**Reducing Fire Hazards in Hot Strip Mills with Fire Resistant Greases**

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**INTRODUCTION**

Despite all of the knowledge and awareness of fire hazards in steel mills, it is still relatively acceptable to have unintended, open flames/fires near employees. These fires are generally the result of uncontrolled processes where there is an ignition source combined with the other elements that make up a fire. This paper reviews the fire risks associated with lubricating grease in hot strip mills and discusses the opportunity for reducing risks with the use of fire resistant greases.

In its most basic form, fire occurs when four elements of the fire tetrahedron are present (National Fire Protection Agency, 2008). These elements are heat, fuel, oxygen and a chain reaction. Without these, fire is not present. However, controlling these risk factors is not easy in the steel industry since these elements are inherent in steel production.

This paper looks at the four elements of the fire tetrahedron and discusses how the use of fire resistant grease breaks the chain to reduce the risk of fires within hot strip mills.

**Background and Significance**

Fires have always been an issue within the Steel Industry. Within the last 12 months, there has been a few notable fires at North American steel plants (Dallas Morning News, 2015; KAST, 2014; and Live5 News, 2014). While there are many sources that contribute to these fires and the sources were not necessarily from lubricants in the steel making process, it is important to consider that every source places steel workers at risk for injury. Understanding the sources of how fires begin and how they propagate provides the background to understand how the use of fire resistant greases can reduce some of these risks at steel plants.

For a fire to start and evolve, it must have four elements present: heat, fuel, oxygen and an uninhibited chain reaction. This is known as the fire tetrahedron. Once a fire is started, it can spread in three different ways (National Fire Protection Agency, 2008). The first is conduction, which is the passage of heat energy through or within a material because of direct contact. The second is convection, which is the flow of fluid or gas from hot areas to cooler areas. The third is radiation, which is heat traveling via magnetic waves, without objects or gases carrying it along.

According to the National Fire Protection Agency (2008), there are four ways to put out a fire.

1. Cool the burning material
2. Exclude oxygen
3. Remove the fuel
4. Break the chemical reaction

In steel plants, the approach to putting out the fire is generally done with variations of cooling the burning material. With a fire resistant grease, the approach is removal of the fuel. This is because a typical mineral oil based lubricating grease is a good fuel source. A fire resistant grease is not as good a fuel source due to it having lower volatility and higher molecular weight relative to mineral oil products. This directly results in higher flash and fire points.

A solid or liquid fuel source relies on vaporization of the medium to act as a fuel. Low vapor pressure at elevated temperature compared with mineral oil reduces the ability of the lubricant to act as a fuel under equal temperature conditions. Furthermore, fire resistant greases are made from materials that have low thermal conductivity requiring more energy input to reach combustion temperatures.

**Purpose and Scope**

The purpose for writing this paper was to provide more awareness of the fire risks associated with the use of mineral oil based lubricants and to help understand how alternative lubrication formulas reduce these risks. This is important for a few reasons. First, fire hazards are inherently part of the steel making process. Second, there is a high tendency to accept the risk relative to the cost of using fire resistant greases. Third and like most industries, making changes within steel processing, lubrication being no exception, can be time consuming.

Since fire hazards are relatively accepted within steel plants, the solutions for addressing the fires, particularly on processing lines, are somewhat rudimentary. This can range from letting grease that has been pushed through a bearing burn itself out when the fuel source is completely consumed. A more advanced method is having an employee use a small extinguisher to put out the fire. The most advanced system is a hard-piped, water-based extinguishing system. However, this can be costly.

Andrew Carnegie revolutionized steel making with technology advancements to speed up efficiencies in combination with an industrial culture that focused on driving out costs to maximize profitability. Many of these process efficiencies also led to safety hazards such as noise, unsafe machinery and other physical hazards such as fire. While there has been many improvements over time, particularly with respect toward safety, the industry has learned to work with dangerous conditions since the beginning. Because heat and fire are needed for production and because lubricating grease is needed to keep machinery operational, there is potential every day for heat and/or flames to come into contact with lubricating grease. For direct cost reasons ($/kg), it is typical for steel plants to use mineral oil based lubricating greases.

