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Modern secondary cooling technology in continuous casting of steel

R. Boyle, J. Frick

Continuous casting machines are now required to cast a wide range of steel grades while maximising production output. Consistent production of prime quality product requires increased operational and maintenance flexibility of the caster so that the optimum casting parameters can be maintained for each steel grade. This flexibility extends not only to the machine elements and control systems, but also to the secondary cooling system and demands more efficient and reliable spray cooling. Attentive design of secondary cooling systems, through cooling zone positioning, nozzle layout, nozzle selection and the use of appropriate secondary cooling control systems can provide these requirements. Minimum down time for maintenance is a key factor in maximising caster production; the use of the latest piping header systems and nozzle mounting arrangements can contribute to minimum secondary cooling maintenance. These header systems provide a rigid and self-aligning mounting for the nozzle, ensuring both nozzle alignment and maintenance accessibility.

Key words: secondary cooling, air mist nozzle, water distribution, vertical piping design

INTRODUCTION

Continuous casting machines are now required to cast a wide range of steel grades, in particular slab casters must cast steels ranging from ULC and low carbon grades to high carbon and high quality pipeline grades. This must be achieved while maximising production output. Consistent production of prime quality product requires increased operational and maintenance flexibility of the caster so that the optimum casting parameters can be maintained for each steel grade. This flexibility extends not only to the machine elements and control systems, but also to the secondary cooling system and demands more efficient and reliable spray cooling. Of particular concern when designing a secondary cooling system are:

- Steel grades to be cast and their casting speeds.
- The roll support geometry and machine segment layout.
- Ease of maintenance.
- Secondary cooling control systems.

This paper focuses on the design of a secondary cooling system that uses the latest nozzle technology to fulfil the production requirements of today's casters. Unlike in the early days, the layout of the secondary spray cooling system is one of the first steps when a new continuous casting machine is designed, or when an existing machine undergoes a major revamp.

NOZZLE LAYOUT

A good nozzle layout is paramount in fulfilling the operational and production requirements. It is essential that nozzle arrangements produce an even heat removal across the strand while maintaining a stable spray pattern. Spray collision with support rolls should be avoided as this will result in inefficient use of spray water and a reduction in heat tran-

Fig. 1 – Staggered nozzle arrangement.

Fig. 1 – Disposizione sfalsata degli ugelli.

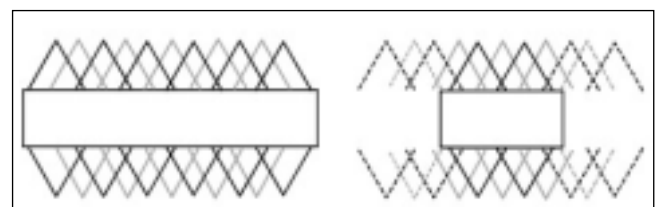
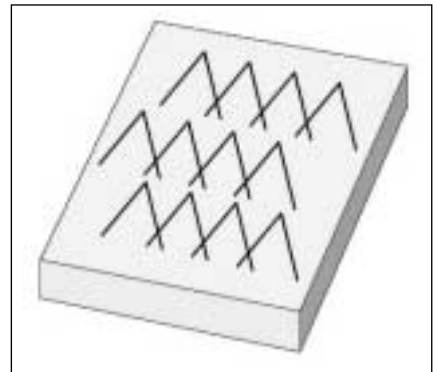


Fig. 2 – Spray width control – alternating nozzles.

Fig. 2 – Controllo della larghezza dello spray – ugelli alternati.

sfer. Generally multi-nozzle layouts should be the preferred arrangement. In the final area of solidification of non critical steel grades, typically the horizontal section of curved casters, it is possible to reduce the number of nozzles in a roll gap to one or two as this is a less critical area for solidification. The staggering of nozzle pairs in consecutive roll gaps, see Figure 1 will ensure even surface temperatures.

Spray width control can be achieved with a multi-nozzle configuration. In a multi-nozzle arrangement the outermost nozzles are systematically turned off in relation to the strand width as shown in Figure 2 where a nozzle layout which alternates the number of nozzles in consecutive roll gaps can be used. If a more finer control is required then an inline arrangement as shown in Figure 3 can be used.

