RESOLVING HIGH IMPACT [1]

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Abstract

Understanding a nozzle's spray impact is critical to setting up the descale headers on the rolling lines. There are many characteristics that alter the impact characteristic of a nozzle ranging from pressure and flow rate to shape and spray distance. Spraying Systems uses a patented technology to help measure and characterize the impact characteristic and the procedure used to measure a spray nozzle's impact pattern is to traverse a small pin, which is attached to a load cell, through the spray to get the localized force generated by the nozzle. This information can then be analyzed to provide impact and coverage characteristics for a given nozzle and spray conditions. This pin can have differing geometries and the movement grid through the spray can also have varying step sizes.The intent of this paper is to investigate the effect that varying the pin size and step size have on the measurement. Determination of movement criteria and pin dimensions will be made to ensure that an accurate image of a nozzle's impact characteristics can be obtained. Understanding the characteristics of both the measurement methodology and spray characteristics of the nozzle itself both translate into better nozzle design and control of the spray characteristics. This, in turn, translates to improved line performance and efficiency through improved spray header design from the perspective of being able to increase impact, improve coverage and decrease water usage.

Key words: Descaling; Rolling; Impact; Coverage.

ANALISANDO ALTO IMPACTO

Resumo

Compreender a força de impacto de diferentes tipos e estilos de bicos é fundamental configurar chuveiros de descarepação em linhas de laminação. Existem muitas características que alteram a característica da força de impacto que vão desde pressão e vazão até formato e distância do jato. A Spraying Systems utiliza tecnologia patenteada que ajuda medir força e a caracaterística da força de impacto e o procedimento utilizado para medir o padrão do impacto de um bico é percorrer um pequeno pino anexado em uma célula de carga através de todo o jato para coletar a força localizada gerada pelo bico. Essa informação pode então ser analisada para fornecer características de impacto e cobertura para um dado bico e condições de pulverização. Esse pino pode ter diferentes geometrias e o seu movimento através do jato pode ter diferentes passos. A intenção deste trabalho é investigar os efeitos que a variação no tamanho do pino e dos passos de movimento tem sobre a medição. Determinação dos critérios de movimento e dimensões do pino será feito para assegurar que uma imagem precisa da característica da força de impacto possa ser obtida. Entender a característica do método de medição e característica do jato de um bico traduzirá em um melhor projeto de bico e controle do jato. Isso também traduzirá em uma linha de desempenho e eficiência através de um projeto melhorado de chuveiro da perspectiva da capacidade de aumentar a força de impacto, melhorar a cobertura e diminuir consumo de água.

Palavras-chave: Descarepação; Laminação; Impacto; Cobertura.

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1 INTRODUCTION

Characterizing the sprays used in the many different applications found within a steel mill is a challenging proposition. These applications range from secondary cooling in the continuous casting process, particulate removal and catalysis in the pollution control systems, dust suppression in the slag pits, pickling applications, roll cooling in the various mills, etc. One of the more challenging and perhaps most critical is the characterization and understanding of the nozzles used to descale the steel in the hot rolling mills. This application is critical to ensuring that a quality product is output at the end of the line.
Descaling the steel has various different components that need to be considered; spray impact, scale removal, surface cleaning, and cooling effects, amongst others. Below, in Figure 1, a diagrammatic representation of this process is provided.

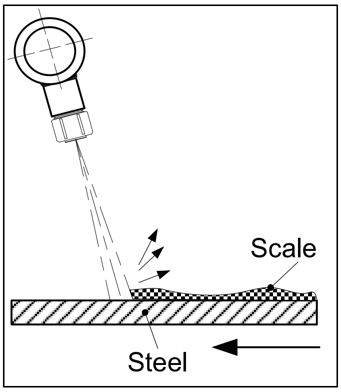

Figure 1: Descaling layout.

The heated steel is growing scale while moving towards the rolling stand. Prior to rolling, a stand of high pressure spray nozzles are positioned to remove the scale from the steel's surface. This requires that the nozzles have sufficient enough impact to break the scale and remove it from the steel surface. To further complicate matters this scale must then be moved off the steel surface. All of this must occur while attempting to remove as little heat as possible from the steel substrate.

