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LUBRICATION OF A SEAMLESS PIPE SIZING MILL[1]

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Abstract
This paper examines the application of hot rolling lubricant to a single stand vertical breakdown mill and a 3-stand sizing mill producing seamless Oil Country Tubular Goods. Prior to the program currently in place, there was no hot rolling lubrication program on either mill. The mill survey performed describes the status of operations prior to introduction of the rolling lubricant. From the mill survey conducted, specific areas for enhanced performance and operational targets were identified. The areas highlighted through the survey were all capable of being enhanced with roll lubrication. The next section of the paper outlines the application of the hot rolling lubricant. This description includes equipment engineering and lubricant application. It then discusses measurement of performance through quantitative results and the subsequent benefits the mill achieved. Finally, the paper identifies continuous improvement efforts aimed at enhancing lubricant effectiveness and production efficiencies.
Key words: Hot rolling lubrication; Application unit; Sizing mill.

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1 INTRODUCTION

This paper will describe the application of roll lubricant oil to a multiple stand sizing mill and vertical sizing mill used to produce seamless pipe. In this application the roll lubricant oil is applied to the contact point between the roll surface and the outside diameter (OD) of the pipe. A detailed description of why this program was introduced will be given. The description of why the program was integrated into the sizing mill is important to note because the use of a hot rolling lubricant was not part of the original design of the mill. In most steel hot rolling operations the use of a roll lubricant is not considered in the mill's original design. The next section of the paper will describe the lubricant itself. This description includes the chemistry of the oil and why this type of chemistry was selected. It will include features of the lubricant and how they translated into tangible benefits for the mill. Subsequent sections of the paper then describe the mechanical means of applying the lubricant to the roll surface, a summary of both the qualitative and quantitative benefits achieved with the program, and finally, a description of the upgrade of the application equipment utilized to apply the lubricant and why the upgrades were initiated is presented. In summary, the paper will be divided into the following sections.

- Why the lubricant was introduced.
- Design of the lubricant chemistry.
- Application equipment used for lubricant distribution.
- Performance benefits of the lubricant.
- Application equipment upgrade and expansion of use.

2 THE LUBRICANT WAS INTRODUCED

There has been a long history of roll lubrication providing a benefit to the hot rolling of flat steel strip and structural shapes. It was felt that there were significant similarities in the process for sizing pipe. It was decided to adapt and apply the survey process utilized for hot rolling flat strip and structural steel to the pipe sizing process. The first step was to determine if roll lubrication could possibly enhance mill production and or the OD quality of the pipe. This step took place by performing a complete site survey of the mills rolling processes. The site survey consisted of two parts:

- review of survey questions with mill management and operators to determine if roll lubrication can benefit the mills.
- review of the entry and exit roll cooling water sprays.

The first step of the site survey was the most critical. This step determined if there were productivity or quality needs a roll lubrication program can address. Typically any type of roll lubrication program whether it be for flat sheet, structural and or pipe addresses similar needs for those operations. The needs are typically reducing friction between the work piece and roll, increasing roll life and enhancing the surface quality of the work piece. The determination of the current status of the mill as it related to power available to the mill, current roll life, roll stock removal and outside diameter surface quality was determined through a site survey. Below is a portion of the site survey questions reviewed with mill management and operators.

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Table 1. Mill Survey – Step 1

Survey Questions	Current Status
What are the average tons or pieces rolled between roll changes for each size?	The mill averages ~300 pieces before a roll change on heavy wall, quench and product. These are hard grade steels. The grades are P110 and Q125. On normal product roll tonnages rolled between changes are much higher and can be rolled in their entirety
What is the delay time incurred for a roll change?	~ 30 - 60 minutes for a full roll change.
Is the mill limited by power when rolling certain products?	On hard grade quench and temper product the mill motor will pull high amperage. ~ 300 amps. This is close to the amperage limit of the mill motor of 315.
Are there any outside diameter surface defects that roll lubrication can address?	On both hard grade quench and temper product and on normal grades "chew" and turkey tracks are sometimes seen.

