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AMERICAN METALCASTING CONSORTIUM

Geometric Dimensioning & Tolerancing Casting Quality Tip Series

Case Study 3: Seemingly Complex Made Simple – Position of a Feature and Profile of a Surface

Back in the day, Geometric Dimensioning and Tolerancing could have been named "3D Dimensioning and Tolerancing." Among engineered components, metal or non-metal, castings have the most "3D" attributes to their feature positions and surface profiles. So, GD&T and castings should be very closely allied at the implementation level, but they are not. Although GD&T is now applied to virtually any drawing file output from solid model software, using it in casting designs… at a high level… is rare.

GD&T *is applied at a high level on machined parts*, and for position of machined features on castings, it is also applied at a high level. But, as we learned in Case Study 2, machined features shouldn't be defined as such on casting drawings; instead, whatever the feature or surface, the drawing should simply define the needed tolerance and the required surface texture, where applicable. That allows metalcasting supplier teams the latitude to choose the best combination of mold cavity-making process, net shape upgrading process, and tooling design and construction (including Additive Manufacturing) to figure out how best to comply with the needed tolerances and required surface textures. In that latitude lies tremendous opportunity to reduce final assembled net shape component cost.

GD&T *isn't applied at a high level on as-cast hole positions and diameters nor on as-cast surface profiles.* Yet, that is where GD&T has its greatest potential in enabling more as-cast, net shape, lower cost features. The most likely reason that Position and Profile Tolerances are so underutilized in casting design is the apparent complexity.

So, the purpose of this Case Study 3 is to unravel the complexity and make it simple to understand and apply. Even for updating old 2D drawings, which is the context for this Casting Quality Tip, converting some features to Position Tolerance and some surfaces to Profile Tolerance is worthwhile and powerful. It is powerful because those two tolerancing methods make legacy replacement part castings, produced by a new contract awardee in a metalcasting supplier team, far, far easier to approve at First Article Inspection. That's a substantial time and cost saving opportunity that helps everyone involved. The following examples showcase three simple scenarios of how GD&T can be applied to have a powerful and beneficial outcome.

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As-cast holes are probably the most valuable opportunity to save final assembled net shape cost in both structural and functional castings. So, let's unravel this complexity barrier caused by Figure 1.

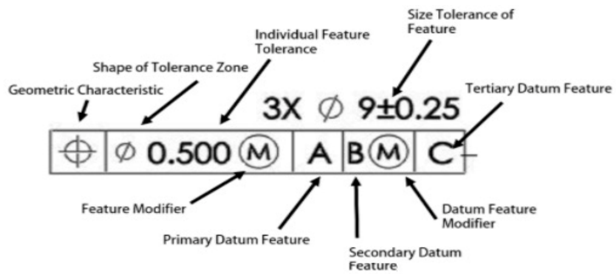

Figure 1

Figure 2 is an actual casting drawing, from the mid-1980s, calling out a cored slot. The casting designer's intent is to provide enough slot size and slot position to enable the casting to be cast in sand. This designer did a good job using GD&T for the design intent. Let's see how the Feature Control Frame for hole size and position shown in Figure 1 actually works:

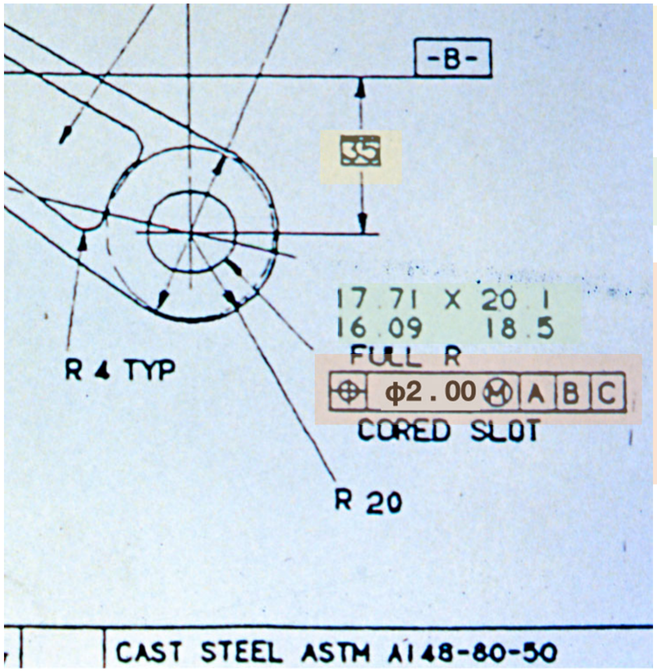

Figure 2

First, the 35mm Basic Dimension from Datum B (in the box) shows the intended "perfect" location of the slot. All of the tolerance for slot size and position is in the Feature Control Frame.

The top of the Control Frame says that the slot size has a range of 1.6mm (20.1-18.5 and 17.71-16.09mm).

