ISSN 1983-4764

INSTALLATION OF SIEFLEX® OIL LUBRICATED TUBE SPINDLES AT NORTHSTAR-BLUESCOPE STEEL[1]

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Abstract

North Star BlueScope Steel is a 50-50 joint venture between BlueScope Steel and Cargill Inc. The plant was constructed in 1997 as a medium-slab caster mini-mill designed to supply hot band coils to both Steel Service Centers and end users. Since the plant's commissioning, North Star BlueScope has continued to upgrade its processes and equipment toward greater productivity via increased reliability. Most recently the plant has completed the replacement of the original grease lubricated spindles with modern oil-lubricated tube-type spindles to eliminate a recurring source of maintenance costs and associated downtime. This paper will open with an overview of the NorthStar BlueScope facility including some history of other reliability related upgrades that have been implemented over the years. It will then discuss the reasons for replacing the grease lubricated spindles, the rationale for selecting oil-lubricated tube type spindles, and the process of making the conversion. It will conclude with a cost-benefit analysis and overall savings realized at the hot mill.

Key words: Spindle; Lubrication; Oil.

[1] *Technical contribution to the 48th Rolling Seminar – Processes, Rolled and Coated Products, October, 24th-27th, 2011, Santos, SP, Brazil.*
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1 INTRODUCTION

Since the start-up of NorthStar-BlueScope Steel, spindle related failures had hampered operations and profitability. In 2003 an internal study to correct these problems resulted in a decision to replace all grease-lubricated spindles with the latest generation of oil-lubricated spindles. This paper will provide details of the spindle related problems and the decision making process to change spindle concept from grease to oil lubrication. We will also provide some design engineering perspective, and the results of the changes to date.

2 MATERIALS AND METHODS

2.1 Background of Northstar-Bluescope Steel

Built in 1997, North Star-BlueScope Steel (NSBS) is a 50-50 joint venture between BlueScope Steel (formerly BHP Steel) and the North Star Steel division of Cargill Inc.. The facility is strategically located to deliver hot rolled bands to Coil Processors, Cold Roll Strip Producers, Original Equipment Manufactures, Steel Pipe & Tube Industry and Steel Service Centers. The technology used at North Star BlueScope Steel allows for a rapid conversion of scrap steel into hot rolled coils. This is a two-part process. The Melt Shop and Caster converts scrap steel into slabs. The Rolling Mill converts the slabs produced into hot rolled steel coils. The coils are computer quality checked and then shipped by rail or truck to customers throughout the mid-west. The general product mix is detailed in Table 1.

Table 1. Material Produced at NSBS

Grade	Thickness Inches (Min)	Thickness mm (Min)	Width Inches	Width mm	Notes
1006 -1008	.050 -.500	1.27 – 12.70	41.5 – 60.0	1055 – 1550	With or without Boron
1018; 1020; 1021	.058 - .500	1.47 – 12.70	45.25 – 60.0	1150 – 1550	
High Strength 35.000 – 60.000 Min. Yield	.0524 - .500	1.33 - 12.70	41.5 – 60.0	1150 – 1550	
High Strength 70.000 – 80.000 Min. Yield	.078 - .248	1.98 – 6.30	41.5 – 60.0	1150 – 1550	
Coil Weight: 600 – 1000 P.I.W					

2.2 NSBS Plant General Description

The EAF is a twin shell, twin shaft AC design. Scrap is feed into the furnace via. a pre-heated shaft. The furnace produces 190 short tons of liquid steel every 40 minutes and is engineered to allow continuous feeding of scrap and/or pig iron, optimizing the energy and cost. The ladle refining furnaces are designed with 18" electrodes, powder and wire injection, alloy conveying, argon stirring and calcium stirring. The ladle refiners are designed to control chemistry, cleanliness and temperature resulting in the optimum slab quality and throughput. The slab caster produces a medium thick slab, 4" (100mm) thick x 41.5" to 60" wide (1055mm to 1524mm). The slab caster is fitted with a conventional rectangular shaped mold, electromagnetic braking, and hydraulic mold oscillating to optimize slab surface and internal quality. Upon exiting the caster the slab enters a 486-foot (148 m) tunnel furnace where temperatures are approximately 2192° F (1200°C).

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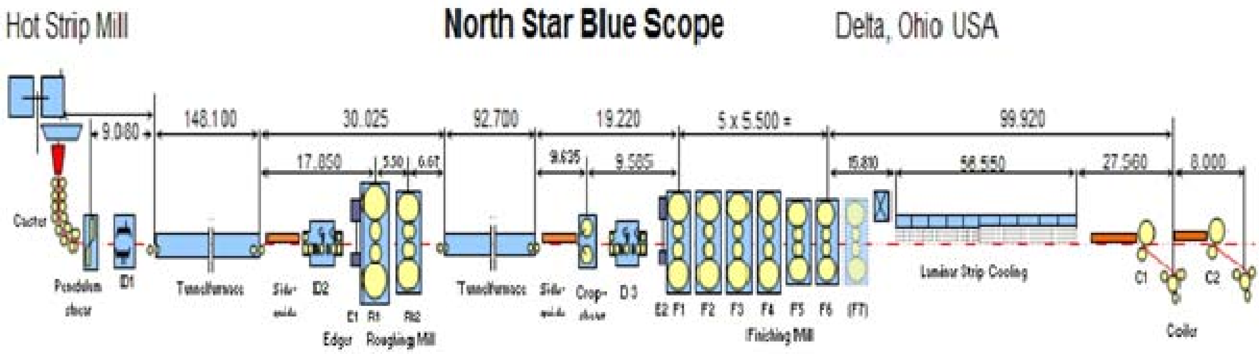

Figure 2. Plant Layout at NSBS.