Making a change from standard mineral oil lubricating greases to fire resistant lubricating greases for steel mills can take time. It is typical for plants to keep doing the same thing as long as it is working (i.e., “if it ain’t broke, don’t fix it”). While it may not be extending the life of the bearing, it is typical to continue to use the same grease over and over. In a basic sense, this is also proper from a maintenance perspective. However, even when there are options to extend the life of the asset (i.e., longer bearing life) and to reduce fire hazards (e.g., using fire resistant greases), making the change is not immediate.

**DISCUSSION**

**Types of Lubricants Used in Steel Mills**

According to Schrama (2006), the steel industry employs four main categories of lubricants in its facilities (1) process lubricants, (2) hydraulic fluids, (3) metal working lubricants, and (4) machinery lubricants. The overview below is from Schrama (2006).

Process lubricants are those that come into direct contact with the steel surfaces during the various pickling, rolling, shaping, plating, and heat-treating operations. Rolling oils used in cold rolling and temper mills are the largest volume fluids in the process lubricants group.

Hydraulic fluids are used in the hydraulic or fluid power systems throughout the plant. A majority of the hydraulic fluids are petroleum based, unless there is the potential for heat or hot metal contact. In those cases, water glycols and ester based fire resistant fluids are used.

Metalworking lubricants are primarily used in the maintenance departments that have machine shops and roll shops. These products consist of cutting and grinding fluids used to remove metal from mill rolls, fabrications and steel mill components.

Machinery lubricants consist of greases, gear oils, turbine oils, circulating oils, pastes and solid lubricants. These are used to lubricate bearings, gears, chains, compressors and sliding surfaces. Often times, machinery lubricants are consumed through central lubricating systems to simplify applying the substance and to save costs.

**Fire Hazards – Hot Mill Rolling Tables**

Because of the nature of steel production, steel plants have hazards in every operation. This requires a “safety first” approach from everyone, including visitors, to minimize the risks of negative outcomes. Within the large context of safety, fire hazards are substantial areas of risks within steel plants.

Fire hazards exist in many places within steel plants. This includes, but is not limited to areas such as the coke oven, blast furnace, melt shop, hot rolling mills, etc. The hot strip mill is a very active area as it processes about 50% of all the steel tonnage produced (Schrama, 2006). The primary purpose of the hot strip mill is to reheat the steel and transform it from large bars into rolled steel. There are several sub processes in the hot mill. In those sub processes, steel is moved throughout the mill on roller tables. The roller tables have bearings that contain lubricating grease.

It has been observed that temperatures in the hot mill furnace can reach up to 2,300°F (1,260°C). Because the process results in molten slag falling off bars as they exit the furnace, it is often the case that slag catches on fire. Simultaneously, excess mineral oil grease that is used on the roller tables becomes a fuel source for a fire. When the slag comes into contact with the excess grease, a fire begins.

To extinguish the fire, the National Fire Protection Agency (2008) describes the four main approaches. These are cooling the burning material, eliminating the oxygen, removing the fuel and breaking the chemical reaction. Typically, steel plants cool the burning material. This is usually done with water either from a system or from a steel worker manually extinguishing the fire.

**Benefits of Fire Resistant Greases in Hot Mills**

In steel plants, the common approach to putting out the fire is done with variations of cooling the burning material. With a fire resistant grease, the approach is removal of the fuel. This is because a typical mineral oil based lubricating grease is a fuel source. A fire resistant grease is not a fuel source because the base oil and additive chemistry are selected based on their ability to resist combustion. Ultimately, the combustible hydrocarbons are removed from the formulation. This results in materials with lower volatility, which minimizes the generation of combustible vapors that are able to ignite and propogate the flame after ignition. Furthermore, some base oils, such as esters require substantially more energy to ignite and sustain fires.

**Summary of Fire Resistance Grease Test Methods**

There are no international or national standards for determining the fire resistance of a grease. There are however methods that are used for hydraulic fluids. These methods were used as the initial baseline methods for test procedures in the development of fire resistant greases. As the laboratory testing provided good insight to fire resistance, further test methods were developed based on field trials and experience to provide better evaluations of fire resistance relative to steel plant processing. The chronology of the iterations are listed below.

