Vacuum Heat Treatment Fundamentals for the Non-Metallurgist

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Heat treatment involves the controlled heating and cooling of a material over specific durations of time to change the material's physical properties to make it suitable for a given application. Heat treatment is usually a small portion of a part's manufacturing costs, however it has a tremendous impact on the part's performance, so proper heat treatment with good process control is essential.

With heat treatment, properties such as hardness, wear resistance, toughness, strength, and machinability can be altered, but keep in mind that optimizing one of these properties will result in trade-offs in other properties. For instance, heat treating a steel to give high hardness and good wear resistance characteristics will typically result in a material with lower toughness. It is important to thoroughly understand the application before deciding what material properties are most important and then work with your material supplier and heat treater to ensure your material will have the properties you need.

High alloyed steels are typically heat treated in a vacuum furnace, which means that the material is surrounded by an inert gas (typically nitrogen) under vacuum and heat transfer occurs through convection and radiation. By heat treating in the absence of oxygen, oxidation of the material can be prevented. Vacuum furnaces allow uniform, well-controlled temperatures and quick cooling of the material. This results in a heat treatment cycle that is very consistent from one time to the next, resulting in very consistent properties of the parts being heat treated. In addition, the absence of air or other gases in a vacuum furnace prevents contamination and decarburization. (Note: decarburization is the reduction of the carbon content of a metal, which occurs at high temperatures [>1300° F] when the carbon in the metal reacts with oxygen or hydrogen gases. This results in lower surface hardness and risk of cracking.)

Vacuum furnaces have excellent process control capabilities, are low maintenance, and are environmentally friendly. All of these advantages make vacuum furnaces the heat treatment equipment of choice for high quality steel parts.

Having the right heat treatment equipment is only the start. Before parts are heat treated, it is important to fixture and/or position them properly to prevent or minimize distortion during the heating and cooling processes. The process controls for operating the vacuum furnace are essential to ensuring the correct heating and cooling rates and times at target temperature settings. Key process control variables include furnace

