More efficient hydraulic descaling header designs

The demand for improved product quality and increased productivity has drawn the attention of mill operators and plant engineers to more efficient hydraulic descaling systems. Nozzle characteristics have been investigated and test procedures developed to measure spray patterns and impact. Improved nozzle characteristics and an optimized spray header design result in higher efficiency of the complete system. When designing a descaling header, other important operational benefits are kept in mind, for example, energy savings and improved product quality. The nozzle manufacturer must have detailed knowledge of the nozzle performance under operating conditions and of the system design.

Figure 1.
Scalemaster HP (high performance) with optimised internal flow geometry

Nozzle spray characteristics

Spray angle. Hydraulic descaling nozzles (figure 1) are normally flat (jet) spray nozzles. The exact definition of the spray characteristics (figure 2), such as spray angle, spray thickness and impact distribution, and the specification of the operation parameters are the first two steps to be taken when a spray nozzle is being designed. The standardization of descaling nozzles based on the nominal spray angle was introduced many years ago and has proved to be advantageous with regard to header design flexibility and product availability. Four spray angles describing the width of the spray are now very common. These are 22°, 26°, 30° and 40° nozzle tips, each available in 13 standard flow sizes. In order to achieve the above mentioned design flexibility, the spray width is identical for all nozzle tip sizes at identical pressures and spray heights.

Spray thickness. The spray thickness (also often called spray depth) describes the width in the minor axis of the spray. The technical evolution of descaling nozzles reduced the spray depth by almost 50 % compared with earlier designs. In modern installations with spray heights around 80 mm spray depths range between 3 and 4 mm only (figure 3).

The impact distribution over the spray width and thickness can be precisely measured and documented. This is essential for the design not only of the nozzles but also for a nozzle arrangement on a header.

Variables of impact

The impact created by the water jet on the target surface is the predominant factor for effective descaling. As per definition the impact is to be calculated as the quotient of the force F (in Newton) and the area A (in mm^2) over which the force is applied: impact = F/A.

Area of impact. Having selected a particular nozzle type (size and spray angle) the force depends only on the water pressure and the water flow. If the water pressure is fixed and limited as in many existing installations, the only variable to play with is the area of impact. As the equation for the impact suggests, the smaller the area the higher the impact is. Spray angle and spray thickness are the two nozzle design parameters affecting the area of impact.

The spray thickness depends on the quality of the internal design of all spray nozzle components. Recent

Jürgen W. Frick, Director International Primary Metals Division, **Lechler GmbH**, Metzingen, Germany.

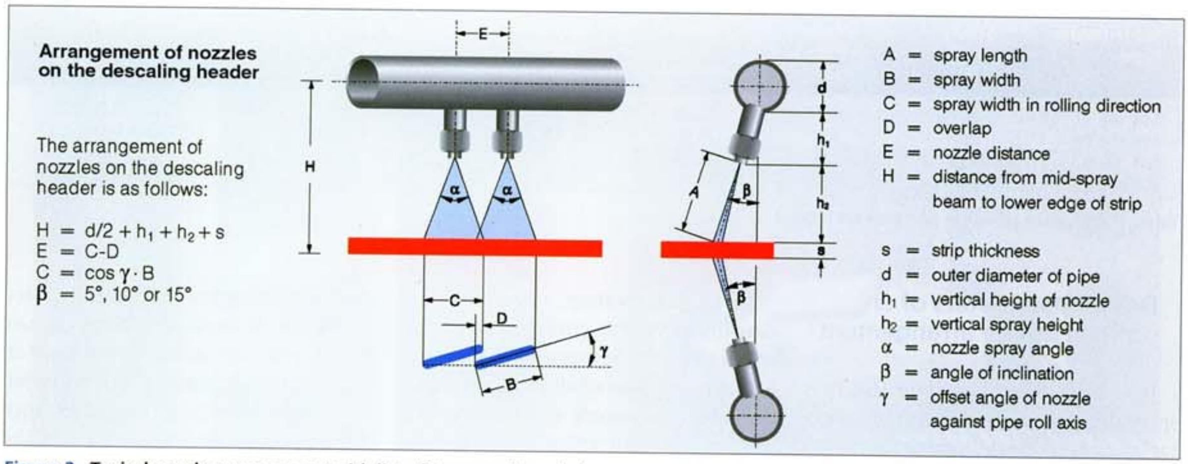

Figure 2. Typical nozzle arrangement with list of terms and symbols

developments have led to a further reduction in spray depth by improving the geometry of the internal water flow zone and reducing the stabilizer wing thickness **(figure 1)**, the result being a more laminar water flow providing a sharper spray jet with a higher impact.

