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DESCALING SYSTEM OPTIMISATION IN A COMPACT ENDLESS CAST AND ROLLING MILL CEM®

Abstract

After the commissioning of the original thin slab mill of POSCO Gwangyang No.1 in 1996 the most significant modification of the plant was the conversion to a Compact Endless Cast and Rolling Mill (CEM®) with direct linkage of the caster and the rolling mill.

During this modernisation the thin slab caster has been revamped completely and the hot coil box has been replaced by a carousel typed one. The 5-stand finishing hot rolling mill has been kept as it was. In order to feed perfectly descaled strip into this mill under the new operation conditions the upgrading of the existing finishing scale breaker in front was the objective of this optimisation project. Minimizing the temperature drop of the strip during descaling by reducing the high pressure water volume has been in the center of the focus.

In the first step the design of existing descaling header and the nozzle arrangement were investigated and benchmarked. Different possibilities for improvements were examined in detail using several validation methods in order to cope with strip waviness and the high requirements on strip surface quality. The solution finally implemented delivers perfectly descaled strip with a descaling water volume reduced by 35% and has thereby significantly contributed to the successful direct coupling of the casting and hot rolling operations.

Keywords

Descaling, Compact Endless Cast and Rolling Mill, CEM, Nozzle, Spray Energy

1. Introduction

Hot rolling predetermines the surface quality of the final product significantly. In order to create ideal conditions for an optimum rolling process accurate descaling is essential. Beyond an excellent descaling performance itself, also side effects have to be considered and should be included in an investigation. Especially the temperature drop caused by the water jets of the hydromechanical descaling system must be respected as well as the homogeneity of the impact distribution over the entire strip width.

A direct linkage of the continuous casting machine to the rolling mill represents a high complex technical challenge because all involved process steps must be exactly synchronized. The unique CEM® technology “allows the slab to be immediately rolled with only minimal in-line reheating” [1].

To complete the idea of an energy efficient production also the descaling in front of the finishing train must be adapted to the actual demand. To achieve this, a detailed investigation of the specific conditions has to be conducted.

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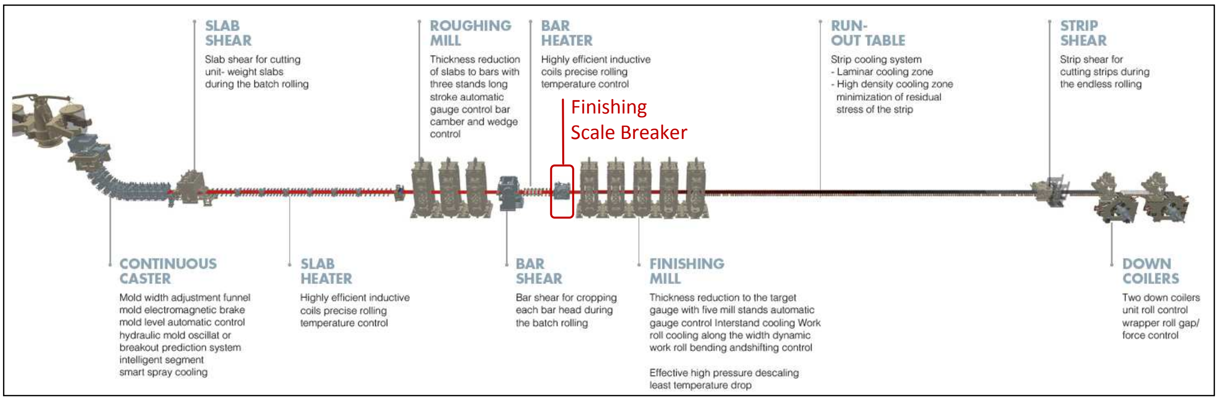

Fig.1: Layout of CEM® with a directly linked configuration [1]

2. Hydromechanical descaling process

The process of descaling using high pressure water jets consists of some different functional mechanisms. In general there are some mechanical and some thermal effects during the process. Since at a real descaling process all of these effects occur simultaneously and also interact with each other, it's not possible to separate them completely. Nevertheless, for research purpose and to better understand the individual effects it could be beneficial to investigate them separately, always keeping in mind their correlation. Eventually all effects, interactions and separate results must be considered together and the best compromise should be selected.

