APPLICATION OF DYNAGAP SOFT REDUCTION TO HIGH QUALITY BLOOMS AND BILLETS[1]

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Abstract
Centre segregation and porosity, in high quality blooms and billets, such as rail and bearing grades, can give rise to inconsistent mechanical properties and potential failure of the final product. Although static soft reduction can be used to improve the internal quality, this is only applicable for one set of casting parameters. Operational flexibility and improved quality, together, can only be achieved with a dynamic soft reduction system that takes into consideration transient casting speed, solidification process and material behaviour. This paper will discuss the successful implementation of Siemens VAI dynamic soft reduction, DynaGap, on bloom and billet casters and the benefits achieved.
Key words: Continuous casting; Soft reduction; High quality blooms; Segregation.

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1 INTRODUCTION

Centre segregation and porosity, in high quality blooms and billets, such as rail grades and tyre cord, can cause inconsistent mechanical properties and potential failure of the final product. The general practice to overcome this problem is to reduce casting speed. Obviously, this affects overall throughput of the caster. Static soft reduction, provided by fixed pinch roll drive adjustment, has been used to improve the internal quality of continuous cast slabs, blooms and billets but the location is only optimised for one set of casting parameters. This means that the casting operation must be kept as steady as possible. Although this is a good condition for continuous casting, the operation window for achieving reduced centre segregation and porosity becomes very small. In reality, operational events make it difficult to maintain steady state for long periods of time. Delays in the arrival of ladles, disruption with the removal of blooms or even tundish changes may require adjustments in casting speed to keep the sequence going. Therefore, casting parameters such as casting speed and superheat can change during sequence casting. Hence, the solidification range moves accordingly (Figure1). In order to have greater operational flexibility, whilst maintaining good internal quality, a dynamic soft reduction system that takes into consideration transient casting conditions, solidification processes and material behaviour must be used. The Simetal DynaGap SoftReduction Technology, which includes an online 3D thermal tracking system, Simetal Dynacs 3D, for the calculation of solid fraction, has been installed on bloom casters to provide improved internal quality throughout the casting sequence.[1] For small blooms and billet formats Soft Reduction has proven more difficult to apply. The latest generation of Simetal VAI Dynagap 3D has now been successfully implemented on a billet caster and although at an early stage the results are promising. This paper will discuss the successful implementation of this technology and the benefits achieved.

2 LOCATION OF SOFT REDUCTION

During the solidification of steel, in between the solid phase and the liquid phase, there is a region which is neither completely solid nor completely liquid. The fraction (percentage) of solid in this ‘mushy’ region is dependent on the thermal properties of the steel grade composition (Figure 1). Segregation occurs in this region due to the enrichment of alloying elements such as carbon, manganese, phosphorus and sulphur between the growing dendrites of the solid shell. The centre macro segregation is then generated by interdendritic fluid flow of this highly segregated material towards the area of final solidification. This flow is further increased due to the thermal shrinkage as the centre becomes fully solid.

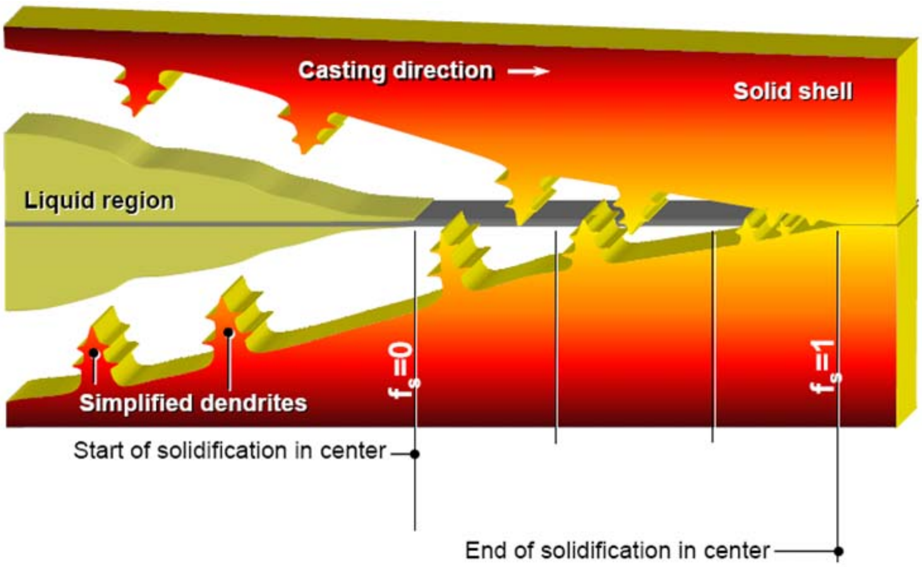

Figure 1. Schematic of the solidification region in the bloom or billet.

