RE-LUBRICATION FREE ROLL LINES FOR CONTINUOUS SLAB CASTING MACHINES[1]

Harald Speck[2]
Tommy Rochhausen[3]

Resumo

In a global steel industry, cost/produced ton is becoming more and more the key factor and companies are more willing to pay attention to a total cost approach and treating maintenance as of strategic important as production itself. Another driving factor are the limitted natural resources and the focus on sustainablity even in devloping countries. This paper is describing a unique solution for the continuous casting process, reducing overall costs and hazardous waste, which has a positive impact environmental aspects as well as on costs. The case describes the requirement, implemention and the proven benefits based on installtions at steel mills in this fast growing industry.

Key words: Rolls; Bearings; Lubrication.

1 *Technical Contribution to the 61st International Congress of the ABM, January 24-27th 2006, Rio de Janeiro – RJ – Brazil.*
2 *Segment Manager Metals, SKF GmbH, Gunnar-Wester-Str. 12, 97422 Schweinfurt Germany, E-mail: harald.speck@skf.com*
3 *Business Engineer Continuous Casting, SKF AB, Von Utfallsgatan 4, SE-415 50 Gothenburg, Sweden, E-mail: tommy.rochhausen@skf.com*

INTRODUCTION

The continuous casting process has gained ground year by year in the steel making industry. Nowadays ~90% of the steel is produced with this technology. Thereof roughly 60 % is slabcasting. Critical components are the slab supporting rollers. There are three options today for lubricating the bearings of slab caster rolls: continuous grease, air/oil, and initial grease only (relube-free). Continuous grease is the traditional approach due to simplicity and low initital cost. Air/oil is proving to be effective, but has a high system cost and questionable reliability in reaching all points. Continuous grease flow can sometimes be un-reliable, and has other problems including removal/disposal of the tremendous quantity of waste grease and negative influences on slab quality and bearing performance. Relubrication free is a “holy grail” for some, sought after in an effort to capture the simplified maintenance and reduced cost of operation promised. A few implementations have been successful. Simply dropping-in sealed bearings in place of none-sealed bearings has not usually worked. As control of caster operation improves, and emphasis on preventive and predictive maintenance techniques or RCM increases, it is time to take another look.

Some machines are better suited to re-lubfree: those with longer sequence casts, and where total cost reduction strategies are moving forward. Increased cooperation between maintenance and production departments, as well as with suppliers, is required. There are challenges with converting existing roll arrangements to re-lubefree, including design changes and new maintenance routines. It may be necessary to convert a whole machine before savings can be realized. It is possbile to buy turnkey sealed roll sytem solutions today, where expertise in bearings seals, grease and other components are combined to optimize the system solution. In this case investment cost might be greater, but realization of savings is faster. This complexity explains why maintenance is of strategic importance and on mill managers agenda today. Our experience in steelmaking plants around the world covers a wide range. The solution called “ConRo” has proven it’s reliability at leading steelmakers in Europe and is on it’s way to penetrate the emerging steel markets globally.

PRESENT STATE OF ROLL LUBRICATION

There are two primary functions of lubrication in caster rolls:

1. Minimize metal-to-metal contacts in the rolling bearings
2. Minimize the ingress of water and scale into the bearings

With relatively small diameter guide rolls, the continuous casting process imposes very heavy loads that are ultimately carried by the rolling bearings. Today’s high quality bearings are generally up to the task, but in order to have optimum performance they need to, as much as possible, have a separating film of oil between rollers and raceways to prevent wear. Due to the slow rotational speed, conditions for building up a film by elastohydrodynamic means are less than ideal (Figure 1). This places a higher burden on the lubricant, and on the need to have a high quality lubricant in the bearing at all times.