Some of the most important effects and mechanisms are described in the following and are indicated in figure 2.

(a) The creation of cracks in the scale layer is indispensable for all subsequent functional mechanisms. The cracks are generated by both, thermal and mechanical causes. The generation can be caused indirectly by a pre-cooling from the back splashing water and directly by the mechanical effect of water impingement (impact force).

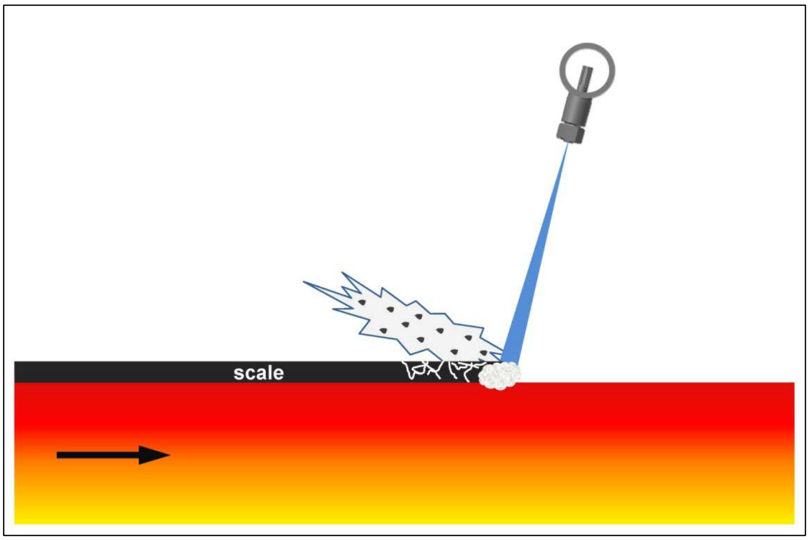

Fig.2: Mechanisms of hydromechanical descaling

(b) Different thermal contraction between the scale and the steel supports the detachment of these two layers furthermore. The thermal shrinking is initiated by the cooling from the water flow of the spray nozzles.

(c) Water penetrating the scale layer through the cracks is abruptly converted from liquid aggregate state to gas (steam) as it hits the hot steel surface. The tremendous and explosively increase of volume ruptures the scale layer and finally leads to flaking [3].

(d) The most obvious mechanism is the pure mechanical effect. The scale is crushed and fragmented by the mechanical force of the water jet and the layer is sheared off [3]. The dominating parameter influencing this mechanism is the impact force typically measured in N/mm² or mN/mm².

(e) For the top side of the strip it’s important that the loose scale particles are finally flushed away from the steel surface in order to prevent pressing them in again by the following rolling stand. This would inevitably lead to surface and/or roll defects.

3. Approach for optimisation

To investigate a specific real descaling situation with the intention to optimise it a benchmarking of the status quo has to be done first. All relevant data and measures have to be collected as well as the boundary conditions for possible modifications. The objective of the optimisation must be clearly defined and focused throughout the entire course of the project.

Then all the above mentioned mechanisms and effects have to be considered. The following excerpt gives a short summary of the major influence factors.

“The principal mechanisms for scale removal rely upon differential contraction of the oxide scale by means of the cooling by the descaling sprays together with mechanical effect of water impingement (impact force). … The cooling effect depends on the specific water impingement and the IP [impact pressure] and is a function of flow rate, stand-off distance, spray angle …, and feed pressure.” [2]

In reality it’s hard and confusing to deal with a lot of different considerations and numbers at the same time. A comparison will be nearly impossible. Hence, a single term which includes most of the parameters for the above mentioned effects and mechanisms is required.

One possibility is to use the “spray energy” – sometimes named “impact energy” – as Silk [3] did it. The spray energy is described by multiplying the impact pressure with the specific water impingement. At this term most of the decisive parameters are included. A first simplified overall impression could be gained by using this term.

$$\mathrm{E} = \mathrm{I} \cdot \mathrm{V}_{\mathrm{spec}} \tag{1}$$

where,

E spray energy [kJ/m²]

I impact force [N/mm²]

V_{spec} specific water impingement [l/m²]

$$\mathrm{V}_{\mathrm{spec}} = \frac{\dot{\mathrm{V}}_{\mathrm{total}}}{\mathrm{b} \cdot \mathrm{s}} \tag{2}$$

where,

$\dot{V}_{total}$ total water flow rate per side [l/s]

b total spray covered width [m]

s material/strip speed [m/s]

Within the single number of the spray energy a lot of factors are included already. All the nozzle and nozzle arrangement parameters such as spray angle, flow rate, spray height and impact pressure are integrated as well as the velocity of the strip. Also the thermal effect is considered in a rudimentary form by the specific water impingement.

