Understanding a Weld's Heat Affected Zone By Testing Low Carbon Steel

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Introduction

During a weld, the base metal reaches very high temperatures. Though only the welding pool becomes a liquid, much of the base metal is still affected. The Heat Affected Zone (HAZ) is the region of the base metal which is impacted by the heat.

Heat Affected Zone (HAZ)

1	2	3	4	5	6	7
Unmixed Zone	Partially Melted Zone	Coarse Grain	Intercritical	Fine Grain	Tempered Zone	Unaffected Base Metal

Metal in the HAZ undergoes one or more phase changes due to the heat. A phase change is defined as the change in the metal's microstructure (how the molecules of the metal are arranged). When the structure is altered, the metal has changed from the parent metal to a different phase. The phases have unique names and temperatures at which they generally begin to form.

A phase change will impact the properties of the metal, such as brittleness and color. These changes can be negative and lead to cracking in the metal being welded.

Phase Name	Forming Temperature
Austenite	725°C - 1370°C
Pearlite	Below 750°C
Bainite	250°C - 550°C
Martensite	Below 230°C

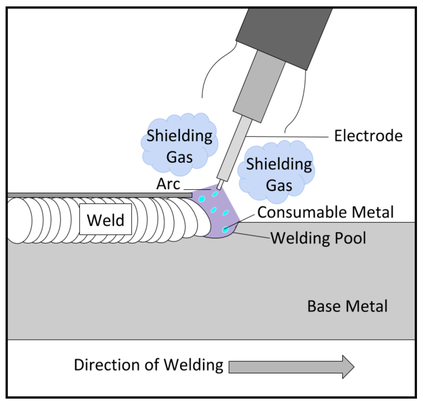
The purpose of this study is to discover more efficient and usable methods of predicting phase changes. In this study, a dilatometer is used to heat a sample of low carbon steel and measure its temperature relative to the dilation and constriction it undergoes. The study particularly focuses on the cooling and contracting of the sample after being heated.

Examining this data allows for a better understanding of the phase changes that occur during the cooling of the metal. The knowledge taken from this study will be used to create a method for welding industries to better predict what might happen to their metal as it cools.

Background: A Basic Weld

- **The electrode** is a tool used to create the weld. It is supplied with heat and electricity, which creates a weld when it comes in contact with the base metal. Electrodes are made of metal which may or may not be consumed by the weld and added to the welding pool.
- **The welding pool** is the liquid part directly under the electrode as it moves along the base metal, causing an instantaneous liquid pool before solidifying into a weld bead. This is because of the extreme heat.

Figure 1: A schematic of a Metal Inert Gas Weld.



- **The arc** is an electrical discharge created by the contact between the electrode and the base metal. It is too bright to look at with bare eyes and can reach temperatures anywhere from 3000 -20000°C
- **Shielding gas** is used to protect the weld from oxygen, water vapor or outside air.

Methods

To better understand the HAZ and how the temperature may cause phase changes in the metal, a dilatometer is used to heat and cool a small sample of metal and observe what phase changes occur. The sample used for the experiment was low carbon steel. Two thermocouples were spot welded to the sample to measure temperature. Finally, the dilatometer was used. The sample was heated at 5K/s and cooled at 1K/s. The temperature and change in length were recorded.

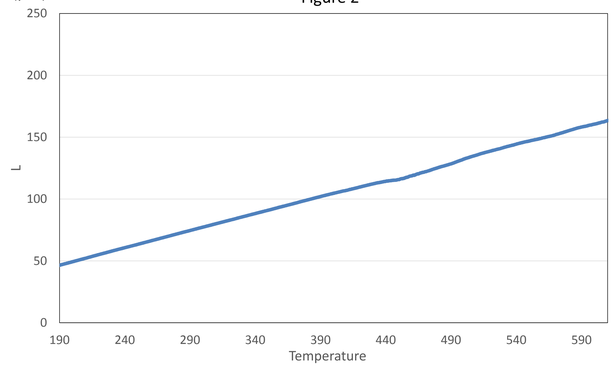
The data was then added to an excel workbook. The purpose of the workbook is to calculate the percentage of each phase remaining at the end. The sample that was tested experienced two phase changes as it was cooling. At around 800 degrees, pearlite begins to form and at around 650 degrees, Bainite begins to form..