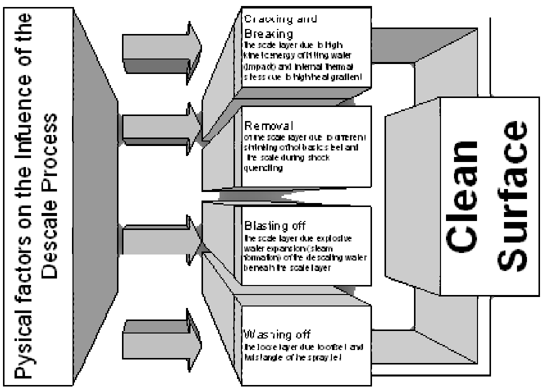

Figure 2: Pysical factors that affect Descale Process.

It is for the reasons mentioned above and shown in Figure 2 that having accurate characterizations of these nozzles is important. Spray impact plays an important part in both helping to break up the scale but also to help provide enough momentum to the water and scale slurry to remove it. The footprint generated by these nozzles is also important. If these nozzles do not overlap correctly, other difficulties are

encountered with regards to product quality. If the nozzles are not overlapped enough the steel can end up with stripes of scale; if overlapped too much there may be problems of overcooling in this super-overlap zone.
The purpose of this paper is to investigate measurement methodologies used to characterize the nozzles used to descale steel. Understanding the information provided by the measurement equipment will allow for an accurate representation of the spray nozzle header when doing the design layout to a new facility or updating an older facility.

1.1 Spray Coverage and Impact

A nozzle's spray coverage, in the most general terms, basically amounts to the two-dimensional footprint that a nozzle generates. There are many different shapes that nozzles can generate but to stay in line with this paper's objectives we will only look at typical descale nozzles. These are generally referred to as high pressure, high impact, flat spray nozzles. Figure 3 shows a representation of the footprint of a single nozzle and that of a linear array of these nozzles.

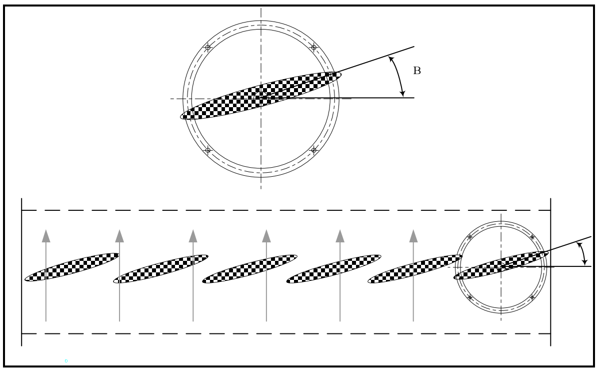

Figure 3: Nozzles footprints

This elliptical footprint representation is somewhat accurate, however, the actual footprint shape may lean more towards a rectangle with curved corners. Different nozzle types: spray angle, capacity, manufacturer, *etc*. all have the same basic footprints with subtle differences.
The footprint that a nozzle generates does not tell the entire story. Through various parts of the area defined by the spray's footprint, varying amounts of water will pass per unit time at varying different velocities. This is referred to as the volume flux of the spray and is usually provided in units of $cm^3/cm^2/s$. This can be measured using some high end instrumentation such as a Phase Doppler Interferometer or as simply as placing a series of troughs below the spray for a specified period of time. If the impact of the spray is measured over multiple small areas of the spray, the footprint can be defined as well. This is typically what is used by the manufacturers of descale spray nozzles. A representation of the trough method is shown in Figure 4 and the impact method is shown in Figure 5.

