Improvement of Work Safety and Reduction of Environmental Issues With Fire-Resistant Lubricants in Steel Plants

Hazards are ever-present in the steel plant environment, and a heightened awareness and emphasis on safety is a necessary priority for our industry. This monthly column, coordinated by members of the AIST Safety & Health Technology Committee, focuses on procedures and practices to promote a safe working environment for everyone.

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Comments are welcome. If you have questions about this topic or other safety issues, please contact safetyfirst@aist.org. Please include your full name, company name, mailing address and email in all correspondence.

Fire hazards in the steel industry is not a new topic and every effort is being made to lower the fire hazards in its production plants. Fire hazards are present in several different forms but fires induced and intensified by mineral oil-based lubricants are notorious and feared. For hydraulic fluids, gear oils and greases, several alternatives are available. This paper explains typical examples in steel plants of successful conversions and the impact on safety and environment. In addition, this paper describes what change can be made to the choice of lubricants to get to a situation with significant reduced risk, enhanced work safety, and a secured productivity in casters, rolling mills and auxiliary equipment.

The steel industry is one of the most demanding in manufacturing as well as one of the most dangerous. A fire can halt production for weeks or even months while causing economic turmoil for businesses. The risk of fire is incredibly high in an environment where extreme temperatures meet flammable materials.

Managing fire-related processes in the steel industry is vital — risk assessments must be undertaken to ensure that all safety processes are followed and that they adhere to industry regulations. Given the nature of steel manufacturing, minimizing and controlling fire hazards is very challenging. This is unsurprising given that steel production requires a significant amount of heat to produce the desired finished product.

Inherent Risk When Using Mineral Oil-Based Hydraulic Fluid

Highly pressurized hydraulic units are used within steel production to operate the equipment using mineral oil-based hydraulic fluid to drive the units. Despite having a good cost-performance ratio there is still an inherent risk that any spill or leak from the units could result in a fire. With processed materials reaching temperatures of ±900°C up to >1,500°C (±1,652°F up to >2,732°F) it's no surprise that the risk of fire is great.

One of the main reasons a fire can start and spread so easily is due to pressurized mineral oil-based hydraulic fluid. When such fluid leaks or sprays onto a surface of hot metal, it can build a vapor of oil droplets that can instantly create an ignition-like explosion and fire ball that has the potential to surge through the area in seconds, causing untold damage.

Several tests exist to simulate fire resistance properties. These tests can be run by Factory Mutual (FM Global) — the testing and approval arm of a major industrial insurance underwriter. Companies using an FM Global-approved hydraulic fluid[2] can reduce their premiums.

To reduce the risk of fire in steel production, many businesses are switching to fire-resistant hydraulic fluids. These fluids have less hazardous properties and are seen as the best way to reduce the risk of a fire.

However, the term fire-resistant is often confused with fire-retardant. Fire-resistant hydraulic fluids can burn under certain conditions. Water glycols fluids (HFC) will ignite if a certain amount of water evaporates while most polyol ester-based fluids (HFD-U) can burn but

will not give the devastating vaporized kind of explosion mineral oil-based hydraulic fluid can generate. However, fire-resistant hydraulic fluids create control of the situation. Only hydraulic fluids that have a very high water content (HFA) fluid can be considered fire retardant.

Types of Fire-Resistant Hydraulic Fluids

High Water-Based Type Hydraulic Fluids (HFA) – These product types are typically supplied as concentrate and are diluted to 2–5% in water by the user. These fluids come as emulsion or as a solution and require specific hydraulic equipment because of the very low viscosity.

Water Glycols (HFC) – Water glycols have a high water content, which provides a strong fire resistance. These fluids represent around 50% of the total fire-resistant hydraulic fluids market. They are commonly used in steel plants because of their high water content. However, while they are fire-resistant their performance can suffer when not maintained properly and components using this type of fluid can have a shorter service life.

Phosphate Ester (HFD-R) – Fire-resistant by chemistry, phosphate ester is an older fluid technology but is formulated with materials that have a carcinogenic, mutagenic, reprotoxic (CMR) reputation. These fluids are notoriously more expensive than mineral oil and need to be well maintained as these products create aggressive acids when they age.

Polyol Ester-Based Fluids (HFD-U) – These fluids are the best alternative to mineral oil despite being more expensive. What should be considered is that they represent a total lower cost given they will greatly reduce the risk of fire and improve work safety in the plant. Besides this they are environmentally friendly.

With polyol ester-based HFD-U fluids, the formation of product vapor does not take place and thus no explosion or fire ball will be generated. The HFD-U fluid might burn as well, but there is no vapor or explosion, and it is limited to the place it comes in contact with, so the situation remains under control.[4]

The performance as hydraulic fluid of an HFD-U is comparable to that of a mineral oil-based hydraulic fluid. Converting a mineral oil-based hydraulic fluid to an HFD-U goes generally without making any changes to the hydraulic unit and without giving in on its functionality.

