HSS WORK ROLLS
SUCCESSFUL IMPLEMENTATION STRATEGIES

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Hot Strip Rolling Mills around the world have been attempting to use High Speed Steel Work Rolls for more than ten years. This shift has been successful in many Hot Mill operations but not so in others. The transition to High Speed Steel Rolls has been slow and steady, but not without trouble. The ability to make high quality, tough products is a necessary focus. There is a cost to create a mill environment that allows these high technology rolls to be successful and the rewards of doing so include lower quality rejections, improved roll performance, lower total costs and a more reliable delivery schedule. Where roll technology changes have been made with a single minded thought – improvement of the quality of coiled strip for the customer – the use of HSS rolls has been successful.

Key Words: Hot Rolling, Roll Technology, High Speed Steel Rolls, Quality Improvement

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INTRODUCTION

High Speed Steel Work Roll use is gaining importance throughout the Steel Industry around the world. After a slow start and ten years of problematic implementation, Hot Strip Mills in nearly every country are either increasing their HSS use or renewing their efforts to use HSS rolls to their best advantage. The trend is evident in both Continuous Hot Mill Rolling Trains as well as the newer Compact Strip Processes.

In spite of the huge volume of information already published regarding the success of HSS trials and performance benefits, much of the steel industry has failed to grasp the most significant benefit of HSS roll use. In many operations, HSS rolls have been put into service without any consideration to change the operating environment while at the same time there is an expectation that these new rolls will solve many chronic problems. In fact, where HSS rolls are successfully used, many changes to mill equipment and operating procedures have been necessary and the combination of these results in the achievement of the utmost in strip surface quality.

HSS TECHNOLOGY

When first used, HSS rolls can identify chronic problems that must be solved: problems in the Process Design, problems in the Roll Shop and problems in the Rolling Mill. At this point (i.e. problem identification), many mills abandon their use. When they do, they give up the greatest opportunity for improvement that the mill may ever have.

HSS rolls do not solve problems. Mills that try to use these roll types because they have a certain quality or operational problem have failed. Many barriers exist for the correct use of these rolls – these barriers are not always technical, nor due to equipment limitations. Moreover, they go beyond financial constraints.

Various HSS Roll Types

Various types of HSS Technology have been offered by the Roll Supply Industry. These include Spin Cast Semi – HSS (Enhanced Chrome type), Spin Cast Tool Steel and High Speed Steel Grades, Forged Tool Steel and Semi – HSS types, the so-called Super HSS types and the very high performance Continuous Pour Clad (CPC) compound cast/forged rolls from Japan. Regardless of the type employed, many common problems are experienced and each operation must examine their specific equipment to understand the changes required. For most, there is a set of common improvements that bring repeatable benefits.

Roll Performance

HSS rolls are typically desirable due to the lure of lower roll costs that results from their high Tonne/mm wear performance. While it is true that HSS rolls can achieve a performance up to four times that of Chrome and seven times that of ICDP types these levels are not achieved easily. See Figure 1.