The answers to the survey questions above indicated the mill could benefit from the use of a hot rolling lubricant. The next step of the process was then to complete the section of the survey that documents the desired status of the mill's management and operators as it related to increases in pieces rolled per roll change and reductions in power usage on hard grade, quench and temper product and reductions in the overall occurrences for outside diameter defects.

Table 2. Survey - Step 2

Survey Questions	Current Status	Desired Status
What are the average tons or pieces rolled between roll changes for each size?	The mill averages ~300 pieces before a roll change on heavy wall, quench and temper product. These are hard grade steels. The grades are P110 and Q125. On normal product roll tonnages rolled between changes are much higher and can be rolled in their entirety	Increase number of pieces before a roll change on heavy wall, quench and temper product ≥50%.
Is the mill limited by power when rolling certain products?	On hard grade quench and temper product the mill motor will pull high amperage. ~ 300 amps. This is close to the amperage limit of the mill motor of 315.	Reduce mill motor amperage by ≥ 15% on hard grade, quench and temper product.
Are there any outside diameter surface defects that roll lubrication can address?	On both hard grade quench and temper product and on normal grades "chew" and turkey tracks are sometimes seen.	Reduce occurrences of "chew" or turkey tracks on both normal product and quench and temper.

Determining the desired status of the mill from the management and operators was needed so that optimum decisions were made on the best means to apply the lubricant and designing the chemistry of the lubricant. In summary there were three areas for improvement discovered:

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1. Increase roll life on hard grade, quench and temper product.
2. Reduce mill motor loads on hard grade, quench and temper product.
3. Decrease the outside diameter surface defect known as “chew” or turkey tracks.

The discovery of these needs made it clear that the introduction of the lubricant on the entry side of the rolls would allow the best opportunity to achieve the desired status.
The optimum physical application of lubricant was critical in order to meet the needs identified in the questionnaire portion of the survey. From the mill configuration portion of the survey process it was learned that each of the roll stands had both a top and bottom entry side spray for roll cooling. Even more critical than this finding was the fact all the top and bottom entry side roll cooling spray patterns were in contact with the entire roll surface. Based on these findings it was determined this would be the means the carry the lubricant to the roll surface. The sketch (Figure 1) below provides simplistic view of the spray application.