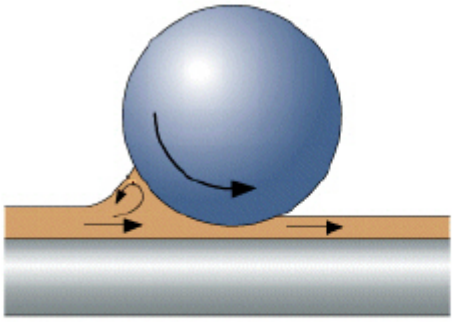


Figure 1. Lube film development

The external operating environment of course is severe. High temperatures, water including saturated steam, and scale are present and must be prevented from reaching the bearings in order to have a long service life. Sometimes the affect of water ingress is not so much corrosion, as it is thinning of the lubricant film and accelerating the rate of wear. It is typical in a post-campaign condition analysis to have wear, as a consequence of insufficient oil film, along with corrosion and heavy denting as predominant observations. Most observed spalling and fractures, which effectively end the bearings' life, is damage which has progressed from this deteriorated surface condition (Figure 2).

Figure 2. Showing wear, corrosion and spalling in bearing raceway

With the aim of minimizing the damage described above, most casters rely on the traditional approach of pumping grease continuously (cycled several times per hour) through the bearings, from a central distribution system, exiting through simple sealing systems (Figure 3). This method of lubricating the bearings and preventing contaminant ingress is generally successful, as evidenced by its wide spread use and its proponents. Systems have improved over the years, routing of distribution lines has been optimized, greases have improved, and system maintenance is routine and fairly simple. In operation, continuous grease systems are generally forgiving of short duration failures: the reservoir is usually ample, and pipes, distributor manifolds, etc., can be replaced. From the standpoint of the original caster manufacturer, the familiarity and acceptance of this method and the relatively low cost make it the standard choice. So this is the starting point from which we can compare other lubrication methods.

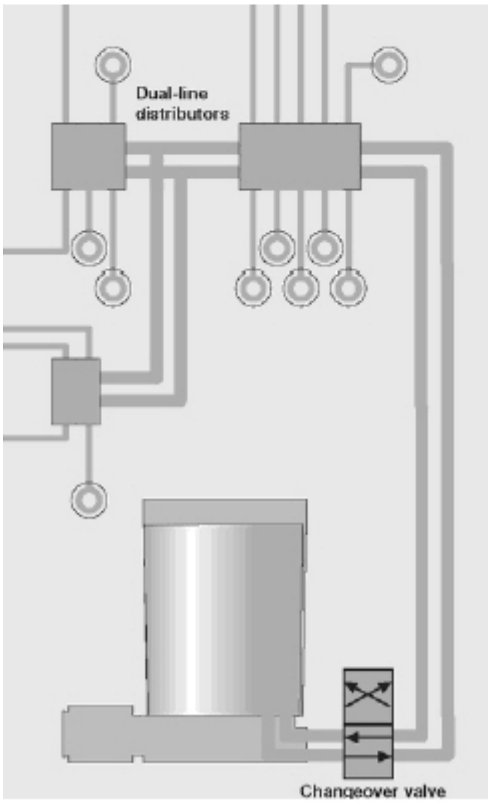


Figure 3. Grease distribution, dual system

Continuous grease lubrication is not problem free. It takes a great deal of energy to pump a sufficiently high-viscosity lubricant, so the selection of grease is usually a compromise of bearing performance for pumpability. There are still failures of the system during operation: grease lines are damaged in breakouts, lines can become blocked, pinched, etc. And there is a cost associated with segment build-up and maintenance. Some users have sacrificed the performance of dual line systems by going to a single line system, in order to reduce line replacement cost. The used grease collects on the housings and segment frame where it attracts scale and mold powder, can catch fire, before it dumps into the cooling water system. The hardened mass can act to block rolls from rotation, with locked rolls then marking the slab surface, a major quality concern. The grease that finds its way into the cooling water system must be removed and separated for disposal as a hazardous waste. Spent grease must be separated from the scale so that the latter can be recycled. There is an effect from the separated grease components that increases bacteria growth, which acts to clog the cooling water spray nozzles.[(1)] It has been reported by several customers that the cost of removing and disposing of the waste grease is as much as twice the initial cost of the grease. After many years of trial and error, lubrication by air/oil is gaining ground. Rather than delivering the oil by means of a thickener, as with grease, these systems deliver a metered amount of oil in a steady air stream (Figure 4).[(2)] There are several advantages, including the ability to more easily try different oils to find the best available for the bearings. The steady stream of air and build-up of pressure in the bearing cavities acts to prevent contaminant ingress, while also helping to cool the bearings which in turn improves lubricant life and function (oil viscosity is kept as high as possible). Without doubt, bearings examined after running with an air/oil system appear in far better condition, and the whole workplace is a cleaner environment. In the absence of the soap thickener and some other additives, the waste lubricant is easier to separate from the cooling water and scale, scale build-up is reduced, and the consequences for the segment frame and slab quality are improved. Over the years, compressors have become more reliable, control systems have become better and easier to use, and the distribution system has also improved. In terms of conversion from a grease system, there are typically no changes needed for the bearing and sealing system, and the installation of distribution lines is not too complicated.

