

ON MICROSTRUCTURE DEVELOPMENT AND INCLUSION GENERATION IN A CONTINUOUSLY CAST RESULPHURISED STEEL

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Abstract— An experimental study on solidification structure development and on endogenous inclusion precipitation in a continuously cast resulphurised steel is presented. Results were obtained by investigating two heats of a free cutting C-Mn steel cast in billets with a diameter of 145 mm. The as cast structure was evaluated by macro- and microscopic analyses. Primary and secondary dendrite arm spacing measurement allowed to estimate the solidification time experienced by the steel in different region of the billet section. Modification of the pearlite vs. ferrite fraction was also studied as a function of distance from billet surface and thus with reference to solidification conditions. Endogenous inclusions of the type MnS and CaO-Al₂O₃ were analysed. Their formation was discussed as a function of the composition of the heats. Also for the inclusions resulting after steel solidification, the data suggested that the effects of local solidification condition and of segregation played a role of primary importance.

Keywords— continuous casting, resulphurised steels, dendrite arm spacing, endogenous inclusions.

I. INTRODUCTION

Over recent decades continuous casting has become a vital part of the steelmaking process due to improved yield and lower energy consumption properties. Concurrently the classical ingot route underwent a dramatic loss of interest and remains competitive only in specialized areas. Steel slabs and billets produced by continuous casting possess a significantly different structure from the products of ingot technology. A full knowledge of the factors affecting structure (e.g. columnar vs. equiaxed structure), segregation of alloying elements, defects formation and inclusion generation is of paramount importance for any further improvement required to increase productivity and quality of continuous casting plants.

A first aspect of great concern in steel products is the billet structure in terms of equiaxed vs. columnar grains. Several investigations were published on the

effects of carbon content, on liquid superheat, on peritectic transformation and on solidification parameters [Irving *et al.*, 1984]. In general terms, the tendency toward columnar or equiaxed structure depends primarily on steel composition. Compositions with intermediate C contents (from 0,10 to 0,50% C) tend to crystallise with an equiaxed central structure [Jacobi and Wünnenberg, 1997]. A large proportion of equiaxed structure is generally recognized as beneficial due to improved segregation distribution and cracking resistance. To this aim, great research effort was devoted to stirring effects and soft reduction (either of thermal or mechanical type) in plant design [Jacobi and Wünnenberg, 1997; Sivesson *et al.* 1998; El-Bealy and Fredriksson, 1994].

Internal quality, mainly evaluated by crack formation and centreline or intercolumnar segregations is a factor substantially governed by strand geometry and by solidification conditions. Again, a fully columnar structure is not appreciated since it increases segregation on the centreline. Amongst the factors affecting segregation is product bulging in the final stages of solidification. When ferrostatic pressure reaches high levels and the constraint imparted by the strand rolls is not adequate, billet or slab thickness can increase. Solute enriched liquid can thus flow through the centreline and solidify as central segregation even if the original structure is of equiaxed type. Similar effects are also reported to be brought about by internal solidification shrinkage that promote a flow of carbon-enriched steel in the final solidification region in the centre of the cast material [Irving *et al.*, 1984; Jacobi and Wünnenberg, 1997; Sivesson *et al.* 1998; El-Bealy and Fredriksson, 1994]. To counteract this phenomenon, a gradual tapering of the roll gaps in the zone of final solidification revealed to be an effective method. A further beneficial effect of this technology is the squeezing action of the strand that may crush the tips of the dendrites of the advancing columnar grains.

Microsegregation behaviour in continuously cast steels is a concurrent aspect that roughly depends on the same variables discussed above. Evaluation of microsegregation is often performed in terms of dendrite arm spacing (DAS) which is considered as a measure of the segregation distance of crystal development during