Originally built by another OEM, the rolling mill is engineered with two roughing stands and six finishing stands (Figure 2). The eight stand configuration offers a wide range of controlled reduction strategies to improve surface, shape and ductility. The rolling mill has two vertical edgers and three descalers to provide improvements in yield and a cleaner surface. The finishing mill stands were equipped with roll shifting and bending which provides superior crown and shape control. Inter-stand loopers were added in 2003. All eight stands are powered with various sized electric motors, reducers and pinion stands. The OEM provided spindles had carburized and hardened or nitrided geared elements with a standard hub gear root-centering crown.

The laminar flow run out table is designed to control coiling temperatures to assure uniform metallurgical proprieties. Coiling temperatures are key to producing ductile material and consistent mechanical proprieties. The two down-coilers are equipped with hydraulic side guards for improved coil presentation.

2.3 SPINDLE TECHNOLOGY

Rolling mill technology has evolved dramatically over the past decades, however the fundamental principal of the rolling mill process has remained relatively the same. For example, a power source, such as an electric motor, turns a shaft or shafts, either directly or through a series of gearboxes and/or pinion stands, which turn shafts typically called spindles, which turn a set of rolls rotating in opposite directions. The material is forced through these turning rolls thereby forming the desired shape and/or size.

Mill spindle technology has not really evolved as dramatically in comparison to the rolling mills capabilities and speeds. Early spindles were typically “wobbler” type male shafts that rotated female “wobbler” boxes. Later “dog-bone” type slippers were used (Figure 3). These slippers had high torque and angularity capabilities, but had limited speed capabilities. Older generation wobblers and slippers required rather high maintenance, and because of their original design and manufacturing practices could fail unpredictably, usually causing auxiliary damage.

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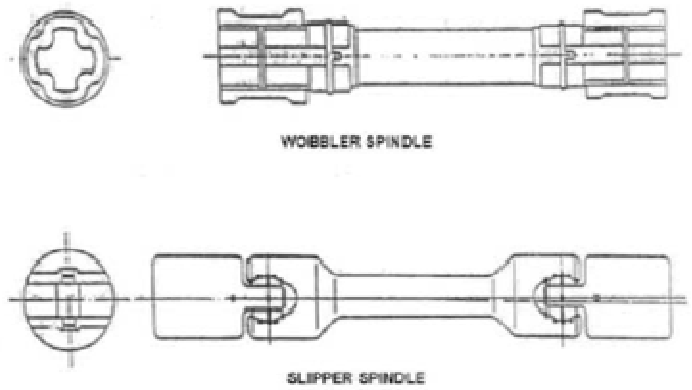

Figure 3. Older Style Mill Spindles

In the 1950's as rolling mill speed and torque requirements increased, geared spindles with a grease lubricant became commonly used. Geared spindles offered higher torque carrying capability and predictability, and reduced maintenance and lubrication costs. Original geared spindles had heat-treated gear teeth, but as rolling torques increased, carburized gear teeth became popular. In higher speed cold mills nitrided gear teeth deceased heat related tooth damage.

New generation rolling mills requirements continue to increase with higher speeds, higher loads, and the rolling of higher strength materials. The increased rolling requirements dramatically increase the heat generated within the rolling mills geared spindles. The high rolling torque in combination with the centrifugal separating of grease at higher speeds means the cooling of the geared elements within the spindle have become a larger problem. The grease used within geared spindles is costly and has a limited lifetime. Once the lubrication carrying elements within the grease breaks down, heat damages the geared teeth. The only truly effective way to prevent heat related damage generated during the rolling process is to safely remove the heat.

2.4 SIEFLEX® CONTINUOUS OIL LUBRICATED SPINDLES

First introduced by SMS Demag AG in the early 1980's, the SIEFLEX ® continuous oil lubricated spindles offer users a reliable way to continuously remove damaging heat from spindles while in operation. Because the oil flows on a regular basis, the need to maintain grease levels and clean-up environmentally unfriendly grease, are eliminated. The oil lubrication concept significantly extends the life of spindle operations and reduces mill downtime.

Since their introduction SIEFLEX® continuous oil lubricated spindles have evolved through several similar design concepts. Early designs incorporated "oil catch boxes" (see Figure 4) mounted on the roll side of the spindle. Many of these designs are still being used today but are being replaced over time with the tube concept.