Other than reducing casting speed, one method to prevent excessive centre segregation and porosity is to apply soft reduction during the solidification process. Small thickness reductions are applied in the region where the liquid is close to the final point of solidification (Figure 2). The deformation must penetrate to the centre in order to squeeze out the segregated fluid in opposition to the casting direction and be sufficient to compensate thermal shrinkage.

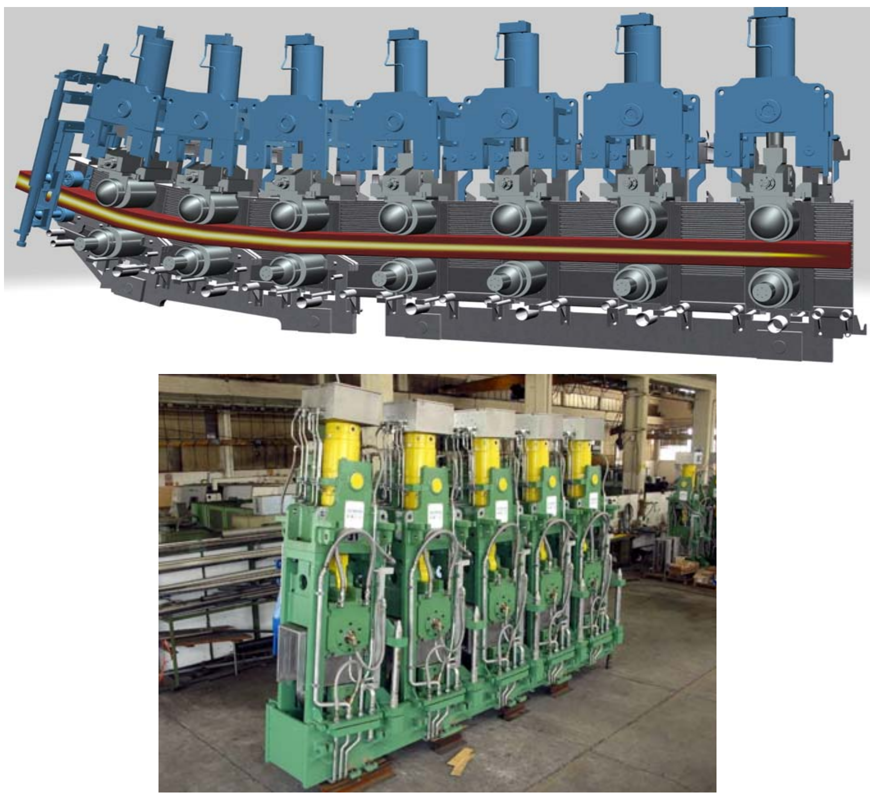

Figure 2. Typical setup for bloom (left) and billet (right) soft reduction pinch roll stands.

It is important to apply the soft reduction at the correct moment during solidification. If too early then reduction simply deforms the outer sides and does not penetrate to the centre. Applied too late and the strand is already solid and the resistance to deformation is too high, resulting in high rolling loads on the equipment. The influencing parameters which determine the soft reduction position are:

- bloom format;
- casting speed;
- steel analysis (thermal properties);
- superheat;
- cooling rate.

The biggest influences on the solidification, for a particular steel composition, are the casting speed and the temperature dependent properties such as heat capacity, latent heat and density. The latest generation, Simetal Dynagap 3D, in combination with the thermal property calculator, Simetal DynaPhase and the thermal tracker Simetal Dynacs3D, is able to predict more precisely the solidification position. This is especially important for billet formats due to the relatively small solidification range between the liquidus and solidus positions.

