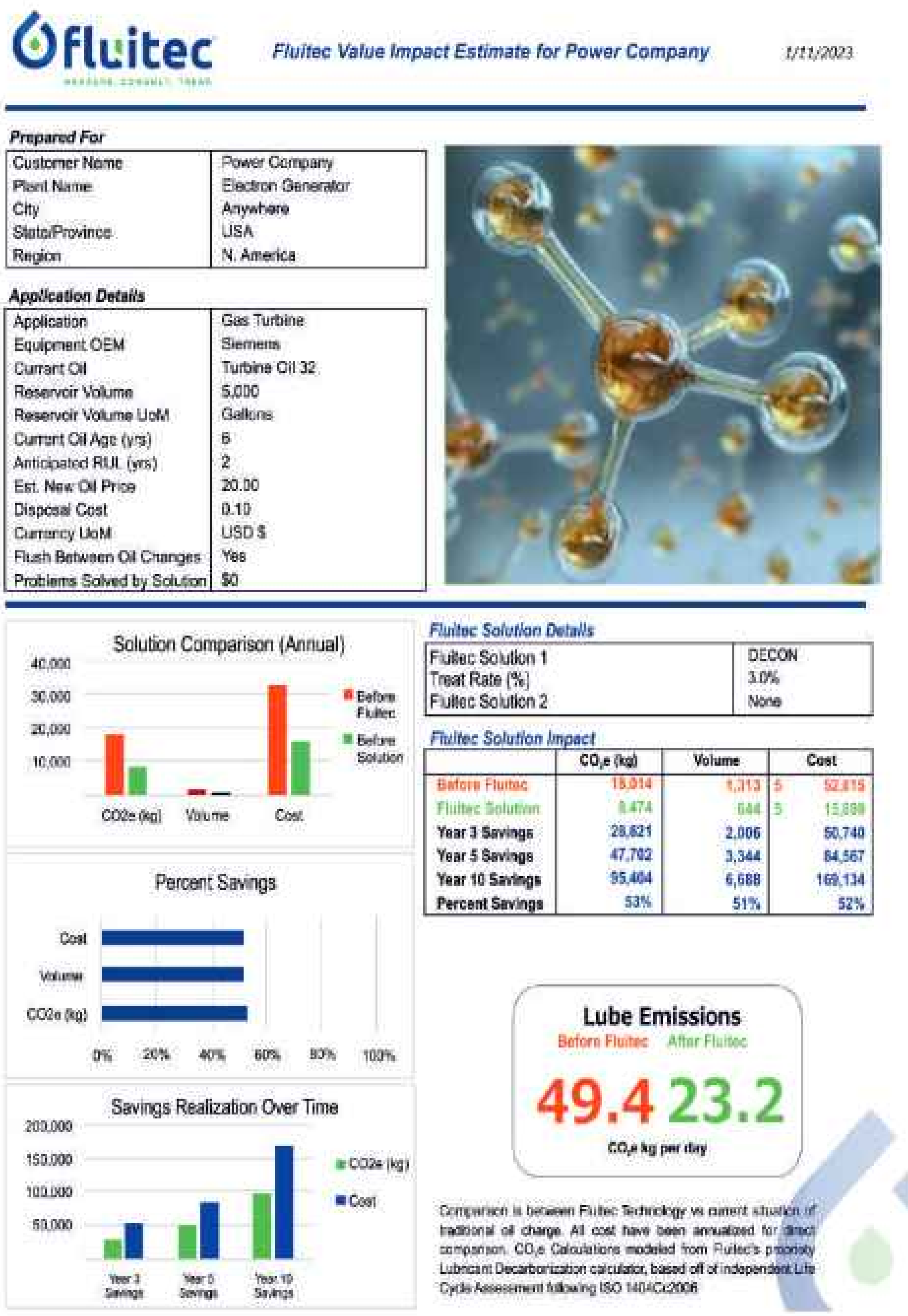
The following are two examples of comparing the sustainability of different lubricants using LCA. The examples illustrate that the product with the highest cradle-to-gate carbon footprint is not necessarily the one with the lowest carbon footprint once a cradle-to-grave analysis is performed.

Case Study 1: Avoiding a "Varnish Flush"

Maintaining a turbine oil with low varnish potential has many financial benefits for a power plant. In addition to increased availability and reliability, one may avoid having to do a "varnish flush" in between oil changes. Flushes are both energy and volume intensive, which accumulates to a sizeable carbon footprint.

For this case study, a solubility-enhancing technology was put to the test to examine its sustainability impact on an in-service turbine oil in the hope savoiding having to perform an oil flush. This technology, which claims to decontaminate lube oil systems, there by helping rotating equipment users avoid the need to perform a varnish flush, was added to an in-service gas turbine oil at a rate of 3%. The gas turbine oil had a 5,000-gallon reservoir and an eight-year life span.