Method 1 – Wick Test

A modified Wick Test was developed. This was based on the Federal Test method 791C-352.1 and the MSHA method ASTP 5004 version 2010-02-12 – The Effect of Evaporation on Flammability. The standard test method consists of checking the flammability of the liquid (by passing a sample-soaked pipe cleaner repeatedly through a flame and noting the number of passes required for ignition), and storing the sample in an oven for the time and temperature required by the speciation, and rechecking flammability.

The modified Wick Test was conducted under the same conditions with the same steps. However, the pipe cleaner (i.e., Wick) was coated with a lubricating grease instead of a liquid oil. This was then passed into, and removed from, a methane fired Bunsen burner, at regular intervals (approximately 30 cycles/sec) until the wick caught fire. Based on several samples and types of products, a minimum cut off of 20 cycles prior to ignition was set to determine fire resistance.

Method 2 – Direct Flame Torch Test

To better represent field conditions in a steel mill, a direct flame test was set up. A metal dish was used to represent a piece of slag steel. A 10g sample of grease was placed in the center of the dish, which was placed on a room temperature hot plate under a fume hood with the exhaust fan turned off.

The method was initially developed using a handheld torch placing a direct flame on high and aimed at the bottom, center of the grease sample. Mineral oil based greases ignited immediately and burned for more than 60 seconds. Samples based on mid range viscosity fire resistant base oils did not ignite.

The method was then standardized with the placement of the flame on the sample for 25 seconds. This was sufficient to ignite all grease samples. The time it took for the flame to self extinguish was then recorded and became another measure of fire resistance.

Method 3 – Hot Washer Test

Using samples that were previously tested under Methods 1 and 2 above, a third testing sequence was developed with customer feedback. This Hot Washer test method consisted of placing a 25g sample of grease on a piece of angle iron and adding a heated washer on the sample of grease. The steel washer was heated to very high temperatures with a propylene oxygen torch until it was red hot. This was meant to better represent conditions in a steel plant where pieces of slag fall onto excess lubricating grease at rolling tables in hot mills.

Method 4 – Ceramic Pellet Test

To standardize the testing, the hot washer was replaced with a Ceramic Pellet/Disk that was heated in a muffle furnace. The ceramic material has a thermal conductivity that is very similar to steel and obtaining these commercially is easier for various laboratories. The furnace was set at 1,500° (815°C) for a four hour period. The Ceramic Disk was then placed in a standard volume of grease held in a metal tray. Because this best mimics steel plant conditions where a piece of slag falls onto excess lubricating grease at hot mill rolling tables, this became the measure of Fire Resistance.

The unit of measure is time it takes for grease to self-extinguish with a pass/fail value. Fire resistant greases are those that self-extinguish in less than two minutes. Those greases taking longer than two minutes and those requiring equipment to extinguish, are determined not to be fire resistant.

**CONCLUSIONS**

Safety hazards are inherent within the steel industry. In particular, fire hazards present a sizeable risk for steel workers 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 greases can reduce some of those risks.

According to Schrama (2006), about 50% of all steel tonnage is processed at the hot strip mill. Within the hot strip mill, the furnace exceeds 2,300°F (1,260°C). As the furnace moves hot bars of steel to the rolling table, the process creates excess slag that falls on to the ground. Simultaneously, the bearings on the rolling table expel excess quantities of grease on to the floor.

Because the grease is typically a mineral oil grease, this becomes the fuel for a fire event. The authors propose that using a synthetic ester oil based grease would reduce the likelihood of the grease catching on fire. This technology is based on the same ester technology used in fire resistant hydraulic fluids. This is further supported in that the ester technology requires a higher energy level to cause and sustain combustion. Additionally, the physical characteristics of this type of grease has a tendency to char and reduce the oxygen needed for fire.

While there are no internationally or nationally recognized fire resistance test methods for lubricating greases, the authors have taken several steps to implement test methods similar to those used for fire resistant hydraulic fluids to demonstrate the fire resistance of lubricating greases. These test methods mimic real world conditions at the rolling tables in hot mills. Therefore, the authors believe that using lubricating greases based on fire resistant base oils, provides hot strip mills with greater protection from fire hazards.

Furthermore, acceptable fire resistant greases can be determined through the Ceramic Pellet Test. The authors are working to develop an industry-wide ASTM standard for all companies to follow. This will help steel plants determine the best solutions for reducing risks.

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