3 DYNAMIC SOFT REDUCTION TECHNOLOGY

To realise dynamic soft reduction it is necessary to control the pinch roll gaps according to the actual solidification, taking into account current and historical conditions. The shell growth at the soft reduction area is influenced throughout its lifetime in the casting machine by many factors, from superheat in the mold to water amounts in the secondary cooling zones. Figure 3 shows the DynaGap system which uses the actual measured parameters from the thermal tracking system Dynacs3D to calculate the correct roll gap settings. Input parameters to this system include tundish temperature, roll gap, format, casting speed, water quantities and, most importantly, steel composition specific thermal properties from the DynaPhase model.

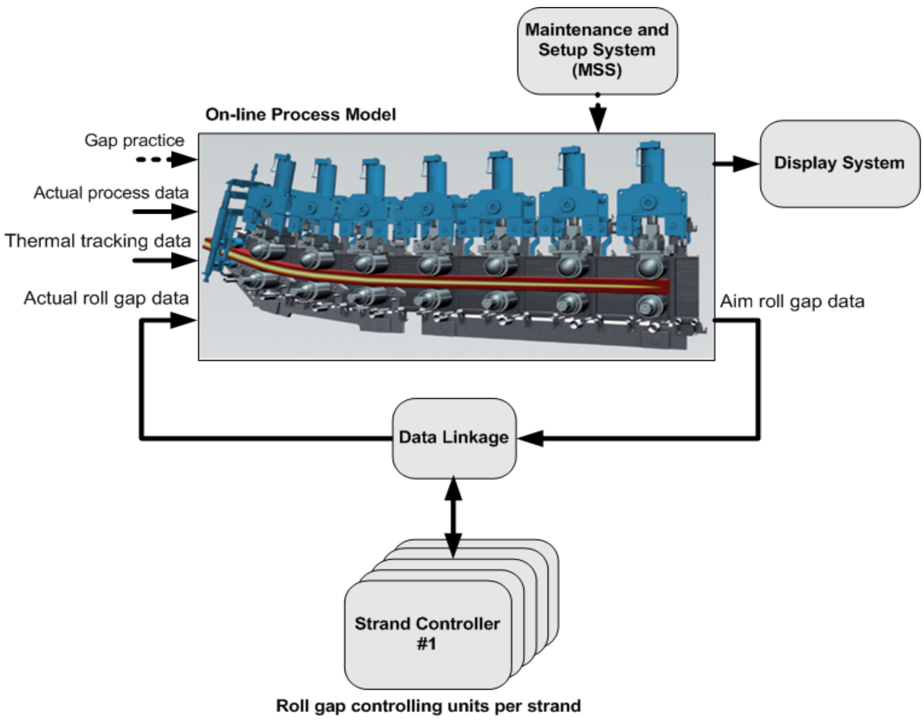

Figure 3. DynaGap system overview.

The benefits of accurate steel composition related thermal properties, as an input to the models, cannot be overstated. Earlier versions of software used simple, group related, data whereby a steel grade group would have a range of carbon content. However, the actual steel being cast may have different carbon or manganese content. The resultant fraction solid, for example, for the differences in composition can have a significant effect on the final solidification. Figure 4 demonstrates the effect in fraction solid range, due to a difference in carbon content of 0.05%, This can shift the final solidification point by 0.7 m.

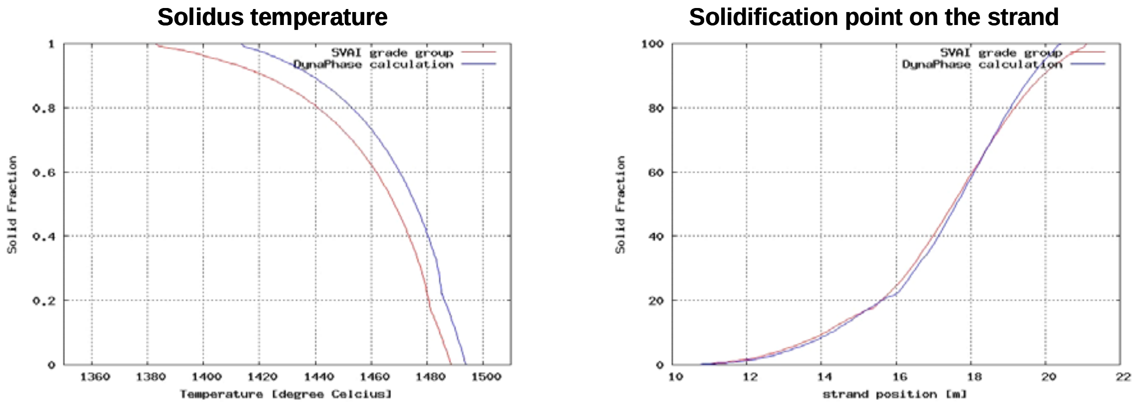

Figure 4. Composition critical solidification.

