BENEFITS ACHIEVED FROM THE INTEGRATION OF A SUPPLMENTAL DIRECT APPLICATION OIL SYSTEM FOR COMBINATION SHEET & TIN TANDEM MILL DESIGNED WITH A RECIRCULATING SOLUTION SYSTEM

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ABSTRACT

The objective of this paper is provide information on the benefits achieved by integrating a supplemental direct application oil system for a tandem cold mill producing sheet and tin products with an original design of only a recirculating emulsion system for the mill. The paper will provide the specific business drivers for the integration of the system. Specifically the drivers included increasing mill rolling speeds to increase productivity. It will describe the current status of production as measured by speeds and roll force without the use of supplemental direction application oil and then show the results achieved with the use of the supplemental direction application oil system. Next, the paper will then describe the engineering and installation of the equipment along with the oil chemistry. Finally, the paper will identify continuous improvement actions with the system aimed at maximizing lubricant effectiveness and production efficiences.

Keywords: Supplemental, Direct Application,

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INTRODUCTION

This paper will describe the utilization of a direct application cold rolling oil by means of a supplemental application system to a 5-stand combination sheet and tin tandem mill. It is important to note the phrase "supplemental application system" indicates the system is used concurrently with a pre-existing recirulcating rolling oil emulsion system. This paper will provide the motivation for evaluating the concept of using a supplementel application system along with a description of the design and control of the system. A description of how the application system was integrated into the mill is critical as this was not part of the original mill design. This paper will also describe the procedure for the installation of the supplemental application system, a general description of the direct application oil and a comparision versus the original recirculating oil including features of the new lubricant that translate into tangible benefits for the mill. A summary of the qualitative and quantitative benefits achieved with the program and a concise description of the transition from the temporary application system to a permanent system to apply the lubricant and manage the application system is provided. This paper includes the following:

- Development of the Direct Application Oil System
- Procedure for System Integration
- Design of the Direct Application Lubricant Chemistry
- Optimization of the Application System and Lubricant
- Conclusion

DEVELOPMENT OF THE DIRECT APPLICATION OIL SYSTEM

The steel industry has been global in nature for decades. Competing in a global marketplace means steel producers must maximize quality and through-put from the purchasing and use of raw materials to the shipment of end products to customers. Simply put, the maximization of quality and through-put allows for a better opportunity to compete in the global marketplace. The idea of introducing a direct application rolling oil system and oil to the 5-stand cold mill that was originally designed with a recirculating oil system was driven by the need to maximize through-put. The novel idea was embraced because direct application of oil by itself was not foreign to multi-stand cold rolling mills. As with most direct application oil systems they provide a means to increase lubrication from coil to coil. It was the flexibility to be able to change oil concentrations coil to coil that made the concept valuable to this specific tandem mill.

The use of cold rolling oil emulsions for maximizing mill production in terms of rolling speeds and metal surface quality has been in practice since the inception of these mills. Many of the original cold rolling oil lubrication systems were designed with direct oil application systems. The systems were simple in design and provided consistent lubrication since the oil was used one-time only. Specifically, once the emulsion was applied to the metal surface it was typically captured for treatment and not reused on the rolling mill. As tandem cold reduction mills have been redesigned over the past 60 years, recirculating rolling oil emulsion systems have become more popular since rolling oils can be captured, filtered and reused resulting in reduced oil consumption and lower oil treatment costs.