Heat removal from the strand is not only a function of spray cooling; other mechanisms are also prevalent, for example heat removal by the support rolls. Heat removed by rolls can have a significant effect on the strand surface temperature

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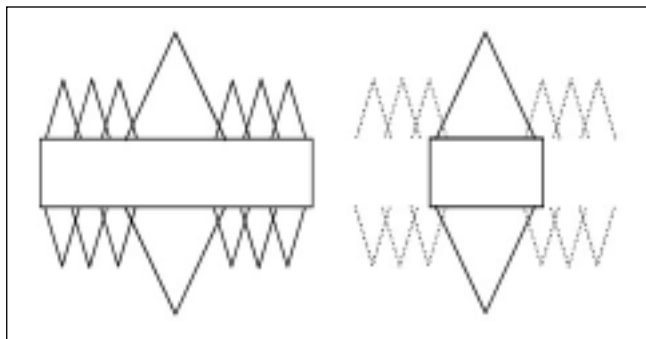


Fig. 3 – Spray width control-inline nozzles.

Fig. 3 – Controllo della larghezza dello spray – ugelli allineati.

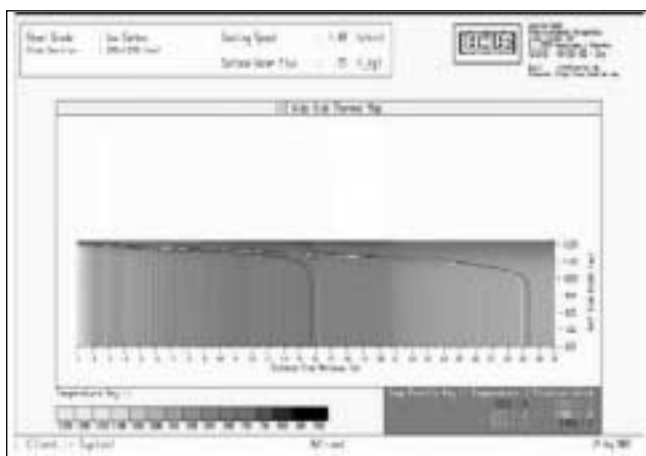


Fig. 4 – Even heat removal by rolls and sprays.

Fig. 4 – Eliminazione omogenea del calore mediante rulli e spray.

and strand solidification conditions. If the heat removed by rolls is considered even across the strand width together with even heat removal by the sprays then ideal solidification conditions as shown in Figure 4 should exist.

NOZZLE SELECTION

Nozzle selection can only occur after derivation of the solidification profiles, the cooling zone layout and the nozzle layout. The heat extraction required to achieve the solidification profiles is converted into cooling zone water flows using nozzle heat transfer coefficients. The specific nozzle flows can then be derived from the maximum water flow associated with each cooling zone. Prior to final nozzle selection, operational factors must be considered, these factors include:

- Spray water temperature compensation factor – heat extraction capability reduces with increasing water temperature, see Figure 5 and can lead to both operational and quality problems. Typically this factor would be applied during hot summer periods.
- Increased flow rate on the outer radius – this is used to equalise cooling on both the inner and outer strand faces by compensating for the gravitational effect on the outer radius.
- Safety factors – any allowance above the calculated water flows.

It is important for today's caster designers to have access to nozzles which have high turndown (control range, min./max. water flow) capabilities for not only operational reasons but also to minimise the nozzle varieties in one particular machine. Both maintenance and inventory managers ap-

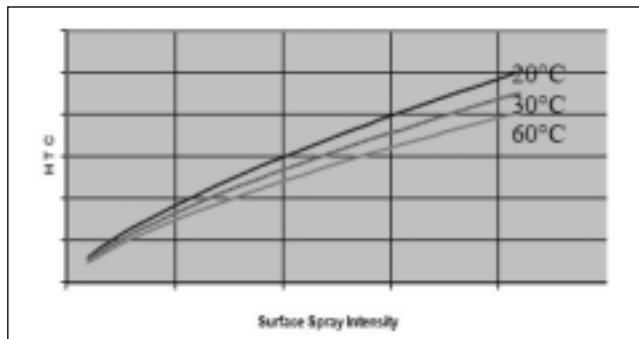


Fig. 5 – Effect of spray water temperature on HTC.

Fig. 5 – Effetto della temperatura dell'acqua dello spray.