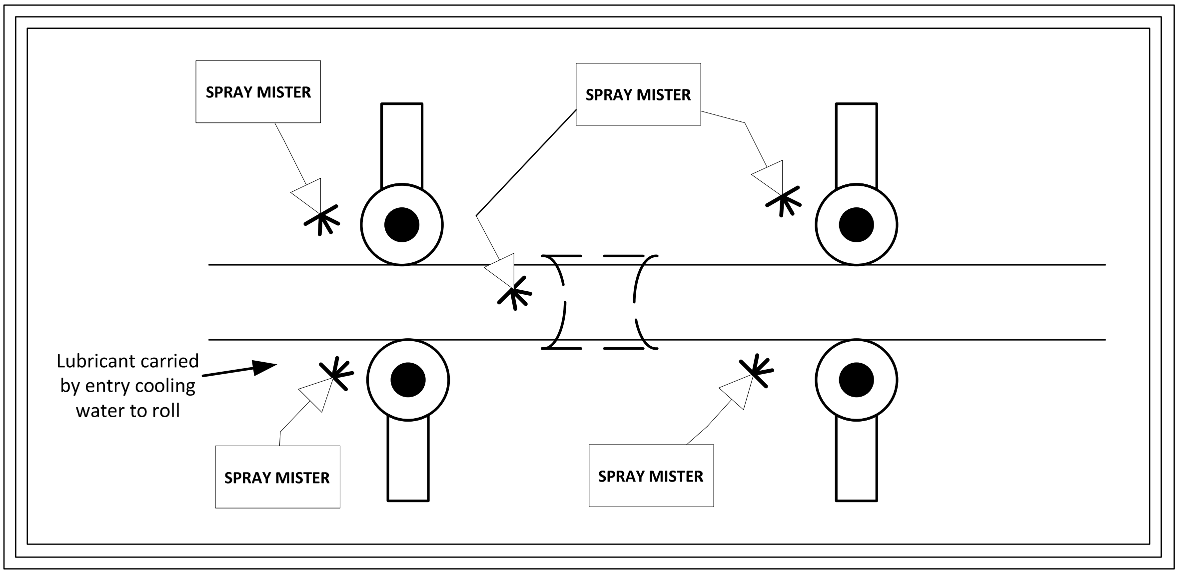

Figure 1. Schematic of spray application.

It should be noted the alternative of designing and installing supplemental entry side sprays exclusive of the existing entry side cooling sprays was considered but not implemented due to the efficiency of the current sprays.
After the means of lubricant application was determined the next step was to select a hot rolling oil lubricant chemistry.

3 DESIGN OF THE LUBRICANT CHEMISTRY

The design of the lubricant for this application was determined based on 2 criteria. The first being the desired mill performance identified in the survey process and the second being the typical roll cooling water characteristics.
In designing a hot rolling lubricant there are several physical components and characteristics of the formula that are taken under consideration. Below is listing of the some of the key components and characteristics of lubricant design. These components and characteristics serve as the foundation for the formulation of hot rolling lubricants.

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Table 3. Lubricant parameters

Hot Rolling Lubricant Property	Description
Viscosity	Controls thermal separation
SAP Value	A relative measurement of lubricity
Extreme Pressure Additives	Provide a chemical film that inhibits metal to metal contact
Particle Size	Dispersion of Oil particles in water phase
Break-out of Oil	Impacts on waste treatment of cooling water

The steel rolling process is a very dynamic process that has many variables which require a lubricant that impacts on multiple variables. In order to have an impact across these ~~various~~ variables the design must break down components that lubrication can affect and build a broad spectrum lubricant that addresses the multiple needs of the process. In analyzing the needs of the process the end result must provide consistent and predictable performance. The hot rolling process introduces the following dynamics that must be considered: High metal temperature, roll metallurgy and surface finish, high volume cooling water with changing chemistry, and a desire to run the mill at the highest speed possible without exceeding the design parameters of the mill.

To accomplish this the lubricant most provide a uniform film thickness applied to maintain good separation between the roll surface and the work piece surface which will minimize roll wear as well as reduce the coefficient of friction to allow the work piece to move through the process at the highest speed. As the lubricant is built the first step is to address the need of thermal separation which in simplest terms is accomplished by using a high viscosity material so that at the high temperature of the process there is still enough film thickness of the applied lubricant to separate to the two metal surfaces at the contact point. This is a constant challenge considering the metal temperature of the process is a temperature at which most organic (oil) components flash off. To impact lubricity the lubricant film most stay long enough at the contact point to prevent metal to metal contact and wear. Additives that impact lowering the coefficient of friction are then integrated into the product. These include a combination of animal and vegetable based fatty materials to provide base lubricity followed by phosphorus and sulfur bearing compounds that are extreme pressure additives that actually chemically bond to the metal surfaces and minimize the potential for metal to metal contact at the contact point. Surfactants are then added that aid in the way that the oil disperses into the water phase and also impacts the way that lubricant "wets" or lays down on the metal surfaces. The lubricant reduces the friction and the water cools the piece. Additives are also included to minimize the oxidation or breakdown of components at applied temperatures and buffering compounds to help maintain the consistency of the water chemistry and how it interacts with the lubricant. The selection of the surfactants also affects the way that the oil and water separate when the cooling water returns to the system for recycling. The residual oil should not readily emulsify in the water phase because it will result in two problems: waste treatment issues and diminishing the cooling efficiency of the water phase.

