

Solidus Temperature

Question

How does solidus temperature in carbon steels affect elemental segregation? What are some of the characteristics associated with elemental segregation? Do you have a formula for solidus temperature? J.O., USA

Answer

In general term, the larger the difference between the liquidus and solidus temperature, the greater the propensity for elemental segregation. Typically, a higher concentration of carbon, phosphorous and sulfur is found near or in the center of a continuously cast billet. Segregation becomes very pronounced in steel grades with carbon greater than 0.65 %. In wire rod material, the size of a black area in the center of a metallographic sample is used to qualitatively determine the amount of segregation. Rod sample elemental concentrations can be analyzed quantitatively across the diameter in an SEM using electron probe x-ray microanalysis.

As carbon concentration increases in the center of the wire rod, strength and brittleness are likewise increased. Due to the nature of continuous casting, segregation is not uniform at all locations along the length of a wire rod. When trying to predict wire rod breakage during drawing operations with no intermediate heat-treating processing, the standard deviation combined with the average segregation is a predictor of breakage. The lower the average and tighter the standard deviation of the qualitative or quantitative tests, the less chance for rod breakage.

The solidus temperature can be expressed as follows:

$$T_{\text{sol}} = 1536 - [415.5(\%C) + 12.3(\%Si) + 6.8 (\%Mn) + 124.5(\%P) + 183.9(\%S) + 4.3(\%Ni) + 1.4(\%Cr) + 4.1(\%Al)].$$

As a quick predictor of segregation potential, an operator may calculate both the liquidus and solidus temperature for any heat of steel within a certain grading range. The greater the difference in temperatures within the same grade, the higher the potential for segregation and wire rod breakage during drawing operations. Elevated tundish temperatures greater than 25°C above liquidus are also known to increase segregation except as described for billets cast using hard cooling.

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