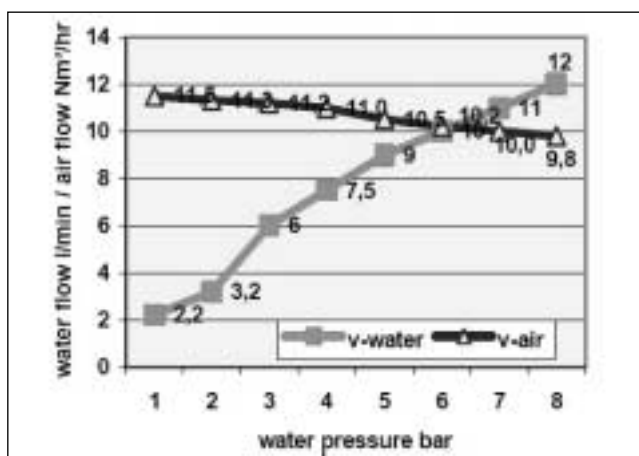


Fig. 6 – Pressure flow diagram of Mastercooler air mist nozzles.

Fig. 6 – Diagramma di flusso degli ugelli per la nebulizzazione d'aria Mastercooler.

preciate this effort. Latest achievements in air mist nozzle research and development are now providing designs with turn down ratios wider than ever before and with lower air consumption. The flow diagram in Figure 6 of a Lechler Mastercooler air mist nozzle shows that a turn down ratio of more than 1:20 at a constant air pressure of 2.5(bar) is not impossible between water pressures of 0.5(bar) and 7(bar).

NOZZLE DESIGN

Within the last 5 years the vertical segment piping developed for the Lechler Mastercooler air mist nozzles with vertical square header pipes has almost become an industry standard design. The air mist nozzles now equipped with plates are bolted vertically onto adapter plates as shown in Figure 9. Once the secondary cooling system layout is completed and the mechanical design of the segments is known, it is the spray nozzle manufacturers task to design nozzles which provide a uniform water distribution across the strand surface and over the entire turn down ratio. Tolerances of $\pm 15\%$ from the mean value can be achieved with a multi nozzle arrangement at water pressures between 1.0 and 7.0 bar. Figure 7 shows the water distribution measurements of a twin nozzle arrangement. The nozzle pitch is 400(mm), the spray height 200(mm), and the air pressure 2(bar) constant and 7(bar) water pressure. All nozzles are mounted outside of the framework at the rear side of the segment with only the nozzle pipe, carrying the spray tip, extending down to the spray position. A very rigid header pipe giving a nozzle self-alignment is the result; the nozzle spray position is always secured. A "Hose less" fluid supply system becomes a standard. Frequent replacement of many expensive water and air hoses is no longer required.

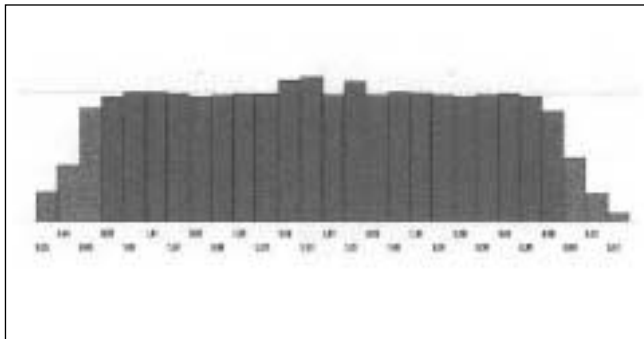


Fig. 7 – Uniform water distribution measurement.

Fig. 7 – Misura della distribuzione uniforme dell'acqua.

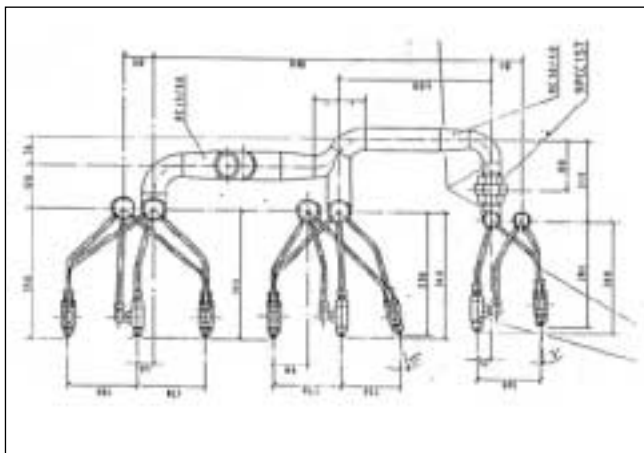


Fig. 8 – Header manifold old design with many small feed pipes.

Fig. 8 – Vecchio tipo di collettore con molti piccoli tubi di alimentazione.