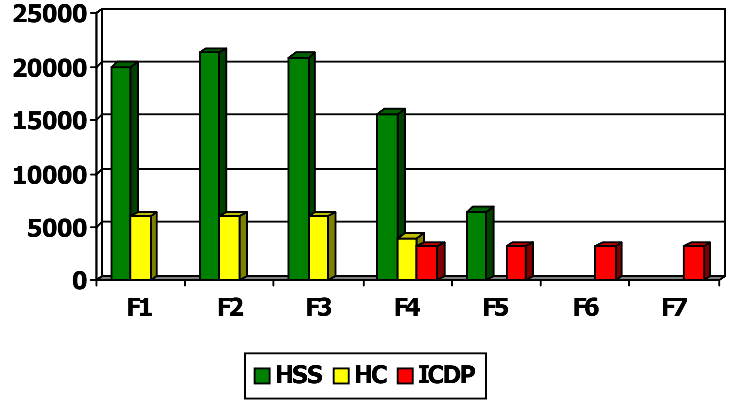
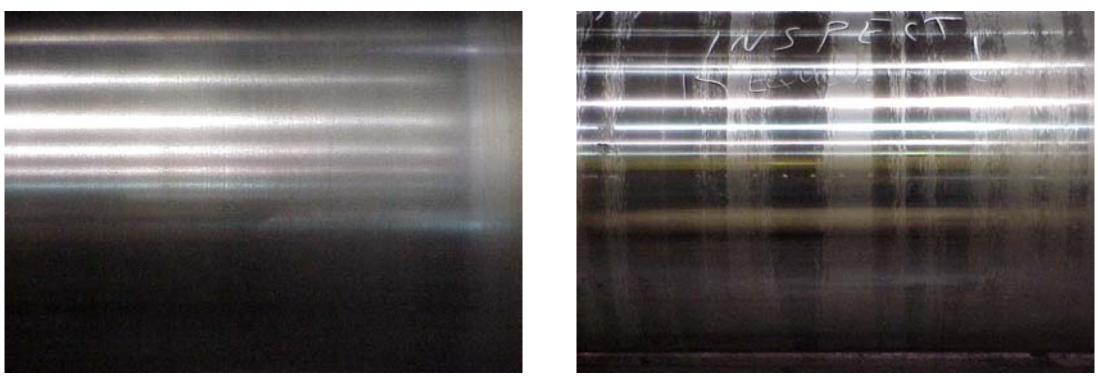


Figure 1. Potential Roll Performance (Tonne/mm)

Two other significant topics arise in any discussion about HSS work rolls and their performance. These are the condition of the oxide and the management of roll grinding. Both are key factors in the optimized use and maintenance of the roll inventory. Oxide condition and its preservation permit the repeated use of HSS rolls without grinding. Deterioration of the oxide due to banding, pealing and roughening indicates that the mill water systems must be improved before high performance can be achieved. See Figure 2.



Smooth oxide indicates the mill condition is suitable for repeated roll re-use. Mill water systems must be improved to achieve desired results in roll performance.	Presence of oxide banding is a precursor to roll pealing. Pealing will prevent optimum use of HSS rolls, and therefore the mill condition is unsuitable for high performance.

Figure 2. HSS Roll Oxide Conditions

VALUE IN USE OF HSS ROLLS

Repeatedly HSS users are asked: “Why are you using HSS rolls – aren't they more expensive?” Depending on the roll manufacturing process and alloy level, it is true that HSS rolls cost between 1.5 and 3 times that of Cast Chrome Work Rolls. However, the higher cost is typically offset by an increase in performance of at least 2X. Achieving higher performance levels up to 3X and 4X that of Chrome rolls is more difficult, but when achieved, it is the result of mill improvements that delivery higher quality levels and less operational trouble. The following are a few of the improvements that have been documented by HSS users.

- Surface Quality Improvement
- Reduced Mill Scale Problems
- Thickness, Crown & Shape Improvement
- Improvement in Delay Level
- Improvement in Customer Delivery Schedule
- Lower Man-hours per Ton Produced
- Reduced Total Cost per Ton Produced

The principle employed is to "Undertake actions in both the Roll Shop and Operations to deliver the targeted roll performance." This principle stems from a famous Japanese saying, "In some cases the roll does not meet the needs of the mill. In other cases the mill use is greater than the capability of the roll." When applied, HSS Rolls are properly employed and delivery significant and measurable savings. This includes improvements in product quality performance, capability for light gauge rolling, and greater performance when rolling difficult products.

BARRIERS TO SUCCESSFUL USE

In many cases, the first attempts to use HSS Work Rolls fail as a result of the existing mill conditions and the lack of any impetus for changing the mill condition. A lack of capital for investments, cyclic profitability, or failure to recognize the true quality cost benefits often results in a decision to abandon HSS trials because of new problems that surface and that can not be corrected.

The level of operational stability often prevents the use of HSS rolls. High mill Cobble rates result in many rolls in inventory having extra grinding to remove firecracks, stress induced cracks or spalls. The extra grinding often renders the cost performance higher than that for previous roll types. Middle and late stand operational problems including crimps and tail end chew up similarly cause roll damage that requires much extra grinding.