In order to address each of the 3 desired performance parameters a lubricant design matrix was developed. The design of each lubricant characteristic was assigned a priority of high, medium or low based on the performance parameter the mill wanted to achieve. The lubricant design matrix is show below.

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Table 4. Lubricant Impact Matrix

	Lubricant Characteristics			
Parameter	**Viscosity**	**SAP Value**	**Extreme Pressure Additives**	**Particle Size**
Roll Life	High	Medium	High	Medium
Motor Amperage Reductions	Medium	Medium	High	Medium
OD Surface Quality	High	Low	High	Medium

The second design criteria for the lubricant was to take into consideration the typical roll cooling water characteristics for the mill. The typical physical properties of roll cooling water are important in optimizing performance of hot rolling lubricants. Critical parameters include water hardness, total suspended solids, and total oils and greases. These parameters all can influence the lubricant's ability or inability to break-out or separate from the water that is used to distribute the lubricant to the roll surface. This break-out of the lubricant from the roll cooling is critical to maximize the lubricating properties of the oil. In general, for hot rolling lubricants, the faster the oil breaks out from the water phase the better the lubrication. Fast break-out rates are a break of 90% + of the oil from the water in 60 seconds or less. This was especially important for this mill considering we were addressing performance criteria of improving roll life.

A secondary benefit of hot rolling oil with a fast break-out rate is removal of residual oil from the recycle water cooling system. During the application of the lubricant to the rolls it is assumed some of the lubricant is a captured in the cooling water after application to the rolls. In an effort to minimize to build-up of this lubricant in the cooling water oil that breaks fast can easily be removed mechanically from the recycle water system by means of skimmers.

In taking into consideration the desired performance parameters identified in the survey and the characteristics of the roll cooling water at the mill the following lubricant was designed.

Table 5. Lubricant property values

Physical Properties	**Typical Values**
Viscosity @ 100º F SUS	545
Sulfur	1.50
Saponification Value	82
% Free Fatty Acid	5.5
%Oil Break-out @ 60 seconds in mill roll cooling water	≥ 90%

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4 APPLICATION EQUIPMENT USED FOR LUBRICANT DISTRIBUTION

As previously mentioned hot rolling lubrication systems are not typically part of original rolling mill designs. In this application of rolling oil to the mills this was also the case. Due to these circumstances this presented a situation in which managing the upfront expense of installing a lubrication system would need to be considered. Based on there being 6 application points (3 roll positions X 2 rolls per position) and all points being in close proximity to each other a modular lubricant distribution was designed. In addition to considering the proximity of the application points in the design of the unit, the consideration of upfront cost was addressed.
The modular unit was designed with the capability of supplying 10 application points in consideration of future expansion of the program, having the spare application points available in case of failures and based on minimal incremental costs increases for the additional application capabilities. After determine the number of application points to distribute lubricant the following steps were completed to finalize the unit design.

4.1 Pump Selection

A type of pump needed to be selected to serve two functions. The first function needed was to have the capability of recirculating the oil in a closed loop continuously for entire rolling campaigns. The second function was to have the capability to move the 400 SUS oil. The pump type selected was gear pump due to its ability to being able to be run continuously, its ability to move the viscous lubricant and its low cost.

4.2 Control of Oil being Applied or not Applied

The design of the modular application unit had to take into consideration the non-continuous rolling of the pieces of pipe. In other words, the lubricant only would need to be applied to the roll surfaces when a piece of pipe was in the contact with the rolls. Based on this criteria it was determined normally closed solenoids would be used as a simple and effective means to control whether lubricant was sent to the mill stands or not. The signal at the mill selected to energize or open the solenoids was a hot metal detector (HMD) located prior to stand #1. The approximate distance of the HMD to the stand #1 rolls was about 6'. Specifically, when the heat from the front end of shell was picked up by the HMD the solenoids for stands #1, #2 and # would be energized and lubricant would be distributed in the existing entry side top and bottom roll cooling sprays. Consequently when the heat from the tail end of the shell was lost the HMD would signal the solenoid to de-energize.

