CHAMFERING: Hard vs Soft Parts and Before vs After Heat-Treating

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For years, I have always told people who ask me that my machines pretty much don't care if a part is hard or soft. When I was asked to write on this topic, I stopped and thought and realized I have never really done anything to verify my beliefs directly.

Examining my sample shelves, I found several parts that had not been deburred yet. I chamfered one part as a baseline, which was *soft* (pre-heat treat). I then heated two parts up until the parts were non-magnetic and quickly water-quenched them — a very rudimentary form of heat treating. Filing on the parts showed they were significantly harder than the non-heated parts. Experience tells me they are in the mid-to-high 50's on the Rockwell C scale. The soft parts are probably in the low-to-mid 20's — also on the same C scale.

The exact hardness of the gears is not important for my test. I just need two hard gears and two soft gears; then, I'll run them on my machine using the same set-up with the same grinding wheel, working pressure, and speed. Afterward, I will measure the differences in the chamfers.

I had already run the control soft part first, so I ran the two hard parts and followed by running another test soft part. Visually, there was no difference between any of the parts. Using calipers and measuring the actual chamfer width I found no difference either. As a result, for this very simple test, the hard parts and soft parts had exactly the same size chamfer after being processed on a James 562 deburring machine using the same set-up for all parts.

This simple test verified what I have always believed, but now I have an actual back-to-back controlled procedure test to verify what I have been saying for years. This test confirmed that this specific alloy of steel had no effect on chamfering when the material was hard or soft.

What I am *not* saying is that all materials chamfer the same. Carbide gears are probably the slowest material on which to create a chamfer, and aluminum is the fastest, but not by much when compared to regular steel. Aluminum is a gummy material and plugs up abrasive medias, making it an elusive material to grind consistently. Hard and soft versions of each material type in my experience will have similar results, meaning there will be little measurable difference in chamfer size and depth after using the same deburring process. Again, different materials require different types of abrasive media to achieve proper grinding results.

We have yet to find a material that we cannot create a chamfer and/or edge finish on. As to whether we chamfer before or after heat-treating — that's a very different story.

Figure 1 The four parts referenced in the article; No. 1, on bottom of stack, is the first soft part; No. 2, just above and on top of No. 1, is the first heat treated part after processing; No. 3 is next and on top of No. 2, and is the second heat treated part after processing; and No. 4 is the last soft part on top of No. 3, having been processed last. (Photo James Engineering).

There are always exceptions to blanket statements, but in general, chamfering and edge-finishing before heat-treating is always best. On large gears the chamfer prevents the induction heat treating process (if used) from overheating and actually melting the tip and end of the gear profile. On these large gears a rather large chamfer is required for this very reason. In the heating, quenching, and cryo-processes of heat-treating, the sharp and rough edges of a gear tooth are at risk of forming stress cracks. Chamfering and edge-finishing dramatically neutralize or reduce this risk.

Often, after heat-treating, gears are ground to final size; this requires a bigger chamfer than the "blueprint" specifies should be applied; so, after grinding the material removed, the chamfer is brought back to the print specifications. The ideal process is to apply an abrasive brush to the gear edge and profile (both sides) after final grinding. This final process removes the sharp edge produced by the grinding process on the chamfered edge closest to the ground gear profile. Depending on the application and type of gear, this final chamfer size is more important as the gear flexing and stress levels increase in frequency and pressure.

We all know gears carry their loads — from one set of engaged teeth to the next set of engaged teeth — rapidly and seamlessly at staggering frequencies. When the loads are big and a gear's teeth are flexing with loading and unloading to a higher degree, edge chamfers and surface finishes matter with regard to gear life and safe operation. Such continuously rapid flexing can cause cracks to form on the gear edges, unless the chamfer is the right size and has the right surface finish. My job is to build machines that can achieve optimal results with the greatest efficiency, lowest operating cost, and highest quality of chamfer and surface finishes on every part.

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