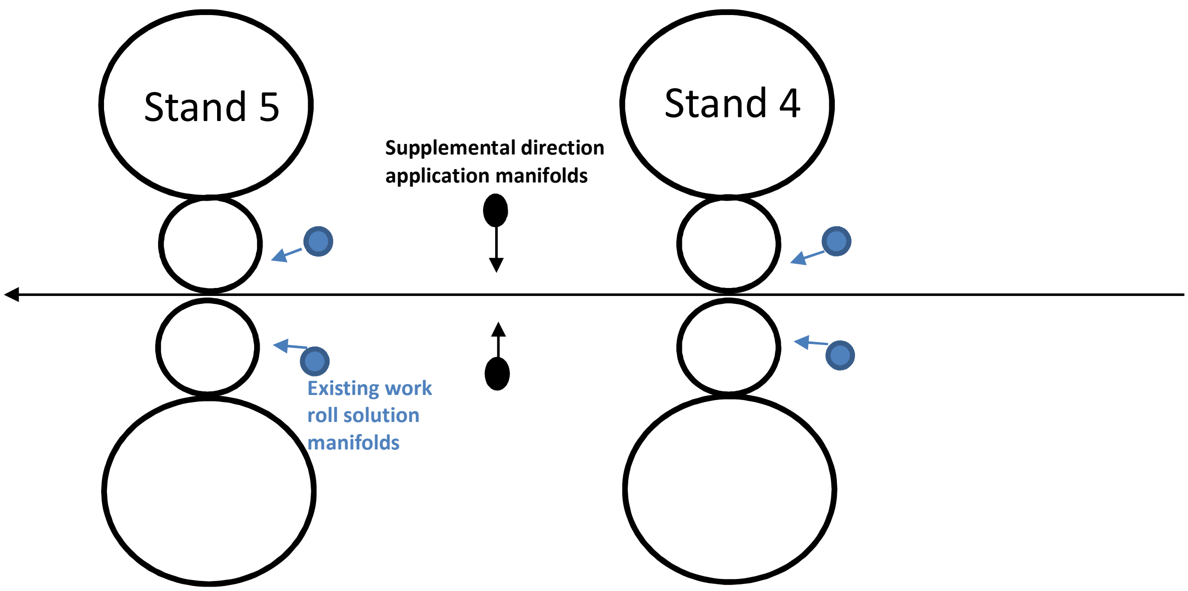
Most designs of direct application oil systems allowed for concentrations of the rolling solution to be changed quickly. Concentrations could be changed from coil to coil because the emulsion is made in a "batch system" or "in-line" system. Batch make-up systems were simple in design. For example, various size pots ranging in volume from 200 liters to 1000 liters were used to supply each specific stand(s) of a mill with a pre-set concentration of the rolling emulsion. In contrast to recirculating emulsion systems that typically have system volumes ranging from 80,000 liters to 400,000 liters, direct application batch systems are more flexible with regard to changing emulsion concentrations based on important parameters such as strip width, gauge and grade.

Based on the design of the batch or in-line systems and the flexibility they provide to vary oil concentration from coil to coil the idea of being able to increase lubrication for light gauge sheet and tinplate was embraced. The increased lubricity would allow the roll forces to be reduced and therefore rolling speeds to be increased without sacrificing metal quality. With the concept being accepted by the mill the next step was to design a simplistic application system. The next section of this paper will describe the procedure used for implementation of the application system.

PROCEDURE FOR SYSTEM INTEGRATION

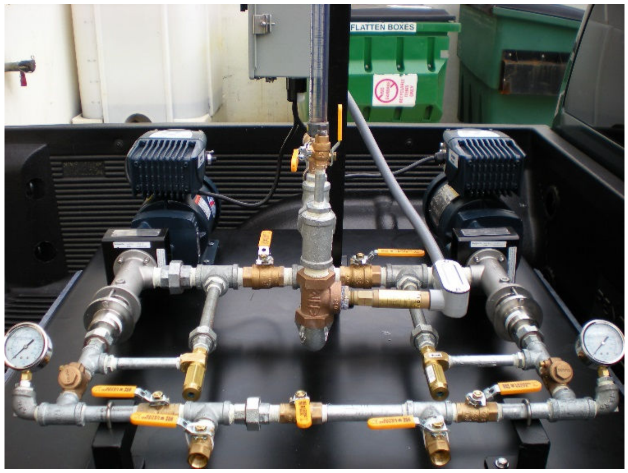
The basis of the installation procedure used centered on the need to provide a simplistic means to prove the concept that integrating a supplemental direct application oil system could reduce rolling forces to allow for faster speeds. Figure 1 indicates where the direct application manifolds were positioned.

Figure 1



The existing rolling solution was center fed to each of the 4 direct application manifolds (2 manifolds per stand). This design was implemented in order to reduce the expense associated with piping runs needed to supply the normal rolling solution make-up water. Each manifold was 2.54 centimeters (cm) in diameter. The rolling solution pressure to each direct application manifold was equivelant to the pressure supplied to the existing work manifolds at ~5.5 bar. The flow for each direct application header was set at 30 liters per minute (lpm). This was accomplished by using 7 flat spray nozzles for each manifold each rated at a flow of 4.2 lpm at 5.5 bar. Each direct application manifold was center fitted with a hot tap in order to provide an entry way for injection of the neat direct application oil allowing the concentration of the rolling solution in each specific header to be increased above the concentration of the existing recirculating emulsion. The mechanism used to meter in the neat direct application oil is shown in Figure 2.

