A Simplified Guide to Heat Treating Tool Steels

When we consider that the greater overall costs of most tools and dies are incurred prior to heat treatment and further that proper heat treatment is critical to the successful application of tooling, this so-called "hardening" process is placed in it's proper perspective of importance. While there are a number of specialized procedures which can be employed in the heat treatment of tool steels, the purpose of this discussion is to review the basic heat treating process, it's steps and terms, and perhaps offer some helpful hints along the way.

The Heat Treating Process

The process consists of:
A) PREHEATING the Annealed tool, typically at 1250 degrees F.
B) AUSTENITIZING (Soaking at High Heat).
C) QUENCHING – Quench to Hard Brittle (Martensite) condition.
D) TEMPERING (Drawing to desired hardness).

Annealing

Tool steels are furnished in the annealed condition which is the soft, machineable and necessary condition for proper heat treat response. The exceptions to this are the prehardened steels such as P-20, Brake Die, Holder Block and Maxel Tooling Plate which are furnished at 28/32 HRC and used at that hardness.

Tool steels should always be annealed prior to re-hardening and annealed steels should be re-annealed after welding. Unlike hardening which requires a quench after soaking at the hardening temperature, the essence of annealing is very slow cooling from the annealing temperature. By way of example, A2 tool steel is annealed by heating to 1550 degrees F, soaking for two hours at temperature, furnace cooling 50 degrees F per hour to below 1200 degrees F followed by air cooling. Some shops anneal late in the day after all other heat treating has been finished by simply soaking the part to be annealed at the proper annealing temperature and then turning the furnace off. The next morning the part is fully annealed and ready for handling.

Preheating

Preheating plays no part in the actual hardening reaction and is often considered an unnecessary step. However, preheating performs at least one major function, it minimizes thermal shock, thus reducing the danger of excessive distortion, warping or cracking. As a matter of fact, intricate tools and particularly high speed steels, are often preheated in two steps: one below the transformation temperature and the second right at the transformation temperature. Preheating does not require "soaking" but the tool should be equalized at the preheat temperature. Remember, always bring your tools up with the furnace to the preheating temperature.

Austenitizing (High Heat)

Austenitizing depends upon time and temperature, thus the common term, soak at high heat. Of the two, temperature is the most critical. Never exceed the high heat range for the grade. Excessive temperature will cause erratic results. Classic symptoms of overheating are low as-quenched hardnesses and, depending upon the alloy content, shrinkage and loss of magnetic properties. Soaking time should always be after the steel has caught up with the furnace temperature. With the exception of high speed steels, a rule of thumb for soak time is one half hour per inch of thickness with a forty-five minute minimum and if in doubt over how long to soak a tool, soak it longer – never less. High speed steels are essentially equalized with the furnace temperature as opposed to soaking due to the fact that the high heat range is so close to the melting point. Essentially, high speed steels are equalized at the austenitizing (High Heat) temperature in minutes of furnace time, never soaked.

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Quenching

Quenching must be done promptly in the medium prescribed for the grade with the exceptions discussed further. Actually, Water Hardening steels are properly quenched in brine. A pound of salt to a gallon of water is a good guide. Oil Hardening steels should be quenched in circulated commercial quenching oil which has been heated to 100/125 degrees F. In either case, the liquid quenching bath should contain sufficient volume to prevent the bath from exceeding the proper bath temperatures. Air Hardening steels will harden in still air in small sections. However, medium to large sections may require a light, evenly distributed fan blast. A fan blast on only one side of a section may cause uneven quenching which will result in warpage.

Large sections in certain air hardening grades will not develop full as- quenched hardness unless they are started in oil. This process is commonly called interrupted oil quenching. Simply stated, the tool is quenched into oil until the section just turns black followed by air cooling. S7, an air hardening -shock resisting tool steel, is a classic example of a steel which will not develop full hardness in larger sections unless it is given an interrupted oil quench.

High Speed steels are basically considered oil hardening, however, to minimize distortion, high speed steels are commonly hardened with an interrupted oil quench or quenched in hot quenching salt at 1000 degrees F followed by air cooling.

Obviously, vacuum heat treating furnaces do not allow quenching outside of the furnace unless the vacuum furnace has been equipped with an attendant oil quenching zone. Small and medium sections of air hardening steel will develop full hardness when quenched by the inert gas backfill. However, larger sections will not develop full hardness unless the inert gas backfill has sufficient capacity. Some vacuum furnaces have an adjustable large capacity pressure pump to insure sufficient gas flow to develop faster quenching rates. Do not temper until the tool reaches about 125 degrees F (handling temperature). If tools cannot be promptly tempered, placing them in a container of boiling water (212 degrees F) will prevent cracking due to quenching stresses until tempering can be accomplished.

Tempering (Drawing)

Upon quenching, tool steels are in a highly stressed condition. To avoid cracking, tools should be tempered immediately after quenching. As with Austenitizing, tempering is dependent on temperature and time. The temperature must be closely controlled, to develop the desired hardness range. For tempering time, a rule of thumb is one hour per inch of thickness with a two hour minimum. Longer tempering times are not detrimental and it is essential that the steel is soaked at temperature after the steel catches up with the furnace temperature. While one thorough tempering cycle is sufficient for the lower alloyed tool steels like Wl and 01, the more highly alloyed grades such as H13, S7, A2, D2 and the High Speed steels require multiple tempering cycles. A rule of thumb is that liquid quenched steels may be tempered once, air hardening steel require a double temper and high speed steels should have a triple temper. All steels must be cooled in air to about 125 degrees F prior to the next tempering cycle.

Stress Relieving

Like preheating, stress relieving is not a part of the hardness reaction. However, in order to minimize distortion, particularly in tools which have had a considerable amount of machining and tools of intricate and/or unbalanced design, stress relieving is an economical insurance. Annealed tool steels are stress relieved about 150 degrees F below their Critical Temperature. For most grades a 1200/1250 degrees F temperature is used and soak times are similar to tempering. Heat treated steels may be similarly stress relieved at a temperature about 25 degrees F lower than the last tempering temperature. This is a good policy for steels which have been EDM'd in order to relieve stresses from the stressed “white layer zone”.

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Surface Protection

It is very important to protect the surface of tools from carburization (absorption of carbon) unless tools are to be intentionally carburized for additional surface hardness. In the case of intentional carburizing, a specific carburizing cycle is employed. Likewise, it is important to protect tools from de-carburization (the loss of carbon from the steel's surface) during the heat treating cycle.

Various methods are employed to prevent these detrimental changes to the surface of tools during heat treating. Atmosphere controlled furnaces and vacuum heat treating furnaces are two current methods. Stainless steel foil is commonly used to wrap tools in a relatively air tight package. This is a very effective method if atmospheric controlled or vacuum furnaces are not available.

When using "stainless wrap" it is good practice to cover sharp edges with a small piece of wrap to prevent tearing out of corners. Also, never quench tools in the wrap, it acts as an insulator from the quench resulting in low as-quenched hardnesses.

We at Gateway Metals, Inc. truly care about your tooling and have published the above heat treating guide as a service to our customer-friends.

If you desire further information on heat treating and/or tool steel grade recommendations for your specific applications, call Gateway Metals, we'll be pleased to hear from you.

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