The cost and carbon footprint of adding the solubility-enhancing technology were compared and measured against the value of not having to perform a flush during the next oil change. The results can be viewed in Figure 4.



fluitec

Fluitec Value Impact Estimate for Power Company 1/11/2023

Prepared For

Customer Name	Power Company
Plant Name	Electron Generator
City	Anywhere
State/Province	USA
Region	N. America

Application Details

Application	Gas Turbine
Equipment OEM	Siemens
Current Oil	Turbine Oil 32
Reservoir Volume	5,000
Reservoir Volume UoM	Gallons
Current Oil Age (yrs)	6
Anticipated RUL (yrs)	2
Est. New Oil Price	20.00
Disposal Cost	0.10
Currency UoM	USD $
Flush Between Oil Changes	Yes
Problems Solved by Solution	$0

Fluitec Solution Details

Fluitec Solution 1	DECON
Treat Rate (%)	3.0%
Fluitec Solution 2	None

Fluitec Solution Impact

	CO_2e (kg)	Volume	Cost
Before Fluitec	18,014	1,313	$ 52,815
Fluitec Solution	8,474	644	$ 15,899
Year 3 Savings	28,621	2,006	50,740
Year 5 Savings	47,702	3,344	84,567
Year 10 Savings	95,404	6,688	169,134
Percent Savings	53%	51%	52%

Comparison is between Fluitec Technology vs current situation of traditional oil change. All cost have been annualized for direct comparison. CO_2e Calculations modeled from Fluitec's propriety Lubricant Decarbonization calculator, based off of independent Life Cycle Assessment following ISO 14040:2006

By using solubility-enhancing technology and avoiding having to perform a lubeoil system flush, this turbine would avoid generating 18 metric tons of CO_2e peryear. A calculation like this would be challenging without performing a cradle-to-grave LCA. As with most sustainable lubrication practices, avoiding a varnish flush also saves considerable money for the power plant.

Case Study 2: Replenishing Turbine Oil Antioxidants Instead of Performing an Oil Change

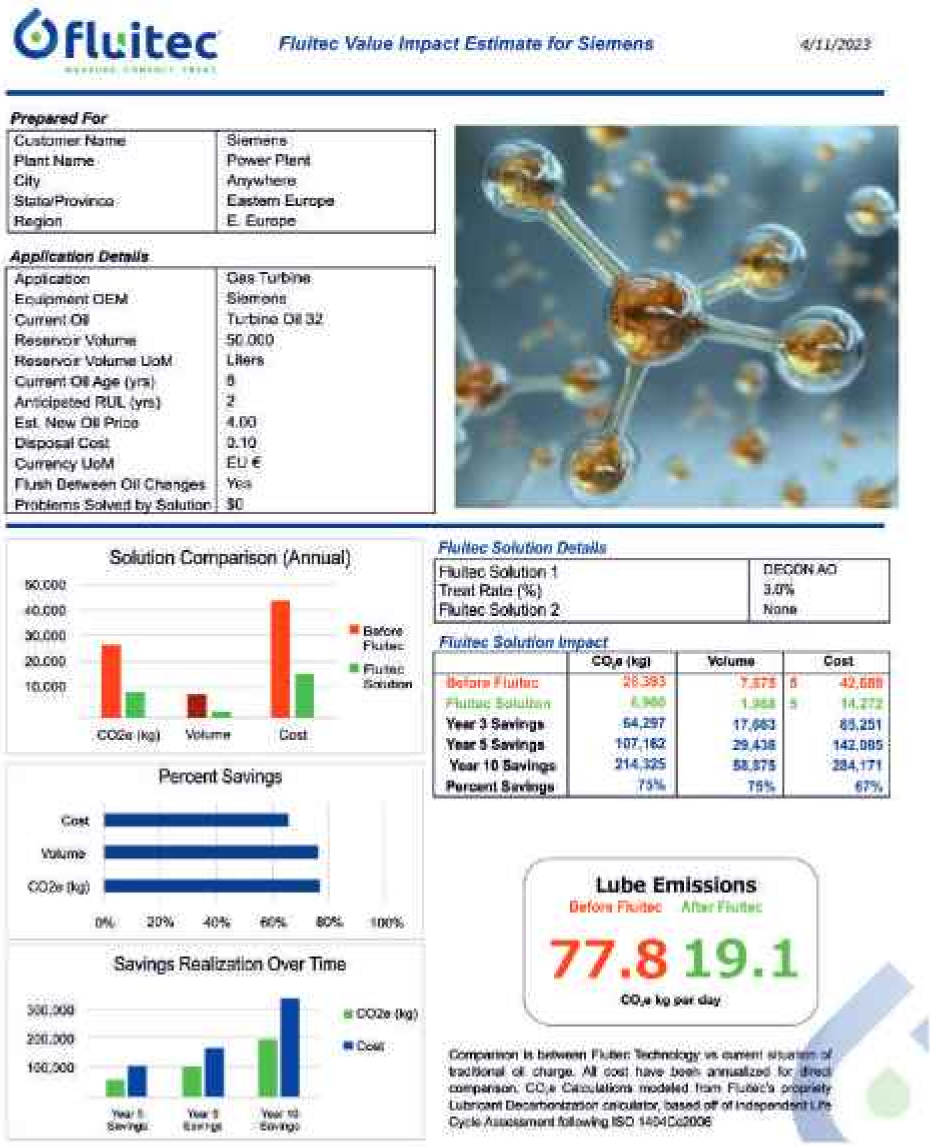
Antioxidants are sacrificial components in turbine oil formulations. The life of a turbine oil is largely dictated by the rate of antioxidant depletion, with the condemning limit by most OEMs and industry bodies stating that action needs to be taken when the antioxidants reach 25% of their original value.

