Predicting Size Change from Heat Treatment

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One of the questions a commercial heat treater is most frequently asked is, "How much, if at all, will my part shrink or grow?" While the heat treater would love to be able to give a precise answer to this question, in most situations volumetric size change during heat treatment cannot be accurately predicted (at least not accurately enough to allow for final machining and/or grinding to close tolerances prior to heat treatment).

The answer to the dimensional change question is extremely complicated and involves hundreds of variables. Heat treating can add its own set of unique variables as well that will affect part size change. While a precise forecast of a part's size change cannot be expected, by considering each of these potential factors, a heat treater can provide a reasonable estimate that can help the shop prepare for final machining operations.

Variables Affecting Dimensional Change

- Material grade
- Variation in material properties (chemistry, homogeneity, grain size, number and type of inclusions, and hardenability)
- Part orientation versus grain orientation
- Starting microstructure
- Heat treatments performed at the mill (dozens of variables)
- Manufacturing process and sequence of operations
- Residual stress state (from manufacturing)
- Heat treatment after component manufacturing (dozens of variables)
- Hardness range (initial, final)

Variables Related to Heat Treating

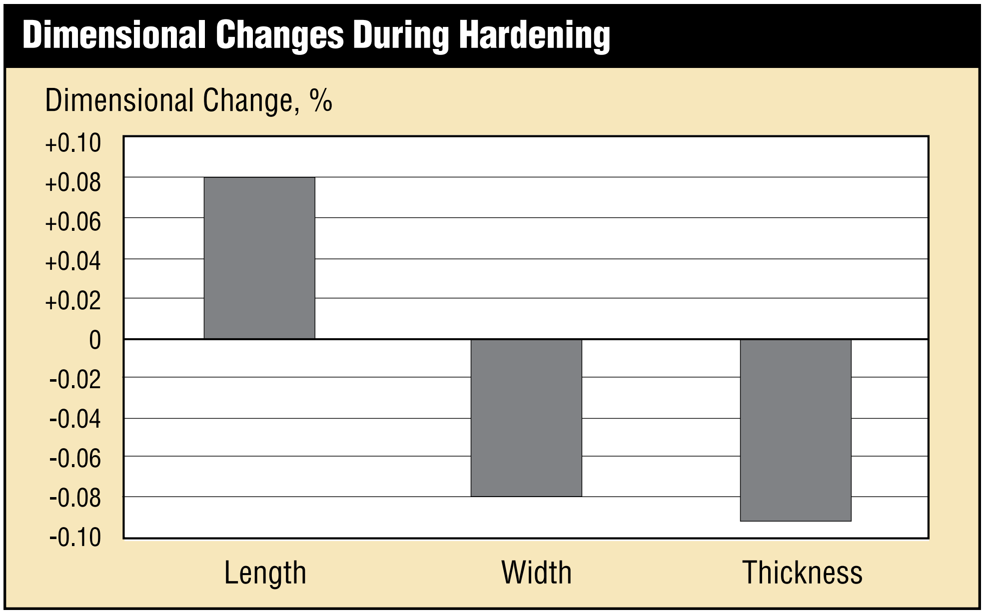
- Type of process selected (annealing, hardening, nitriding, carburizing, and so on)
- High-heat process (anneal, normalize, austenitize), temperature and soak times
- Low-heat process (age, temper, stress relief), temperature and soak times
- Furnace temperature uniformity
- Furnace repeatability
- Quenchant type
- Quench rate
- Part size
- Load size
- Load configuration
- Part orientation/fixturing
- Type of furnace atmosphere
- Deep freezing or cryogenic processing
- Number of tempering cycles

Estimating Size Change

Experimental work has been done on many materials to show the effects of heat treatment on size change. The effects are different for every material grade. Figure 1 (p. 24) shows how part size changes on a 3.15-inch cube of D-2 tool steel during hardening. Notice that the part size grows by 0.08 percent in one dimension, while shrinking in the other two directions. This graph demonstrates how knowing the part orientation from the mill-supplied bar is important when trying to plan for size change during heat treatment.