The lack of a comprehensive Quality Management System may prevent the correct assessment of HSS rolls in service. Feedback from downstream operations or customers is necessary to understand the value in use of HSS rolls compared to other types. The lack of an up to date Roll Data Analysis System also prevents the correct assessment of HSS roll performance, compared to other rolls. Without a comprehensive analysis of roll performance the judgment of HSS use reverts to one of roll price or the number of occurrences of extra grinding.

NECCESSARY IMPROVEMENTS FOR HIGH PERFORMANCE

Various rolling mill improvements have been reported over the past ten years in mills where HSS roll use has increased. These include:

- Work Roll Cooling Flow Rate
- Use of Roll Gap Sprays
- Mill Draft Schedule Improvement
- Interstand Strip Cooling Sprays
- Mill Tightening Program for Cobble and Crimp Improvement

Work Roll Cooling System

Most Hot Mills have initially used HSS rolls without consideration of the very different oxide condition they develop. The results have varied widely, but for most, there was insufficient roll cooling water flow to protect the oxide from heavy growth and pealing. Over the past 10 years, a rule of thumb has developed stating that the roll temperature should be maintained at 55°C. Where temperatures exceed this target and increase above 80°C, most mills report heavy pealing, banding or high temperature roughening of the roll surface. This translates into scale streaks or rolled in scale problems on the strip product.

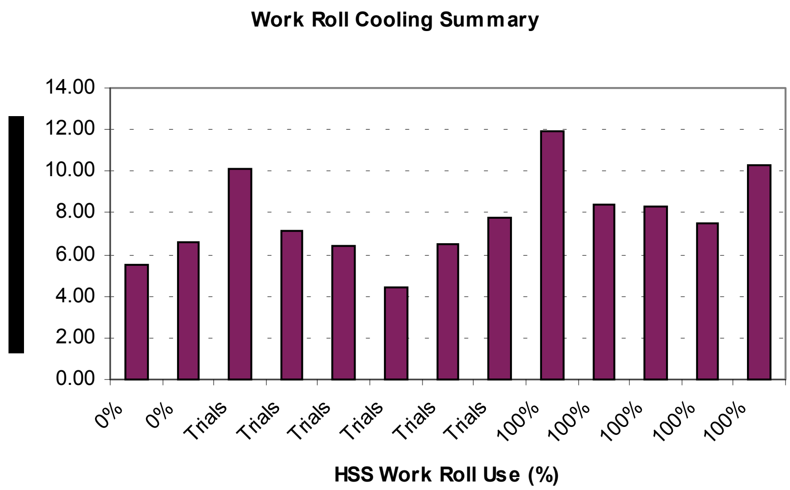


Figure 3. Typical Roll Cooling Water Flow

In many cases, mills have doubled the volume of roll cooling water applied to the rolls. Figures 3 and 4 show the wide range of roll cooling volume existing in many integrated and compact Hot Mills today. In general, where HSS rolls have been successful, the roll cooling volume falls in the range of 8.0 to 10.0 Liters/minute/mm roll width/stand.

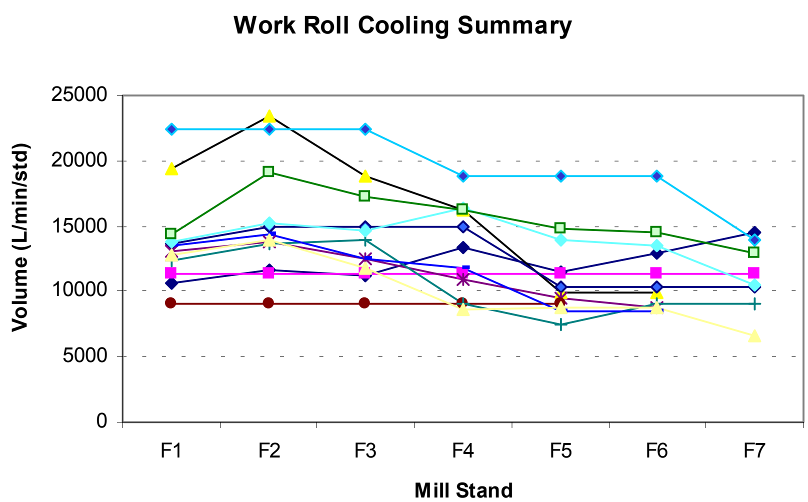


Figure 4. Mill Stand Roll Cooling Water Flow (1)