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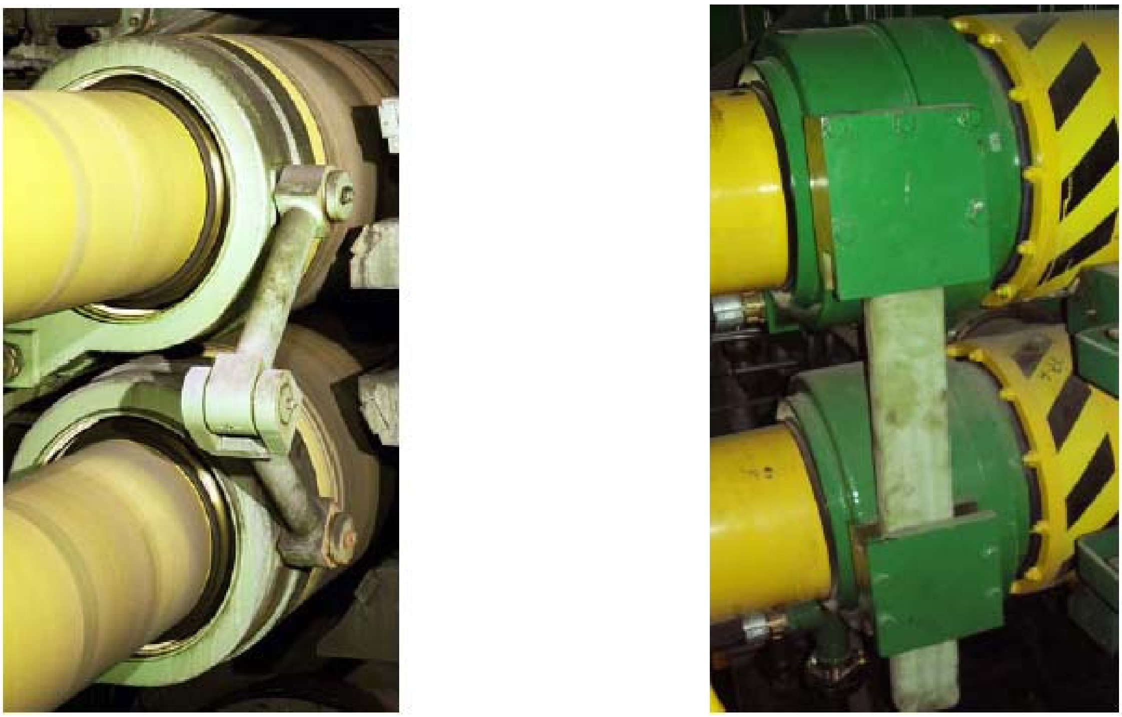

Figure 4. Designs of Roll Side SIEFLEX® Oil Lubrication Systems.

The SIEFLEX® tube concept (patented by SMS Demag AG) is a spindle with completely internal oil flow (Figure 5 and 6) thereby reducing maintenance to the lowest possible level. Clean, temperature regulated oil from the rolling mills lubrication system is introduced into the spindle from the driven end and transferred to the roll side through a central lubrication duct. The oil is circulated through the roll side geared elements and is transferred by means of an externally mounted tube back from roll side to an oil collecting hood mounted at the driven side. The heated oil is than transferred back to the rolling mills oil circulating system for cooling and cleaning (Figure 7). Continuous lubrication has several advantages; at 3.96 gallons (15 liters) per minute it continually cools the geared elements and removes potential contaminants that could damage the spindle. The circulating oil has always-equal quality and temperature thereby eliminating heat generation that could destroy the geared elements.

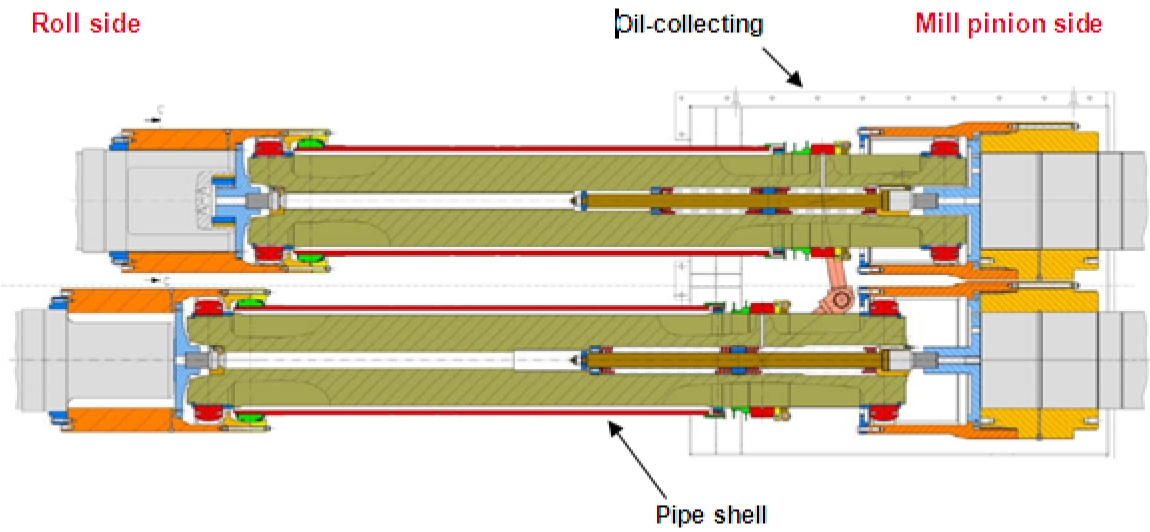

Figure 5. SIEFLEX® Oil Lubricated Tube Spindle for Hot Strip Mill.

