Pinch Rolls

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INTRODUCTION

PINCH ROLLS comprise an entire family of non-reducing rolls that are used to redirect the travel of a strip mill product and to provide strip tension for a downstream process. Pinch rolls are used in nearly all the metallic strip producing industries including steel, aluminum, brass and bronze. These rolls are found in hot and cold strip mill applications and in specialty processing lines like continuous picklers.

Regardless of the specific application, the pinch rolls must perform their function without negatively effecting mill productivity or product quality. One of the most demanding pinch roll applications is that of the hot strip steel mill coiler. Due to the constant desire to increase hot strip steel mill productivity, strip quality, and coil presentation, the coiler pinch rolls are now accepted as highly critical components in the hot strip steel mill. Consequently, it is for this pinch roll application that most of the technology advances in materials and mechanical design have taken place in recent past.

HOT STRIP STEEL MILL COILER APPLICATION

In the hot strip steel mill coiler application the pinch rolls are a set of top and bottom rolls at the entrance to the coiler. Their purpose is to receive the head end of the hot band and direct it into the coiler area. In addition, the pinch rolls also provide back tension for the strip during coiling. A schematic of the pinch rolls in this application is shown in Figure 1.

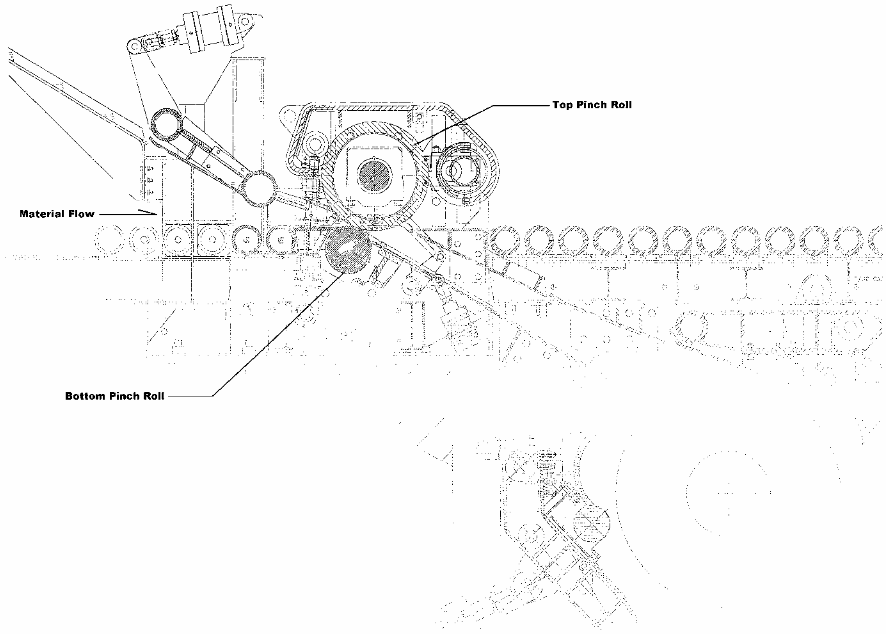
In most cases, the top pinch roll is engaged (in contact) with only the head-end and tail-end of the hot band during coiling. However, in some mills, the top roll is engaged continuously throughout the coiling process in order to create a slight tension on the hot band as it is coiling. This is done in order to create a tighter coil and enhance coil presentation. In all cases, the bottom roll is engaged with the hot band during the entire process of coiling. Control on the pinch rolls can be semi-manual or fully computer controlled.

Being the last set of rolls in the hot strip mill that the hot rolled product contacts, the demands placed on these rolls have intensified with demands of increased hot mill productivity and higher hot strip quality.

An increase in hot strip mill productivity typically means that the rolls will be subject to longer hot strip lengths (larger coils), longer campaigns, and increased tonnage over the life of the rolls. These productivity requirements imply that the pinch rolls possess resistance to wear, thermal stability, high thermal conductivity, and through-hardness.

As in all hot strip mill applications, the materials that contact the hot product must possess good thermal properties. The pinch roll application is no exception to this rule. With longer coils being coiled, and longer campaign lengths, the amount of heat generated at the surface of the pinch rolls can lead to severe surface deterioration of both the pinch rolls and the hot strip. A material with a high thermal conductivity will dissipate the heat more rapidly and thus reduce the surface deterioration and risks of friction welding. A material with a low modulus of elasticity will be less susceptible to cracking due to thermal stresses. Thermal stability refers to the ability of the material to maintain its heat-treated properties under the elevated temperatures experienced during service. A material with good thermal stability will maintain its strength and hardness at elevated temperatures and be less susceptible to softening while in service.

