Important design parameters and user-friendly features of modern air mist nozzles for slab- and beam blank casters

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The demand for improved product quality and increased productivity has focussed attention on the need for more efficient spray nozzle systems for secondary cooling. Nozzle characteristics must be investigated and test procedures developed to measure cooling patterns and heat transfer. Improved nozzle design and air/water systems provide better water distribution and this reduces surface defects, corner cracking and core segregation. There are also important operational benefits which enable expansion in the product mix and production capacity.

Of particular concern are :

- Nozzle type selection according to the product mix and machine design
- Heat transfer coefficient measurements of the spray nozzles
- Air-water ratio
- Water turn-down ratio
- Water distribution
- New methods of nozzle mounting and new header pipe designs
- Nozzle maintenance and modular component system
- Beam Blank Casters

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NOZZLE SELECTION ACCORDING TO MACHINE DESIGN AND PRODUCT MIX

A defect free slab, bloom or beam blank and an economical operation are the objectives to be achieved by the spray nozzle cooling system. The nozzle manufacturer must have detailed knowledge of the behaviour of the nozzles under operation conditions and the machine segment design.

SPRAY NOZZLE HEAT TRANSFER COEFFICIENT (HTCs) MEASUREMENTS

In order to select the correct spray nozzles for every machine position the HTCs of the spray nozzles have to be measured. One method to measure the HTCs of spray nozzles is the 'moving nozzles' test which is shown in Figure 1. A steel plate with 24 thermocouples, embedded at a depth of 2.5 mm, is heated to a temperature of, for example, 1200°C in an atmosphere of inert gas.

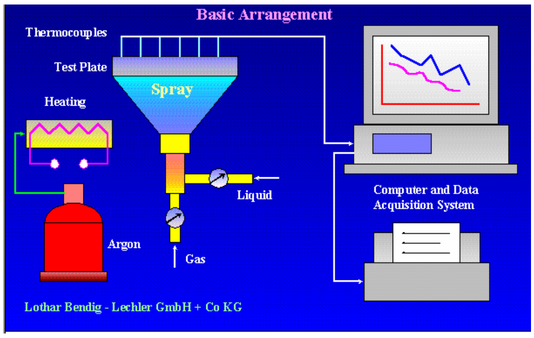

Fig.1: Scheme of the "Moving Nozzle" HTC measuring facility

The top surface of the plate is isolated whereas the bottom side is cooled by the nozzle to be tested. The nozzle in the manifold is placed in a movable arm so that the nozzle moves parallel to the plate by means of a computer controlled electric motor.
To simulate movement of the strand from one roller gap to another, the computer actuates the removal of a deflector plate in order to start the cooling process. The nozzle then moves from left to right with the deflector open and then in the opposite direction with the deflector closed.

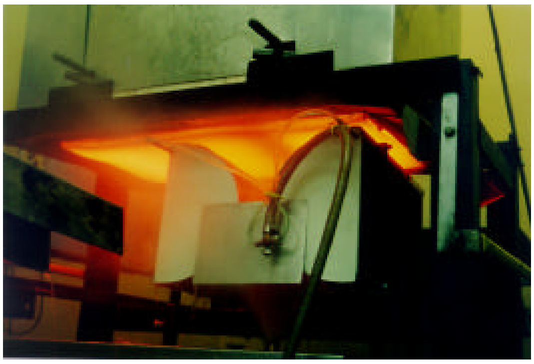

Fig. 2: "Moving Nozzle" HTC measurement facility

The dark strip on the hot plate shown in Figure 2 is the area where the spray impinges from the bottom side. The temperature of the water and the plate are measured simultaneously until the plate attains the same temperature as that of the water. The temperature history records and information on the nozzle position in relation to the plate are stored in a data logger. These data are then used as for evaluating the heat transfer conditions and for computation of HTCs. The HTC values are vital input data into thermo mechanical models which are used for the layout of secondary cooling systems.