Of course, specific optimisation objectives require additional detailed investigation on these specific points. The analysis of particular issues has to be performed on top of the basic examination.

4. Optimisation at the CEM® finishing scale breaker

At the finishing scale breaker investigated within this project, two pairs of descaling spray headers are installed. Each pair consists of one top and one bottom header (see figure 3). The first pair is operated at 300 bar water pressure and the second at 400 bar. The initial installation shows 33 nozzles at each spray header which have to cover the maximum strip width. The vertical spray height of the headers is adjustable and is set to h0.

All relevant values – especially the spray energy – have to be measured or calculated in order to benchmark the existing situation. This is helpful during the subsequent course of the project to compare optimization proposals with the initial situation.

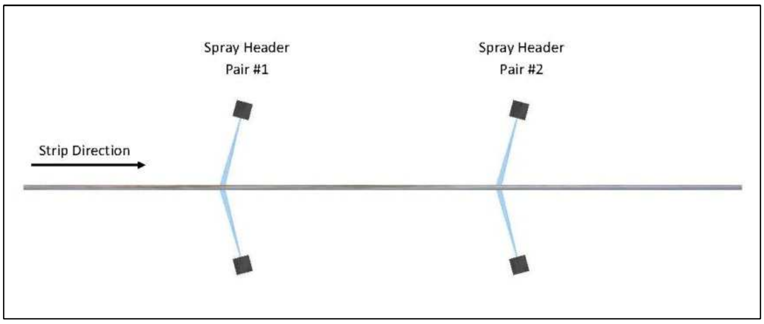

Fig.3: Schematic side view on the two pairs of spray headers at the finishing scale breaker

The primary objective for this optimisation is to reduce the water flow at the finishing scale breaker in order to minimise the temperature drop of the strip. Consequently the additional but not less important objective is to reduce the energy consumption for generating the high pressured water and reheating the strip.

Due to the intended direct linkage of the continuous caster with the rolling mill the velocity of the strip during descaling will be reduced. Without any modification this would increase the temperature drop at the scale breaker furthermore.

The modification of the operation conditions at the mill also changes the demand to the descaling system. To bring the required reheating in front of the finishing scale breaker to a minimum and the surface quality to a maximum is a clear indication to aim for a descaling solution with high impact pressure in combination with low water flow rate.

A first proposal for the optimisation maintains the spray energy according to (1) as at the existing situation. This is little risk to the process and opens new opportunities already. The nozzle arrangement has been adapted to the new conditions at the mill by modifying nozzle type and flow rate while maintaining the spray height (h1=h0). Achieving the identical spray energy as at the existing situation 20% of the water flow can be saved by the new nozzle arrangement of the first optimisation proposal as indicated in figure 4.