Figure 1. General arrangement of pinch rolls in hot strip steel mill downcoiler.



Both abrasive and adhesive (frictional) wear mechanisms occur in the pinch roll application. The percentage of each of the wear mechanisms depends on the pinch roll material being used.

Abrasive wear results when a harder material removes particles from a softer surface. In the pinch roll application, the hardness of the hot strip being coiled is soft relative to the hardness of the pinch roll, and therefore, the hot strip itself does not abrasively wear the pinch rolls. However, extraneous materials (scale, mill debris, and hard particles carried by the coolant and transferred through the water sprays) invoke abrasive wear [1].

Adhesive, or frictional wear, results from the scuffing action between two surfaces that come into contact. Adhesive wear occurs when appreciable heat is generated by friction between the surfaces. Often, projecting surface asperities present on the roll and product being coiled are locally heated when the surfaces come into contact. The localized heat can cause the surfaces to gall as a result of frictional welding. Upon further relative motion, the particles tear out and produce new asperities on the roll surface [1].

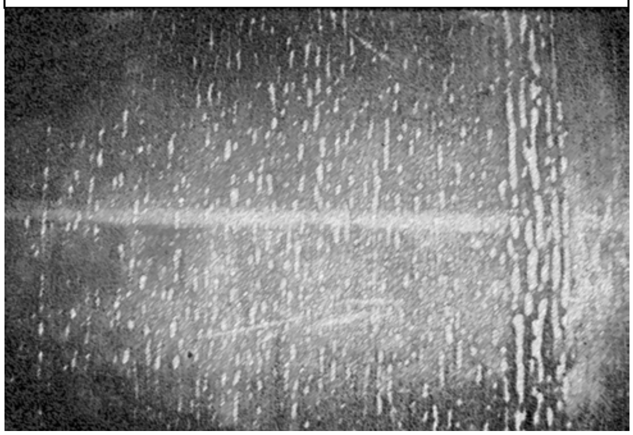
Obviously the resistance to wear, either abrasive or adhesive, or both, is a direct function of the pinch roll material, its hardness, and its microstructure. However, certain mill-related variables can accelerate wear of the pinch rolls. Such variables include keeping the top pinch roll engaged throughout coiling, using unfiltered coolant, inadequate spraying of the hot strip to remove scale and extraneous debris, operating the rolls in misalignment, and improper tension control between the pinch rolls and the coiler.

The ability of a pinch roll to be through-hardened is a positive attribute when considering overall performance. A through-hardened material has a consistent hardness throughout the cross-section and thus can be used to scrap size without re-hardening, re-sleeving or welding. Also, application stresses can be more evenly distributed over the entire hardened cross-section.

In addition to the above productivity requirements, the pinch rolls must also possess resistance to “pick-up” to ensure adequate hot strip surface quality.

Pick-up, as it is referred to in this text, is a condition whereby foreign material becomes adhered to the surface of the pinch roll during service. The foreign material is usually adhered metal from the actual product being rolled. Figure 2 is a photograph of a forged steel bottom pinch roll exhibiting a severe pick-up condition.

Figure 2. Forged steel bottom pinch roll exhibiting a severe pickup condition.



Pick-up on a pinch roll occurs when the product being coiled becomes fused to the roll surface due to extreme localized temperatures and pressures. When small imperfections or raised areas on the hot strip pass through the roll bite, they are subject to localized temperatures and pressures significant enough to cause them to become friction welded to the pinch roll surface. Once welded to the surface of the roll, the areas are pulled from the product as it continues through the roll bite. The picked-up material on the pinch roll surface will harden as it passes by the water sprays. As the pinch roll continues to coil, the pick-up can transfer marks on any subsequent hot strip being coiled, thus drastically degrading the surface quality of the hot strip.

The amount of pick-up that occurs is mainly a function of the pinch roll material, but is aggravated by certain mill-related variables such as poor tension control between the pinch rolls and coiler, poor surface and edge quality on the hot strip, inadequate water-cooling, and improper setup relative to the side guides. The sparking often seen at the entrance of the coiler is actually small particles of hot strip and/or pieces of the side guides flying into the pinch.