AIR-WATER RATIO

A higher water flow is not the only factor decisive for the heat transfer coefficient. The nozzle spray angle and spray height are playing an important role, too. Both determine the spray foot print (width and depth of spray) and are therefore, factors of the water jet density (water flux) and the jet impact. Besides these two variables the ratio between the compressed air volume and the water flow must be considered as another important factor. Spray cooling on the strand involves boiling and the formation of a steam layer on top of the steel surface. The compressed air is providing the kinetic energy necessary for penetration of the droplets through this steam layer.

Modern air mist nozzle designs also help to reduce investment and operation costs in connection with the compressed air control system instrumentation and the consumption of compressed air. The very high volumes of expensive compressed air consumed by early generations of air mist nozzles are no longer acceptable.
This high air consumption was the reason for controlling the air pressure versus the water flow in continuous casting machines of some makers. In same of these machines the air pressure is reduced, at low water flows / pressures for slow casting speeds, to only 1 bar. However, air pressure control reduces the nozzles turn down ratio because of the common internal mixture of both water and compressed air.
For variable air pressure control system programming a new user-friendly flow diagram has been established which visualises the air-water ratio more easily, Figure 3.

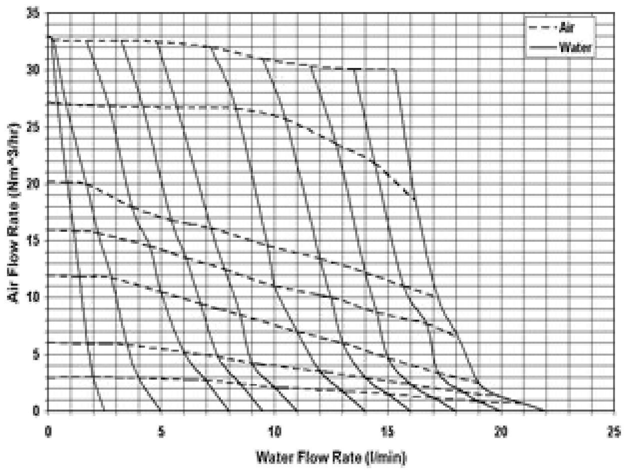

Fig. 3: New air-water flow diagram. Water pressure vertical solid curves, air pressures horizontal dotted curves

On the other hand, recent machine installations in Europe, the US and in Asia by leading plant manufacturers utilise air mist nozzles operating at constant air pressure with a reduced air consumption over the entire turn down ratio, but still maintaining the necessary air-water ratio at the maximum water pressure / flow and casting speed, Figure 4..

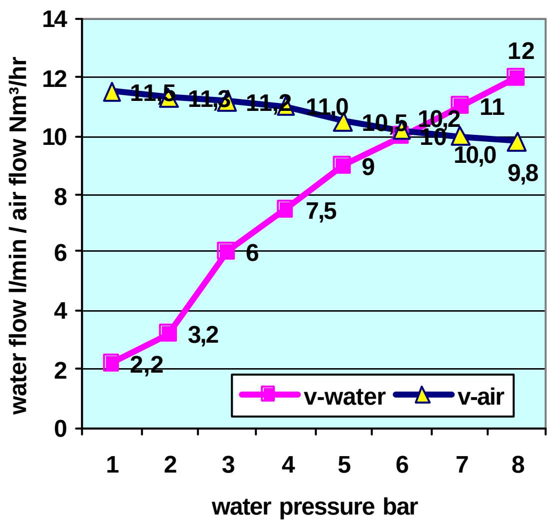

Fig. 4: Air-water flow diagram MasterCooler, p-water 0,5bars to 7,0 bars, p-air 2,0bars constant

WATER TURN DOWN RATIO

Variations in casting speeds as a result of normal operation practises such as start-up, ladle or tundish changes and because of the product mix (different steel grades and strand dimensions cast) require a certain turn down ratio of the spray nozzles. It defines the range between the minimum and maximum water flow rate over a certain water pressure range. It is also important to state the air pressure(s) and if it is constant or variable. It is desired to have air mist nozzles with a wide turn down ratio in order to keep the nozzle varieties in one particular machine at a minimum. Both maintenance and inventory managers appreciate this effort.