Figure 2 shows the dimensional change of D-2 tool steel during tempering. D-2 is a transformation hardening tool steel that requires both a hardening and tempering step during the heat treating process. The dimensional changes on hardening (Figure 1) and tempering (Figure 2, p. 24) should be added together when trying to estimate total size change. Final part hardness is determined by tempering temperature. Figure 2 demonstrates why the hardness requested by the customer will have a drastic affect on size change.

In another example, according to a Latrobe Steel data sheet, 17-4 precipitation hardening stainless steel can typically be expected to shrink by 0.0004 to 0.0006 inch/inch (size change per unit of length) when aging from Condition A to Condition H-900 and 0.0018 to 0.0022 inch/inch when aging from Condition A to Condition H-1150.

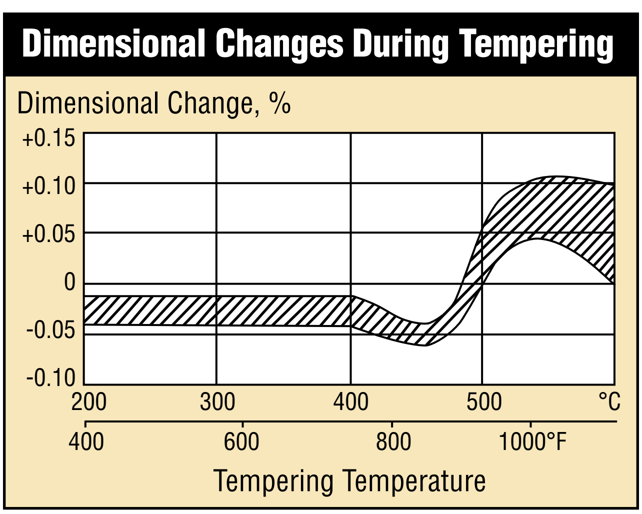


▶ Fig. 1. An Uddeholm data sheet shows that when D-2 tool steel, 3.15" × 3.15" × 3.15", is austenitized at 1,870° F (1,020° C) for 30 minutes and quenched in a vacuum furnace with 2 bar nitrogen overpressure, it grows in one dimension while shrinking in the other two.

Communication with the heat treater, experimentation and process control can help to provide fairly accurate, consistent/repeatable size change estimates.

Consistency is Key

Recently, a manufacturer embarked on a project to help minimize its post heat treatment machining costs. The company is a tooling manufacturer that designs and supplies round dies made of 440C stainless steel in sizes ranging from 2-inch diameter × ½-inch thick to 8-inch diameter × 1-inch thick.



▲ Fig. 2. The dimensional changes on hardening and tempering should be added together. The minimum recommended machining allowance is 0.15 percent per side, assuming that stress relief is performed between rough and semifinish machining, as recommended. If not, machining allowances must be increased accordingly.

The company's first step was to meet with the heat treater to discuss its needs. Discussion during the meeting helped to clarify that the amount of size change during heat treatment was not important. What was important was that it needed to be consistent part-to-part, load-to-load and batch-to-batch.

The manufacturer and the heat treater proceeded to list all of the variables that would affect size change during heat treatment. From that list, a shorter list was made of variables that could be controlled during the process. These factors included the steel supplier (both mill and service center), chemistry, condition of the steel, manufacturing sequence, heat treatment and required hardness.

Within the heat treatment process, the heat treater committed to precisely controlling the parameters for load size, load configuration (spacing/racking/fixturing), ramp rates, soak times, preheat temperature, austenitize temperature, quench rates and tempering temperature.

By controlling all of these variables, and repeating the process on a weekly basis, the tooling manufacturer is now able to predict the size change during heat treatment of dies (all sizes) to within ± 0.001 inch, which provides a significant time and cost savings in post heat treatment processing. ■

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For more information from the Herring Group Inc., call 630-834-3017 or visit *heat-treat-doctor.com.*