From the previous discussion it becomes obvious that the pinch roll application requires a material that possesses a balance between the critical properties of wear resistance, resistance to pick-up, good thermal stability and conductivity, and through-hardening capability.

MECHANICAL DESIGN

Top Pinch Rolls

The top pinch roll is typically a four-piece fabricated shell design. The components consist of the shell, which can be made of several different materials, two hubs or centers, and a through shaft. The hubs are generally made from carbon steel forged discs. The shaft, requiring a reasonable level of bending and torsional strength, is generally made from heat-treated low alloy forged steel. The components are assembled by shrink fitting, and held in place through mechanical stops, shaft keys and face keys. Weld is sometimes used to affix the components, but certain shell materials are not easily weldable. A slight variation in this typical design features stub shafts welded into each hub, instead of the through-shaft, but this design is becoming less common as the length of the shaft is becoming longer. Newer features on the top pinch roll coiler assemblies, such as counter-balancing components on the idler end shafts and hydraulic-controlled side guides, require the shafting on both the drive and idler ends to be longer.

Most of these designs, regardless of the shell material selected, can be slightly modified to accommodate re-sleeving although the economic benefits of resleeving have not been justified in the past.

The components must be machined to tight tolerances and the components must mechanically fit precisely together, as the top pinch roll must be balanced for proper operation in the mill. The standard balancing specification used is ISO 1940/1-1986, G6.3 at 360 RPM.

The outside body diameter is nominally 36.0” (914.4 mm), ranging from 30.157” (766 mm) to 36.5” (927.1 mm). A common size is 35.433” (900 mm), which is the size found in the newer compact strip mill hydraulic coilers.

Bottom Pinch Rolls

The bottom roll is typically in the 16-20 inch (406.4 – 508.0 mm) diameter range, with the most common size now being 20 inches (508 mm).

Two designs are used. A sleeved, two-piece design that incorporates a shell mechanically attached to a through-shaft, and a solid design. Which design is chosen is usually dependent upon the material selection. If the roll is heat-treated forged alloy steel or carburized steel then normally the bottom roll will be a solid forging. A hybrid of the solid design would be a bottom pinch roll made via the Continuous Pouring Process for Casting (CPC) process, in which the roll is indeed solid but the surface material is different from the core material. If the roll is iron, then the design could be a sleeve on mandrel type.

MATERIAL TECHNOLOGIES

The most common pinch roll materials are classified below into families of materials, with the most frequently used materials in each of these families reviewed where appropriate.

Each of the materials mentioned below has a set of properties that results in its own unique performance characteristics. The relative strengths and weaknesses of these characteristics will be reviewed, as well as general procedures utilized in the material manufacturing process. Specific producers may have different processing techniques than those outlined below.

TOP PINCH ROLLS

Several materials are available for use as top pinch roll sleeves. The sleeve material dictates the performance of the pinch rolls in the application, and thus will be the focal point of the material review. For the most part, the component (shafts, hubs, etc.) material is common throughout most of the designs regardless of the sleeve material.

Cast Iron Based

The most commonly used top pinch roll material group is the cast iron based materials.[1] The cast iron group consists of as-cast gray irons, centrifugally cast and heat-treated alloy gray irons, and indefinite chilled (white irons), all of which are used in the pinch roll application.

Gray Cast Iron

The gray iron based materials are melted in an electric furnace, and then typically static cast into a sand mold. This reduces the cooling rate of the iron from the molten state, and allows the formation of graphite. Primary carbides can also be present in the microstructure, usually at the eutectic cell boundaries. The as-cast hardness is generally in the 38-44 HSC range. The sand-casting processes does not necessarily optimize the density of the material, i.e., casting voids can occur which could render the shell material unusable in critical pinch roll applications. Also, a high degree of chemical segregation can result within the casting, causing irregular and sometimes unpredictable wear.

The gray iron based materials exhibit good thermal properties, including thermal conductivity and thermal stability. The wear resistance is good due to due to the presence of the graphite microconstituent. The graphite provides a natural lubricating element and promotes the formation of hard oxide at the surface of the rolls. The low as-cast hardness of the gray iron can limit the wear resistance of the material.

Centrifugally Cast, Heat-Treated Alloy Gray Iron-Bemcalloy®

This specialty material is also an alloy gray cast iron. However, these rolls have an advantage in being horizontally, centrifugally cast and supplied in a quenched and tempered condition.