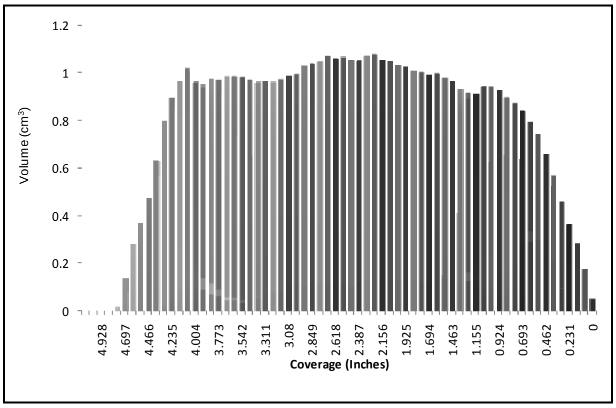

Figure 4: Trough data (Coverage x Volume)

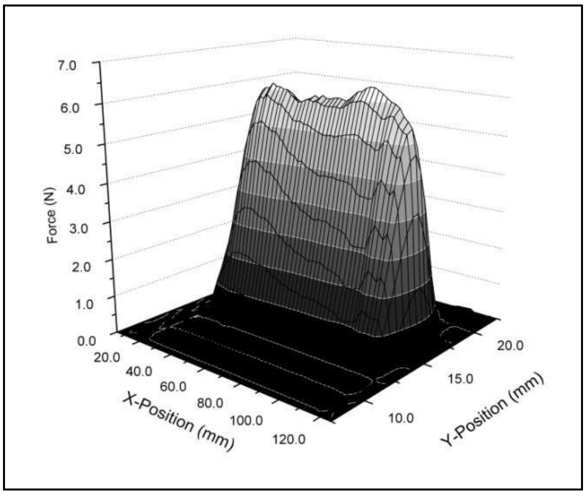

Figure 5: Impact data (Position x Force)

Measuring the spray coverage using the trough method has some inherent limitations. Measurement resolution is physically limited to the dimensions of the trough/tubes used to make the measurements. Also, since the width of these sprays is typically on the order of 12mm (≈ 0.500in.) or smaller, getting sufficient resolution to measure spray thickness using this method is difficult.

The impact tester measurement can produce a very fine resolution of the spray footprint. These measurement resolutions are normally on the order of 2mm (0.080in.) or smaller. Determining the spray coverage from a nozzle using this methodology is of primary concern to this paper and will be discussed further in the experimental setup and methods section.

As can be seen by comparing Figures 4 and 5, the volumetric distribution is provided through the measurements made using the trough collection method. This is not provided using the impact test method; the measured force is provided in lieu of the volume flux distribution. It is the conjecture of the author that the impact distribution and the volume flux distribution are proportionally related. This can be surmised by the fact the force being measured is a function of the liquid flow rate and liquid velocity as shown in Equation 1. Planned future work is expected to be done to more definitively show this to be the case.

$$\vec{F} = \rho \cdot Q \cdot \vec{V}$$

2 EXPERIMENTAL SETUP AND METHOD

Determining the measurement resolution required to accurately provide the spray footprint dimensions and localized impact forces of a high pressure, high impact steel descale spray is the object of this work. To do this, Spraying Systems Co. has designed and built measurement equipment utilizing a three-dimensional motion control system also incorporating a load cell and data acquisition equipment to facilitate force measurements. A photo of the equipment is shown in Figure 6.

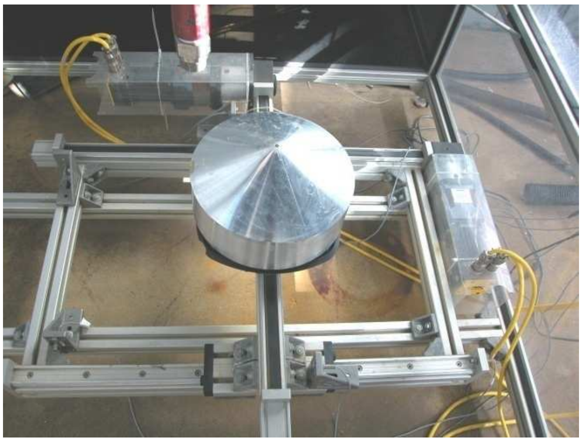

Figure 6: Impact Measurement Equipment

To obtain the measurements as shown in Figure 5, the load cell is traversed through the spray in steps. At each step location a force measurement is made. These measurement locations are then combined with these force measurements to provide an image of the force distribution measured from a given nozzle.
The process begins by placing the load cell measurement pin directly below the center of the nozzle. The load cell is then traversed in the lateral direction until there are no longer any measureable impact forces being registered. The load cell then begins to move through the measurement matrix. This motion control procedure is shown in Figure 7.