The traditional approach when the life of the antioxidants has been consumed and the oil is at the end of its life is to drain, flush, and recharge the system with new turbine oil. However, this consumes outage resources and is expensive, so many plants have considered simply replacing their antioxidants instead.

Custom-made antioxidant concentrates can be added to turbine oils, provided the correct up-front qualification tests are performed to certify compatibility. This emerging practice has been done successfully in hundreds of turbines and is a cost-saving alternative to the old model of dump and replace. It seems that this would also be environmentally beneficial, however, to quantify this, an LCA is required.

Below is an example of a large frame cogeneration system with a single shaft configuration. Since the system is in Eastern Europe, a whole new set of assumptions is required compared to the first case study. Transportation and the percentage of oil that is refined versus incinerated are two examples. Figure 4 shows the results of adding an antioxidant concentrate to the in-service oil.

In this case, over 200,000 kgs CO_2e are estimated to be saved over a ten-year period, which translates to almost 60 kgs CO_2e per day. The power plant also benefits from cost savings, waste reduction, and other benefits.


Fluitec Value Impact Estimate for Siemens 4/11/2023

Prepared For

Customer Name	Siemens
Plant Name	Power Plant
City	Anywhere
State/Province	Eastern Europe
Region	E. Europe

Application Details

Application	Gas Turbine
Equipment OEM	Siemens
Current Oil	Turbine Oil 32
Reservoir Volume	50,000
Reservoir Volume UoM	Liters
Current Oil Age (yrs)	8
Anticipated RUL (yrs)	2
Est. New Oil Price	4.00
Disposal Cost	0.10
Currency UoM	EU €
Flush Between Oil Changes	Yes
Problems Solved by Solution	$0

Solution Comparison (Annual)

Percent Savings

Savings Realization Over Time

Fluitec Solution Details

Fluitec Solution 1	DECON AO
Treat Rate (%)	3.0%
Fluitec Solution 2	None

Fluitec Solution Impact

	CO_2e (kg)	Volume	Cost
Before Fluitec	28,393	7,875	$ 42,688
Fluitec Solution	6,960	1,968	$ 14,272
Year 3 Savings	64,297	17,683	85,251
Year 5 Savings	107,162	29,438	142,085
Year 10 Savings	214,325	58,875	284,171
Percent Savings	75%	75%	67%

Lube Emissions

Before Fluitec After Fluitec

77.8 19.1

CO_2e kg per day

Comparison is between Fluitec Technology vs current situation of traditional oil charge. All cost have been annualized for direct comparison. CO_2e Calculations modeled from Fluitec's propriety Lubricant Decarbonization calculator, based off of independent Life Cycle Assessment following ISO 14040:2006

Other Strategies to Manage Oils in a More Sustainable Way

There are multiple other lubricant management strategies that can lower the carbon footprint of your lubricant program, including:

- Selecting the best-performing oil for your application, resulting in longer drain intervals and lower maintenance costs.
- Implementing an oil analysis program to optimize the drain intervals of your oils. Keep in mind that not acting when oil analysis warrants not only increases maintenance costs but can also dramatically increase your carbon footprint.
- Avoiding varnish. In addition to failed components, deposits can create an insulating layer on bearing surfaces resulting in higher temperatures, which lowers the system's energy efficiency.
- Re-refining an oil at the end of its life. Creating a circular economy with your lubricant at the end of its life by re-refining instead of incinerating will reduce your lubricant program's carbon footprint.
- Minimizing contamination ingression. Studies have shown that contamination is responsible for up to 70% of premature machinery failures. Deploying a strong contamination control program not only saves significant operational costs but will also reduce the associated carbon footprint.

Summary

As the saying goes, "If it doesn't get measured, it doesn't get managed." In the case of achieving sustainable lubrication, using cradle-to-grave LCA principles allows you to measure and improve the sustainability of your lubricant program. This paper illustrates how to perform these calculations, and as the case studies illustrated, the initial carbon footprint of the lubricant does not necessarily mean decreased sustainability.

WHAT AM I LOOKING AT? **3 QUESTIONS IN OIL ANALYSIS**

I promise this is an article on oil analysis.

"Captain Ross," the colonel yelled as he held up a freshly unearthed piece of metal. "What am I looking at?"

"Colonel, that's part of the right rear strake," I told him while adjusting my chemical warfare gear.