Roll Gap Sprays

Roll Gap Sprays (a.k.a. Roll Bite Sprays or Anti-pealing Sprays) are being added to older Hot Mills and are being provided in new mills as a normal feature of the design. The purpose of these sprays is to quench the interstand strip immediately ahead of entry to the bite. By lowering the strip temperature in the bite, the heat transfer to the roll is reduced, thereby reducing the near surface temperature of the roll. Oxide development is greatly reduced and the resultant oxide adheres to the roll and provides a protection against scale defect problems. See Figure 5. Where employed, Hot Mills report a dramatic reduction in oxide banding, roll pealing, and high temperature roughening. These mills also report a corresponding reduction in rolled in scale defects on their product.

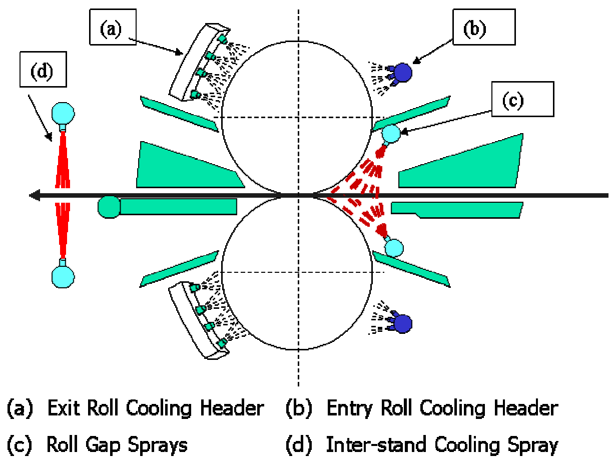


Figure 5. Employment of Roll Gap Sprays

Mill Draft Schedules

Entry Stand draft schedules often require adjustment to ensure a smooth transition from one stand to the next and avoidance of mass flow errors that can cause Cobbles. This is especially important for the rolling of light gauge products. See Figure 6. Where force patterns are allowed to peak or spike in a specific stand, many problems result, including chatter, gagging, and poor shape.

Mill cobbles can be prevented by improvement of interstand shape, head end tracking, revised level practices and the elimination of catch points in the interstand equipment.

Interstand Strip Cooling Sprays

Interstand Strip Cooling Sprays are now being installed on new Hot Strip Mills and being added to older mills to allow the practice of high speed low temperature rolling. The main advantage of these sprays in terms of rolls is the prevention of oxide tearing in the roll gap. Lower strip temperature prevents the development of hard scale. Additionally, the use of rolling oils and low friction roll types also benefits the reduction of scale defects that develop in the roll bite.

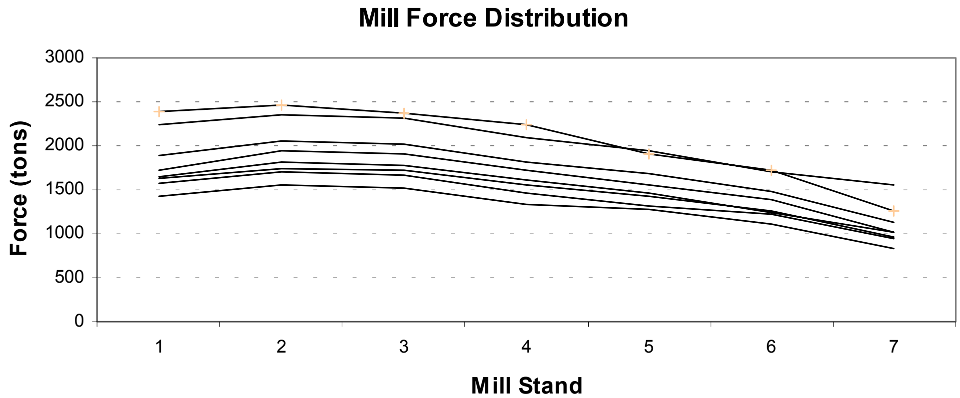


Figure 6. Mill Stand Force Changes (light gauge product)