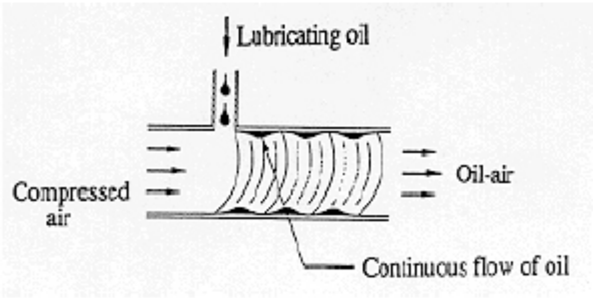


Figure 4 Principle of oil air lubrication

The drawbacks to converting to an air/oil system include the initial cost, the prove-in phase (including potential loss of production) for adjusting and optimizing, and the potential for more un-planned stops during operation. Installation and maintenance of the distribution lines and blocks is also critical: for example, there is far less tolerance for dirt in the system. Basically, there is a small quantity of oil in each bearing cavity that is replenished by the system. In the event of a broken or blocked line, power loss or other system failure, this small reservoir is used up quickly; and loss of the air stream will increase the amount of contaminates entering to an unacceptable level. The problem must be corrected quickly in order to avoid a catastrophic bearing failure that could lead to a locked roll and premature segment removal. The goal of increased segment life may be difficult to meet for top segments, with their typical 150 or more bearing positions, probably due to problems in achieving balanced flows to all positions for the whole campaign.

Relubrication-Free

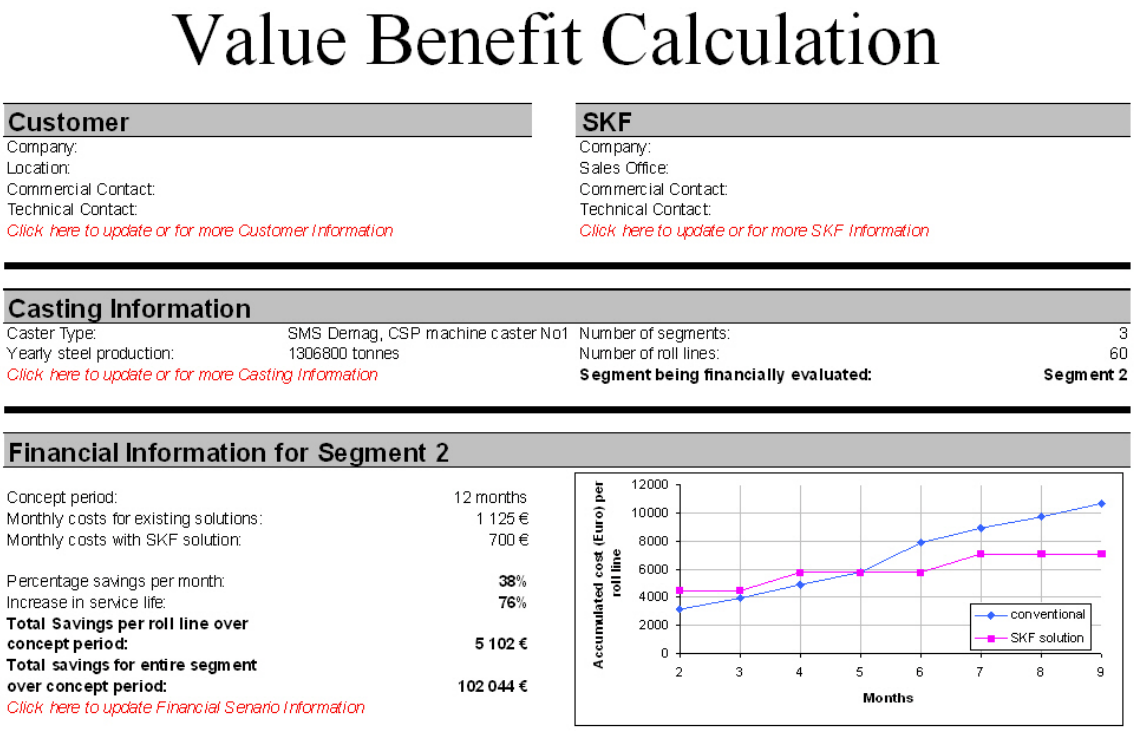
That brings us to relubrication-free roll systems. The principle is simply to rely on sealed bearings, and to lubricate them initially but not during operation. The main advantages are to:

1. Save money by avoiding the great quantity of grease normally used,
2. Avoid the cost of installing and maintaining a relube system,
3. Not be subject to an unreliable delivery system during operation,
4. Reduce the impact of the waste grease on the cooling water system, and
5. Reduce scale build-up, with the same positive quality impacts noted above for air/oil.

The amount of grease to be saved and the cost associated can be substantial. For example, considering that each bearing should receive 4-8 cc of grease per hour, and that there are an average 600 bearings per strand, that means approximately 25,500 kg (11,600 lb) of grease per strand per year. At $2 per kg, that's $51,000 per year of grease going through the bearings and then into the environment. If the rolls have 2 splits, there can be twice as many bearings and twice the grease usage.(1) However, other savings can far overshadow the grease consumption.(2) Projected identifiable annual savings can be seen in the following table. Not all areas have assigned values, and the assumptions behind others can be argued, with large variations between plants, why each caster needs to be evaluated individually. The basic calculations were made for a single strand, 2.0 Mton/year conventional slab caster.

Table 1. **Added value / savings**

Added Value	Savings (US$)	Affects
No central lubrication system	150,000	OEM
500 hrs eng. work	50,000	OEM
Assembly of central relubrication system	20,000	OEM
Energy savings	?	User
Environmental issues	?	User
Fewer planned and unplanned stops, losses	250,000	User
Less flamming	?	User
Water treatment costs	?	User
Less hazardous waste disposal	100,000	User
Reduced maintenance	500,000	User
No grease for relubrication	50,000	User



Graph 1. Example of value benefit/payback calculation

It is also possible to improve bearing performance (reduce wear and lengthen service lifetime) by using a very high quality grease, formulated for higher temperatures and wear reduction. The cavities external to the bearing are also filled with grease during roll assembly, hopefully one specifically selected to enhance the sealing function (high stiffness, resistance to water wash out). So the advantages are similar to the air/oil system, but without the costs associated with system installation, operation and maintenance. The external seals become critical components, whether mounted in the roll body (for fixed-axle designs) or in the housings (for rotating axle designs). This has been the most often neglected area of relube-free attempts. Seal manufacturers will state that for maximum life, or minimum wear, the interface between static and rotating parts must be well lubricated. This is difficult to achieve in the continuous caster environment, with the steady pressure of cooling water spray and the presence of abrasive contaminants. In successful installations, the seal design typically includes a sacrificial member, intended solely to keep out the larger contaminants and to protect the inner member.