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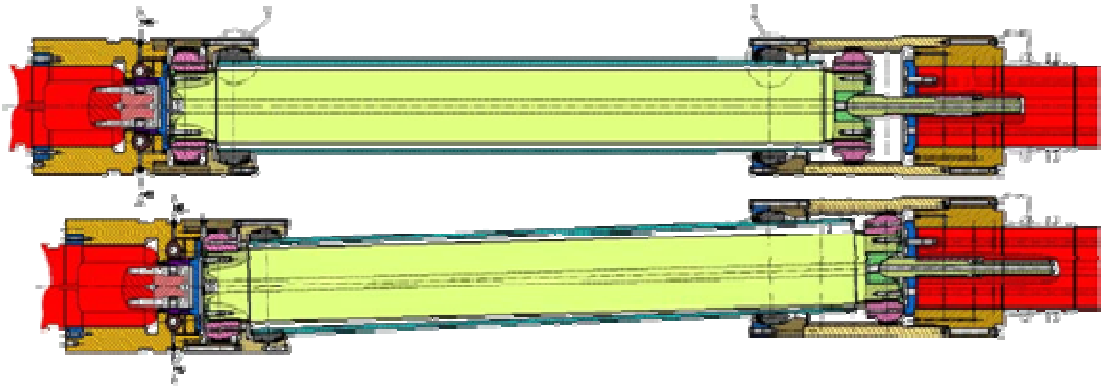

Figure 6. SIEFLEX® Cold Mill tube spindle with oil lubrication through pinion shafts

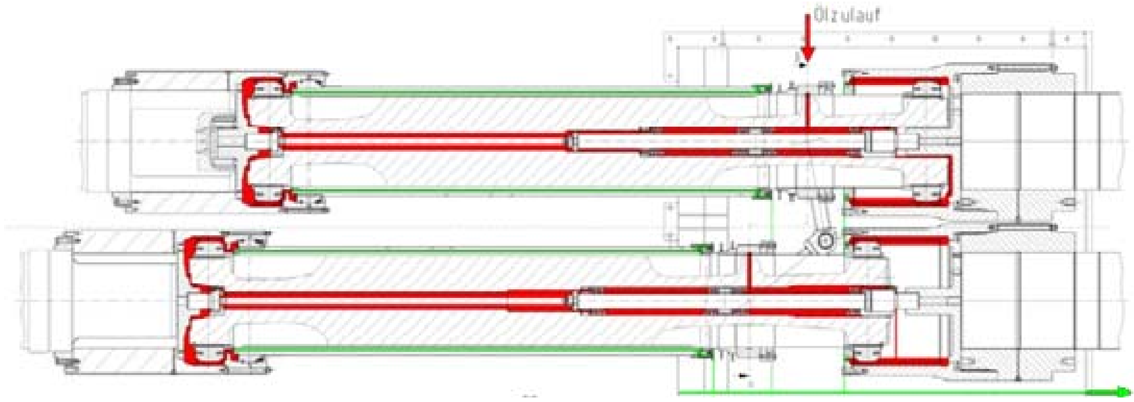

Figure 7. Oil Flow of SIEFLEX® Oil Lubricated Tube Spindle – Inflow in RED, Outflow in green.

2.5 History of Spindle related issues at NSBS

As previously mentioned, from the start-up of NSBS, all eight stands of the hot strip mill were equipped with grease-lubricated spindles. These spindles were carburized and hardened or nitrided (depending on the stand) with root centering in the male hub gear (Figure 8). The roll end casings were provided with replaceable wear keys mounted in the flats.

Figure 8. Original Tooth Configuration of Geared Elements at NSBS

From the time of start-up through the first five years of operation the grease lubricated geared spindles were identified as a major contributor to maintenance costs and mechanical downtime. Various corrections were attempted but as the mill

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increased production, spindle related costs and downtime increased proportionally. In 2003 an internal study was conducted and NSBS decided to upgrade all grease spindles to an oil lubricated type. NSBS solicited various vendor costs and engineering concepts, and after a careful selection process, which included cost-benefit analysis (Figure 9), chose the latest SIEFLEX® oil lubricated tube spindles patented by SMS Demag AG (Figure 10).