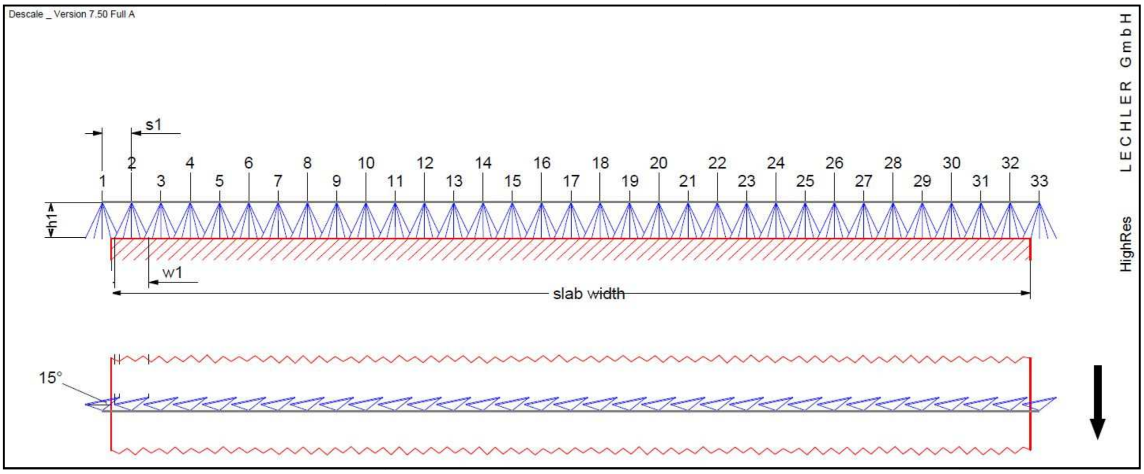

Fig.4: First proposal for new nozzle arrangement at finishing scale breaker

In a second step a much more profound optimisation proposal has been elaborated which also contains a modification of the vertical spray height as well as a change of the nozzle types and further reduction of water flow. This second proposal adapts the descaling closer to the new demands and reduces the water flow by 36%.

To compare the different proposals and also the existing situation roughly the spray energy is quite good for an overview as it consists only of one single number. To select the most promising installation in a well-founded way it’s essential to look more detailed to some additional measurements and evaluations particularly with regard to the specific conditions, issues and objectives.

One of these additional investigations is an erosion test on an aluminium plate as shown in figure 5. The nozzle sprays for a defined time to an aluminium plate which is statically positioned. This could be a good method to get a visual impression of the expected spray imprint and the mechanical component of the descaling process (impact pressure).

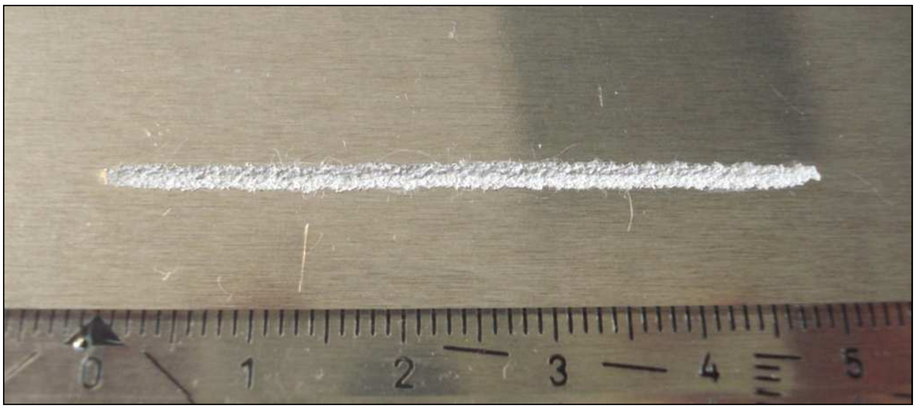

Fig.5: Aluminium plate erosion test

Beyond impact measurements at a single nozzle it's much more accurate and realistic to perform impact measurements at two adjacent nozzles spraying at the same time on a plane surface. This allows to study the effect of water layer and interferences especially in the overlap area and nearby. Also the expected overall impact distribution could be visualised by this new measurement possibility. For this measurement it's indispensible that the impact sensor is embedded in the plate and it must be possible to adjust the offset (twist) angle, the inclination angle and the nozzle spacing (pitch) accurately to the real designated values. As such measurements could only be performed in a laboratory also the pump capacity must be high enough (up to 130 l/min at 400 bar) to feed two nozzles with the high pressured water. Figure 6 shows such a measurement in operation and a typical measurement protocol is given in figure 7.

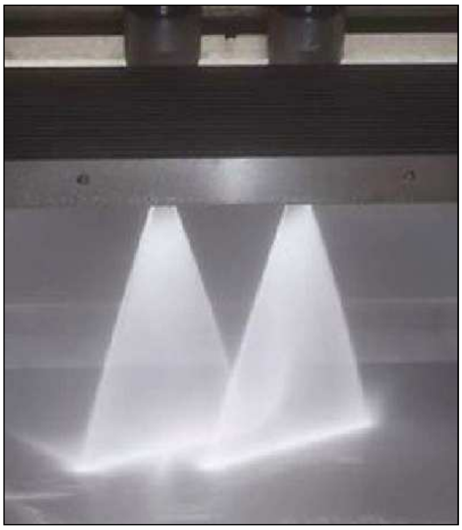

Fig.6: Impact distribution measurement with embedded sensor at Lechler laboratory