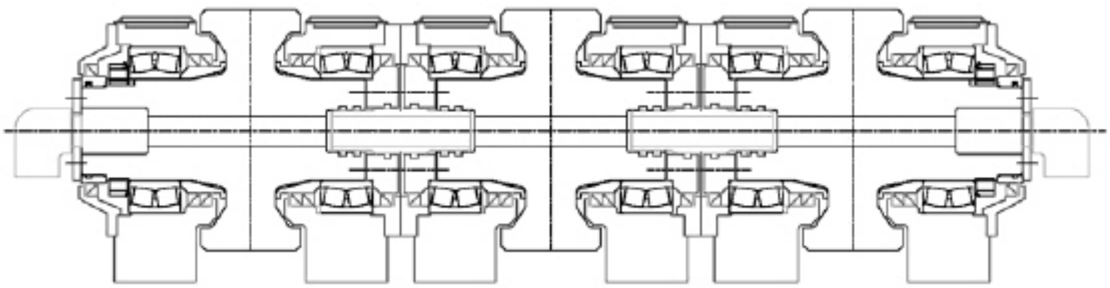


Figure 5 Example: conversion to seald bearings, relubrication-free

There are two aspects to thermal growth and shrinkage which are also important. There appears to be a strong connection between thermal cycling and ingress of moisture. The face of a bearing moving inside its housing acts as a fairly large piston, displacing grease outward during thermal growth and inward during cooling cycles. This tendency increases with the use of sealed bearings, as there is no passage through the bearing. (use of internally floating bearings, such as CARB® can reduce this problem.) Further, the volume of air trapped in the various cavities expands and contracts. So roll arrangements will aspirate moist air from outside during cooling cycles, and this moisture can become trapped, resulting in corrosion of bearing surfaces or in increased wear due to the negative influence on the lubricating film described above. These problems can generally be dealt with by incorporating various features in the roll system design. This problem also helps to explain why some casters, operated with short sequences or frequent changes in, for example, cast material grade or slab width, have not performed well with sealed bearings (or even with continuous automatic lubrication systems, not properly tuned). There are limits to the amount of grease inside the bearing, to the life of the seals, to the number of thermal cycles, and to the number of overload events for any roll system. For the first two items anyway, it seems that somewhere around one to 1-1/2 million tons cast is a good target for operation completely relube-free. There are a few installations where the life of the roll systems and the segments has been increased by injecting a reduced quantity of grease between the bearing and the external seal. Most of this grease acts to purge water and contaminates, while some will mix with the bearing grease by passing under the seal lip. There are other installations where a single-sealed bearing is used, also reducing the volume of grease or oil/air mixture required. In any case, once system life is established, minimum cost or maximum reliability typically occurs with a preventive maintenance routine, where segments are taken out of service on a schedule rather than run to failure.

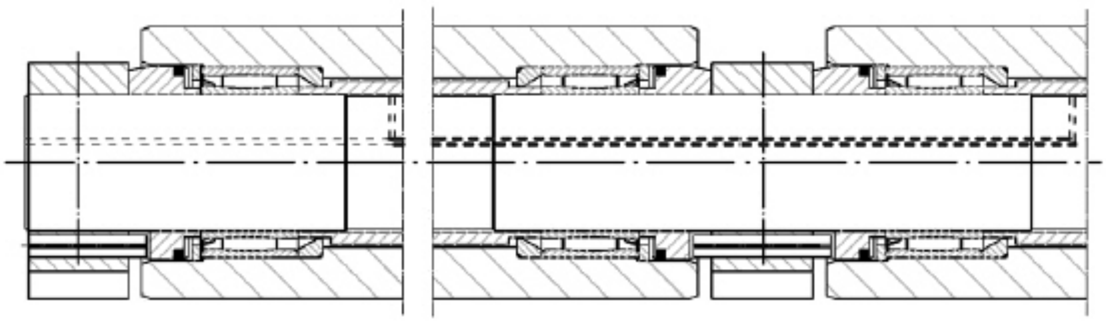


Figure 6. Example: typical single seal arrangement

In order to reap all the savings associated with relube-free roll systems, some mills believe it is necessary to convert every segment, including spares, for the entire machine. Depending on the extent of the design changes needed, this can be a big obstacle, and can take a long time to realize, especially if the technology is implemented piecemeal on a trial and error basis. If the service lifetimes of lower segments already exceed about 1.5-2.0 Mtons, it may be difficult to actually improve on that converting to completely relubrication-free, although there would still be a cost savings. There is an easier way, which is to purchase turnkey roll systems that have been designed specifically for a particular segment in a specific machine. The supplier of such systems needs to have a high degree of expertise in bearings, seals, lubrication and other component design, as well as a history of successfully optimizing systems and high-quality production.