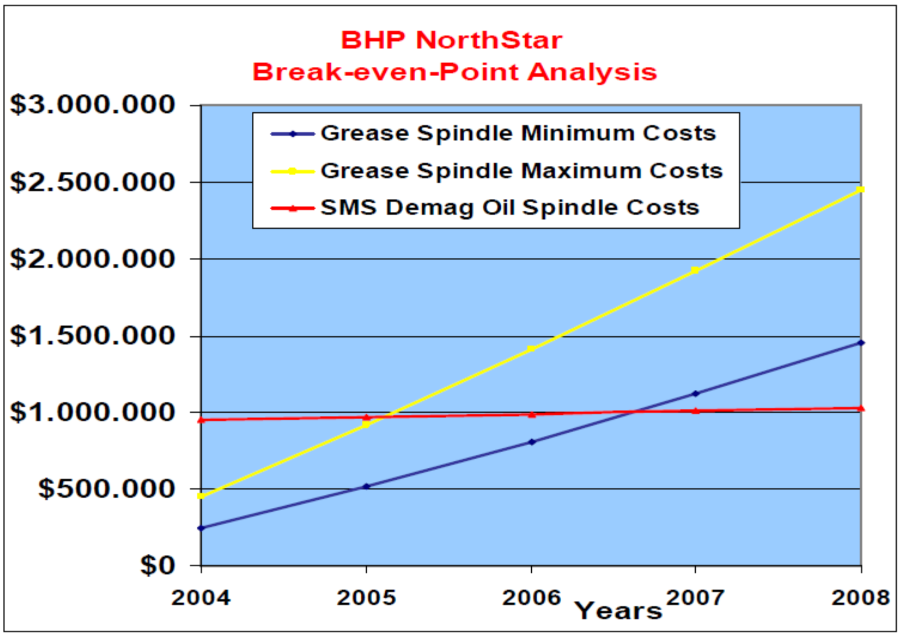

Figure 9. Original Cost-Benefit Analysis based on 2004 information

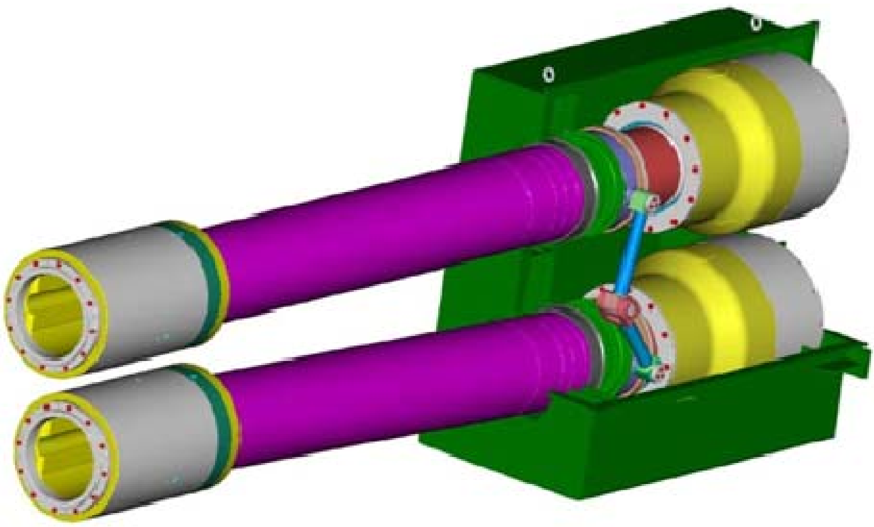

Figure 10. Conceptual Drawing of SIEFLEX® tube spindle concept.

2.6 ENGINEERING OF SIEFLEX® OIL LUBRICATED TUBE SPINDLES

A complete analysis of the various spindle related problems at NSBS was completed by SMS Demag AG. The problems were broken down as follows:

1. **Internal parts damage related to torque capacity issues** – These issues were analyzed using destructive and FEA analysis (Figure 10). In short it was discovered that the torque transmitting capability of the originally supplied grease lubricated spindles was insufficient to

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transmit the actual torques required for rolling at NSBS. Therefore the new design tube type oil lubricated geared spindles needed to be designed to transmit much higher torques. The geared element materials and geometry of the SIEFLEX® oil lubricated tube spindle were improved to increase torque transmitting capability, and all stands were designed with standard carburized and hardened teeth to increase wear resistance and strength. The replaceable keys in the roll end casing were replaced with SMS Demag standard carburized and hardened integral bore casing, thereby increasing the cross section and corresponding strength of the casing by over 25% (Figure 11).

Figure 11. Gear breakage after 4 months service.