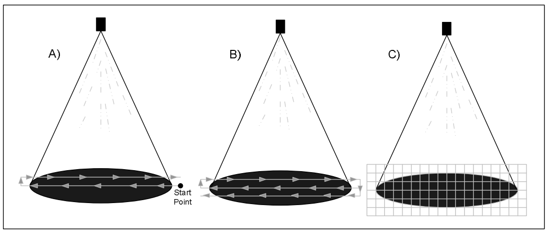

Figure 7: Load cell path through the spray coverage.

The load cell will follow the pattern as shown in Figure 7a and 7b. At each point, as shown in Figure 7c, the load cell is stopped and a measurement is made. The distance between each node, or step size, is set manually through the equipment user interface. Step size selection is an arbitrary process.
Standard convention is to set the step size equivalent to the diameter of the pin being used on the load cell; typically 2mm (0.079in). To obtain better detail, a finer resolution step size can be used (eg. ½ pin diameter). For the purposes of this work a 2mm (0.79in) pin was used with step sizes of 0.50mm (0.20in), 1.00mm (0.39in) and 2.00mm (0.79in).

3 RESULTS AND DISCUSSION

Figure 8 shows the same nozzle measured at the same pressure and height but with varying step size. Figure 8, 9 and 10 show measurements made with step sizes of 0.50mm (0.20in), 1.00mm (0.39in) and 2.00mm (0.79in) respectively.

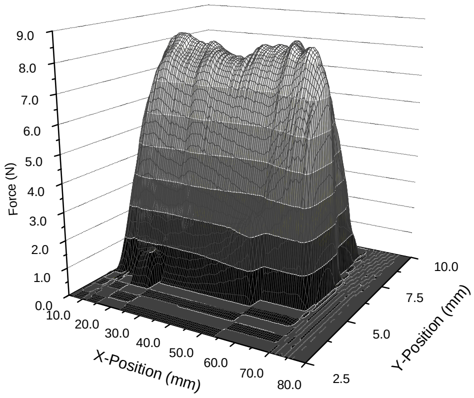

Figure 8: Impact measurement made with step size of 0,50 mm.

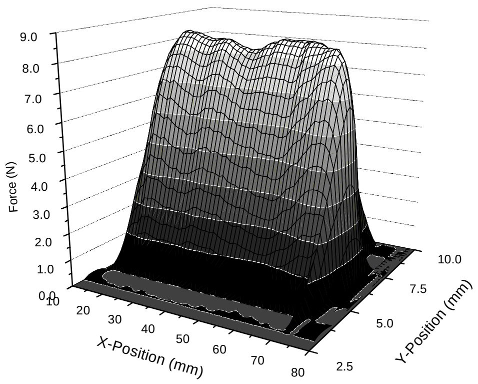

Figure 9: Impact measurement made with step size of 1,00 mm.

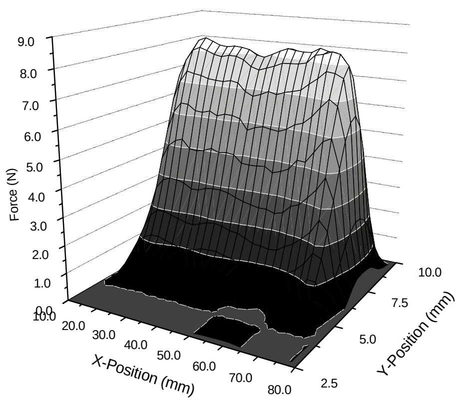

Figure 10: Impact measurement made with step size of 2,00 mm.

Comparing these three plots, significant similarities are noticed. However, closer examination reveals some less glaring details. Though the shape remains generally the same, it is much more detailed as the measurement resolution increases. These plots also seem to exhibit a small decrease in the footprint of the spray as the resolution increases.

It is this trend that raises questions about the effect measurement resolution has on typical parameters used to characterize these nozzles: Total Coverage, Effective Coverage, Spray Thickness, Maximum Specific Impact and Average Impact.