4.3 Control of Lubricant Flow to Each Roll Position

A significant consideration in design of the modular rolling oil application unit was engineering the capability of precisely controlling the lubricant flow to each of the stands. The control for this capability was completed in a two-fold manner. The first design consideration was installing fixed orifices at the point in which the lubricant injected into the entry side cooling water for each roll. The second designed consideration was to incorporate needle valves just after each of the solenoids on the

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modular designed unit. This simple yet effective design allowed pressure to determine the lubricant flow to each of the roll positions.
In summary, the design of the modular unit approach allowed shortened the period of time from when the decision was made to evaluate lubrication on the multiple stand sizing mill to actual implementation. The period of time from when the decision was made to evaluate the program until the evaluation was initiated was a 17 day period. In addition to the design shortening the implementation period it also took into consideration the concern of the expense of designing and fabricating a system to evaluate a program that was not in existence at the mill. Below is a picture of the original unit used for the initial evaluations of the roll oil.

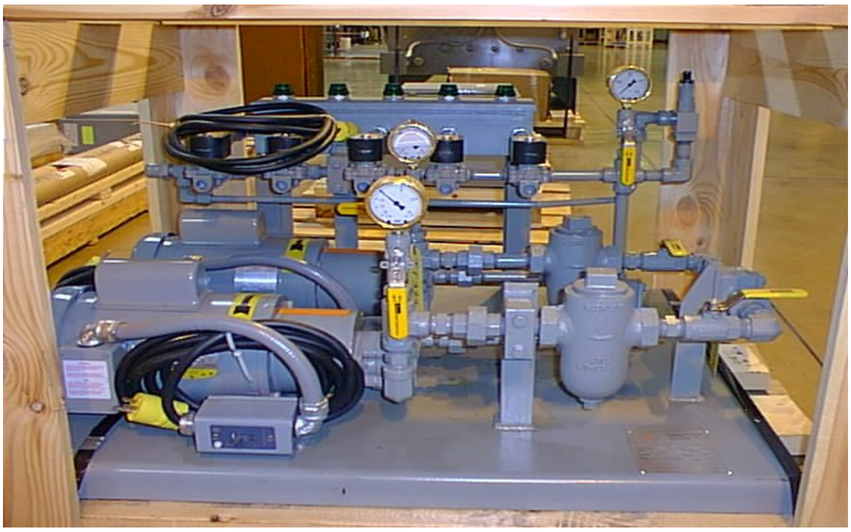

Figure 2. Photograph of trial evaluation equipment.

5 PERFORMANCE BENEFITS OF ROLL LUBRICATION

The performance benefits of the application of the lubricant were measured over a 30 day period. During this period of time selected campaigns were rolled with the use of the lubricant. This selective process was used to enable the data to be evaluated closely as to allow modifications to be made that positively affected the performance of the lubricant. The data and observations made were all directly related to determining whether the 3 goals of the lubrication program were met. In addition to data directly related to the pre-established goals, the measurement of total oil and greases was made to determine if the introduction of the oil would have any impact on the quality of the cooling water. This data collected and observations noted are listed below:

a. Average pieces rolled of hard grade, quench and temper with roll lubrication
b. Average motor amperage on hard grade, quench and temper pipe with roll lubrication
c. Occurrences of chew or turkey tracks with roll lubrication
d. Level of total oils and greases in roll cooling water with roll lubrication

Upon conclusion of the initial 30 days of evaluations the data indicated the following results.