One hundred miles behind the Republican Guard during the Gulf War was not aplace you could hurry to get your chem-gear on if you had to. Not for an Air Force officer, very unaccustomed to being this close to the enemy or to carrying an M-16.

"How do you know?" the colonel asked while examining an almost indistinguishable hunk of junk.

"Because," I said, "I know every single part of this airplane."

The airplane was a crashed Air Force asset, currently spread out over two miles of unforgiving wasteland that was now ours to investigate. We had about eight hours on the ground before the Navy Seals came back for us. One hundred miles behind enemy lines, a lost aircraft, two miles of scattered and charred evidence, wearing full chem-gear, five Air Force officers (with guns), eight hours on the clock, and we had to figure out why this plane crashed. No pressure.

We didn't have a lot of equipment, but what we did have was incredible analytical skills. From that spot and piece of airframe, we could reconstruct exactly how the aircraft impacted the ground and came apart. An entire investigation was conducted, reported, and filed and advancements in aviation warfare were made because of the absolute recognition of what we were looking at.

I don't have many great war stories, and even fewer that I might use as a pseudo-segue into maintenance and reliability. But, I hope you'll agree that being certain of what you are looking at can get you closer to a successful conclusion. How certain are you of what you're looking at?

Oil Analysis Results: Three Questions to Ask Yourself

I promised an article on oil analysis, but I wanted to introduce the aircraft story because I hope to use it, metaphorically, throughout this message.

As a near-40-year practitioner of maintenance and reliability, let me cut to the chase. When looking at the results from an oil analysis, the three most important questions to ask yourself are:

1. What is the condition of the oil?
2. What is the condition of the additives?
3. What is floating around in the oil?

I like to think that my ability to analyze evidence is as strong as anyone's. As one might imagine, aircraft crash investigation training is intense. In a clean, antiseptic classroom, you learn how to forensically piece together "what happened". One such laboratory recreation was simply the fuel door from an F-16. That's it. Just the door. Nothing and no one else was ever recovered.

The intent of an official crash investigation is to discover what happened, and, more importantly, to find out how the Air Force can keep it from happening again. No punitive measures can be taken by law. Simply investigate and prevent.

Our oil analysis should pursue a similar path of investigative curiosity and preventive measures. ISO 14224 instructs that "leadership will determine what to measure, how to measure it, and what to do with that measure." Considering that the lubrication process and systems are in fact "systems," and perhaps the most important systems of all, wouldn't it make sense that the leadership use this instruction to calculate the health and performance of the lubrication and its systems?

I think it does.

"Systems" is an important word, as is "performance". One aspect necessary to conduct a crucial analysis is to understand the system and another important feature is to understand the needed and demonstrated equipment performance.

The Society for Maintenance and Reliability Professionals states in their globally recognized Body of Knowledge that "stakeholders that can influence performance and safety must have a complete process understanding." This leaves little room to rationalize a substandard understanding of what it takes to make a system or process run efficiently and effectively.

It's highly unlikely that if your gearbox shells out due to improper lubrication that the consequences will be grave. Imagine that gearbox strapped to a jet aircraft at 48,000 feet traveling at Mach 2. Or worse, as our incident aircraft, traveling 50 feet off the ground at Mach 1+. Not a lot of room for error.

Let's break down those three important questions to ask yourself when you receive the results from your oil analysis.

Question One: What is the Condition of the Oil?

The results of an oil analysis review should indicate if the oil is up to the task and serviceable. Viscosity is the chief characteristic of a lubricant and the best indicator of the oil's ability to perform its essential duties, which include:

- Reducing friction.
- Absorbing and reducing shock.

When an aircraft is involved in an incident, specifically a crash, all the servicing equipment used on that aircraft prior to launch is impounded for further review. This includes the fuel and lubrication equipment. Also, the investigating maintenance officer will conduct a thorough review of the aircraft records and interview those associated with the aircraft. The purpose is to determine if there is any evidence that the airworthiness of the aircraft was suspect.

Question Two: What is the Condition of the Additives?

Additives are introduced into the lubricant asa way to aid or enhance its inherent features, and an oil analysis should provide great insight into their condition. Common additives include:

- Rust and corrosion inhibitors
- Anti-wear
- Viscosity improvers
- Anti-foaming
- Extreme pressure

When considering additives for lubrication purposes, it is vital to also look at the environment the system will be operating in. This means not only understanding the physical environment, but the conditions the additives will be subjected to, such as total hours of continuous operation and the starting and stopping frequencies. By investigating and analyzing the condition of the additives, we can gauge how our entire system is performing.

It's difficult to imagine a smooth transition into a metaphor for aircraft incident investigations other than to point out that the operating context of the aircraft's mission must be determined before you can actually conduct an effective evidence analysis. This helps in:

- Creating alternative scenarios.
- Determining what evidence might be found at a possible crash site.
- Creating a plan to make a crash site safe for investigators.