- Total Coverage: Full width of the spray as defined by the measured values.
- Effective Coverage: Width of the spray as defined the area within the spray that has impact values greater than or equal to 85% of the maximum impact value.
- Spray Thickness: The average thickness as defined by the measured values.
- Maximum Specific Impact: The maximum force per unit area that is applied to the surface at the point of impact.
- Average Impact: Amount of force applied per unit area of the spray. The average specific impact is derived from the area within the spray that has impact values greater than or equal to 85% of the maximum impact value.

This study investigated two different descale nozzles having different spray angles and capacities. These measurements were made holding the spray distance and pressures constant.

Table 1

Nozzle	**P** (bar)	**H** (mm)	**Spray Angle**	**Capacity** (GPM @40psi)
3230	200	100	32°	3.0
1507	200	100	15°	0.7

These nozzles were selected to see if any difference could be found by the change in resolution based upon either spray angle and/or capacity. These nozzles have significant differences in both spray angle and capacity so it was thought that any changes due to the measurement resolution would readily exhibit themselves.

- *Thickness:* Figure 11 shows a plot of the spray thickness versus the step size. There is a definite trend for the data to portray the spray as thicker the coarser the measurement resolution becomes. This was subjectively seen above in Figures 8, 9 and 10. This trend is now definitely documented in the data.

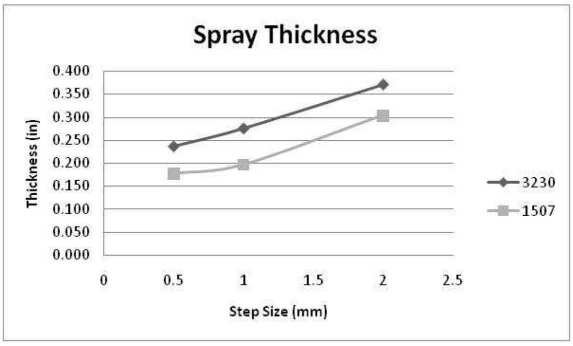

Figure 11: Step Size x Spray Thickness.

- *Coverage:* Figures 12 and 13 provide a plots showing the change in spray coverage as a function of measurement resolution.

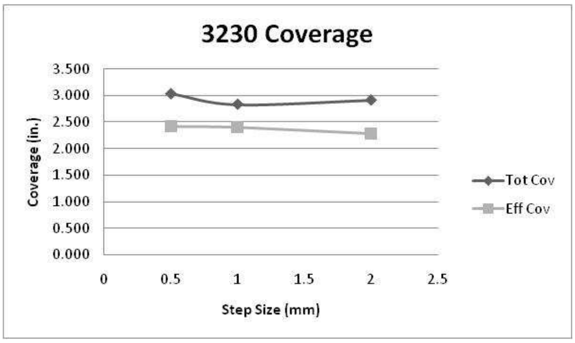

Figure 12: Step Size x Spray Coverage for a 3230 nozzle.

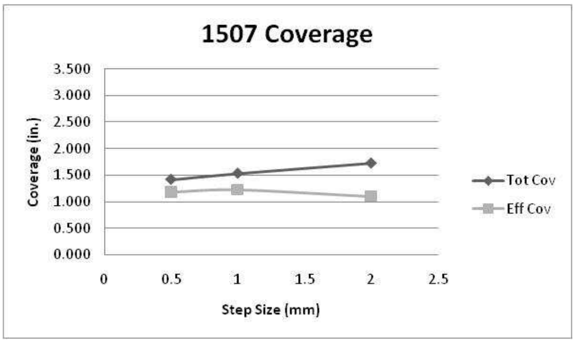

Figure 13: Step Size x Spray Coverage for a 1507 nozzle.

The trend here is a bit less obvious than the plot showing spray thickness (Figure 11). It appears that the spray coverage, whether total or effective, remains relatively constant across this resolution range. This may be good news in that coverage can be a key parameter used in setup of descale spray headers and if this value remains relatively independent of measurement resolution, most data sources can be considered reliable. Before this conclusion can be drawn, further work will need to be done.