Spray height. The spray height plays an important role as it has a direct effect on the spray width, and hence on the area of impact. Due to the typical convergence of each spray jet it is unfortunately not possible to apply a simple trigonometrical equation to describe the change of the spray width as a function of the spray height in order to calculate the area of impact.

Furthermore, the convergence differs between different nominal spray angles (22°, 26°, 30° and 40°) and depends on the water pressure. **Figure 4** shows how effectively the spray height can influence the impact without putting any additional kW power into the system.

Real descaling experiments were conducted with a silicon steel test sample under conditions typical for descalers in a thin slab plant. With a 26° Scalemaster nozzle a reduction in spray height from 136 mm to 90 mm at a pressure of 240 bars and a flow of 27.9 l/min resulted in a remaining scale reduction from 24.9 % to 16.2 %.

In practice it is never possible to utilize the full increase in impact because the spray width narrows and a higher number of smaller nozzles become necessary to cover the entire width of the rolled stock **(figure 5)**.

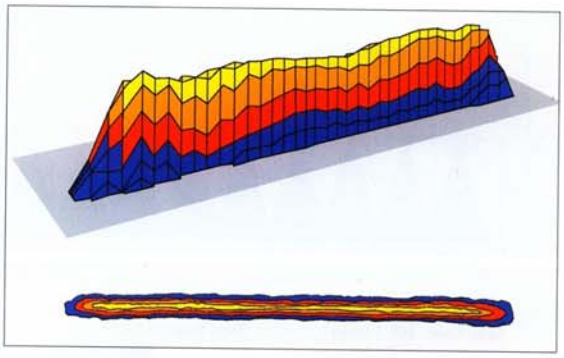

Figure 3. Impact measurement of Scalemaster HP, 40° with 90 l/min at 400 bar, max. impact 2.3 N/mm² at 80 mm spray height, spray thickness 4.0 mm

Nevertheless, significant improvements could be achieved in both product quality and cost savings in existing rolling mills by reducing the spray height.

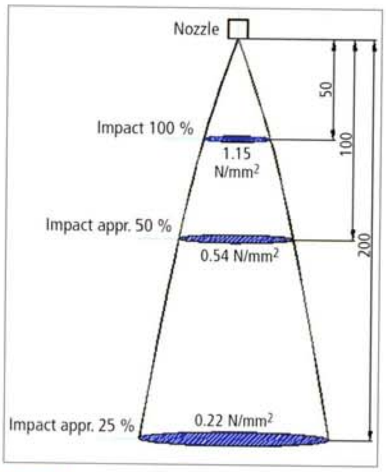

Figure 4. Effect of spray height on impact for a Standard Scalemaster with a flow of 25.5 l/min at 200 bars and 26°

Spray angle. For a given nozzle size, water pressure and spray height, also the influence of the spray angle on the impact is quite significant because it changes the area of impact **(figure 6)**.

Water pressure and flow. It is common knowledge that both the water pressure and the water flow are approximately proportional to the impact. More detailed investigations have shown the following results:

Since the spray thickness tends to narrow at higher pressures the impact rises 2.1 times when for a given nozzle the water pressure is doubled.

Since the spray thickness tends to widen with the nozzle size, increasing the nozzle until at a given water pressure is doubled rises the impact only by a factor of approximately 1.85.

In a direct comparison of different water pressures **table 1** shows the influence of this parameter on the impact.