These are just a few examples of things that have added to the complexity of an investigation:

- Jet Assisted Take Off equipment (JATO)
- Armaments – bombs and bullets (requires EOD-explosive ordinance disposal)
- Counter measures – chaff and flares (both can be extremely dangerous)
- Dual cockpit configuration, but only one aviator on board, or any configuration of airmen – how many souls on board?
- Ejection seats (very dangerous if the ejection wasn't initiated)

We located a TOW Anti-tank missile launcher in the center of the major aircraft material in the incident mentioned at the beginning of this article. An anti-tank missile launcher?

Question Three: What is Floating Around in the Oil?

Evidence of metals or other such debris that is reported in oil analysis findings gives us great insight into what might be wearing or-failing. Sludge in a gearbox might be a result of oxidation and could be evidence of the reduction of an antioxidant additive. There is a lot to learn from what's floating around in the oil.

Below is a short list of where the wear can come from:

Aluminum – Pistons, bearings, pumps
Barium – Rust and oxidation inhibitor additives
Calcium – Detergent/dispersant additives
Copper – Bearings, bushings
Molybdenum – Excessive pressure additives
Iron – Gears
Silicon – Dust/dirt, defoamant additives
Tin – Journal bearings, bearing cages

There is a very direct comparison between this characteristic and an aircraft crash investigation. If you recall the story that started this article, I was able to quickly and accurately identify the piece of metal my commander had unearthed. I was able to do this, as I explained, because I knew everything there was to know about this airplane. In truth, I really did.

Do you recall the SMRP's directive in their Body of Knowledge, which I also mentioned earlier? "Stakeholders …must have a complete process understanding." Our investigation team was able to deduce, in very short order, the complexity of a crash site because we had a complete process understanding. On that team were:

- Commanders
- Pilot members
- Flight surgeons
- Weather officers
- Maintenance officers

Each of us was highly knowledgeable about the systems we were responsible for, to the point that a random piece of wreckage, no longer than four inches, could be positively identified. Not only did we have systems knowledge, we knew that there would be signs of distress, and we knew what to look for. For example:

- Indicator pointers (needles) in a gauge will make an impression on the inside of a gauge's glass to show their position upon impact.
- Broken light bulbs that are on during impact will leave a light layer of sootinside the remaining glass.
- If a jet engine is running upon impact, the compressor's fans will be bent in the direction of rotation, and there will be dirt (or ground debris) through out the engine.

Just like the tell-tell signs of component wear found in oil analysis comes from what you find floating in the oil, the tell-tell signs of an aircraft crash investigation can be found by analyzing the evidence provided by the "little" things.

Conclusion

Sadly, our entire investigation was further thrust into the spotlight to determine an absolute root cause because of our uber-limited resources. At the time, this was a highly classified aircraft. Both pilots were lost in the accident, and the entiremission was conducted under classic radio silence. All we had was the evidenceon the ground and the piecing of other forensic evidence. This loss was catastrophic.

There was one tiny factor that could have altered the events of that day. I'm not at liberty to divulge this factor, but it would have been a turning point. A difference maker.

This is truly a poor transition, but I want to bring this point home. Each day weget another piece of the puzzle. If we are tracking and trending what will be"evidence" to an investigator, how much better and more focused are we going to be knowing that we could avert disaster?

Do we know our systems and processes well enough to recognize the significance of the insignificant?

Do we have a complete understanding of the process and systems?

Anything less than complete and comprehensive won't get it done in the 21 Century.

I probably don't know you. The fact is, I'd hate for us to meet for the first time while I'm sitting in your boardroom, looking at you and wondering if you knew what you were looking at?

About the Author

John Ross, President of Maintenance Innovators has been a practitioner of maintenance and reliability for over three decades. A former Captain in the United States Air Force, he has been recognized as a distinguished public speaker, technical writer, and presenter. He is a certified Lean Manufacturing facilitator, Process Safety Management SME, and a CMRP.

Bryan Debshaw | Noria Corporation

ENHANCING EQUIPMENT PERFORMANCE: THE ROLE OF OIL ANALYSIS AND PARTICLE COUNTING

Monitor Internal Conditions from the Outside
Oil analysis is a diagnostic, predictive maintenance tool for monitoring and evaluating lubricant and equipment conditions. Participating in an oil analysis program allows you to see what's happening inside your equipment to identify issues, prevent catastrophic failures and increase equipment reliability.

Testing and analysis provide vital information as to the condition of both the oil and the equipment being tested. Wear particles and contamination concerns can be identified using several methods and, if left unchecked, can severely affect equipment performance and reliability or cause a significant failure. In addition, sources and causes of equipment issues like abnormal wear, lube degradation, and component failures can be identified and mitigated.

Predict Maintenance
Playing a crucial role in predictive maintenance strategies, oil analysis results can help foresee maintenance needs by providing early indicators of potential issues, including fuel dilution, excessive idling, and component malfunctions. Establishing and monitoring trends within the oil properties can identify changes or deviations from normal operating conditions and may reveal deteriorating conditions, increased contamination levels, and degradation of the lubricant.