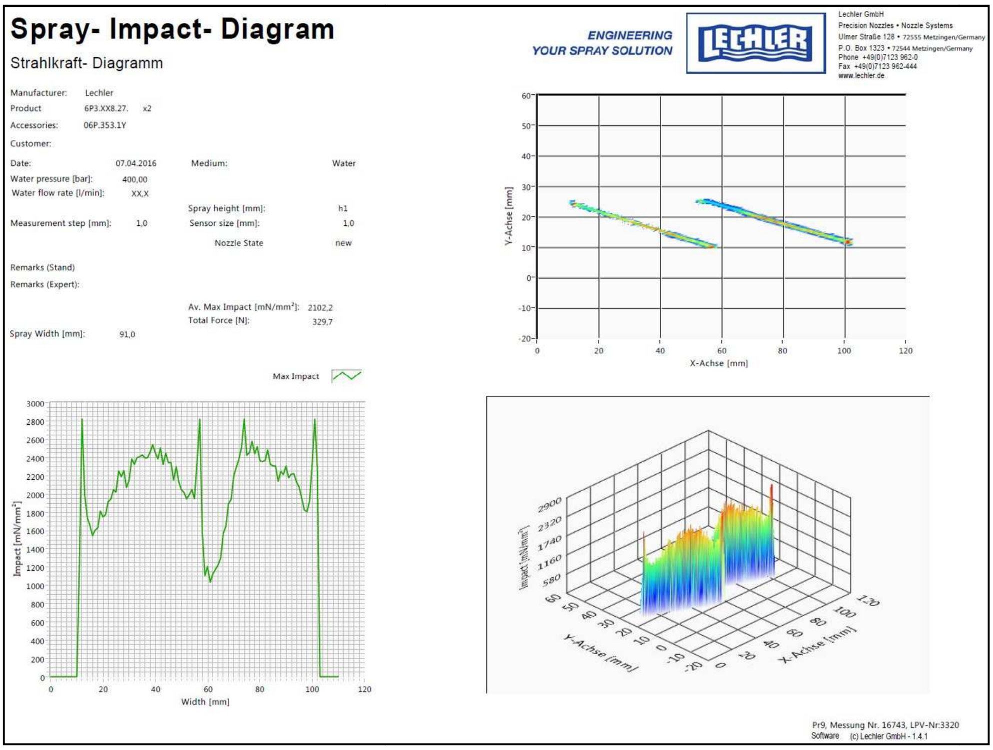

Fig.7: Impact measurement at two adjacent nozzles as per first proposal

Evaluating all calculations and measurements of the different opportunities the solution of the second proposal (see figure 8) with a vertical spray height of h2 (with h2=h0*1,36) shows the best overall results. This is the best compromise with regard to a homogeneous impact distribution, a high impact level and a low flow rate. The temperature drop of the strip could be minimized and a lot of energy for reheating and also for the high pressure pumps could be saved by 36% reduction of flow.

Since the mechanical design of the spray headers including quantity and spacing of the nozzles is identical at proposal one and two it is possible to easily switch between both proposals due to adjustable header spray height. Therefore, these two proposals are ideal to approach very close to the actual demand of descaling with the new operation conditions. Finally the installation according to proposal two could be confirmed as adequate under the real operation conditions.

