“Caster filtration for continuous cast copper rod”

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Abstract:

Caster cooling water systems become contaminated with acetylene soot, graphite, and oils restricting heat transfer. Reduced heat transfer between copper wheels, dam blocks and steel bands result in reduced copper rod production, life of copper wheels, dam blocks and bands plus increased maintenance of heat exchangers and cooling towers. This paper describes a process utilizing gravity filtration and separation chemistry that has yielded significant operational savings in production and environmental costs.

The majority of the world's continuous cast copper rod is manufactured by wheel-belt or twin-belt bar casters. This includes the processes of SCR, Properzi, Essex, and Contirod. The casting machines use steel bands and copper alloy components including wheels and dam blocks to form a continuous copper cast bar from molten copper. In the process of producing the copper cast bars, acetylene soot, graphite and oil coating are applied to the wheels and dam blocks as protective thermal barriers.

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Introduction

While it is well known that heat transfer is of paramount importance in casting a sound cast bar and resulting rod quality little attention has historically been given to water quality used on the various copper continuous casting machines.

The author discusses the basic wear components, heat transfers and casting cooling water systems of the various wheel-belt and twin-belt casting processes in an effort to stress the importance of water quality, water cleanliness and to further advance the knowledge of the practitioner.

Finally, the author presents an efficient, simple and economical method for filtration of the casting water that uses proven gravity filtration technology combined with separation chemistry. This new filtration methodology has yielded significant product enhancements and cost savings. The filtration results presented have been an accumulation of 12-months of actual operating data.

Caster water system contamination

In the process of producing copper rod by means of the continuous cast method, soot, graphite or carbon black and oil is applied to the caster wheel, dam blocks and steel bands as protective thermal barriers. As molten metal is poured onto the caster wheel or dam blocks and formed into a bar, the carbon-based thermal insulators often referred to as lubricants, also act as a mold release. The solidified bar is then cooled with rinse water before being rolled into rod. This rinse water becomes contaminated with the carbon and oil materials which was applied to the caster wheel or dam blocks resulting in:

- Reduced rod production
- Reduced life of wheels & dam blocks
- Increased maintenance of heat exchangers
- Increased maintenance of pumps
- Increased water usage
- Wirebreaks
- Reduced life of casting belts
- Increased maintenance of cooling towers
- Equipment and structural corrosion
- Environmental, safety and health issues

Overview of casting processes

The majority of the world's continuous cast copper rod is manufactured by wheel-belt or twin-belt bar casters. This includes the processes of SCR, Properzi, Essex, and Contirod. The casting machines use steel bands and copper alloy components including wheels and dam blocks to form a continuous copper cast bar from molten copper.

The wheel-belt processes are very similar in concept.[1-7] Liquid metal is transferred from the melting process to a copper alloy wheel and poured or siphoned into a mold cavity. Mold cavity profile design or mold section is typically a trapezoidal or U-shape in its periphery. The wheel profile forms 3-sides of the cast bar and a long endless steel band forms the other side resulting in a water-cooled continuous mold. Controlled water-cooling is applied to the backside of the steel band and copper alloy wheel. Wheel diameters determine the production rate or expected output.

It is important to understand that initial solidification of the liquid metal begins as a pure heat sink into the mold and a thin crust if formed before the cooling system sprays begin to cool the mold and precipitate further solidification of the cast bar. The solidification front takes the form of a long “V” with the center being the last place to completely solidify. The exact “V” shape varies with metal chemistry, and other variables noted in the text under optimization of solidification. Position, alignment and adjustment of the cooling sprays are critical in controlling the solidification. Water flow rates, water pressures, and water quality is of utmost importance in controlling this “V” shape solidification and maintaining contact between the solidifying cast bar and the copper wheel and band. Tapered cooling is used in an effort to maintain correct contact. A slight air gap is unpreventable as shrinkage begins during cooling.[3]

The twin-belt bar caster consists of an inclined, moving, water-cooled, rectangular mold. The mold is formed of two parallel steel belts held in tension, forming an angle of 15 degrees to the horizontal, wrapped around pulleys, which move the belts.[5] The sides of the mold consist of two endless chains of machined bronze dam blocks, linked together by a steel strap. The height of the dam blocks determines the height of the cast bar, and the horizontal separation of the dam block guides determines the width. Both belts are cooled on the backside by a longitudinal high velocity water film. The dam blocks are cooled on the return loop in a cooling chamber. The rectangular mold maintains contact with the bar on all four sides. The dam block guides may also have water-cooling to enhance heat extraction. The center of the cast bar is again the last place to solidify.