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Table 6. Roll life comparisons

	Roll Life Performance		
Parameter	Hard grade, Q & T without oil	Hard grade, Q & T with oil	% Increase
Roll Life	~300 pieces	~600 to 1000 pieces	100% to 233%

Table 7. Motor amperage comparisons

	Motor Amperage Performance		
Parameter	Average amps for hard grade, Q & T without oil	Average amps for hard grade, Q & T with oil	% Decrease
Motor Amperage	~300 amps	220 - 240 amps	20 - 26%

Table 8. Surface Quality Comparisons

	OD Surface Quality		
Parameter	Occurrences of chew or turkey tracks without oil	Occurrences of chew or turkey tracks with oil	% Decrease
OD Surface	Frequent	Eliminated	100%

Finally testing of oil and greases in the cooling water influent to the mill indicated no change from the levels seen prior to the introduction of the roll lubrication program. This oil and grease analysis of the water and performance data indicated the means of oil application was both efficient and effective.
In summary the performance of the roll lubrication application demonstrated improved roll life, decreased sizing mill motor amperage and improved outside diameter surface quality without detrimental effects to the roll cooling water system. Because there was improved life, reduced motor amperage and improved outside diameter surface quality, the achieved the benefits of being able to reduce roll change delay time, power consumption and quality.

6 APPLICATION EQUIPMENT UPGRADE AND EXPANSION OF USE

Once the benefits were achieved at the sizing mill an upgrade of the application equipment was initiated. The first upgrade was the design and installation of a 600 gallon day tank to store the lubricant. During the evaluation period 330 gallon intermediate bulk containers were used to supply oil to the application unit. The day tank functions as a permanent reservoir tank positioned in close proximity to the mill. The 600 gallon capacity steel tank provided a safer means of oil storage because the intermediate bulk containers were plastic totes in a metal cage. The day tank was also designed with electric heaters to maintain optimum lubricant temperature and was furnished with a sight glass to allow both mill operators and maintenance personnel to determine volumes. In addition to the sight glass the tank had the

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capability to be fitted with floats that would trigger mecroid switches for automatic re-fill. The next upgrade was the gear pumps used to supply lubricant to the mill sprays. Larger capacity gear pumps were installed to increase the pump discharge pressure. This increase in pressure expanded the capabilities of varying lubricant flow to the roll sets. In addition to the larger capacity pumps, a second pump was installed on the modular designed application unit to function as a back-up in case of a failure of the pump in use. The final portion of the equipment upgrade was the installation of one-way check valves to prevent back flow of roll cooling water to the application unit and day tank. Since the lubricant is only applied to the rolls when the pipe enters the sizing mill back flow of roll cooling water through the orifice of the lubricant atomizer takes place. With the installation of the one-way check valves immediately after the two way solenoid valves this condition was minimized. The engineering upgrades of the application equipment were all focused on repeating the performance achieved during the evaluation period.

The next step in the evolution of the program was the expansion of the lubricant to the breakdown sizing mill. Since the mill functions as a means of reducing the outside diameter of the pipe it was prone to premature roll wear and high mill motor amperage on hard grade pipe. The expansion of the lubricant application to this mill was a rather simple process for the three reasons. The first reason was the means of carrying the lubricant with the existing roll cooling water was already proven on the multiple stand sizing mill. The second was the design of the lubricant had proven itself to be effective and thirdly the modular designed application unit had spare solenoid valves that were utilized to inject lubricant into the roll cooling water for the mill.

The benefits achieved with applying lubricant on the mill were similar to the multiple stand sizing mill. First, increase roll life and secondly reduced motor amperage. The third benefit achieved at the multiple stand sizing mill of improved OD surface quality was not as critical on this mill because it was positioned before the multiple stand sizing mill.

7 SUMMARY

In summary, the use of a roll lubricant in the hot or warm rolling of seamless pipe can best be described as a potential method of enhancing productivity and quality. This opportunity is dependent on the current status of the mills performance related to roll life, mill motor capabilities and outside diameter surface quality.

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