Latest achievements in air mist nozzle research and development are now providing designs with turn down ratios wider than ever before with a lower air consumption. The flow diagram in Figure 5 of nozzle type 1PM.013.16.17 also shows that a turn down ratio of 1:23 at a constant air pressure of 2,5bars is not impossible between water pressures of 0,5bars and 7bars. This turn down ratio is approximately 2 to 3 times wider compared with common nozzle designs.

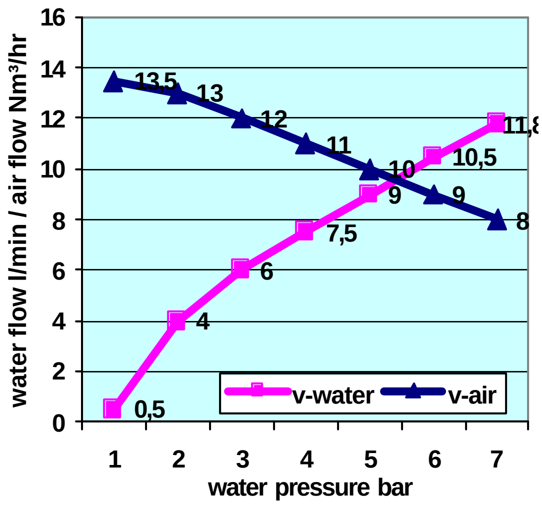

Fig.5: Nozzle type 1PM.013.16.17, p-water 0,5 to 7bars, p-air 2,5bars constant

WATER DIS TRIBUTION

Once the secondary cooling system layout is completed and the mechanical design of the segments is known, it is the spray nozzle manufactures task to design nozzles providing an uniform water distribution across the strand surface and over the entire turn down ratio. Tolerances of +/- 15% from the mean value can be achieved with a multi nozzle arrangement at water pressures between 1,0 and 7,0 bars.

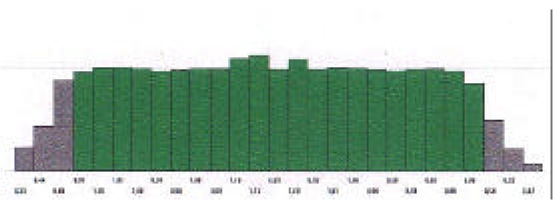

Fig.6: Water distribution of a twin nozzle arrangement, pitch 400mm, height 200mm,

Figures 6 shows a water distribution measurement of a twin nozzle arrangement. The nozzle pitch is 400mm, the spray height 200mm, at an air pressure of 2bars constant. This excellent quality of distribution can be maintained between 1bar and 7bar water pressure. The maximum difference is 13,9% over and 11,2% below the mean value. The spray width stays constant at 1300mm which is another achievement of modern air mist nozzles technology.

In order to widen the turn down ratio it is common to apply a minimum water pressure of 0,5bar. At such a low pressure however, the spray widths of the two nozzles is reduced resulting in a lower water density in the overlap area. The difference in water distribution can drop as much as 50% below the mean value. This disturbing fact led to further HTC measurements focussing on the overlap area at low water pressures. The sprays were directed in one line at 0° offset angle.

The measurement performed with two air mist nozzles (nozzle axis at Z positions 0 and 400mm), at 0,5bars water pressure and 2bars air pressure, confirmed a low overall HTC but showed a surprisingly little drop of the HTC in the overlap area (Z position 200mm), Figure 7. Hence, surface defects in the overlap area are neither to expected nor experienced in existing installations.

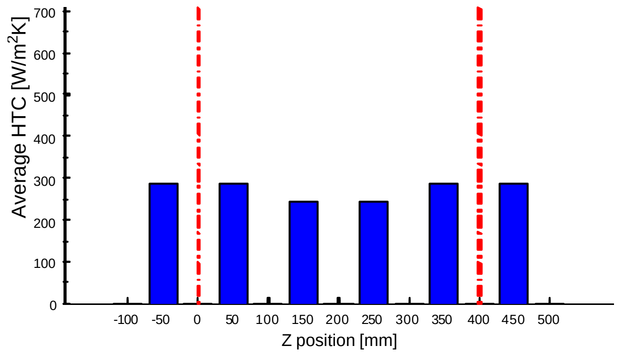

Fig. 7: HTC measurement 2 MasterCooler Nozzles, p-water 0,5bars, p-air 2,0 bars constant, pitch=400mm, spray height=200mm

Tight water distribution tolerances help to minimize transverse and corner cracks. Because of the convergence of the spray and the effect which the air-water ratio has on the spray jet, their nominal spray angles can no longer be the only design criteria for a multi nozzle arrangement. It is the spray nozzle manufacturer who shall be responsible for the uniformity of the water distribution across the strand width over the entire turn down ration. Tolerances must be specified for every machine because of the different boundary conditions.

