Testing O1 Tool Steel . . . Again

Part 1: Using Some Scrap Pieces to Test Several Heat-Treat Variables

We recently changed from Canola oil for quenching to Quenchall 28 second oil. We also modified our quenching process by using an electric heater to get the oil temp up for quenching. Due to an earlier failure of some knife tips, we also decided to add a mixing process to maintain the oil temperature constant from top to bottom. This required a mixer attached to a drill combined with thermal probes top and bottom.

The new quench oil system approach allows us maintain constant oil temp over the entire quench oil column. In order to keep the oil temperature below the maximum temperature (< 140° F) for our testing, we used a frozen aluminum bar, plunging it into the oil when the oil exceeded maximum temperature. Since most of the pieces were small, the frozen aluminum bar did the trick.

Since we have a bunch of scrap pieces of O1 tool steel (artifacts of the knife making process, some shown below), we decided to test some other process variables to determine their effect on toughness.

We started with nine (9) pieces of scrap O1 tool steel, shown below after coating with anti-scale paint. We focused on impact testing, instead of just bending as we had done in previous tests. Because the pieces vary in thickness and length, we considered this first set of tests to be preliminary.

We hardened all of the pieces at 1460° F and tempered all of them at 750° F. Most of them we snap tempered at 330° F while waiting for the furnace to cool to tempering temperature. Others we allowed to rest at room temperature while the furnace cooled for tempering (~1 hour). We varied how fast we cooled them from snap temper and final temper. “Fast” cooling means cooled in water. “Direct” means no cooling from snap temper to final temper. “Slow” applied to post-final temper, allowing them to air cool slowly. These variables and results are presented on the following table.

Some scrap pieces from knife making (We have a lot more!)

Nine pieces of scrap O1 tool steel used for testing different variables

Test Parameters and Preliminary Results

Piece #	Quench seq	Oil temp	Oven	Test	Cool rate 1	Cool rate 2	Comments	Dim (inches)
1	1	107	Yes	Impact	fast	fast	thick piece relative to 7 - 9--strong tip	0.25 x 0.375 x 6.3
2	2	114	Yes	Impact	direct	fast	thick piece relative to 7 - 9	0.25 x 0.375 x 6.3
3	8	128	Yes	hardness	direct	slow	thick and wide piece--removed 2nd to last	0.312 x 1.25 x 5.0
4	9	141	Yes	hardness	direct	fast	thick and wide piece--removed last	0.312 x 1.50 x 5.1
5	3	121	Yes	Impact	fast	slow	handled pounding better than other pieces	0.281 x 0.281 x 4.8
6	4	123	Yes	Impact	fast	fast	handled pounding better than other pieces	0.281 x 0.281 x 4.8
7	5	127	No	Impact	no oven	slow	Cooled for 1 hour after quench before temper	0.211 x 0.312 x 5.4
8	6	124	No	Impact	no oven	slow	Cooled for 1 hour after quench before temper	0.211 x 0.312 x 5.4
9	7	127	No	Impact	no oven	fast	Cooled for 1 hour after quench before temper	0.211 x 0.312 x 5.4

Notes:

All oven temps: 330° F

All oven times: 1 hour

All furnace temps: 750° F

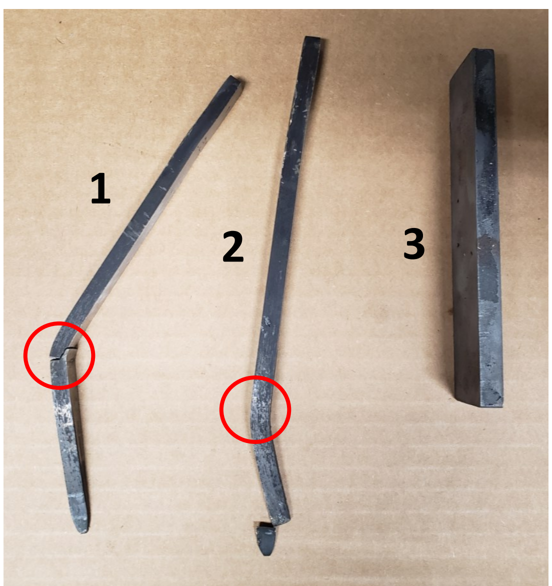
All furnace times: 2 hours

Cool rate 1: after oven

Cool rate 2: after furnace

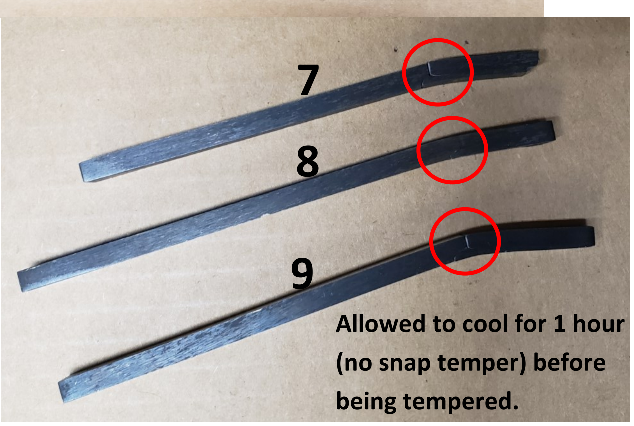
All pieces: break tests done on thin side