- *Impact:*Impact is probably one of the most key parameters required by a mill in the set up of any descale header. This value provides them with information regarding how pressure and water they will require to sufficiently removing the scale from the steel to provide them with a quality product. Figures 14 and 15 show the measurement results for these two nozzles. There is more of a trend to be noticed in these two plots than shown in the coverage plots (Figures 12 and 13).

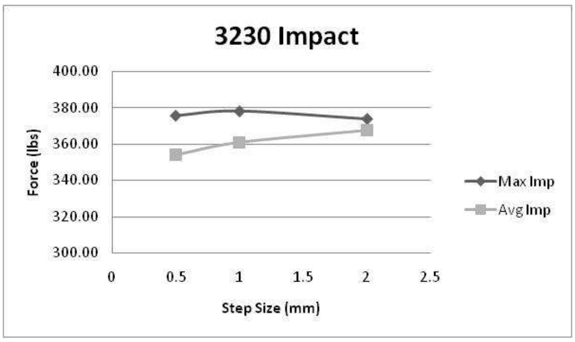

Figure 14: Step Size x Spray Impact for a 3230 nozzle.

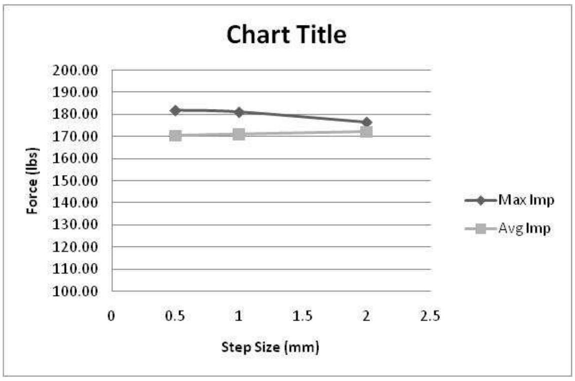

Figure 15: Step Size x Spray Impact for a 1507 nozzle.

There is a definite divergence between the maximum impact and the average impact as measurement resolution increases. It does not seem that the maximum impact changes very much over this range but that there is a decreasing trend in the average impact with increasing resolution. This is probably due to a much more defined area for the 85% threshold value used to define the average impact value. Oddly though, with this being said, there might be the expectation that there should be a change in effective coverage. This is not seen in the data and the author at present does not have an explanation for this.

5 CONCLUSION

An attempt to study the measurement resolution of spray impact tester was made with the intent to show how the resolution effected the typical output data: Total Coverage, Effective Coverage, Spray Thickness, Maximum Specific Impact and Average Impact. Two different nozzles were measured with constant spray heights and pressures. The step size of the impact sensing element was changed (0.50mm (0.20in), 1.00mm (0.39in) and 2.00mm (0.79in)). and the resultant data between runs compared. All of this work was done using a 2mm (0.80in) pin.

Within the data provided it is seen that measurement resolution does not appear to significantly change either total or effective coverage. This runs counter-intuitive to expectations, particularly when one notes that there is a definite change in both the thickness of the spray with measurement resolution as well as a decrease in the average impact with an increase in measurement resolution.

The decrease in spray thickness can objectively be observed as shown by comparing Figures 8, 9 and 10. This is then objectively shown in the data as displayed in Figure 11. However, spray coverage and spray impact seem a little less willing to show any trends in the measurement ranges attempted. There is a definite decrease in average impact as resolution increases regardless of capacity or spray angle. The maximum impact value remaining relatively constant make some sense in that unless the resolution became too coarse to measure the maximum values, this value should not change. Explaining the change in average impact while noting zero effective change in coverage appears to be more challenging.

The work for this paper was intended to be more extensive. There were specific challenges with system design to ensure that the obtained data was accurate. The work in refining equipment design is continuing so that more thorough investigation of these effects can be made. Follow up work is expected to include changes to pin size as well as step size. To attempt to follow trends more smoothly differing pressures, spray heights and nozzles will be measured to determining if these are general trends across varying nozzles and capacities or if there specific idiosyncrasies relative to the different nozzles.