Turnkey Roll Systems

As with most applications, it is important to look at the complete roll line as a system. A typical customer will develop their roll line service life in an alternating-step fashion. What this means is that first the lowest life-limiting factor will be addressed until it is replaced by a new target. For example: if the bearing life is keeping the roll line life short, it will be addressed and improved upon until roll surface wear or seal life becomes the limiting factor. These various components will be worked on until the overall roll life is to an acceptable level. The downside to this approach is that these components are usually improved upon independently from one another and the roll line is not looked upon as a system; bearing manufacturers are asked to provide technical assistance to help improve bearing life, roll mantle shops assist on welding specifications and procedures, etc. Competences are not shared from the development of one component to another; therefore the roll line service life is not addressed as a system, with mutual influences taken into account. In a customer survey conducted by SKF with various continuous caster end users and OEMs, simplified logistics was an area identified for improvement from suppliers. Customers were hoping to find suppliers to bundle various competences into systems, leading to turnkey solutions, taking the onus off of the customer for final quality and service life responsibility. In response to market demand, SKF designed and launched “ConRo”, relubrication-free roll systems incorporating bearings, seals, housings, grease, roll bodies, and if required water connections (rotary joints). Rather than a pre-designed roll line, which is stocked and sold as a standard component, the “ConRo” is a specifically tailored roll line for a specific customer requirement. Since the roll line is a modular concept, the individual components can be adjusted to address the overall requested service life of the roll line. During the initial stage of the inquiry it is important to understand the service life and failure modes of the existing roll lines. By understanding this, the system can be tailored to address these issues and therefore ensure a suitable service life meeting the customer’s expectations. SKF is also responsible for maintaining the roll systems, ensuring consistently high quality for new as well as repaired “ConRo”. By having a roll line that is designed to achieve a specified service life, maintenance costs can be better controlled. By having a consistent and reliable function over time, steel producers can better plan their maintenance budget, and can reduce this budget through the benefits of a completely relubrication-free roll line. Stahlwerke Bremen (5) adopted this idea, where they used the ConRo as one of their platforms to improve the performance of their operations. They have achieved repeatable service lives of 6 months in the top segment and 22 months in the lower segment – relubrication-free.