NEW METHODS OF NOZZLE MOUNTING AND HEADER PIPE DESIGNS

Because of their internal mixture, air mist nozzles require two separate feed pipes for compressed air and water. Until recently small diameter hydraulic pipes were used to feed 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.

The conventional air mist nozzles mounted on these small pipes are hidden inside the segment frame work as shown in Figure 8.

Fig. 8: Air mist nozzles fed and installed by means of small and long hydraulic pipes

Having the nozzles mounted so close to the strand makes maintenance (cleaning or adjustment) impossible unless the segment is removed from the machine. Moreover, in case of a break out nozzles must be replaced completely which is very costly.

Strand surface defects can often be traced back to misaligned spray nozzles. Header pipes such as shown in Figure 8 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.

Within the last 2 years the vertical segment piping with square air and water main header pipes almost became an industry standard design. The air mist nozzles now equipped with plates are bolted vertically onto adaptor plates, Figure 9.

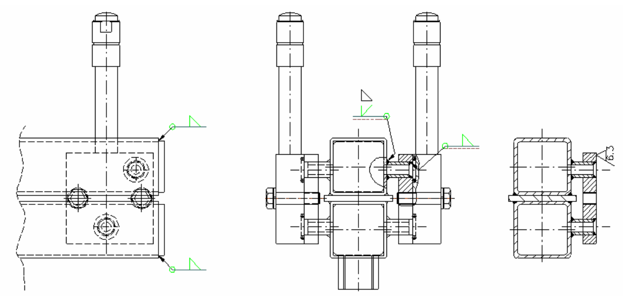

Fig.9: Lecher Master Cooler SMART Air mist nozzle with vertical plate connection and square pipe header manifold

Small diameter fluid feed pipes are no longer necessary. All nozzles are mounted outside of the framework at the rear side of the segment with only the nozzle pipe, carrying the spray tip, reaching down to the spray position. A very rigid header pipe and a nozzle self alignment is the result. The nozzle spray position is always secured. A “Hoseless” fluid supply system becomes also possible, Fig. 10.

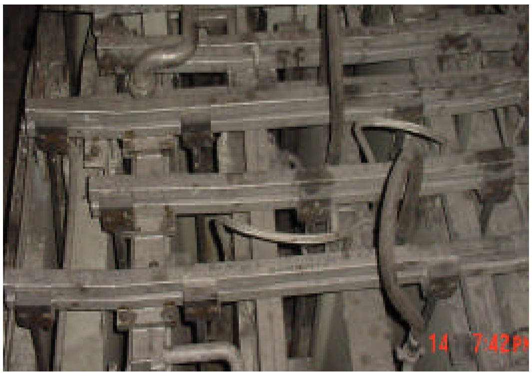

Fig . 10: Square pipe headers carrying Master Cooler SMART type air mist nozzles at HKM/Germany SMS-Demag 2-strand slab caster

Nozzle maintenance and modular component system

Having the air mist nozzles mounted very close to the strand makes maintenance (cleaning or adjustment) impossible unless the segment is removed from the machine. Air mist nozzle bodies are sometimes also difficult to clean because of their internal geometries.
Modern slab casters having “Edge/margin Control” often require bent nozzle extension pipes. This leads to a very large number of different tailor made nozzles varieties which must be kept in stock as spares. Moreover, in case of a break out nozzles must be replaced completely which is very costly. New nozzle designs utilizing the modular concept with the cartridge mixing chamber and the split pipe provide solutions for this problem.