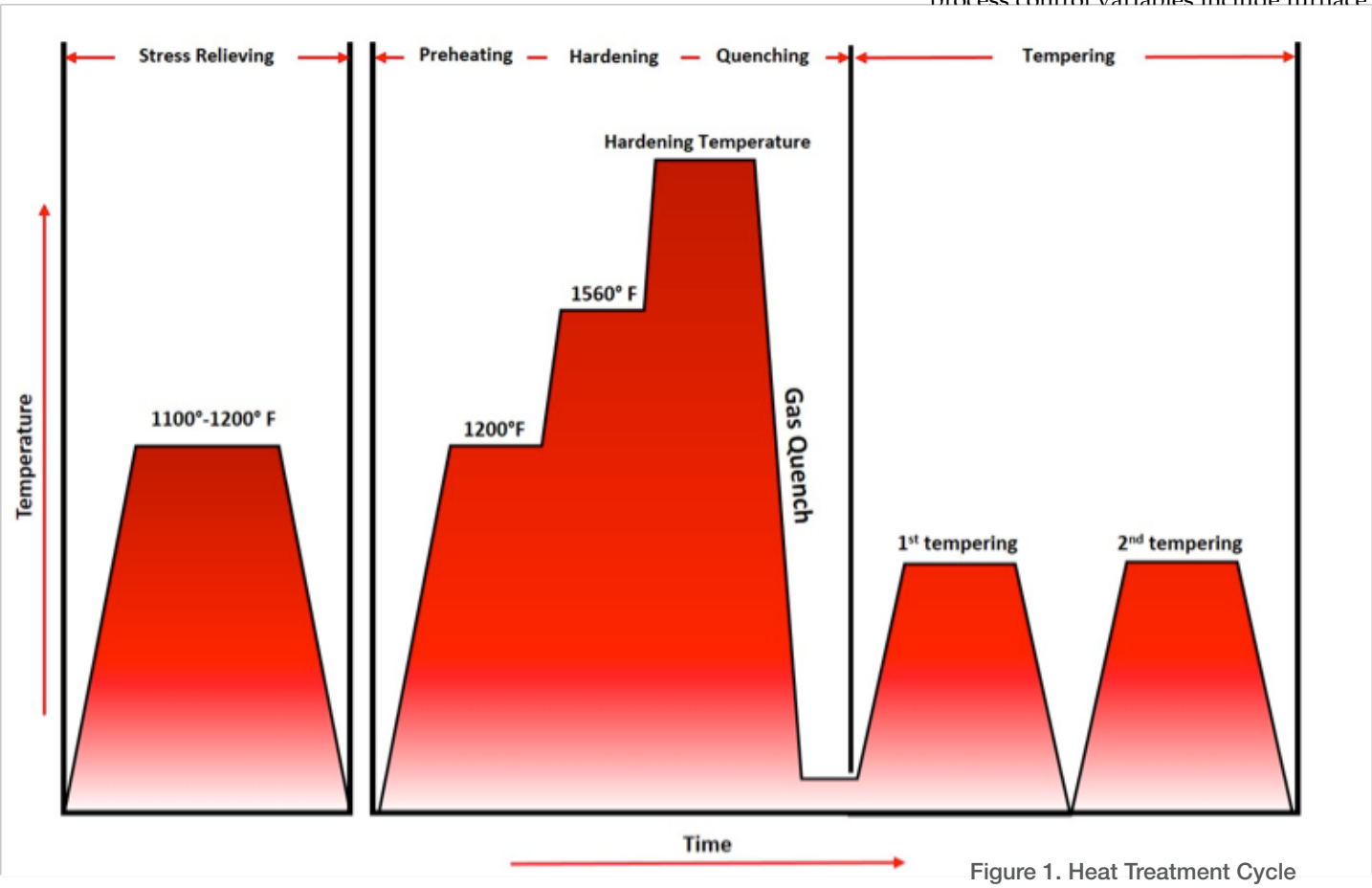

Figure 1. Heat Treatment Cycle

Figure 2. Inside a Vacuum Heat Treatment Furnace at Kinetic

pressure, furnace temperature, and quench gas flowrate. These key variables control the temperature, time, heating rates, and cooling rates which make up the "heat treatment recipe" for a given material and application.

Figure 1 shows an example of a typical heat treatment cycle for a tool steel. First the parts are stress relieved, followed by the hardening process, then quenching, and finally, two stages of tempering.

1. Stress Relieving is a heat treatment process in which a metal is held at a constant temperature that is below its phase-change temperature, followed by controlled cooling. For tool steels, stress relieving is done at 1020-1300°F for a minimum of two hours followed by slow cooling to 930°F then continued cooling in air. The purpose of stress relieving is to remove or reduce the internal stresses of a metal, since these stresses can cause cracking, distortion, loss of tolerances, and failures. Stresses can be a result of machining operations, high temperature operations (e.g. welding), or phase transformation.

2. Hardening is increasing the hardness of a material by heating and cooling it in a controlled manner.

3. Quenching is rapidly cooling a heat-treated material in oil, water, or high-pressure gas. In a vacuum furnace, high pressure gas is used. In ferrous materials quenching, after heating above the critical temperature, produces a harder metal.

4. Tempering is a heat treatment process used to bring the metal to a slightly lower hardness and strength while improving its toughness. This is done by reheating a hardened material to a temperature below the critical range and then cooling again. Most applications require that quenched parts be tempered. Tool steels are usually double-tempered and for some applications even triple-tempered.

The Kinetic Co., Inc. is a 3rd generation manufacturing firm located in Greendale, WI. Our primary products are industrial knives for many industries including paper, steel/metals, wood, food processing and packaging. In addition, Kinetic offers machining, grinding, heat treating, and wire EDM services. Our capabilities include CNC turning and milling, I.D. and O.D. grinding, Blanchard and surface grinding, EDMing and vacuum heat treating. Our state of the art facility is home to skilled machinists, engineers, and technical support professionals, many of whom have decades of manufacturing experience. Please visit our website (knifemaker.com) if you would like more information.