Establishing a trending history of oil analysis for equipment components can give early indications for maintenance activities like oil changes, filter replacements, and component repairs before the concerns turn to failure.

Oil Analysis Value: More Than Testing
Standard oil analysis tests include Elemental Analysis by ICP, Fuel Dilution, Nitration/Oxidation, Acid Number/Base Number, Viscosity, Particle Count, and many more. Each of these tests, performed by an accredited laboratory, provides equipment users with test results with severities, a review by a Data Analysts team, and maintenance recommendations to address the identified concern.

Effectively interpreting your sample test results and acting timely is where a world-class, successful oil analysis program differs from others – and has the greatest return on investment (ROI).

Numerical test results are indicated on the oil analysis sample report, and these results include:

- Wear metals
- Contaminant metals
- Multi-source metals
- Additive metals
- Contaminants (fuel, soot, water)
- Fluid properties (viscosity, acid number, base number, oxidation, nitration)

For each data set, results are flagged by severity, and a data analyst comments after reviewing the results.

	Wear Metals (ppm)										Contaminant Metals (ppm)			Multi-Source Metals (ppm)						Additive Metals (ppm)				
Sample #	Iron	Chromium	Nickel	Aluminum	Copper	Lead	Tin	Cadmium	Silver	Vanadium	Silicon	Sodium	Potassium	Titanium	Molybdenum	Antimony	Manganese	Lithium	Boron	Magnesium	Calcium	Barium	Phosphorus	Zinc
BL	1	0	0	0	0	0	0	0	0	0	6	9	0	0	65	0	0	0	1	1200	1200	0	1239	1312
19	9	0	1	0	6	1	0	0	0	0	3	2	0	0	64	0	0	0	9	977	1131	0	1096	1193
20	3	0	0	1	2	0	0	0	0	0	3	2	0	1	65	1	0	0	14	968	1182	0	1047	1200
21	4	0	0	1	2	0	0	0	0	0	2	2	0	1	61	0	0	0	10	938	1123	0	1094	1193
22	13	0	0	1	10	1	0	0	0	0	3	31	123	0	77	0	0	0	4	861	1098	0	886	1077
23	11	0	0	1	6	0	0	0	0	0	3	17	56	1	62	0	0	0	6	831	1020	0	899	1044

Figure 1. Lubricant Analysis Reports Test Results for Wear, Contaminant, and Additive Metals

A systematic approach to interpreting results can help you better understand the data and make informed maintenance decisions. Comprehending each specific testing parameter and severity can help determine what the value represents and how it relates to the overall performance and health of the equipment and lubricant.

Contaminants			Fluid Properties					
Fuel Dilution %	Soot %	Water %	Viscosity 40°C cSt	Viscosity 100°C cSt	Acid Number mg KOH / g	Base No. D4739 mg KOH / g	Oxidation abs / cm	Nitration abs / 0.1mm
		<.1 - FTIR		15.6	2.34	8.49	11	5
4.5 - GC	0.2 - E2412	<.1 - FTIR		12.6		5.83	14	9
<2 - Estimate	<.1	<.1 - FTIR		13.2		6.90	11	6
4.5 - GC	<.1	<.1 - FTIR		12.9		8.01	12	8
6.9 - GC	0.2 - E2412	<.1 - FTIR		11.6		4.17	14	10
>10 - GC	0.3 - E2412	<.1 - FTIR		10.1		4.62	14	9

Figure 2. Lubricant Analysis Reports Test Results for Contaminants and Fluid Properties

Baseline values and trends can be established by collectively analyzing historical data from previous samples and comparing them against baseline reference samples. Baselines serve as ideal reference points for comparison and should represent normal operating conditions for the equipment.

Addressing Problematic Particle Contamination with Oil Analysis

The most common cause of component failure is the contamination of particles. This includes external particle contaminants, such as dirt or sand, and the microscopic pieces of metal generated during equipment operation that work their way into the lubricant. Through several oil analysis tests, including Particle Count, Particle Quantifier, Analytical Ferrography, and Filter Debris Analysis, these particles can be identified and quantified, and the root cause investigated.

Particle Count

Particle count is a valuable test for determining fluid and system cleanliness in filtered systems such as:

- Hydraulics
- Turbines
- Compressors
- Auto/power-shift transmissions
- Recirculation systems
- Filter gear systems with a fluid viscosity of approximately ISO 680 or less

Particle count testing measures all particles accumulated in a system, including metallic and non-metallic particulates, dirt, fibers, biological growth, etc.

Several test methods exist to quantify the particles when measuring the number of particles within a used lubricant. Results can differ by instrument and laboratory, so it's important to know what method is used on your oil sample and understand how the test methods can influence your results.

The Automatic Particle Counting method uses an instrument to count the particles in a sample. The particle count instrument has a laser and sensor to detect and measure the number of particles via light omission. Typically, the results are presented as the number of particles per milliliter at several different micron sizes.

Particle Quantifier

To measure the concentration of sizeable ferrous wear particles in used lubricants, particle quantifying (PQ) is the preferred test method. Particle quantifying technology measures the density of ferrous debris without a particle size limitation and assigns a value based on the degree of metallic content present in the sample.