Wear components

The various casting processes utilize similar wear components for forming the cast bar. Low carbon or stainless steel band materials and copper alloy wheels or dam blocks are typical wear components. The alloys and construction design, including material thickness has a significant influence on heat transfer and solidification. Wheels and dam blocks are made out of high conductivity materials. While the useful life of wear components is mainly determined by thermal cycles and cycle frequency of the component assuming good casting techniques, more failures from stress corrosion cracking is being observed.[11]

It is felt the initial belt cracking is a result of exposure to high temperatures and thermal cracking. However, once the material develops initial cracks, the “corrosive environment” continues the belt deterioration. This induced cracking is a result of tensile stress and a corrosive environment. Therefore it is important to control chlorides, hydroxides, and oxygen within the cast water system environment.

Wear components are typically changed out and replaced on timed cycles before failure occurs. Wheel and dam blocks are routinely reconditioned or cleaned by various methods including high pressure water, sandblasting, and wire brushes to remove carbon and hard water deposits.

Casting wheel/dam block and belt lubrication

While the importance of mold lubrication has evolved the lubricants themselves have changed little over the years.[8] The majority of wheel-band casters still use soot derived from burned acetylene gas combined with either air or oxygen for the wheel and belt coating. Most twin-belt casters use oil on the bands and a water-soluble graphite on the hot face of the dam blocks. Many use oil on the cold face of the dam blocks for reducing friction between blocks and dam block guide faces.

The lubricants act as a mold release agent to prevent copper adhesion to the wear components described and to protect the wear components from direct contact with the hot metal being cast. In reality, most lubricants act as a thermal barrier or insulator. The mold lubricants are typically sprayed on, resulting in significant over spray. The over spray reports to the caster water-cooling systems as a contaminate. It is estimated that small wheel-belt casters generate 5 cubic ft (26 Kg) per day or 10-tons (9300 Kg) per year of carbon soot that reports to the caster water system. Over spray can be as much as 50% of the total soot used. Applying an even uniform coating is critical yet very difficult to control thru the application with spray nozzles. In most cases application is more of an art than science. If the lubricant film is too thick it impedes heat transfer, if too thin damage to wear components or adhesion may result. Coating application is one of the most important parameters of the casting operation.

As information, acetylene soot is a pyrolytic product of rich acetylene and air or oxygen. Additionally, secondary pyrolysis occurs during each casting cycle when molten metal contacts with the soot layer. The amount and quality of the residues after secondary pyrolysis becomes an important factor in determining heat transfer rate during solidification.[8-9]

The most commonly used oil is a Ucon LB product containing alcohol started polymers of all oxypropyle groups and the water soluble graphite is a Dag 136 product being a colloidal suspension of graphite or amorphous carbon.

Potential concerns

Excessive Soot thickness will provide a thermal barrier to heat transfer and may contain moisture. The coating must be dried to prevent moisture carry-over.
Ucon LB is known to create more porosity in the cast bar then soot or graphite's. However, Ucon LB is a very good lubricant for reducing friction.
Dag 136 in excess may also provide a thermal barrier to heat transfer. Dirty and uneven surfaces on wheel, dam blocks and bands can cause an uneven cast bar section. Care must be used not to use lubricant materials containing ammonia, which may cause stress cracks in copper alloys including bronze dam blocks.

Soot and graphite over spray accumulates on the roofs of buildings and equipment and has been known to ignite resulting in safety concerns. All lubricant mold releases have some airborne residuals, which may be cause for health concerns and safety. The over spray residuals are also housekeeping and employee morale issues.

Optimization of solidification and mold life

Optimization of solidification and mold life during wheel-belt and twin belt casting of ETP copper is dependent on:

- Mold cooling
- Wheel & dam block materials
- Wheel diameter
- Water pressure & flows
- Casting speed (RPM)
- Superheat and mold lubrication

- Air gap between the bar and mold
- Surface overheating
- Water quality

Cast Bar & Rod Quality

It is felt the three most important parameters that determine cast bar quality and resulting rod quality is wheel/dam block/band cooling, impurity content of the metal and hydrogen content.[10] It is deemed critical to control and manage the mold release agent application, water quality and cleanliness and established standards to manage impurities. Mold contact to the solidifying cast bar is critical. Water pressures, flows, and temperature are important in maintaining wear component optimum temperatures. Basically, the intrinsic copper quality, minutiae of casting techniques and gas content of the metal determines cast bar and finished rod quality.

Wire Quality

Wheel, dam block and belt surface condition, thickness and uniformity of mold release agent, metal temperature, casting speed and cooling water are significant process variables that must be controlled to minimize the occurrence of centerline voids and resulting “cuppy wire or central burst” breaks during subsequent wire drawing. Uniform heat extraction is required for a homogenous microstructure.[12,13]

Typical cast water system layouts

Most SCR and Contirod processes have dedicated cooling towers and large settling pits to manage the casting water systems. These large systems may have water capacities of 40,000-60,000 gallons (151,416-227,124L).