MAINTENANCE

Because of their internal mixture, air mist nozzles require two separate feed pipes for compressed air and water. Until recently small diameter pipes were used to feed both the fluids and to hold the nozzles in place. Only in special cases, where one fluid was fed directly by a hose, additional supports were provided. Nozzle staggering between the roller gaps within one segment becomes much easier since different nozzle positions can be served from only one header pipe manifold, see Figure 10. The conventional air mist nozzles mounted on these small pipes are hidden inside the segment framework as shown in Figure 8.

Having the nozzles mounted so close to the strand makes maintenance (cleaning or adjustment) impossible unless the segment is removed from the machine. In the case of a break out nozzles must be completely replaced, which is very costly. Strand surface defects can often be traced back to misaligned spray nozzles. Header pipes such as shown are one source of such misalignments. The many small air and water pipes are often out of position due to mechanical impact or thermal reasons. The large number of small, individually bent pipes, are also expensive to manufacture. The nozzles and header pipes with the vertical plate connection are also an ideal solution for beam blank casters with air mist cooling. Instead of a complex manifold only two square header pipes with two nozzles bolted on, are required. The advantages described above are also true here. The bends of the nozzle extension pipes can be made to suit. With the aid of the "Split pipe" design the two nozzles on either side (Pos. 1 and 2 of Figure 11) can be identical with the front pipe turned by 180°, hence one nozzle type can serve both positions in one gap.

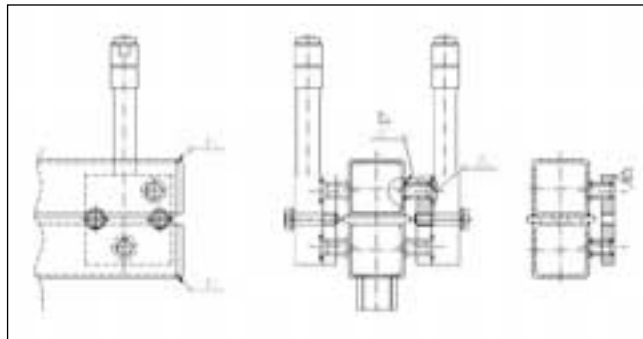


Fig. 9 – Mastercooler mounted on vertical plate and square pipe manifold.

Fig. 9 – Mastercooler montato su collettore con piastra verticale e square pipe.

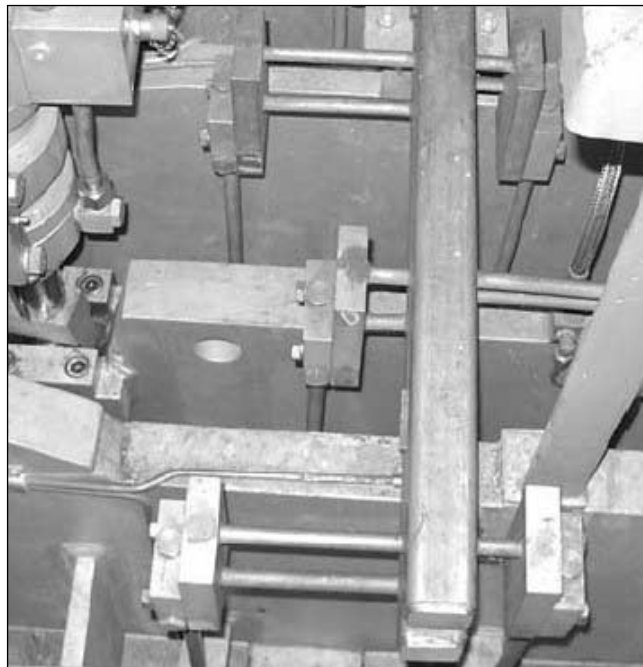


Fig. 10 – Staggered Mastercooler nozzles served from one pipe manifold.

Fig. 10 – Ugelli Mastercooler con disposizione sfalsata serviti da un collettore a tubo singolo.

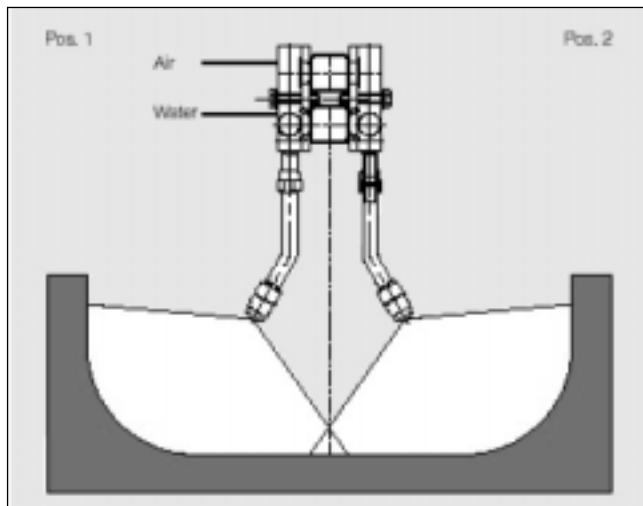


Fig. 11 – Mastercoolers installed in a beam blank caster.