When used in conjunction with AES-ICP, comparing PQ results with ICP results, the severity of an abnormal wear event becomes evident. The ICP will detect the smaller wear sizes but has a limitation with larger (> 7μm) particles. An elevated Particle Quantifier result from the same sample would indicate that the component has begun generating larger-sized wear debris no longer detectable by the ICP. Further testing can then be performed to investigate the size and shape of the particles to help maintenance personnel discover the source of the contamination and assess the damage to the component.

Carefully monitoring iron concentrations with elemental metals analysis (ICP) and the particle quantifier will identify increasing wear trends and alert the operator to a potential problem early on. This will also help act as a cue to have the laboratory perform an Analytical Ferrography test on the lubricant sample to qualify the type and severity of the wear.

Analytical Ferrography is a powerful tool when correctly performed by a trained analyst and provides deeper insights into mechanical wear or contamination. When used in conjunction with metals analysis, PQ, viscosity, acid number, and water content, a well-defined course of action is provided to the user to correct the condition of the unit and the lubricant.

Analytical Ferrography

Analytical Ferrography takes particle contamination identification to the next level by analyzing and characterizing wear particles suspended in lubricating oils. It provides detailed information about the size, shape, composition, and distribution of wear debris, allowing for a comprehensive understanding of the equipment's condition.

Analytical Ferrography involves reviewing a ferrogram (a slide prepared from the sample to study the wear and contamination under a microscope). A portion of the used oil is transferred to a slide on which the ferrous (containing iron) objectsin the oil are collected. After proper agitation, a small amount of the sample is poured through a thistle tube across a glass slide suspended over a powerful magnet. The oil, soot, dirt, and other debris are rinsed from the slide, leaving the ferrous wear visible under a microscope.

Figure 3. Analytical Ferrogram Showing Ferrous Sliding Wear, Lead/Tin Sliding Wear

Analyzing a ferrogram allows the analyst to see the different types of wear mechanisms in the oil. It is not limited by the size of the wear particle, like some other types of testing, meaning that large and small wear is easily identified in addition to clues of possible causes.

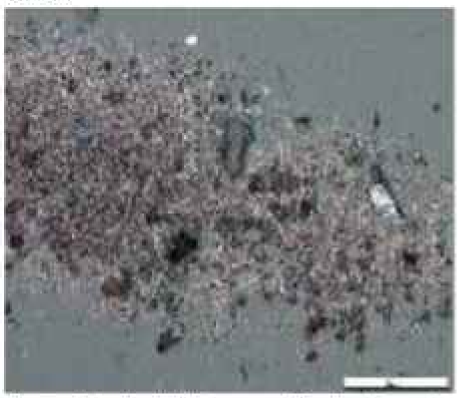


Figure 4. Analytical Ferrogram Showing Corrosive Wear, Abrasives, Lead/Tin Alloy

Filter Debris Analysis

Oil filters installed in equipment systems are designed to remove contaminants and particles that would otherwise circulate and damage the system. However, this also removes evidence that can help determine recommendations to address problems. By extracting the material caught by the filter and examining it, more insight can be gained into the type and magnitude of system wear and contamination.

The Filter Debris Analysis process removes particulates from the filter media and isolates them for laboratory analysis. This includes preparing a filter patch of debris present, an analytical ferrography, and an elemental metal test on any oil that arrived with the filter. A trained ferrographic analyst can then identify the particulates' type, size, and shape. Combined with routine oil analysis testing, this can be valuable in discovering the root cause of equipment wear or catastrophic failure.

Oil Analysis: A Predictive Maintenance Tool

Oil analysis is an accurate and effective tool to detect abrasive particle contamination in lubricating oils with the proper interpretation, which can alert to needed maintenance well before failure occurs. Timely detection of potentially harmful contamination allows maintenance personnel to identify potential sources, take corrective actions, prevent adverse effects on performance and reliability, and improve the overall equipment lifetime.

DEVELOPMENT OF WIND TURBINE GEAR OIL – SERVOMESH WEG 320

Wind Energy Sector in India

India's wind energy sector is led by indigenous wind power industry and has shown consistent progress. The expansion of the wind industry has resulted in a strong ecosystem, project operation capabilities and manufacturing base of about 10,000 MW per annum. The country currently has the fourth highest wind installed capacity in the world with total installed capacity of 39.25 GW (as on 31st March 2021) and has generated around 60.149 Billion Units during 2020-21.