This eliminates the chemical segregation, porosity, and non-optimized microstructure of the as-cast grades.

[1] Based on a 2001 survey of 40 worldwide hot strip steel mills.

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Two grades of the material are used in the pinch roll application. The grades are both hypoeutectic alloy gray cast irons, quenched and tempered to the range of 60-70 HSC. The standard material is alloyed with nickel, chromium, and molybdenum. In addition to these alloys, the premium grade contains niobium, for increased wear resistance. The selected alloys in each specialty grade are present within the gray iron at levels that provide a balance between carbide formation and graphitization. Both grades contain enough of their respective alloys to allow for through-hardening of the standard wall thickness of the sleeves used in top and bottom pinch roll designs. After casting, the sleeve is oil quenched and tempered and carefully cooled to improve the microstructure and properties from the as-cast condition. A microstructure representative of one that is found in the premium-grade pinch roll is shown in Figure 3.

The hardness is 62 HSC (approximately 46 HRC). The microstructure consists of flake graphite (darkest gray constituent), discontinuous primary ferritic carbides (white constituent), dispersed Niobium carbides, and a tempered martensitic matrix. Per ASTM A-247, the microstructure of graphite is classified as mostly VII A5 [3].

Although each of the constituents of the microstructure affects all of the properties, each affects certain properties more than others do. The amount of graphite, the length of the flakes, and how they are distributed in the matrix directly influence the thermal stability and pick-up resistance, but contribute little to the strength or hardness [2]. The metallic matrix in which the graphite is distributed provides the basic strength and hardness of the material. The wear resistance is aided by the natural lubricity of graphite, but is more a function of the metallic matrix, carbide content and carbide distribution [2].

Figure 3. Representative photomicrograph of Bemcalloy C-141 microstructure, 500X (Courtesy Xtek, Inc.)

The Niobium is added to the premium grade to increase the wear resistance. Niobium has the ability to form hard, primary carbides that do not form at the eutectic cell boundaries and, therefore, do not have a negative effect on toughness. Also, Niobium when used as an alloying element in gray iron has been found to reduce the size of the eutectic cell, thereby increasing strength [5]. The Niobium carbides in the tempered martensitic matrix are responsible for the increased wear resistance of the premium material. The niobium carbides provide increased wear through two ways. First, they resist abrasion due to their extremely high hardness. Second, during service, the Niobium carbides can adjust in the relatively softer martensitic matrix so as to distribute the load more evenly across the entire surface, thus minimizing the possibility of dislodgment.

In addition to the Niobium carbides that facilitate the wear resistance, the remainder of the constituents in the microstructure affects the other properties of this specialty material. The flake graphite is present to provide thermal stability and natural lubricating characteristics that provide the resistance to pick-up. The tempered martensitic matrix contributes to the overall strength and toughness, as well as providing an increased hardness for resisting wear. Furthermore, this material maintains the through-hardening capability, excellent thermal conductivity and thermal stability [6].

Indefinite Chilled Iron

The indefinite chilled, or white irons are typically melted in an electric furnace and cast into chilled molds. The high cooling rate of the iron causes the formation of carbides, and prohibits the formation of graphite in the high chilled zone. The amount of carbide decreases with decreasing cooling rates. The slower cooling rates usually occur below the surface of the casting.

The carbides are responsible for the high hardness (62-68 HSC as-cast) and the very good wear resistance of the material. However, the presence of a chill zone and the corresponding variable hardness with depth below the surface, hampers the performance consistency when the roll is used below a certain depth. The poor impact resistance of the material can lead to sleeve breakage under extreme service conditions.

Weld Overlay

Stainless steel weld overlay is a common technology used for pinch rolls. A mild steel shell is used as a base and the weld material is deposited to a depth of about 3/8 inches (9.525 mm). The finished roll is about 45 HRC. The weld material is typically a 400 series stainless steel, but various pinch roll producers have developed their own proprietary weld grades.

The stainless steel weld overlay roll can be re-welded and finished to increase total life of the roll. Sometimes, a carburized roll will be weld-overlaid after the hardened case is worn off.

The main attributes of the weld overlay rolls are wear resistance and crack resistance. However, the weld overlay roll has a strong tendency for strip pick-up particularly in the area of bead overlap.