Scalemaster type	Spray angle [°]	Water pressure [bars]	Water flow [l/min]	Spray jet width [mm]	Spray jet thickness [mm]	Total force [N]	Max. impact [N/mm²]
694.566.27	26	100	18.00	57	3.80	42	0.26
694.566.27	26	200	25.50	58	3.60	84	0.54
694.566.27	26	300	31.20	58	3.40	126	0.84
694.566.27	26	400	36.00	59	3.20	167	1.17

Table 1. **Influence of water pressure on impact**

Design parameters of an optimal nozzle arrangement

It is very clear that even the best spray nozzle cannot come up to expectations when certain important design principles are not followed when designing a descaling header.

Spray jet overlap. For uniform descaling over the entire width of the rolled stock it is essential to also ensure a uniform impact of all jets spraying in one row. The nozzle spacing and the pitches between them are not only directly related to the spray height and spray angle, but also to the overlap of two adjacent spray jets. As illustrated in figure 3 each descaling nozzle shows a certain unavoidable drop in impact at both edges of the spray jet. The characteristics of this "edge drop" depend mainly on the spray angle; the wider the spray angle the larger the width of the edge drop. A nozzle manufacturer should maintain a specific edge drop characteristic throughout all nozzle sizes belonging to one spray angle family.

The width of the overlap of two adjacent spray jets must be equal to the width of the edge drop. Nozzles from different manufacturers show different, i.e. sharper or softer, edge drops. Consequently it is important to define the edge drop for each nozzle or nozzle family for the header designer to work with.

Undescaled stripes on the surface can be caused by excessive overlap. In such a case the spray jet of the nozzle sitting behind the adjacent one creates a water layer on the surface which drastically reduces the impact in the overlap area (figure 7). Another rather frequent phenomenon is that no imprint is visible on the lead plate of the front spray jet due to the fact that the overlap was also too big. In this case also the inclination angle was too big. If the overlap is too small or there is a gap with no water impinging directly on the surface, stripes of remaining scale will eventually lead to rolled in scale.

The nozzle offset angle of 15° against the centre axis of the header pipe is already built into the nozzle tips. This feature prevents that spray jets of one row collide with each other.

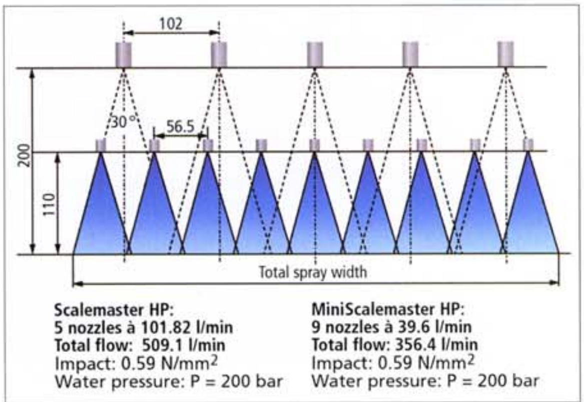

Figure 5. **Example of two nozzle arrangements at different spray heights with identical impact and significant reduction in water flow**

Spray angle	Impact
26°	100 %
30°	88 %
40°	69 %

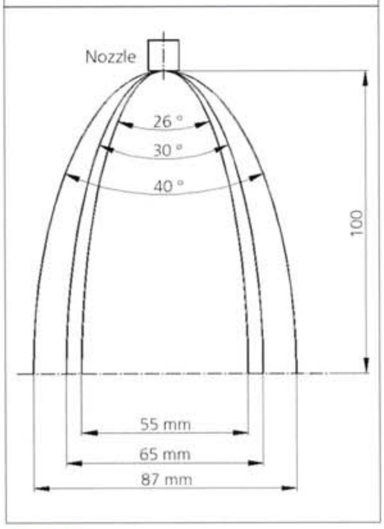

Figure 6. **Change of spray width and impact at different spray angles**

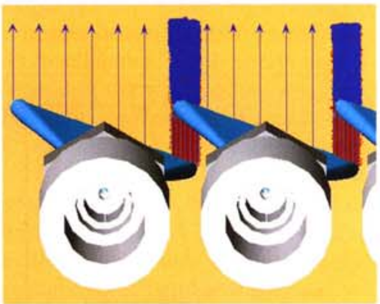

Figure 7. **Water layer effect caused by excessive overlap**

Inclination angle. The effect of the area of impact has already been described above. It is also fact that with an increasing inclination angle both the spray width and the spray thickness grow. Hence the area of impact increases, consequently lowering the impact. Measurements confirmed a