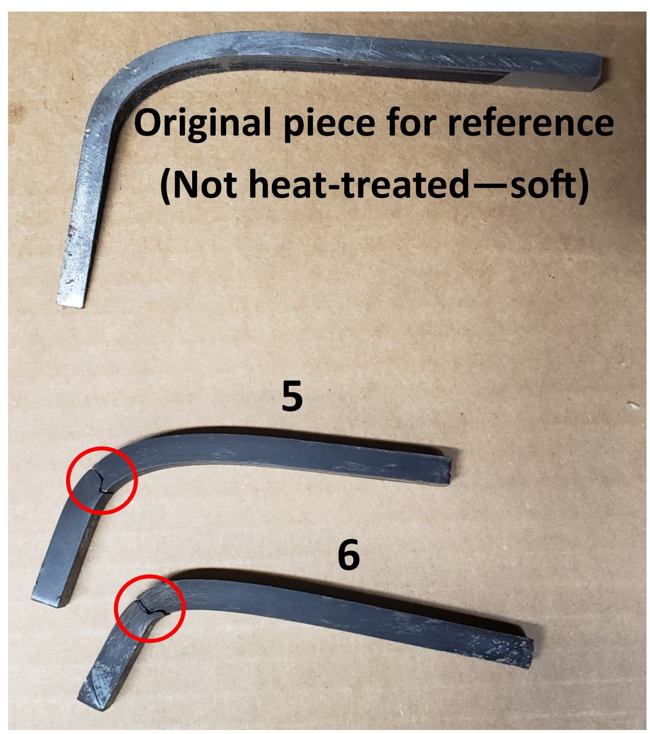
Piece #	Preliminary Results
1	Severely pounded--Broke at ~ 36°
2	Severely pounded--Broke at ~ 30°
3	HRC 50.4--Severely pounded--no discernable deflection--gave up!
4	HRC 50.8--Severely pounded--no discernable deflection--gave up! Then lost it somewhere!
5	Severely pounded--bent to breaking at ~ 77°
6	Severely pounded--bent to breaking at ~ 70°
7	Severely pounded--bent then broke at ~ 4° Sitting out for 1 hour before tempering is a bad idea
8	Severely pounded--bent then broke at ~ 10° Sitting out for 1 hour before tempering is a bad idea
9	Severely pounded--bent then broke at ~ 15° Sitting out for 1 hour before tempering is a bad idea



Notes:

- Break points are circled in red.
- Lost (as in misplaced) piece #4—no idea how! It's out there somewhere!
- Piece #2 was clamped by the tip and took several hits before snapping.
- Piece #5 had more hits close to the top than #6.
- Pieces #7, 8 and 9 were as hard to bend as others, but broke at shallow angles.





Conclusions from preliminary results:

1. Too many variations in test piece size diminished our ability to form any satisfactory conclusions!
2. Since all heat-treated pieces (except 3 and 4) required intense pounding to bend and eventually break, one conclusion is that heat treating made them stronger than the soft reference piece. Since this was an obvious and well understood conclusion, no knowledge was gained in this area.
3. Pieces #1 and #2 only varied in their oven-to-furnace transition. Piece #1 had a rapid cool before the furnace and piece #2 went directly into the furnace from the oven. They both had the lowest temperature quench oil. Breaking points were too close to draw any conclusions.
4. The pieces that did not bend or break, #3 and #4, required greater pounding than I could provide with my sledge hammer. They were the only pieces big enough to allow for accurate hardness testing. They also had the hottest oil temperature when quenched. Tough or thick or both?
5. The pieces that bent the most before breaking, #5 and #6, were also the thickest pieces. Does this mean that thicker pieces bend more before breaking when pounded? Don't know, but probably not!
6. Pieces #7, #8 and #9 had the shallowest bends before breaking. They were, like the other heat-treated pieces, hard to bend and took a great deal of punishment before snapping. They could have broken with shallow bends due to being left out to cool for an hour after quenching rather than having a snap temper before being placed in the furnace for final temper. They could have broken with shallow bends because they were the thinnest pieces (refer to conclusion #4). My assumption, for now, is that they had shallow breaks because they were <u>not immediately tempered</u>. This will be revisited with more consistent pieces to determine the reason.

Summary: <u>Conclusions are inconclusive</u> (Great job!) and require more testing with pieces of consistent dimensions and fewer variables. We will provide the results of those tests in Part 2.

I almost forgot. I tried to video my attempts at breaking the test pieces, but forgot to turn on the camera. Actually, I turned on the camera, but forgot to start recording. I should have waited for the Bearded RAT to assist!