Mill Tightening

Over the past ten years, many mills have adopted a practice of allowing mill specifications to deviate from target levels in favor of maintenance cost reductions. The affect of such deterioration accumulates slowly, until the mill finds itself with a high Cobble rate, high delay rate and Quality costs that exceed maintenance spending. In such cases, it is necessary to undergo a Mill Tightening Program for Cobble and Crimp Improvement. Furthermore, it is often necessary to establish an extensive control project for the reduction of Crimps in the middle and later stands. Such programs are expensive and difficult, as there are many causes for these problems and most often a total improvement back to original specifications must be made before an increment in performance can be achieved.

IMPACT ON ROLL SHOPS

New roll types have changed the value of inspection and testing. Automated testing systems are being installed on all critical machines. Inspection and Detection of cracks have become more important than the basic grinding operation.

Visual inspections continue to be critical to prevent catastrophic failures as equipment can not yet differentiate defects. Extensive training is required for defect differentiation and choice of optimum grind program. Measurement of Hot and Cold roll wear profiles for model calibration and determination of mill stability must be done on a regular basis. Grinding temperature must be controlled to ensure rolls are ground in cold state.

Roll Management Practices

Coiled strip products are now more difficult to produce and strip surface is critical. There is an increasing demand for improved Crown and Shape and reduced physical tolerances are being applied to more and more products. These factors have an impact on roll management practices – especially where HSS rolls are employed.

- Rolls must be maintained in perfect condition
- Roll use (# of campaigns) must be maximized
- Roll condition must be continuously checked
- Roll grinding must be minimized
- Roll inspection and defect detection has a greater roll in performance

Roll Inspection

Where HSS roll use has been optimized, roll related problems including roll failures, have been eliminated. A key factor in this optimization is the roll inspection function. As roll performance increases, roll grinding decreases and the roll inspection function increases.

Eddy Current and Ultrasonic Inspection techniques must both be used:
- Employment of Eddy Current Test for surface inspection: Eddy Current method is more sensitive to surface breaking cracks, however requires extensive knowledge of defect types and characteristics.
- Employment of Ultrasonic Testing for subsurface inspection: Ultrasonic tests detect manufacturing defects at the shell/core interface as well as porosity and sub-surface cracks initiated by cyclic stresses.

Each mill must develop inspection criteria and threshold limits for each roll type to allow rolls to be maintained in a safe condition while not removing extra shell material and increasing costs unnecessarily.

ROLLS FOR TOMMORROW – FOR THE FUTURE

Roll Supply and Use

Roll use must become an Industry Core Competency. Four factors impress the importance of the roll in the flat rolled process.
- High Cost (total spend, expense)
- High impact on Quality
- High impact on Operating Level (scheduled & unscheduled delay)
- High cost to maintain (shops, equipment, transportation)

The application of the correct roll and control of its condition is a high cost, high impact function that must be carefully instituted. This responsibility can not be successfully turned over to a third party.

Core Competency requires comprehensive control methodology. Rolls will never be successfully managed apart from the User. Roll maintenance may be managed apart from the User but not as well. Roll Suppliers must connect with their clients to provide targeted service. An exception to this need would be for an outdated and understaffed support operation.

Hot Mill Improvements

Hot Mill Roll Shops must get on board the improvement train. Piece rates, quotas and metal removal pay structures must be stopped and eliminated. Shop operators must become knowledgeable tradesmen, focusing on inspection, detection, differentiation and execution of world class operating practices. In some cases, roll shop personnel are being integrated with rolling mill crews. Along with the coil quality inspectors roll related decisions extend beyond change and repair.

Roll Suppliers must meet or exceed the expectations of Steel Mill Customers to survive. As with the production of flat rolled steel, there is an oversupply condition in the Roll Making Industry. Many Roll Makers have little new technology to offer – their supply must become diversified. They must grasp new technology to deliver vastly superior products that enable strip mills to effectively compete.

The Hot Mills that use rolls can not stand still with conventional roll technology. Demands for increased quality, yield and efficiency with lower cost will drive roll users to implement new technology. The operating environment will change to ensure that the use of these high performance rolls is successful.