Generally smaller capacity processes such as Properzi and Essex as well as the Encore Wire SCR process use a closed loop cooling process that uses heat exchangers cooled by a central process-cooling tower. These systems have water capacities of 5,000-8,000 gallons (18,927-30,283L).

Each system design has advantages and disadvantages. The dedicated cooling towers and large capacity pits allow for additional settling time for the water contaminates including soot, graphite and oils making turbidity easier to control until entire system becomes contaminated. The dedicated systems normally have more cooling capability than the closed loop systems.

The closed loop systems typically have lower operating costs including chemicals, water usage, and no caster cooling tower maintenance. Clean out and recharging of the system is easier.

Typical caster water treatment

Varying amounts of water discharge, referred to as blow down or purging is used to control water hardness and turbidity levels for these processes. Water quality is usually controlled as a function of conductivity and turbidity by nephelometric turbidity units or NTU readings.

Since soluble and insoluble copper is also introduced into the casting water systems from the casting process it also must be managed. Local municipalities usually regulate the amount of copper that can be discharged directly into municipal water systems.

In most cases the discharged water must be processed thru a water treatment plant or the copper levels must be significantly reduced prior to discharge.[15] This may require additional filtration and/or precipitation of the copper from the contaminated water stream.

In the late 1990's a casting wheel water treatment system was developed and introduced to SCR processes for enhancing casting wheel life. The treatment system is a combination of chemicals and procedures that are applied. The objective of the system is to keep the soot or carbon suspended in the water whereas it may more evenly coat the wheel mold cavity and the outside surfaces of the wheel. A proprietary polymer is used to disperse the soot. Developed procedures bring awareness of the importance of turbidity and water hardness. Water is continuously discharged or blown down to control turbidity and reduce total dissolved solids.

Prior Art Water treatment Program

This water treatment system has been used by the author and hence referred to as prior art. The system has proven to be an improvement over no water treatment or just blow down. It is not however very effective in removing copper or other tramp contaminates. Small casting systems require large amount of blow down in an effort to maintain turbidity in recommended ranges of 80-120 NTU. Clean out of settled carbon, sludge, and copper contained in water systems is required. The chemical and maintenance cost of the system are moderately expensive but offers an option for water treatment.

- New wheel surface etch treatment
- Chemical additions of polymer
- Turbidity control by water discharge
- Pre-startup wheel coating
- Sulfuric acid for hardness control
- Conductivity control by water discharge

The equipment and supplies includes treatment chemicals, feed pumps, colorimeter, conductivity meter, reagents, indicators and devices for measuring alkalinity, hardness and titration.

Water quality

Water quality of the caster water system is important to manage including total copper, alkalinity, conductivity, turbidity, temperature, total hardness, ph, silica, iron, sulfate, chlorides and bacteria.

Hardness minerals; calcium, magnesium, chlorides, carbonates and sulfates and non-hardness minerals including; sodium, potassium chlorides and sulfates will cause corrosion.

Chlorides, copper particulate, and low pH also accelerates copper uptake into solution, decreasing wettability and increases water surface tension which reduces water quench rate and overall cooling ability.

A number of rod mill facilities use stainless steel piping on the caster water system due to the corrosive environment.

The author has installed a reverse osmosis system to advert the problems associated with hard water as described above. The machine selected has proven to be durable, with simple installation and generates high quality water production.

Machine description

Reverse Osmosis Machine
GE Water & Process technologies
Model E4H-27K
Permeate Rate: 4.3 m3/h (18.8 gpm)
Concentrate Rate: 1.4 m3/h (6.3 gpm)

Reverse Osmosis Machine

Due to the extremely fine sub-micronic particulate size of the carbon material, it has been virtually impossible until now to remove it from the rinse water by conventional filtration methods including ultra filtration, which the author has tried. Shown in table 1 are water quality results and table 2 shows particulate size of carbon in the caster water before filtration.

	Before RO & Filtration	After RO & Filtration
Ph	8.0 ppm	8.0 ppm
Alkalinity	125 ppm	625 ppm
Hardness, total	169 ppm	32 ppm
Calcium total	155 ppm	30 ppm
Magnesium, total	14 ppm	2.0 ppm
Copper, Total	12 ppm	0.05 ppm
Iron, Total	14 ppm	0.08 ppm
Molybdenum	2 ppm	2 ppm
Phosphate, total	601 ppm	2 ppm
Chloride	224 ppm	14 ppm
Carbon, total	10 ppm	112 ppm
Turbidity	>400 NTU	<80 NTU
Oil/grease	140 ppm	ND

Table 1

Size Range	Count/100ml
2-5 micron	127,000,000
5-15 micron	97,500,000
15-25 micron	4,632,175
25-50 micron	699,545
50-100 micron	32,000
>100 micron	800

Table 2

State-of-the-art solution

After the earlier failure of using ultra-filtration to filter the contaminated caster water, Filtertech developed a proprietary separation chemistry product that enables the contaminates to be filtered out using a simple flatbed gravity filter. In April 2008 Encore Wire Corporation installed the new unit.