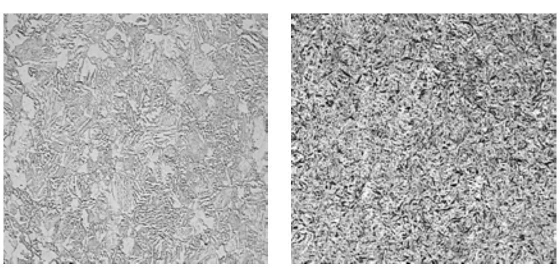
The 420 stainless steel roll has demonstrated long and successful campaigns in mills where pickup is not an issue. However, the greatest disadvantage is the depth of weld deposit, which is less than half of the usable shell thickness in most mills. Because of this, the stainless rolls require re-welding on a routine basis.

Carburized

Carburized rolls are produced by subjecting a mild carbon steel sleeve to a long (100+ hours) cycle in a furnace whose atmosphere is carbon rich and which is at 1700-1800°F (927-982°C). Carbon diffusion can be as great as 3/8 inch (9.525 mm) deep, but more commonly is 1/4 inch (6.35 mm). The depth of carbon diffusion is referred to as the total case depth. The effective case (depth to 50 HRC when fully hardened) is usually about 75% of the total case depth. Following the carburizing cycle, the sleeve is liquid quenched to produce a martensitic structure and tempered to improve the heat and crack resistance. Final hardness is typically 50 HRC, resulting from a temper of 600°F (315°C). A representative photomicrograph of the carburized case and core material is shown in Figure 4.

After the sleeve is carburized, it is assembled onto the hubs and shaft, and the working surface is finished. This process reduces the final effective case depth to about 0.180 inches (4.572 mm) [2].

Figure 4. Representative photomicrographs of an 8620 carburized case (A), 200X and core microstructure (B), 200X.



Carburized rolls provide excellent wear resistance through the carburized case. When the carburized case is removed through wear and through grinding, the underlying material is very soft and has poor wear resistance. At this point, it is not unusual for the sleeve to be weld-overlaid with 400 series stainless steel chemistry. Rehardening or recarburizing is not an effective process at this point.

Carburized rolls are subject to firecracking, which eventually lead to spalls. These firecracks will often preferentially initiate at a grain boundary, especially where grain boundary carbides and intergranular oxides can exist as the result of the long carburizing cycle. This effect can be minimized through very good control of the carbon potential. carbon control reduces the diffusion driving force, lengthens the furnace time, and results in a lower carbon martensite.

As the carburized roll is consumed and begins to expose the softer core material beneath the case, strip pick up increases, potentially causing quality issues with the hot band and increasing the requirement for the roll to be cleaned up. The main disadvantage of the carburized roll is that the depth of hardness is only about l/4th of the usable shell thickness in most coiler pinch rolls.

BOTTOM PINCH ROLLS

In most cases, the top pinch roll materials are also applicable to the bottom pinch rolls. In addition, bottom pinch rolls can also be manufactured from two other sources: forged and hardened alloy steel and Tool Steels that are applied via the CPC process. Both are only applicable for solid bottom rolls. Weight constraints and the unavailability of used rolls for remaking prohibit the used of solid forged steel rolls in the top pinch roll application.

Forged and Hardened Alloy Steel

The source material for a steel bottom pinch roll can either be a new forging, or the pinch roll can be remade from a previously used roll, such as a scrapped cold tandem mill roll. In the case of a new forging, the chemistry is either a medium carbon hot strip mill roll alloy, or in some isolated cases, a standard oil quenched and tempered 4340 steel. In the case of remade pinch rolls, the material would vary and the selection would be limited to the availability of scrapped rolls. The chemistries available would typically be in the 2.0%-3% Cr, 0.7-0.8%C range.

The bottom pinch rolls produced from forged alloy steel are normally quenched and tempered to a hardness of about 75 HFRSC. The result is a roll that is wear resistant, but susceptible to pickup and firecracking [7]. Its main advantage is the relatively low cost.

Continuous Poured Clad (CPC) Tool Steel

The CPC process can be used to produce clad bottom pinch rolls, but the use of the process for this application has been limited to date. This process cannot be used to manufacture the top pinch roll shells, as they are too large in diameter. The core material is usually a 4140 steel in the form of a solid steel bar or steel pipe. The shell material is melted in an induction furnace, and the CPC equipment is used to clad the shell material to the steel core. The composition of the shell material dictates whether the roll is furnace cooled or cooled at ambient temperature.