The mixing chamber for air and water is no longer machined directly into the nozzle body but has been integrated into a new component which is the cartridge.
Since the cartridge can be removed form the nozzle block “On Line Maintenance” for cleaning can be carried out where the nozzles are accessible inside the cooling chamber Figs. 11 & 12.

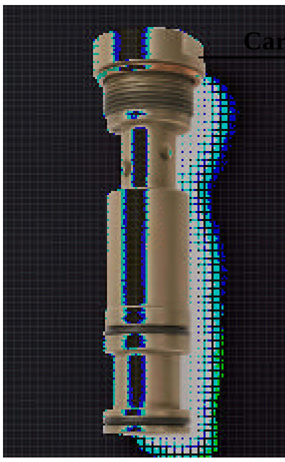

Fig. 11: Cartridge

Fig 12 : MasterCoolerSMART Cartridge complete nozzle

The “Split Pipe” version allowing to separate the front part carrying the nozzle tip and nut from the body, is a standard feature of the new Master Cooler SMART Cartridge. A “Modular” component handling system becomes possible. Except the nozzle tip and the extension pipe all components are standard items quickly available. Reduced costs for spare parts stocking is the positive effect.
The nozzle’s body together with the remaining part of the pipe can be retained. A self aligning design identical to the one of the nozzle tip also secures the correct spray direction at the joint between the body and the extension pipe Fig.13.

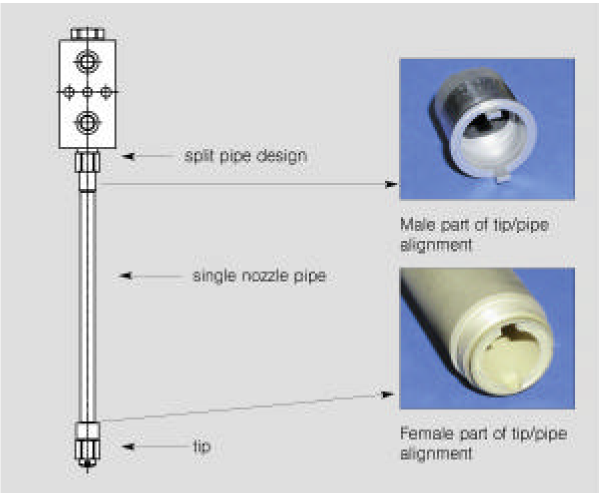

Fig. 13: MasterCooler SMART Cartridge tip and pipe self alignment

At both the Master Cooler SMART and Master Cooler SMART Cartridge the mixture of compressed air and water takes place away from the hot zone inside the mixing chamber which is an internal part of the nozzle body . The nozzle body is bolted onto the mounting plate of the square pipe headers. Hence, only one single nozzle pipe, exempt of any restrictions, supplies the premixed fluids to the nozzle tip.

Beam Blank Casters

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 three header pipes, small specially bent fluid feed pipes and a fluid distributor, 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 can be identical with the front pipe turned by 180°, Figure 14.

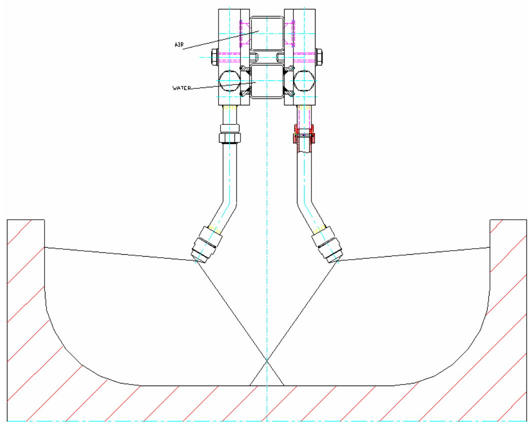

Fig. 14: MasterCooler SMART twin arrangement with vertical plate connection for beam blank cooling

Summary

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:

- Reduced incidence of surface defects and crack formation
- Reduced maintenance and operation costs
- Improvement of operation safety
- Enlargement of caster product mix

The modern air mist nozzle and header pipe technology can be incorporated into new machines as well as into existing casters for blooms, beam blanks, slabs and thin slabs.

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