The separation chemistry coagulates and flocculates the sub-micronic particles into a stable floc. Once formed, the floc is removed with a High Performance Deep Bed Gravity Filter as shown in Figure 1. The process with special features uses a coagulant/flocculating agent, which is not sensitive to overdosing or chemical instability but is consistently repeatable. The very small percentage of flocking agents used is removed with the accumulated solids via the filter media. The filter cake improves filtrate clarity through depth filtration as shown in figure 2. The clean caster water is virtually free of carbon and oil contaminates as shown in figure 3. The separations chemistry's main function is to reduce turbidity.

Fig. 1

Fig. 2

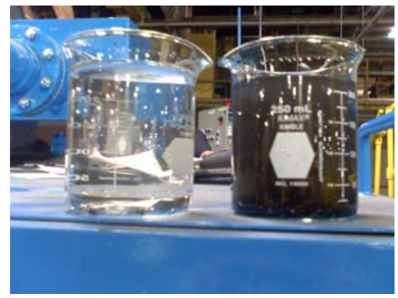

Fig. 3

Equipment description

Caster water filtration system
Filtertech Model HGF4-1000
50 gpm high performance gravity filter
304 stainless steel material
One 250 gallon mixing tank
One 250 gallon floc tank
51 inch filter media
Filter tank length approx. 10 feet (290)
Width 6'7" (173)
Height 3'11" (119)

Process overview

The dirty caster water is pumped on a controlled bypass basis from the caster water pit or reservoir tank by the caster feed pump to a mixing tank that is specifically sized and designed for the flow rate to be treated. The separation chemistry is then added to the caster water in the mixing tank by way of a volumetric solids feeder and is stored in a bulk solids hopper requiring only periodic replenishing. The feeder utilizes a variable speed drive that can adjust the feed rate of the separation chemistry to coincide with changes in flow rate of caster water to the system. During the mixing process, the chemistry becomes hydrated, and its long chain molecule is unraveled. The sub-micronic articulates become entrapped in the molecule to form a much larger floc particle, which is removed through efficient gravity bed filtration. Specially designed mixers are used to minimize size reduction on the developing floc particles. Once completely mixed the caster water overflows by gravity intothe Model HGF "High Performance" Deep Bed Gravity Filter. As the caster water passes through the filter, the flocked solids are removed by the disposable filter media, thus allowing only the clean water to drain by gravity back to the reservoir tank for reuse.

The Model HGF Deep Bed Gravity Filter has specific features for the application which include the following:

• Deep operating bed with extended liquid pool for increased pressure drop across the media.
• Multi-function media index assembly.
• Low velocity internal and external inlet header to enhance separation of chemistry prior to entering the filter.
• Extended discharge ramp to enhance drying of filter “cake” prior to discharge.
• Fully-automatic media indexing and low media sensor.
• Positive filter side seals.

The cost of operation of this treatment system consists of the chemistry, filter media, electricity and very minimal manpower requirements including changing the filter media and filling the feeder.

Benefits

- Employee health & safety enhanced
- Zero cast water discharge
- Enhanced bar & rod quality
- Reduced piping, equipment, and material corrosion
- Reduced maintenance costs
- Reduced operating costs
- Increased rod production
- Allows for carbon, oil mist and stream removal
- Enhanced employee morale and housekeeping

Improvement data

	Before	After
Cast wheels (pounds)	13,868,069	36,613,756
Bands (hours)	45	81
Heat exchanger cleaning	Monthly	Annually
Hi-pressure pump rebuild	Quarterly	9-months
Multiwire breaks	Base 26 awg	18% reduction
Caster blow-down	25 gpm	Zero discharge
Turbidity	>400 NTU	<80 NTU
Hollow cast bars	Base	75% reduction
Production increase	Base	5%

12-months of operating data

It is expected that other casting systems results may differ from Encore Wire due to system layouts and operating practices. The somewhat low casting wheel life is a result of Encore Wire pushing system capacity well beyond design capacity yet wheel life has still almost tripled.

As expected, wheel reconditioning costs including sandblasting, and machining has also been reduced significantly. Production increase is a result of less downtime associated with change out of wear components and ability to run at higher casting speed longer.

Conclusions

With good water chemistry and filtration of the caster water, significant improvements can be realized in rod quality, operating costs, production, safety, housekeeping, morale and the environment. Zero discharge of caster water can be attained.

The filtration concept discussed herein has potential for many other uses including process cooling towers, wastewater, pickling system rinse water, as well as other casting processes including aluminum.

The ability to direct steam, oils, mist, fumes, soot, and other carbon contaminates away from the casting area to the caster water for clarification has great potential for all the rod casting systems discussed.

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