The chemical composition of the shell material can be tailored depending upon the operating environment of the coiler [8].

MILL PRACTICES

The pinch rolls in the hot strip steel mill application must economically perform their function without negatively effecting mill productivity and strip quality. Most of the mill practices including material selection, change-out criteria, campaign length, crowns/tapers, engagement practice, alignment, and maintenance procedures were established by optimizing both the productivity and quality aspects of the specific mill. In addition to the main economic aspects of procurement and cost of operation, variables such as roll size, mechanical design, number of in-line coilers, size of coiler, roll consumption rate, and product can dictate how the pinch rolls are selected and used.

The information presented in the following sections was taken from a survey of 40 worldwide hot strip steel mills that included both the integrated and compact strip mill type. The survey included nearly all the hot strip steel mills in North America, but also includes mills from Central and South America, Europe, and Asia. The survey was current at the time of printing.

Performance Criteria

Hot band that is to be re-rolled in a temper or cold mill is usually intended for surface critical/surface exposed applications such as auto body panels. The main performance criterion is surface quality for these applications. Therefore, pinch rolls must not impart surface imperfections onto the strip during coiling. Pinch roll pickup can be responsible for surface imperfections on the coil. If the main desire is to maintain an optimum surface, then material selection should be based on the pickup resistance.

In processing hot band that is to be applied in less surface critical applications, slight surface imperfections may be tolerable, throwing the emphasis on productivity. In these cases, some pickup resistance may be sacrificed for greater wear resistance. Figure 5 tabulates some of the performance criteria typically considered when balancing between productivity and quality, and the corresponding material variable that controls each.

Figure 6. Pinch Roll material usage distribution of 40 worldwide Hot Strip Steel Mill Coiler applications.

Roll Type	Indefinite Chilled Cast Iron	As-Cast Gray Iron	Centrifugally Cast & Heat-treated Alloy Gray Iron	Stainless Steel Weld Overlay	Carburized	Hardened Alloy Forged Steel	CPC – Tool Steel
Top Roll	1	5	28	6	0	N/A	N/A
Bottom Roll	0	1	21	8	0	10	0

Figure 5. Performance criteria to consider when selecting pinch roll materials.

Performance Variable	Performance Criteria	Controlling Material Variable(s)
Campaign Length	Maximum ex: 3 Months	Wear Resistance / Pickup Resistance
Total Tons Coiled Capacity	Maximum ex: 3 million tons	Wear Resistance / Depth of Hardness
Tons Coiled per Stock Loss	Maximum ex: 2200 T/0.001"	Wear Resistance/ Damage Resistance
Total Cost per Ton Coiled	Minimum ex: $0.008/T	Price / Wear Resistance / Depth of Hardness
Roll Scrap Rate per Year	Minimum ex: 0.5 / year	Wear Resistance / Depth of Hardness
Typical Grinding Stock Loss	Minimum ex: 0.020"	Pickup Resistance / Damage Resistance
Pickup Resistance	Maximum ex: No pickup	Material Microstructure

Material Selection

The selection of material is primarily based upon the performance criteria required for the specific mill, however, the physical size of the rolls may restrict the use of certain materials. For example: the outside diameter of the top pinch roll is too large for the CPC process to be used; a top pinch roll would be too heavy to be made from a solid hardened forged alloy steel, or the journal dimensions on bottom rolls may inhibit the use of a sleeved design. Barring these physical restrictions, the material choices are broad enough to offer the highest performance charcteristic that is desired for a particular application. Figure 6 below shows the primary pinch roll material in the 40 worldwide hot strip steel mills surveyed.

Crowns / Tapers

A crowned or tapered pinch roll can aid in guiding the strip into the coiler. The amount of crown/taper on the top rolls can differ from those used for the bottoms. The various crown/taper combinations between top and bottom pinch rolls used throughout the industry are shown in Figure 7. Roll profiles vary from mill to mill. Thirty-five percent of the mills surveyed do not crown/taper either the top or bottom rolls, yet twenty-five percent of the mills crown/taper both rolls. The balance of the mills crown/taper just one of the two rolls.