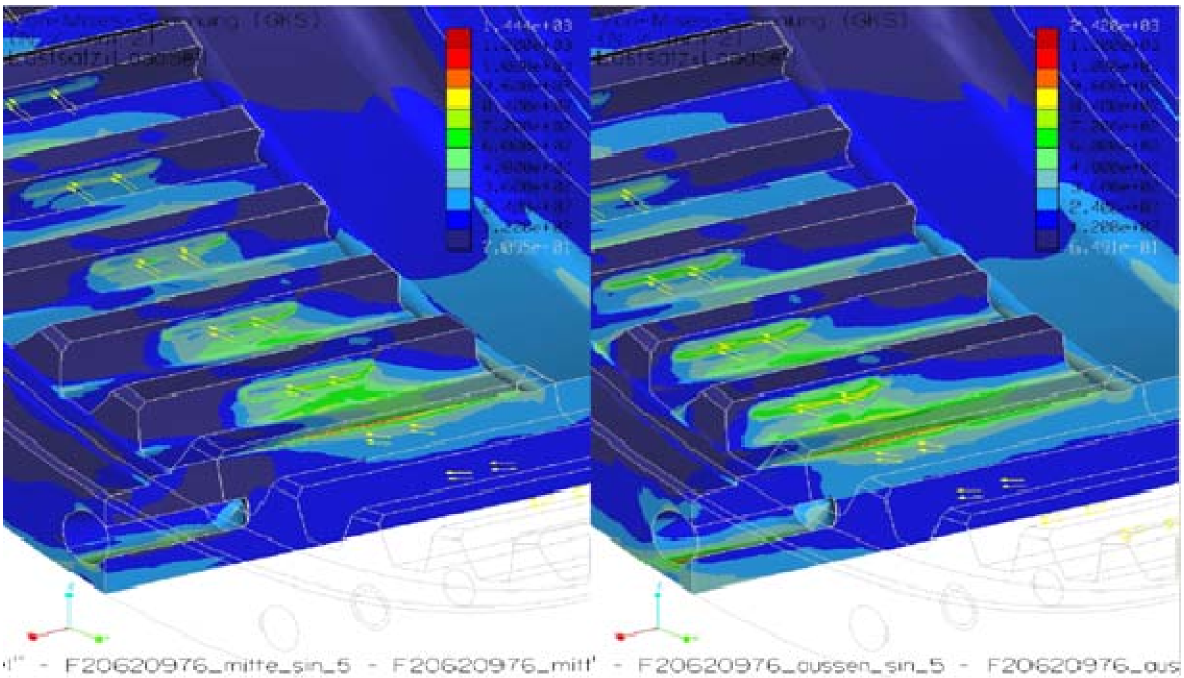

Figure 12. FEA Analysis of New Design Roll End Casing Gearing.

2. **Internal parts damage related to heat** – As with the issues described above, the heat damaged parts were destructively analyzed. Increased heat was the result of grease loss, lack of grease replenishment, and grease separation as a result of centrifugal forces, particularly in the higher speed stands (Figure 13). Fortunately, as a function of their

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design, the SIEFLEX® oil lubricated tube spindles remove heat from the internal cavities of the geared spindle. Therefore, the heat related damage experienced at NSBS would be eliminated simply by changing the lubrication concept.

Figure 13. Grease Removed from Original NSBS Spindles

3. **Lubrication loss and related clean-up impact** – Lubrication loss is the most common problem with grease lubricated spindles. No matter the sealing materials and design, grease loss most commonly occurs during roll changes. At NSBS large catch basins were designed and installed under the roll and drive end of the spindles (Figure 14). Over time these basins became full of expelled grease and needed to be removed and cleaned. The second highest cause of grease loss is the breaking down of the grease in operation. In simplistic terms this occurs when the internal heat destroys the elements within the grease that carry the oil within the grease. If the spindles are not re-greased frequently, related heat damage is accelerated. Unfortunately the only way to grease the spindle is to stop the mill, thereby increasing scheduled and un-scheduled downtime. It was anticipated that all these grease related challenges could be eliminated with the introduction of the SIEFLEX® oil lubricated tube spindles.

Figure 14. NSBS Grease Catch Pan.

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2.7 INSTALLATION & START-UP OF THE SIEFLEX® OIL-LUBRICATED TUBE SPINDLES AT NSBS

The installation of the SIEFLEX® oil lubricated tube spindles was phased in over an 18-month period with the highest priority given to the highest maintenance cost stands. Stands R2 and F2 were installed first in June 2005 (Figure 15 and 16), F1 in June of 2006, and F5-F6 in November 2006. Initial minor challenges occurred with spindle angularity resulting from un-anticipated roll changing equipment design and mill operational procedures. Both NSBS and SMS Demag AG addressed and solved these challenges promptly.