Figure 2



This unit is a skid mounted assembly. Each of the two pumps are progressive cavity pumps and each motor is variable speed allowing the neat oil flow rate to be precisely controlled. Beyond the precise flow control provided by the pumps and variable speed motors a calibration column was installed on the discharge side of the pump to allow validation of the oil flow rate. From the discharge side of each pump a 1.27 cm diameter high-pressure hydraulic hose was fed to the hot taps located on each direct application manifold. The direct application oil was supplied from a 1250 liter tote container and positioned within 2 meters of the skid mounted pump and motor assembly. This basic direct application oil delivery system was designed to limit the investment cost needed to demonstrate the benefits of a supplemental lubrication system.

The next step taken to validate proof of concept was to target a segment of the mill's production mix where increased rolling speeds were desired. In this mill's specific case 0.18 millimeter (mm) finish gauge tinplate was produced. This portion of the product mix had speed limitations due to occurences of frictional pick-up in the latter stands of the mill. It was deduced this problem was due to the need for more oil in the roll bite of the latter stands. Typical 5th stand speeds for this product ranged from 1,220 meters per minute (mpm) to 1,274 mpm with a targeted oil concentration of 6% for the recirculating solution. It should be noted this mill had a single solution system with a volume of approximately 180,000 liters. The initial control signals to activate the pump motors were manual. An on/off toggle switch was installed in the mill control pulpit. When the signal was in the off position and the mill was using the recirculating solution the manifolds were applying the same concentration solution through both the work roll manifolds and the direct application manifolds. When the mill control pulpit operator placed the switch to the on position the neat direct application oil was injected into the header and allowed the oil concentration in the direct application header to be increased based on the motor speed. In summary, this allowed more oil to be applied on the surface of the strip that could be carried into the top and bottom roll bite thereby increasing lubricity and allowing for increased rolling speeds.

The final step in the procedure to validate the supplemental direct application system and oil was to set an initial concentration (15%) that would be supplied through each of the direct application headers and confirm an increase in lubricity. Roll forces per stand on the 0.18 mm gauge material were measured and recorded with and without the supplemental direct application oil. In addition, measurements of the roll forces, where the strip had the same width, steel grade and interstand tensions, were recorded during the trial.

DESIGN OF THE DIRECT APPLICATION LUBRICANT CHEMISTRY

Direct application oils are typically designed to quickly plate-out on the strip surface with a controlled oil particle size. This translates into the oil having the ability to separate from the water phase of the emulsion while maintaining uniformity. This general behavior is acceptable since the distance between where the rolling oil is combined with water, (or in this case the recirculating emulsion), to the application is short. Specifically in this application the distance from the injection point to the strip surface was less than 1 meter. The target "break-out rate" was 90% after 60 seconds where the break-out rate is defined as the speed at which the oil clearly separates from the water phase. For this specific mill break-out test, a 250 milliliter graduated cylinder was used to collect a sample from the direct application header and then allowed to sit for 60 seconds before measuring the percent of oil that separated from the water. For example, the target percentage of oil was 15% through the manifold. Based on this target we needed to visually observe 33.75 milliliters of free oil separated from the water phase within the 250 ml graduated cylinder.

Beyond the oil break-out rate there were other critical considerations in the design of the direct application oil including the requirement for compatibility with the recirculating emulsion. Specifically, since all the mill stands shared a single emulsion system the direct application oil would become part of the recirculating emulsion system after application to the strip surface. Based on this consideration the overall premise was to mimic the key physical parameters and components of the recirculating oil. These are listed below and are common for cold rolling oils.

- Saponification value
- Viscosity
- Sulfur Content
- Extreme Pressure Additives
- Anti-Wear Additives
- Anti-Oxidant

For the proof of concept stage the only difference between the direct application oil and the recirculating oil was the emulsifier system. In general terms the amount of emulsifier in the direct application oil was less vs. the amount in the recirculating oil. The basis for this decision was to allow a fast plate-out of the application oil on the strip surface and large controlled oil droplets. Specifically, the goal was to have a mean particle size of 45 microns. This was the same mean particle size of the recirculating system emulsion. With the direct application system installed and a specific oil developed for the design of the application and the recirculating coolant system the next step was the evaluation, data collection and interpretation of results.