If a pinch roll is to have a tapered profile, the taper is usually specified in terms of thousandths of an inch per foot of taper (mm of taper / meter of length) beginning at a certain distance from the ends of the body. This implies that the center of the body is flat. For example, a common taper for a top pinch roll with an 80" (2032 mm) long body is 0.024"/ft (2 mm/meter) on diameter beginning 15.0" (381 mm) from each end of the body. In the survey, the taper used on the rolls ranged from 0.015"/ft (1.25 mm/meter) to as much as 0.200"/ft (16.8 mm/meter). The distance from the end of the body at which the taper begins is a function of mill size (roll body length). In addition to the taper, the rolls often have a chamfer at each end of the body.

In some cases a true continuous crown is applied to the rolls. In these instances, the crown is simply specified in thousandths of an inch (or mm), meaning that the roll is that much larger on diameter in the center as compared to the ends. The amount of crown used is similar to the amount of taper described above. In most cases, crowned rolls also possess a chamfer at each end of the body.

Change-out Criteria

Changing out the pinch rolls in the coiler area often takes a full turn to complete, and therefore, is usually done during a scheduled mill downturn. Both the top and bottom rolls are changed-out at the same time. As with most mill practices, there is little consistency in change-out criteria between various mills. Since the bottom roll is always in contact with the strip being coiled[2], and since the circumference of the bottom roll is approximately 50% that of the top pinch roll, the bottom roll wears out much faster than the top roll. Consequently, it is primarily the bottom pinch roll that determines when the rolls need changed-out under normal circumstances. Only if there is an instance that would cause the top roll to fail or wear out prematurely, or if the bottom pinch roll material performs better than the top pinch roll material, would the top pinch roll control when the rolls are changed-out.

In some cases the pinch rolls are changed-out on a set schedule in the mill. The campaign lengths have been traditionally based on past practice. This change-out criterion does not maximize roll performance, as it does not take into consideration the capacity at which the mill is operating. Therefore, a roll may be changed-out prematurely if the mill is running at a low percentage of capacity. Over the life of the roll, this will result in a greater number of costly change-outs and a greater amount of stock loss due to more frequent redressing.

Figure 7. Distribution of Crowns/Tapers Combinations.

Hot Strip Steel Mill Coiler Pinch Rolls	Top Pinch Roll Crowned/Tapered	Top Pinch Roll Flat
Bottom Pinch Roll Crowned/Tapered	10	6
Bottom Pinch Roll Flat	10	14

A more practical change-out criterion would be based on the amount of product coiled. Such a criterion may be to change the rolls after 1,000,000 tons (909,100 tonnes) are coiled. This would allow the mill to more fully realize the performance capabilities of the pinch roll material. In this criterion, it is assumed that the pinch roll will perform consistently from time to time, the product being coiled is similar, and that each of the pinch rolls in inventory are of the same material. The pinch roll material used would have a significant impact on the performance consistency over time. A material that is through-hardened, i.e. possesses the same hardness and metallurgical properties from starting diameter to scrap diameter, would show a more consistent performance over the life of the roll than a material that possesses a hardness gradient, i.e. hardness decreases with decreasing diameter.

The change-out criterion that maximizes the campaign length is one that takes into account the actual worn diameters of the roll. For instance, one such criterion would be to change out the rolls when the crown(s) of the roll is (are) completely worn away and the ends of the rolls touch when they are brought together. Another might be to change out the rolls when there exists at least a 0.100” (2.54 mm) gap between the roll faces. This method requires that periodic measurements be taken while the rolls are in the coiler, which requires that the mill be down for a short period of time.

Campaign Length

[2] It should also be noted that if there is more than one in-line coiler in the hot strip mill, in most cases, the bottom pinch roll in the earlier coiler(s) will be in contact with the strip even when a downstream coiler is coiling the product. Essentially the bottom pinch roll in an upstream coiler is an extension of the Runout Table when a downstream coiler is operating, which may explain why the wear rate would appear to be worse for bottom rolls in earlier coilers compared to those of the last coiler.

The campaign length depends on the pinch roll material, change-out criteria, and other mill-related variables such as product being coiled and crowning practice. Under normal operating conditions and with the mill running at near full capacity, then the average campaign length (in weeks) of bottom pinch rolls for the surveyed mills is shown in the table (Figure 8) for various materials. The campaign lengths shown in the table are based on average performance numbers, in terms of tons coiled/0.001" stock loss for the respective materials. Included in the data were campaigns that were shortened due to the need to remove the pinch rolls due to quality problems (mostly pickup). The cases in which the change-out criterion is a set length of time were not included in the data represented in the table. If the change-out criterion is based on roll wear measurements, as described above, then a larger crown/taper could conceivably increase the campaign length.