Finding a Solution to Safety

The steel industry has several options when it comes to reducing the risk of fire. One thought is to change the design of the units in order to avoid mineral oil leaking close to hot surfaces. While this would allow a company to keep the same oil technology, it doesn't avoid using a straight hydraulic oil (HLP) coming in close contact with a hot surface or stopping the formation of pools.

Many steel plants have intricate and expensive fire extinguisher systems installed on-site. This allows them to keep the same oil technology, but the risk of fire is still present as the fire ball might be past the extinguisher before it switches on.

The option that can have a significant impact on fire reduction is to change the hydraulic fluid to a water glycol HFC type. A downside to this is that these fluids need proper maintenance. Due to pressure limitations, expensive system adaptations can be necessary. Systems suited to operate these kinds of fluids are generally more expensive.

Finally, a steel plant could change the hydraulic fluid to an HFD-U type. The performance of the fluid in this instance is closer to a mineral oil-based lubricant but there is still a risk of a controllable fire on a 900°C (1,650°F) surface.

Steel production is an industry where there is always going to be a high risk of fire. With operations involving red-hot steel and boiling molten metals, using water-free, polyol ester-based fire-resistant hydraulic fluids instead can improve the safety in plants significantly, without jeopardizing the productivity and performance of the production line. There needs to be a safety first mentality from everyone in the plant, including visitors.

Driving Forces of Pool Fires With Mineral Oil-Based Lubricants

A driving force in pool fires is the relative low auto ignition temperature of mineral oil in combination with a relatively low specific heat and high heat of combustion.

1. The auto ignition point of mineral oil (300°C/572°F) is much lower than that of an HFD-U (460°C/860°F).
2. The specific heat, which expresses the energy needed to heat 1 g mineral oil 1°K, is 10–15% lower for mineral oil (1.7 J/g.K5) compared to polyol ester-based HFD-U (2.06 J/g.K).
3. The heat of combustion of a mineral oil-based hydraulic fluid is typically about 43–44 kJ/g, whereas an HFD-U, polyol ester fire-resistant hydraulic fluid has a heat of combustion of

about 38 kJ/g. So chemically an HFD-U fluid generates 10–15% less heat during combustion.

Just on physical facts it can be stated that less energy is needed to heat mineral oil-based lubricants to reach the temperature needed to auto ignite (which is already relatively low). The relative high heat of combustion of mineral oil-based lubricants acts therefore as an auto catalyst in the process to keep the fire burning.

Examples of How the Use of a Fire-Resistant Lubricant Can Improve Safety and Reduce Fire Hazards in High-Risk Areas

There are many examples where fire hazards in the steel industry can cause a serious accident. One instance occurred at a steel plant in Central Europe at the welder in a pickling line. The problem appeared when a hydraulic hose was damaged severely. The mineral oil-based hydraulic fluid gave a jet on the just-welded area causing a huge flame. This ignited the wide surrounding as well as the pickling line in operation in the same hall. The result was that both pickling lines could not be used for about eight months.

The impact for the company was huge as it had just these two pickling lines and the process flow from the hot mill to the cold mill within the steel plant was disrupted. Hot-rolled coils had to be shipped to external pickling companies. The cost was enormous and soon after the welder was switched to a fire-resistant hydraulic fluid (HFD-U, in this case QUINTOLUBRIC 888) to avoid this from happening again.

Another example happened in a rail mill in Southern Europe. A red-hot rail missed the roll bite, derailed and hit a hydraulic pressure line at full speed. The hydraulic system was operated with mineral oil-based hydraulic fluid. The hydraulic fluid came in contact with the red-hot rail, gave an oil mist, ignited, exploded and turned the whole mill into an inferno in less than a second.

The damage obviously was huge and affected the surrounding area and cables. The mill was not operational for at least 10 days. During this time, the mill as not able to produce and to supply their customers. The use of a fire-resistant hydraulic fluids could have prevented this inferno.

Conclusions

Safety hazards are inherent within the steel industry. In particular, fire hazards present a sizable risk for steelworkers as the nature of steel production requires significant heat to produce the desired finished products. Minimizing and controlling the hazards is very challenging and this paper explains how fire-resistant lubricants can reduce some of those risks.

Because lubricants are typically mineral oil based, this can become the fuel for a fire event. The author proposes that using a synthetic ester oil-based hydraulic fluid would reduce the likelihood of catching fire and keeping the situation under control. This ester technology is used in fire-resistant hydraulic fluids for many years in the steel industry.

References

1. Contributions from T. Mattern, Quaker Houghton during the drafting of the article.
2. Smith, P., "Industrial Fluids With Low Fire Hazard," FM Approvals: FM Approved Industrial Fluids, retrieved 2021, https://www.fmapprovals.com/products-we-certify/understanding-the-benefits/fm-approved-industrial-fluids.
3. ISO 6743-4:2015. 3 December 2020, retrieved 2021, https://www.iso.org/standard/60483.html.
4. www.youtube.com/watch?v=Qpoj9XnK4aw, retrieved 21 October 2021.
5. Engineering Toolbox, Liquids and Fluids – Specific Heats, 2003, https://www.engineeringtoolbox.com/specific-heat-fluids-d_151.html. ✦

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