PERFORMANCE BENEFITS OF THE APPLICATION AND LUBRICANT

Multiple trials of the supplemental direct application system and oil were conducted and data was captured over a period of 45 days. During this period of time select production schedules were targeted. Specifically, the goal was to select schedules that contained >10 coil blocks of the 0.18 mm gauge of the same strip width and steel grade. This selective process was used to provide a sufficient number of data points with and without the use of the direct application oil. As previously discussed, the key measurement criteria was roll force for the mill stand utilizing the supplemental lubrication system. A summary of data is provided in Table 1,

Table 1

Trial	Total Coils	Coils Without Direction Application Oil	Coils With With Direction Application Oil	Average Stand 5 Speed (mpm)	Average Stand 5 Roll Force (Tons) Without Direct Application Oil	Average Stand 5 Roll Force (Tons) With 15% Direct Application Oil	% Delta Roll Force (Tons)
1	24	12	12	1268	918	789	14.05%
2	21	10	11	1296	921	785	14.76%
3	28	14	14	1305	925	780	15.67%
4	32	16	16	1280	909	774	14.85%
5	20	10	10	1298	911	770	15.47%
Totals	**125**	**62**	**63**	**1289(avg)**	**916**	**779**	**14.95%**

Data from the trials indicated the use of the supplemental direct application system and oil results in reduced roll forces. We concluded that the increased volume of oil on the strip surface was responsible for this reduction. Qualitative performance evaluations were conducted via inspection of the top and bottom surface of the strip rolls for instances of frictional pick-up. The surface inspection of the coils selected showed no frictional pick-up. With the combination of reduced rolling forces in stand 5 and no instances of frictional pick-up demonstrated the next step of the evaluation was to determine if a reduction in rolling force created the opportunity for increased rolling speed without creating frictional pick-up. A summary of data is provided in Table 2.

Table 2

Trial	Total Coils Using Direction Application	Direct Application Oil %	Average Stand 5 Speed (mpm)	Average Stand 5 Roll Force (Tons) With 15% Direct Application Oil
1	31	14.9	1425	898
2	28	15.5	1439	887
3	32	15.2	1460	890
Totals	**91**	**~15**	**1441**	**892**

Based on the trials conducted with the use of the direct application system and oil the mill speeds were able to be increased by ~ 12%. The roll force reduction achieved was able to allow the mill speeds to be increased while not creating occurrences of friction scratches on the strip surface.

OPTIMIZATION OF APPLICATION SYSTEM AND LUBRICANT

As previously indicated the installation of the application system to demonstrate the benefits of supplemental lubrication was based on simplicity. With the benefits now proven the focus was to transition to a more automated application of the oil. The first adaptation of the application system was to initiate the direct application oil (start and stop the motors for the pumps) supplied through the application spray manifolds based on mill rolling speeds. Specifically, when light, hard gauge tin and sheet products were being rolled the injection of the oil into the manifolds started once the stand 5 speeds reached greater than or equal to 300 mpm. This was after threading the mill. Subsequently, when the mill was decelerating at tail out and the speed decreased to less than 300 mpm the injection of the oil was stopped. Beyond this control, the other adaptation was the installation of a 1500 liter neat oil tank with a heater and fluid level indication system.

Additionally it was observed during the trials that the direct application oil needed to have a lower pour point vs. the recirculating system oil in use. As described, the neat direct application oil was injected at the spray manifolds. Since the direct application system is a selective application that is only utilized during production of specific mill products the oil can stagnate in the supply lines for an undetermined period of time. The period of time ranged from a few hours up to 24 to 48 hours. This dormant time between use created a condition, depending on ambient temperatures, where the oil could reach a temperature below its pour point. When this occurred, time to clear the supply lines of the semi-solid oil was required, i.e. no direct application oil would flow through the manifolds. Based on the need for the system to be consistent each time it was used, regardless of the time period in between use, a lower pour point oil was developed. For this specific mill oil with a pour point of 0 degrees Celsius was developed.

CONCLUSION

In summary, the use of a supplmental direct application oil system for cold rolling is a mechanism for enhancing mill productivity with minimal capital investment. The main consideration for using this type of system is dependent on the current status of the mill's performance as it relates to desired rolling speeds and productivity. In this specific application mill speeds could be increased by ~12% resulting in increased productivty.