Engagement Practices

As previously mentioned, the top roll can be engaged for either all or part of the coiling operation. From the survey, it appears that the engagement practice utilized by a mill is a function of coiler type (Figure 9).

Figure 8. Average campaign lengths for various bottom pinch roll materials.

Bottom Pinch Roll Material	Campaign Length (weeks)
Cent Cast & HT Alloy Gray Iron	7.5
As-cast Gray Iron	5.3
Stainless Steel Weld Overlay	4.5
Hardened Alloy Forged Steel	4.2

Mills equipped with hydraulic controlled coilers typically retract the top pinch roll during coiling, usually after the strip has made several wraps around the coiler mandrel. The rolls are typically re-engaged when the tail-end of the strip exits the final finishing stand of the hot mill. Also, the data suggest that if the top pinch roll is engaged continuously, then the mill is also more inclined to utilize a crown/taper on the top pinch roll. This is likely done to increase the campaign length of the rolls since the top roll will wear at a considerably faster rate if when it is continuously engaged.

Figure 9. Engagement practices utilized for various coiler types and crowning practices.

Coiler Type	Top Roll Crowned/Tapered	Top Roll Flat
Hydraulic Controlled	Engaged Continuously = 3	Engaged Continuously = 1
	Retracted During Coiling = 3	Retracted During Coiling = 9
Pneumatic Controlled	Engaged Continuously = 13	Engaged Continuously = 6
	Retracted During Coiling = 0	Retracted During Coiling = 5

Maintenance

The pinch rolls in the hot strip steel mill are nearly always the responsibility of the hot strip mill maintenance department, unlike the hot mill work rolls and backup rolls that fall under the roll shop. In most of the mills surveyed, the pinch rolls were reconditioned by outside contractors. Reconditioning consists of removing the worn profile and any damage by turning or rough grinding, followed by finish grinding of the appropriate crown/taper. The average amount of stock loss due to grinding is mainly a function of the roll material, and its ability to resist pickup and damage. The average grinding stock loss may be as minimal as 0.015"(.381 mm) for the gray iron based material, or as much as 0.105" (2.67mm) for Stainless Steel weld overlay, or a carburized material.

In some cases, reconditioning involves a complete teardown and inspection of the pinch roll assemblies, followed by regrinding, re-profiling, and rebuilding. This reconditioning schedule may occur after each campaign in the mill or only after several campaigns. Typically the pinch rolls are torn down at the mill and only the rolls themselves sent out for reconditioning.

SUMMARY

The above text shows that the hot strip steel mill coiler pinch rolls are regarded as highly critical components, greatly effecting mill productivity and product quality. Many variables can control the performance of the pinch rolls, most of which are related to mill practices and material selection.

Although the discussion revolved around the hot strip steel mill coiler application, most of the material requirements and comparative discussions can be related to other, more ancillary, pinch roll applications.

REFERENCES

1. Iron Castings Handbook, Iron Castings Society, Inc., 1981, pp.517-526.

2. J.M. Senne, "An Overview of Coiler Pinch Roll Technology," 39th Mechanical Working and Steel Processing Conference Proceedings, ISS, Vol. XXXV, 1998, pp.496, 497.

3. "ASTM A-247," Annual Book of ASTM Standards, Vol. 03.01, 1994, pp.113-114.

4. F.T. McGuire et al, "Gray Iron," Metals Handbook, Vol. II, 8th Ed., 1964, pp.359-363.

5. C.H. Castello Branco and E.A Beckert, "Niobium in Gray Cast Iron," Niobium Technical Report, NbTR-05/84, March 1984, pp.1-3.

6. D. D. Rhodes et al, "Recent Developments in Coiler Pinch Rolls," 41st Mechanical Working and Steel Processing Conference Proceedings, ISS, Vol. XXXVII, 1999, pp.496, 497.

7. L. Arnold, "Miscellaneous Rolls," Rolls for the Metalworking Industries, ISS, 1990, p. 275.

8. A. Yamamoto et al, "The Continuous Pouring Process for Cladding (CPC) Various Alloys as Applied to Table, Looper, Wrapper and Pinch Rollers," 2001.

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