Figure 8.
Size comparison between Scalemaster nozzle types

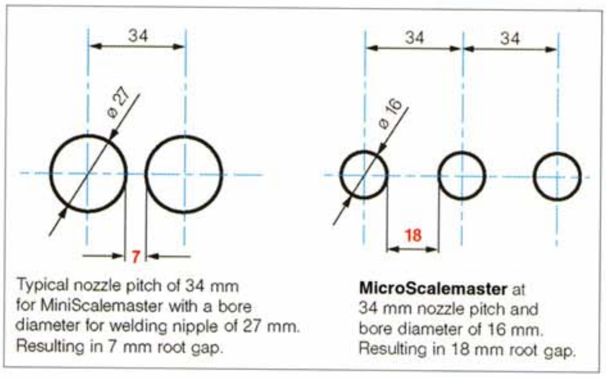

Figure 9.
Comparison of hole diameters and root gap width of welding nipples

drop in impact by approximately 18% when the inclination is increased from 15° to 30°. A vertical spray would be ideal in terms of impact, however, in practise it is desired that the water loaded with scale particles is directed against the material flow (rolling direction) in order to prevent entrainment into the roll bite. On the other hand the descaling water should not travel too far upstream, for instance into the furnace. This can easily happen with inclination angles set at more than 15°.

Special solution Micro Scalemaster

During the early stages of hydraulic descaling nozzle development a very robust and large set of components, such as the Standard Scalemaster **(figure 8)** nozzles with outer diameters well beyond 40 mm, was the solution for spray heights often greater than 300 mm.

In the meantime plant requirements have changed significantly. For thin slab plants the slab cooling rate during descaling had to be reduced. The descaling of sections (heavy medium & light), rails and rounds has become common, just like the descaling of forged products.

All these applications have in common the requirement of small outer nozzle dimensions suitable for spray heights between 50 and 100 mm. Moreover, it is desirable to keep the welding nipple diameter of the descaling nozzle to a minimum, reducing the "Swiss cheese perforation effect" on headers and spray rings, especially on those with small nozzle pitches. The Micro Scalemaster featuring an outer welding nipple diameter of only 16 mm (Standard Scalemaster 43.5 mm, Mini Scalemaster 27 mm) allows complicated spray ring designs **(figure 9)**. It also helps to reduce the header pipe wall thickness for flat product descaling in thin slab rolling mills. This is a remarkable cost saving factor.

Conclusion

The successful introduction of surface detection systems in rolling mills confronted rolling mill operators, mill designers and nozzle manufacturers with more descaling issues than ever before. The formation of scale caused by complex thermochemical mechanisms is influenced by the chemical properties of the steel and the upstream production processes such as continuous casting and reheating. Hence, not every problem of rolled in scale can be solved by optimising the nozzle and header arrangement. However, experience has shown that a systematic problem solving approach is necessary to identify and eliminate the shortcomings of a descaling system. The points discussed in this article are intended as a guideline. All points described have been proved through real measurements and confirmed by numerous plant installations.

The new products, such as the Scalemaster High Performance and the Micro Scalemaster, are solutions for state-of-the-art rolling mills. They are indispensable components for the production of high quality steel at competitive costs. ■

References

[1] Büchele, W.: New developments in descaling hot rolled products. MPT International, 5/1995

[2] Schürmann, S.: Measurement and mathematical approximation of the impact of descaling nozzles. Hydraulic Descaling Conference, London Sept. 2000

[3] Wolf, M.M, Scale formation and descaling in continuous casting and hot rolling. I&SM 1/2000

[4] Frick, J., Optimisation of nozzle arrangements on descaling headers. 4th Intern. Hydraulic Descaling Conference, London 4/20