Rolls will be purchased from a Global Supply Market. Roll makers no longer owned by an integrated steel plant must work harder to satisfy their customers. Roll customers have an international supply market in which currency fluctuations are a significant part of the cost. Roll purchases will therefore be driven by total cost model analysis.

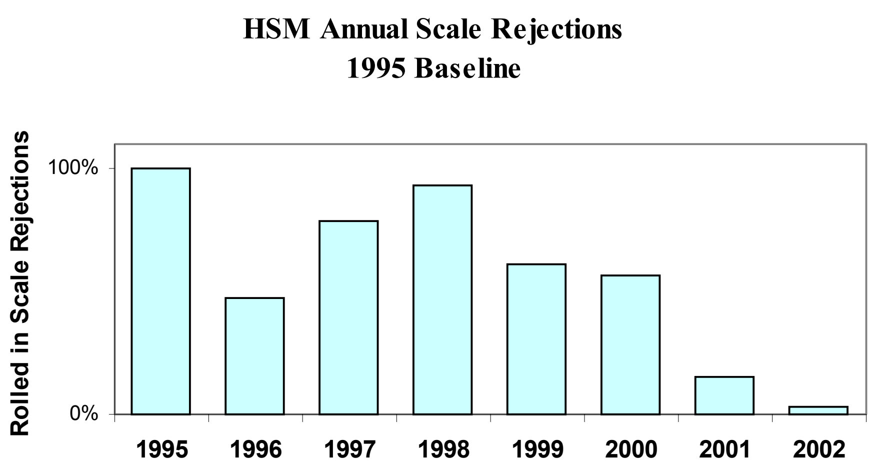


Figure 7. Quality Improvements Results track Roll Performance [2]

Total Cost

Every Mill has a desire for low price in their supplies and services – "Price is always important!" However, for rolls, the purchase price tag must not overrule the purchase decision. The total cost or total value in use must be assessed in order to make the best decision. Many mills are now using "Total Cost Models" to make roll purchase decisions. These include the following factors:

- Purchase price tag for a new roll
- Cost of failures (Loss of useful material, value of downtime, cost of collateral damage)
- Value of down time for roll changes (scheduled, unscheduled)

- Cost of labor, equipment use, materials & supplies
- Cost of Poor Quality: defective coils, rework, repairs, yield & impact on delivery performance

Roll performance increases as practices are improved in Manufacture, Operations, Maintenance and Roll Shops. Product Quality becomes perfect. Total Cost decreases. See Figure 7.

HSS SUCCESS – HOW TO ACHIEVE IT

HSS roll use has been highly successful in some Hot Mills and has also been a complete failure in others. Where they have been successful, the following issues have been resolved.

- Roll Technology is implemented by a competent team with representatives from all interested departments
- Improvements are driven by a targeted improvement in product quality
- Mill operating environment is improved to accommodate new technology
- Roll Users and Makers cooperate to achieve the highest steel mill product quality and therefore profit
- Improvements in Roll Performance - not roll price - reduces total cost of rolls Many trials were completed to find the best structure and chemistry of the roll
- Much effort is spent to improve mill stability (reduce Cobbles and Crimps)
- Length of mill campaign (multiple usages without grinding) is increased significantly – up to 400%.

CONCLUSIONS

Where they have been successful, HSS roll integration has been driven by a targeted improvement in Hot Rolled Strip Surface Quality. Savings in the Cost of Poor Quality are used to justify the improvement of mill equipment and operation, along with the much needed improvement in Roll Shop equipment and practices.

Successful implementation of the World Class HSS roll practices results in improved Quality, a more stable operating environment and permits the manufacture of more difficult high value products. The end result is greater opportunity for steady profitability independent of the cyclic price margins of commercial quality products.

ACKNOWLEGEMENTS

1. Sidenor Villares Technical Report; Renato Rufino Xavier, Eduardo Cannizza; Acos Villares; June 2003.
2. Roll Performance – A Technical Overview and Future Outlook; Rolls 2003 Conference Proceedings; Edward Kerr, Ron Webber, David McCaw; April 2003.