Fig. 11 – Mastercoolers installato in un impianto di colata di bramme.



Fig. 12 – The new Lechler Billetcooler full cone air mist nozzle.

Fig. 12 – Il nuovo ugello nebulizzatore conico Billetcooler Lechler.

NEW AIR MIST NOZZLES FOR BILLET AND BLOOM CASTING

When air mist cooling becomes necessary for a billet or bloom caster, flat jet nozzles may not always be the best choice. This is especially true where the formation of Halfway Cracks may be experienced. This type of crack has been shown to be caused by reheating of the strand surface after it has passed the sharp heat extraction zone beneath a spray jet. During this reheating process the surface expands and imposes a tensile strain on the hotter and weaker inner material, which can then crack. The use of flat jet nozzles intensifies this effect. Full cone nozzles or oval cones provide a softer cooling by extracting heat over an extended surface area. These two spray patterns are the standard for single fluid water secondary cooling systems, however there has not been an adequate version using air mist. Common full cone air mist nozzles show unstable spray performances, very high air consumptions and a tendency to clog very easily. Oval cone air mist nozzles are often flat jet nozzles with multi slot orifices. Non uniform spray patterns and the

very narrow easy to clog slots, made these nozzles barely more than a compromise. With the new Lechler Billetcooler Figure 12, a new generation of full and oval cone air mist nozzles it is now possible to utilise air mist cooling in billet and bloom casters as effectively as in slab casters. The compact block design allows mounting both on horizontal spray bars and on vertical “Banana” nozzle headers, Turn down ratios as wide as 1:14 have been achieved at water pressures between 1.0 and 10.0(bar) at 2(bar) air constant. Nominal spray angles for circular full cone nozzles range between 60° and 90°. Free passages with 2.0mm in diameter are approximately three times larger than before for a nozzle size with flows ranging from 0,5(l/min) at 1(bar) water pressure and 5.0(l/min) at 7(bar) water pressure at a constant 2(bar) air pressure. Extremely critical cooling problems have successfully been solved in a 5-strand bloom machine casting more than 250 steel grades and also critical stainless steel rounds.

CONCLUSION

The benefits for the user but also for the machine designer described in this paper are well established facts. The most important of them are: o Reduced incidence of surface defects and crack formation o Reduced maintenance and operation costs o Improvement of operation safety o Enlargement of caster product mix o Increased caster production The modern air mist nozzle and header pipe technology can be incorporated into new machines as well as into existing casters for billets, blooms, beam blanks, slabs and thin slabs.

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A B S T R A C T

TECNOLOGIA MODERNA DI RAFFREDDAMENTO SECONDARIO NELLA COLATA CONTINUA DELL'ACCIAIO

PAROLE CHIAVE:
processi, acciaio, colata continua

Gli attuali impianti di colata continua devono essere in grado di fondere un'ampia gamma di tenori di acciaio, massimizzando nel contempo la capacità produttiva. Una produzione efficiente di prodotti di prima qualità necessita una maggiore flessibilità operativa e una maggiore manutenzione in modo da mantenere parametri di colata ottimali per tutti i tipi di acciaio. Questa flessibilità non riguarda solo agli elementi dell'impianto e ai sistemi di controllo, ma si estende anche ai sistemi di raffreddamento secondario e ri-

chiede un raffreddamento spray più efficiente e affidabile. Un'attenta progettazione dei sistemi di raffreddamento secondario, che includa il posizionamento della zona di raffreddamento, la disposizione e selezione degli ugelli, come pure l'impiego di adeguati sistemi di controllo del raffreddamento secondario possono soddisfare queste necessità. La riduzione al minimo dei tempi morti per la manutenzione rappresenta un fattore chiave nella massimizzazione della produzione; l'utilizzo dei più innovativi sistemi di collettori e la disposizione degli ugelli possono contribuire a minimizzare la manutenzione dell'impianto di raffreddamento secondario. Questi sistemi di collettori prevedono un assemblaggio rigido e auto-allineante dell'ugello, che ne assicura sia l'allineamento che l'accessibilità ai fini della manutenzione.