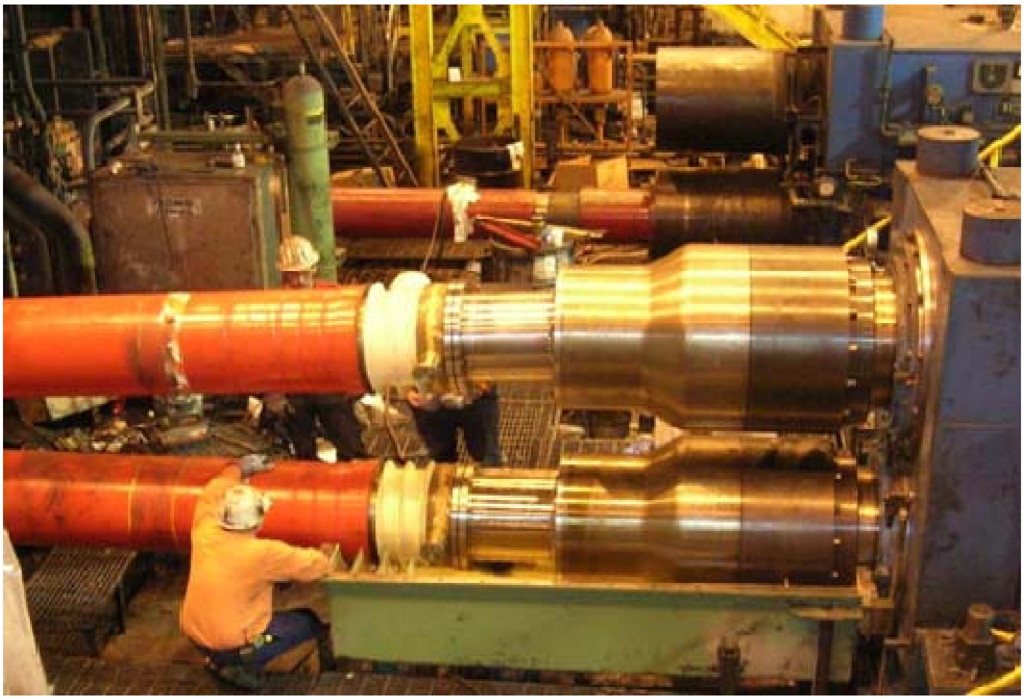

Figure 15. Installed SIEFLEX® Spindles in F2 without Oil Collecting Hood

Figure 16. Complete F2 SIEFLEX® Installation June 2005
(Note - OEM Grease Lubricated Spindle in F1 can be seen in the background)

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3 RESULTS AND DISCUSSION

Since the installation of the SIEFLEX® oil-lubricated tube spindles in stands R2, F1, F2, F5 and F6 at NSBS overall maintenance costs in these stands has decreased dramatically (Figure 17). In general there has been a 75% decrease in the stands converted, and of these repair costs, a very high percentage could be attributable to non-spindle related issues such as the rolling higher strength materials or rolling mill accidents.

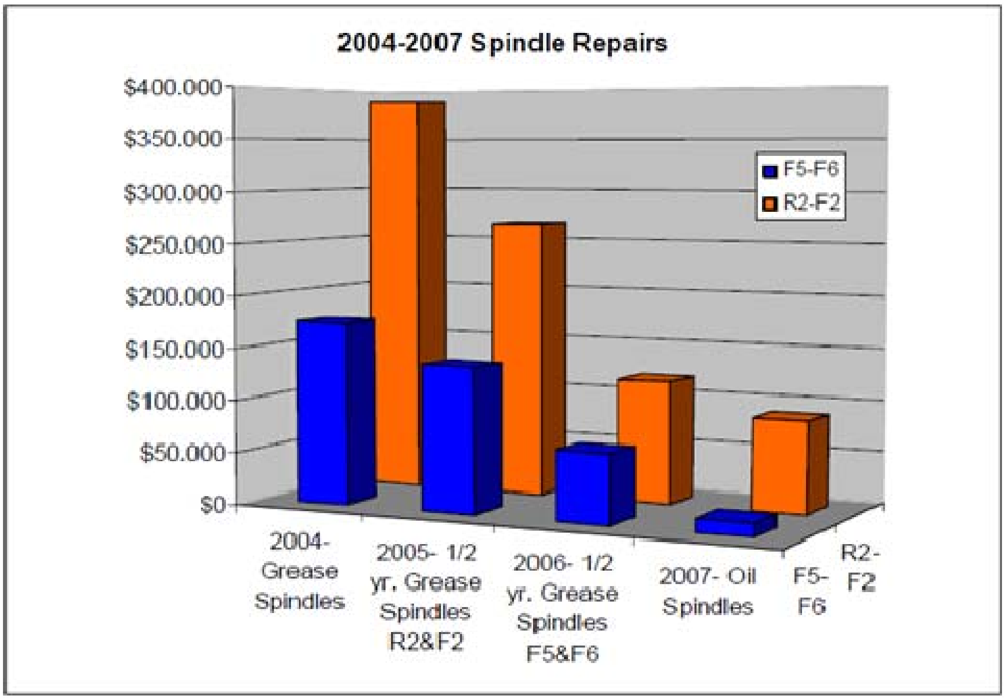

Figure 17. Total Spindle Repair Costs Before & After SIEFLEX® Conversion

Additionally, costs related to greasing and grease removal had not been factored into the original cost-benefit analysis. These cost savings were much higher than anticipated (Figure 18). Grease consumption has dropped 60% and these figures still include three stands of grease spindles.