Wind Mill Lubrication

Wind turbine lubrication exists at the very extremes of industrial gear applications in terms of temperature, load weights, bearing wear, maintenance, accessibility and basic lubricant performance. Most of the wind turbine gearbox manufacturers have compiled or are in the process of compiling new lubrication specifications. These specifications are more stringent than those for industrial gear applications, and more accurately reflect true operating conditions, including low-temperature conditions. Structure of the wind mill is as under:

The gearbox is situated just where the winds are the strongest - as high as 300 feet. A special gearbox oil filter, separate from the

normal oil cooling system, ensures high oil cleanliness. This is a key factor in desert or arid conditions where airborne dust can get into gearboxes, act as an abrasive, and eventually lead to (three-body) contact fatigue failures. The FAG FE 8 bearing test, which is part of the standard DIN 51517 Part III specification, is required by all gearbox manufacturers. Nonetheless, oil drain intervals have rested between 8 and 12 months. The expectations for new generation oils for offshore applications could be a drain interval of up to three years.

The ultimate gearbox oil for wind turbine application should have the thermal stability of a top-tier hydraulic oil combined with the EP properties of current gear oils. In addition, the components added to prevent micro- pitting need to be carefully selected to ensure that surface activity is balanced. Additionally, turbine gear oil specifications are beginning to reflect demand for higher lubricant performance through testing for enhanced oxidation and corrosion resistance, and improved bearing and long-term operational performance.

The Ultimate Solution

With continuous focus on innovation while exploring, creating, and delivering value to the customer under Make In India campaign, SERVOMESH WEG 320 was developed meeting DIN 51517 Part III specification with OEM requirements of FAG FE8. The product (Servomesh WEG 320) is tailor made for the wind turbine gear oils for catering this niche segment. The product not only meets viscosity temperature behavior & oil service life standards but also has excellent resistance to foaming. The product is designed for excellent filterability & demulsibility characteristics.

Starting with 'zero' penetration and success in the wind energy segment, the product was offered to Inox Wind, India's leading wind energy solutions provider servicing IPPs, Utilities, PSUs, Corporates and Retail Investors. While instilling the belief that an Indian Company can actually supply a competitive and 'value for money' formulation, negotiations were carried out. The customer saw the potential and capability in Indian Oil and placed **the first ever purchase order for direct supplies of both initial fill and maintenance business with SERVOMESH WEG 320 without any trial.**

Today, IOC stands with 100% business for wind turbine gear oil with M/s Inox Wind

It is pertinent to note that the development of wind turbine gear oil by IOC is the first such offering by an Indian company. Wind energy is a niche market segment, the successful supply and post supply seamless operational efficiency by IOC has been a great breakthrough in this segment.

BPCL COLLABORATES WITH IIMK- LIVE TO EMPOWER START-UPS IN INDIA

Bharat Petroleum Corporation Limited ("BPCL"), a Fortune Global 500 Company & a Maharatna Energy Conglomerate, and IIMK LIVE, the incubation centre of Indian Institute Of Management, Kozhikode ("IIM Kozhikode"), have joined hands to strengthen the growth of start-ups in the clean energy and deep tech sectors, as part of the 'Project Ankur' initiative of BPCL.

BPCL's Start-Up Scheme "Project Ankur" aims to develop a supportive ecosystem that nurtures entrepreneurship in the country by backing innovative ideas and concepts that have the potential to grow into start-ups. By joining hands with IIMK LIVE, BPCL aims to provide essential incubation, mentorship, and training to selected start-ups, amplifying their potential for success.

Ashutosh Sarkar, Executive Director of IIMK Live and Sameet Pai, Head of Corporate Strategy, BPCL after signing MoU

Through 'Project Ankur,' BPCL has already funded over 30 impactful start-ups, including companies like M/s Genrobotics, M/s Detect Technologies, M/s Anthill Creations, M/s Cygenica, and M/s EyeROV. These success stories stand as testament to the transformative power of innovation, bolstered by dedicated support.

INDIAN OIL WELCOMES WORLD NO. 1 PARA-ARCHER, MS. SHEETAL DEVI, INTO ITS ILLUSTRIOUS SPORTING ROSTER

In a momentous event held today, Ms. Sheetal Devi, the World No. 1 para-archer, was welcomed into the IndianOil family, making her the first para-athlete to join IndianOil sports fraternity. Mr. Shrikant Madhav Vaidya, Chairman, IndianOil, presented the tenure-based engagement letter to Ms. Sheetal Devi, celebrating her remarkable journey in the world of para-archery.

Padma Shri Dr. Uma Tuli, Founder, Amar Jyoti Charitable Trust, Padma Shri & Arjuna Award Winner Ms. Deepa Malik, and functional directors of IndianOil, Mr. V. Satish Kumar, Director (Marketing), Ms. Sukla Mistry, Director (Refineries), Mr. Sujoy Choudhury, Director (P&BD) holding additional charge of Director (R&D and HR) and Mr. N. Senthil Kumar, Director (Pipelines) and IOCians were also present on the occasion.

Welcoming Sheetal to IndianOil, Mr. Vaidya said, "Indian Oil has a longstanding commitment of supporting the sporting talent in the country and nurturing world class champions. Ms. Sheetal Devi will be a shining star in Indian Oil's Sporting Galaxy". Admiring Sheetal's courage and resilience and her journey as the world's first armless archer in the world, Mr Vaidya offered the Company's steadfast support to her in realising her dreams and win more laurels for the nation.