Assumption: For this test, it was assumed that Bainite and Pearlite stopped forming at the same temperature.

Results

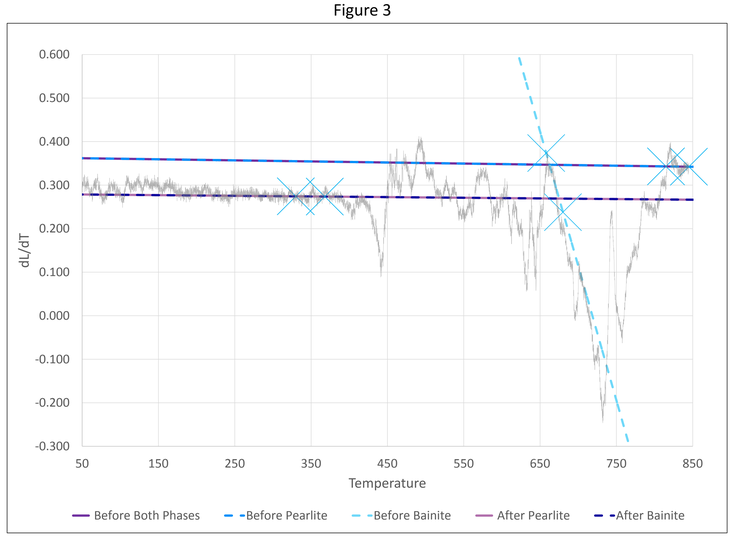
This graph represents the cooling of the sample from around 600° to 200° relative to its change in length (µm).

Figure 2



This graph represents the derivative of the change in length. This means that it is graphing every small change dilation. The extreme dips and rises in this graph represent the phase changes. Tangent lines were placed on various points through.

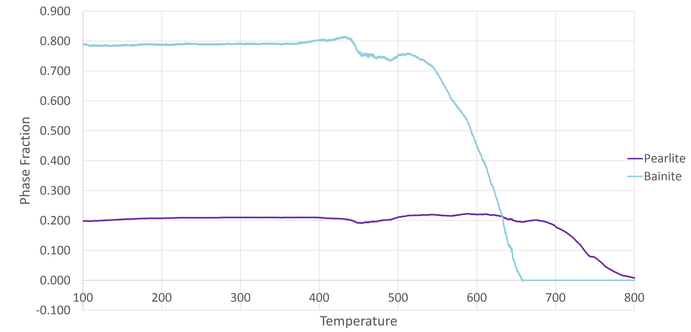
Figure 3



Conclusion

Phase	Bainite	Pearlite
Final Percent Remaining	82%	22%

Figure 4

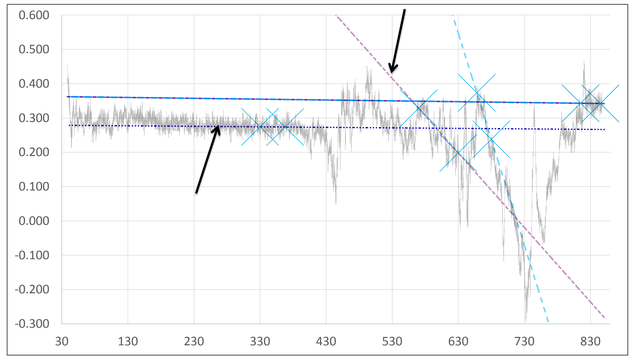


Future Work

It is important that the assumption that both phases end at the same temperature must not be made in future work. This is key to creating more accurate results. Here are the results without the assumption:

Phase	Bainite	Pearlite
Final Percent Remaining	82%	263830%

Figure 5



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