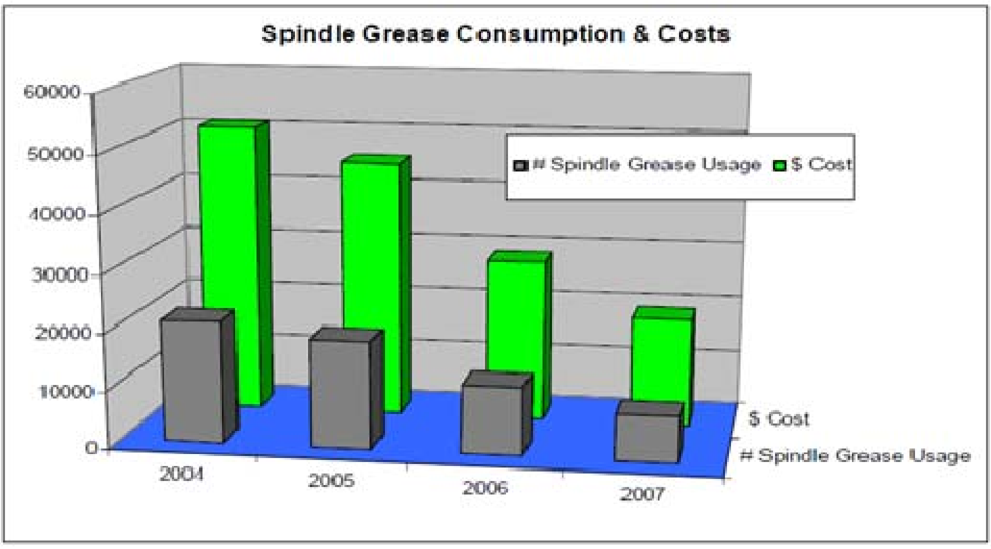

Figure 18. Total Grease Consumption

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Scheduled and un-scheduled spindle related downtime has also decreased dramatically (Figure 19 Note – these figures include mill issues and still include three stands with grease lubricated spindles.). For example F5-F6 has not experienced any spindle related scheduled or unscheduled downtime since conversion, and R2-F2 has only experienced spindle related downtime which can not be attributed to spindle performance (i.e. mill wrecks).

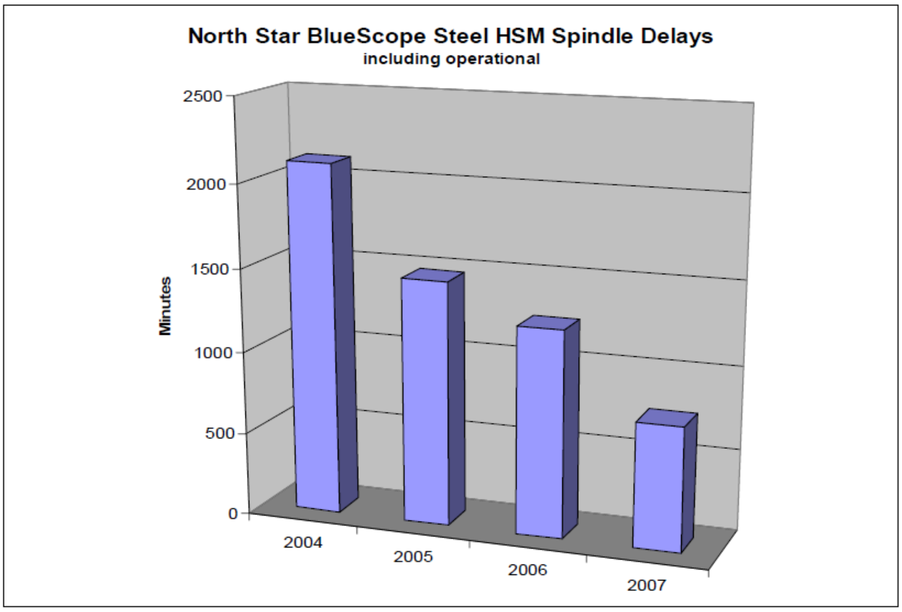

Figure 19. NSBS Spindle Related Delays.

After about 18 months service (approximately 3.2 million tons) in stands F5-F6 two spindles were removed for a precautionary inspection. As can be seen, wear and heat related damage has been eliminated for the gear teeth (Figure 20), in fact the gear teeth still exhibit typical break-in wear patterns. The roll end casing wear was virtually un-measurable. The spindles were re- assembled and re-installed. The next planned precautionary inspection removal will be after four years service (an additional eight million tons). The previously used grease lubricated spindles best performance was about 700,000 tons, and virtually all parts needed to be replaced at that point.

Figure 20. F5-F6 After One Year Service & two million tons.

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The new oil lubricated spindles from stands R2 -F2 were removed several times since initial installation mainly due to mill operational issues. Each time removed and inspected the gear teeth were measured and photographed (Figure 21). Resulting wear life of the geared elements and casings are comparable to those in the F5-F6 stands detailed above.

Figure 21. R2-F2 After two million tons rolled.

4 CONCLUSIONS

The introduction of SIEFLEX® oil lubricated tube spindles at NSBS has been successful beyond the initial cost– benefit analysis. Installation and start-up challenges were overcome with inter-company cooperation. The overall cost savings are higher than anticipated and continue to accelerate. NSBS has committed to finalize the purchase and installation of the remaining three stands in the near future.

Acknowledges

The authors wish to thank NorthStar-BlueScope Steel and SMS Demag AG for their continued support in producing this paper.