The latest DynaPhase model is able to calculate the required thermal properties either off-line by steel grade specification or online with the actual steel grade composition (Figure 5). Then the actual fraction solid is calculated throughout the strand using the thermal properties for the steel composition being cast and gap set points are sent to the pinch roll gap controller according to the metallurgical requirements.

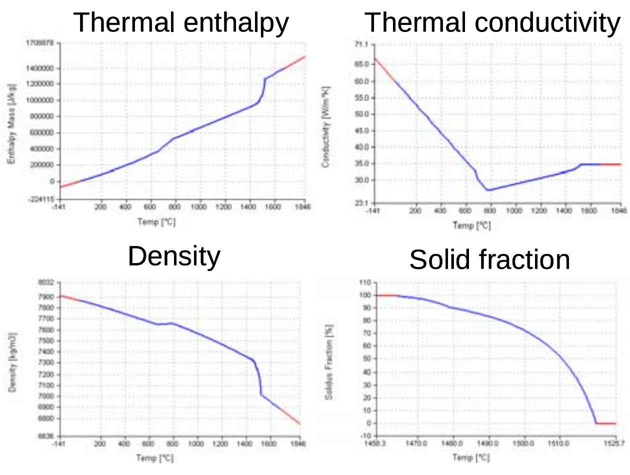

Figure 5. Steel grade related thermal properties.

Because the strand thickness can vary, due to shrinkage depending on the steel temperature, an important aspect of the dynamic soft reduction system is the measuring roller before the pinch rolls. This provides a reference thickness entering the first pinch roll. The reference value from the measuring roll, compensated with the shrinkage of the strand, is then fed to the first pinch roll in order to set the correct roll gap. The subsequent pinch roll gaps are then, in turn, fed forward to the next pinch rolls.

Within an off-line maintenance system, the metallurgist can predefine a "Gap Practice" according to steel grade requirements. The gap practice can define not only the total amount of reduction over the required fraction solid range but also the distribution of the reduction. Figure 6 shows typical displays from the Level 2 system, giving information about strand temperature, the solidification range and the region of soft reduction for the chosen gap practice.

Figure 6. Display of the online DynaGap Soft Reduction system.

4 DYNAMIC SOFT REDUCTION APPLICATION AND RESULTS

The flexibility of the DynaGap operating system allows for many alternative soft reduction patterns to be tested. During earlier installations of the system in Panzhihua Iron & Steel Co and Wuhan iron & Steel Corporation, trials were carried out to confirm the benefits of Dynamic Soft Reduction.[1,2] Subsequently, the application of Dynamic Soft Reduction has been successfully carried out on rail bloom casters, including Nanjing, China and Steel Dynamics Incorporated, USA[3] and now Handan, China. Figure 7, highlights the consistency of the internal quality throughout sequence casting with changes in casting speed. The benefits of dynamic soft reduction have been demonstrated not only in the as cast bloom but also in the final product (Figure 8).

More recently, the latest generation of DynaGap 3D has been successfully installed on a billet caster where the aim was to increase casting speed whilst still maintaining the internal quality. Unfortunately, at the time of writing, the final results are not available but the as cast product showed the same (or even better) internal quality with a 10% increase in casting speed compared to a strand without Dynamic Soft Reduction.