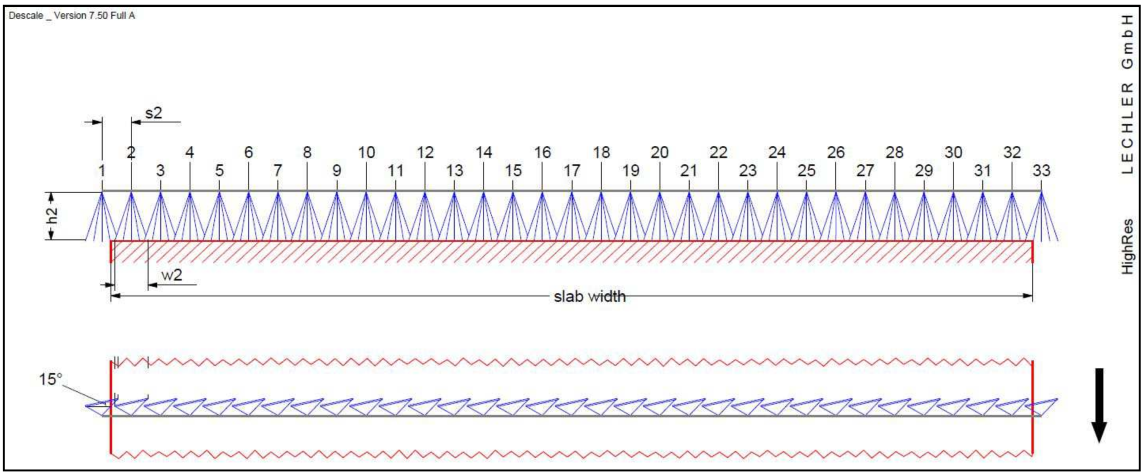

Fig.8: Second and final proposal for new nozzle arrangement at finishing scale breaker

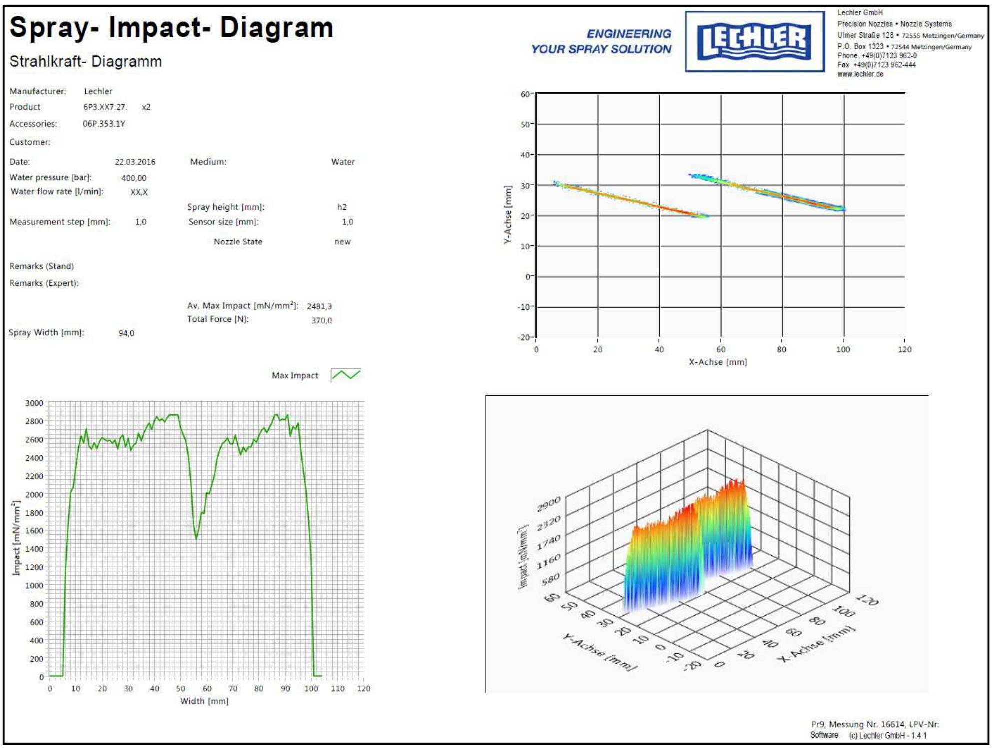

Fig.9: Impact measurement at two adjacent nozzles as per second proposal

5. Summary

Since product range and process parameters change over the life time cycle of a steel mill also the descaling situation should be adapted to the actual demand. Energy efficiency can be increased due to lower required reheating and less power needed for the pumps. As the specific conditions are different in each mill, it's necessary to investigate the individual situation and demand in detail.

After the direct linkage of the continuous casting machine with the rolling mill the finishing scale breaker has been modernised successfully. The temperature drop at the strip during descaling has been minimised by a reduction of water flow rate. At the same time the descaling quality has been improved. This was possible due to a comprehensive investigation of the specific conditions including several different methods such as the calculation of the spray energy and the impact measurement at two adjacent nozzles.

Eventually, there is a massive saving of energy by reducing the water flow by 36%. In combination with the improved descaling quality this shows how energy efficiency can be increased by a modernised and enhanced nozzle arrangement.

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