Hardening Steel - A General Overview

Hardening steel is probably the most common process we are asked to do at Therm-Tech of Waukesha. In this month's article, I would like to give a general overview of the nuts and bolts of the process of hardening.

Hardening can be achieved on most steels. The largest exception to this is 300 series stainless steel. The most important component for us as heat treaters with respect to the hardening operation is the chemistry of the part we are heat treating. Alloying makes our job easier when it comes to hardening steel. Some of the most common alloying elements in the steel we heat treat at Therm-Tech are manganese, chromium and nickel. These elements greatly increase the hardenability of steel. The consequences of the addition of alloying elements allow the heat treater to use a less severe quenchant, e.g. oil, and still achieve a fully hardened structure. Heat treating a plain carbon steel, e.g. AISI 1045 steel, would require a water or polymer quench to achieve maximum hardness.

The first step in hardening steel involves heating it at some prescribed rate to what is called the austenitizing temperature. Austenite is a phase in steel which occurs at an elevated temperature that varies depending on the chemistry. At this temperature you have a single phase present. A good comparison to this aspect of the process would be taking a glass of water and putting a teaspoon of sugar in it. You could now think of the glass as having two phases, water and sugar crystals. If you then stir it, (adding energy) the sugar dissolves, you now have a solution and a single phase once the sugar is dissolved. When we heat steel, (adding energy) it's similar to stirring the sugar water mixture. Once the steel component we are heat treating reaches temperature uniformly it becomes a solid solution, that is, it is completely one phase called austenite.

After a period of soak assuring temperature uniformity throughout the entire section, the next step in hardening is quenching the component. The quenchant and quench rate are dictated by the type of steel and the alloying elements. The goal of quenching is that we are trying to achieve a completely martensitic microstructure. Martensite is the hard phase of steel and is only achieved by quenching from the austenite phase. As quenched the steel part is at its maximum hardness and strength level, (hardness can be used as a measurement of strength.) However due to the tremendous stresses caused by this process it is also in a very brittle state. It must be reheated, (tempered) at some lower temperature to reduce the risk cracking due to high internal stresses.

Tempering is the last step in the hardening process. Tempering generally decreases the strength of the steel component but adds ductility. This is achieved because tempering causes very small carbides to precipitate reducing internal stresses. It is critical that this process begins immediately after hardening to eliminate the probability of cracking due to high stress levels existing in the as quenched state. The final hardness/strength level varies with the tempering temperature. The minimum temperature for tempering is 300F. At this temperature there are minimal losses of hardness and strength but all probability of cracking due to stress are removed. The maximum tempering temperature for a hardened component is typically in the range of 1300F. Above this temperature the martensitic structure begins to break down back to the original phases that were present prior to hardening.

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