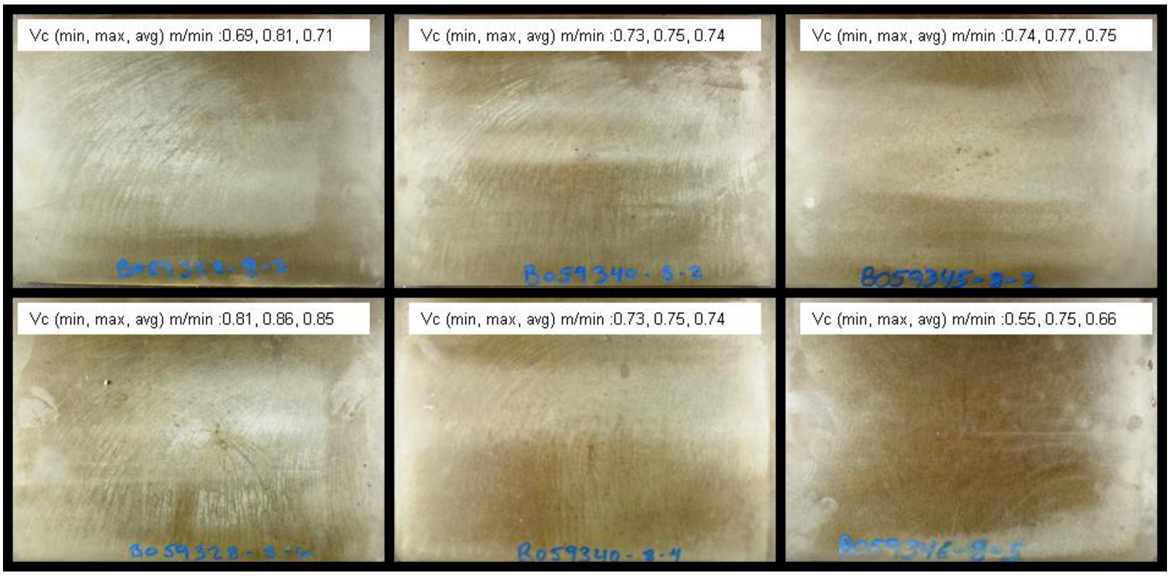

Figure 7. Cross section showing internal quality of rail bloom throughout sequence casting.

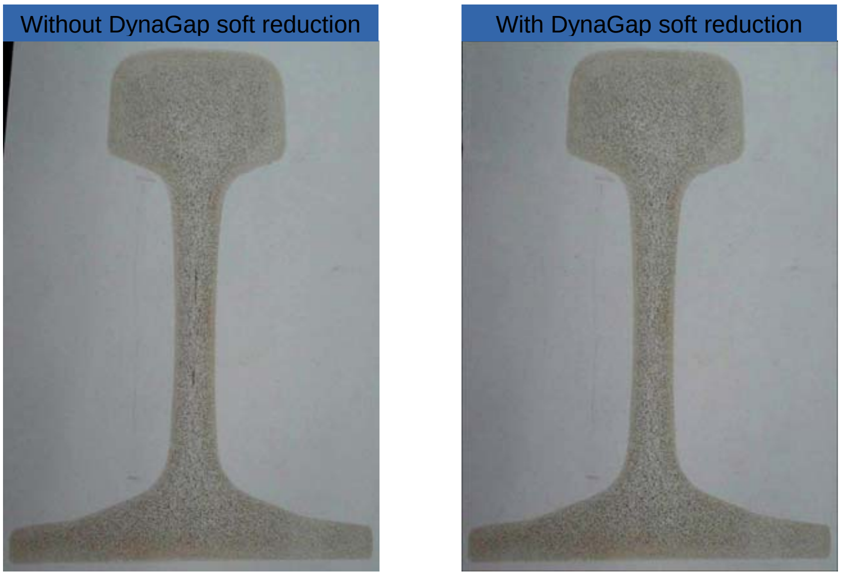

Figure 8. Benefit of dynamic soft reduction for final product.

5 CONCLUSIONS

Throughout the past years, the emphasis on improved internal quality has introduced several process steps to reduce centre segregation and porosity.[4] One step forward is mechanical soft reduction. However, a static soft reduction zone puts a restriction on the overall operation and makes it more difficult, in practical terms, to maintain consistent quality throughout the sequence. It is essential to have good input data, such as temperature dependent thermal properties and reliable thermal tracking to ensure successful application of soft reduction, in the correct location, during steady state and changes in casting parameters. This can only be achieved with a sophisticated technological packages called Simetal DynaGap 3D.

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