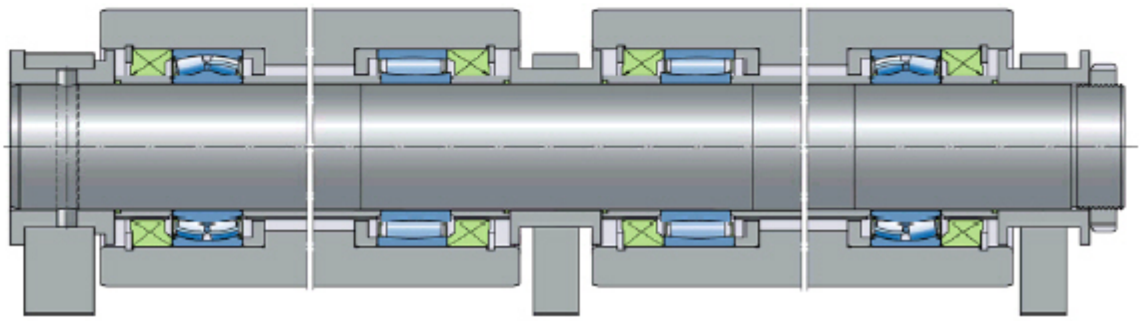


Figure 7. SKF ConRo system for slab and thin slab caster top segment

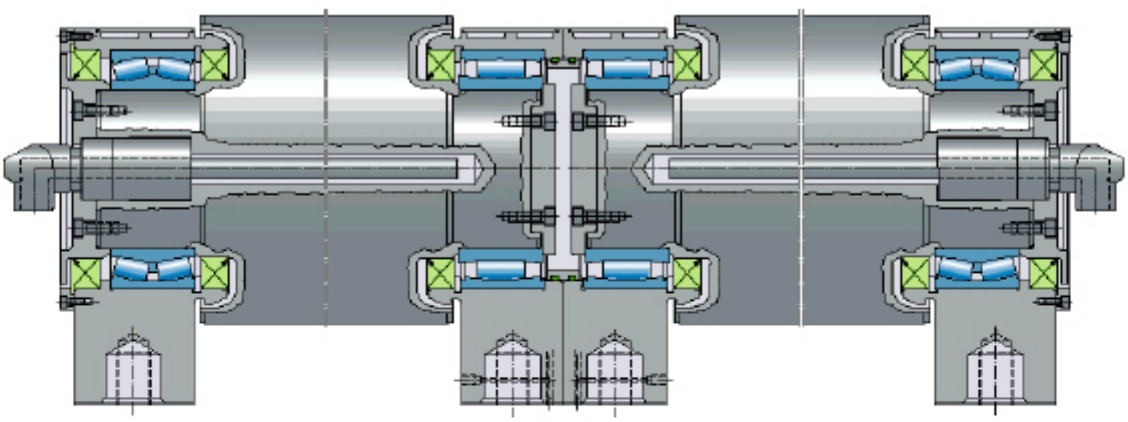


Figure 8. Typical Lower Segment SKF ConRo

COOPERATION

Complete implementation of a relube-free roll system can be a significant project, for a critical part of a steelmaker's assets. Organizationally, it is typically the Caster Maintenance Department of the Steelmaking Division of the mill that is most interested in making improvements, as they are generally accountable for the overall maintenance cost. This department is closest to issues surrounding roll design (after the OEM warranty period), assembly, component procurement, lubrication system maintenance and installation, and segment tear-down and build-up. Today, many mills subcontract segment maintenance to a third party, who may be paid on a cost per ton based contract. However, the most important ongoing savings may go to the Operations or Production Department, or Quality, or perhaps the Environmental Department. There can be completely different objectives and rewards for each of these departments, and assigned budgets that are not prepared for the investment needed for a system upgrade, which is to be implemented by the over-burdened Maintenance Department, with dictates from Purchasing to reduce acquisition costs quarter to quarter. The Maintenance Department, and especially an outside subcontractor, probably does not see sufficient savings to justify the expense and risk during the prove-in phase. So these various parties must have a cooperative structure and culture, and incentives to see such a project through to a successful completion. A target and strategy for overall cost reduction is difficult to achieve across an organization, and has stalled some projects. A close working partnership also needs to be formed with the system suppliers. The supplier, in addition to providing the technology, can assist with tracking performance by analyzing the condition of bearings, seals, lubricant, other components of the roll and the system as a whole. This is often accomplished as rolls are taken out of service for renewal. They should be able to work with component manufacturers to ensure tolerances of mating parts are tuned. The provider of the roll system should be responsible for the performance of the components and for making ongoing improvements. It can be that the system supplier can also serve as a focal point to keep the various customer departments informed and in concert.

OUTLOOK

With the growing nos. of installations and the use of a so called SKF Caster Analyst system, measuring load and temperature, an indepth knowledge about the operating conditions was developed. Furhter developments will focus on a more robust system design as well as on improvements of the maintainability in order to reduce costs further. In the limited window of time while North American steel producers are seeing record profits, it would seem to be an opportune time to invest in maintenance strategies and technologies that are intended to reduce the long-term costs associated with maintaining and operating the continuous slab caster. Evaluation of overall costs, reasons for downtime, and benefits may indicate that relubrication-free roll systems will be helpful in that regard. There are many examples of successful conversions of existing roll arrangements, and known pitfalls to avoid. An extension of this approach, with a potentially shorter implementation time and even greater benefits in terms of reliability, is a turnkey system such as the proven SKF ConRo family of solutions.

Acknowledgments
We would like to express our thanks to our loyal customer partners for agreeing to share their successes, and we gratefully acknowledge the many inputs from our colleagues around the world of SKF.

REFERENCES

1 S. Brell and A. Pask, "Reducing spray blockage on BHP's slab caster", AISE Steel Technology, May 2000, pp.43-46
2 T. Nugent, T. Lonsbury, J. Didwall and P. Schrof, " Continuous caster roll life improvement at Bethlehem Steel, Sparrows Point", Iron and Steel Engineer, June 1998, pp. 52-56
3 A. Dasgupta, SKF India, "Applications Parameters of Bearings in Continuous Casting Machines", Iron and Steel Review, October 2000, pp. 19-22
4 J. Bode, SKF Germany, "New Bearings for Continuous Casting Machines", Asia Steel, 1998
5 Thomas Müller, Stahlwerke Bremen and Michael Lawton, Editor; "Rolls in the hot spot" EVOLUTION, Business and Technology Magazin #2/05, April 20th 2005