The text and symbols in the rectangle say that the position of the cored slot can lie in a diameter of 2.00mm if the slot is at the minimum size. That's what the "φ 2.00 M" means. However, if the size of the slot is larger, within tolerance, the position of the slot can drift beyond the 2.00mm position diameter. That makes sense when thinking about assembly with a bolt to another part, looking at fit possibilities in 3D. A larger slot will work if it is slightly out of position.

The actual casting was made in the resin shell sand mold process, capable of 1° draft. The casting is 12mm thick, so the draft would use up 0.21mm of the slot size tolerance. If the very accurate cast iron tooling used in the resin shell process is

built to a slot size of 17.3 x 19.7mm to allow for 1° draft and any small error in the machined slot size in the tooling, then the diameter for slot position increases to 2.00 + 1.2 "bonus" tolerance for a larger than minimum-sized slot. In the old Coordinate Tolerance (+/-) system, a Position Diameter of 3.2mm is +/- 1.12mm. In English units, that is +/- 0.044 inch for position of the cored slot. In the resin shell process, that is doable… and it was.

Another powerful GD&T Position Tolerance capability for castings is a cored hole to be bored to net shape by machining. Figure 3 shows the opposite "Material Condition" specification: L for Least Material. "Least Material" means that a large cored hole has minimum tolerance to be out of position. That makes sense in 3D. If the cored hole is large, then there is less machine stock for the boring cut.

So, in this case, GD&T allowed for the casting tooling to be built to the small side of core size tolerance to allow more tolerance for the core to be away from its perfect position… and still assure that the bored hole will clean up as it is machined.

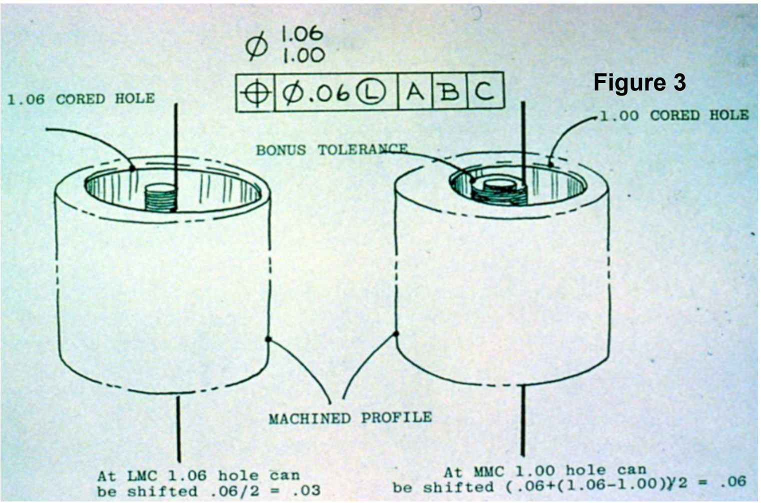

Figure 3

Perhaps the best way to illustrate the power of GD&T Profile Tolerance in designing castings for producibility (and for successful First Article Inspection) is to show a *crazy, but real example*. Here is one!

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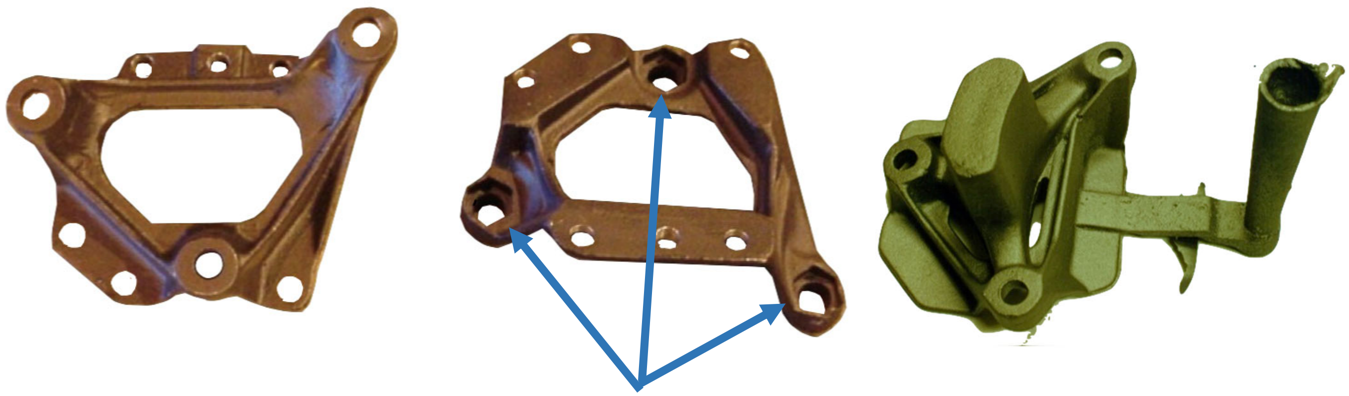

Figure 4

This is a bracket that mounts a steering gearbox to the frame rail of an 18-wheeler. The bolts that attach the gearbox to the bracket are trapped behind the bracket and the truck's frame rail. So, notice with the blue arrows, the as-cast hex profile to trap the heads of the hex bolts so that the nuts can be tightened from the front without having a wrench in the back.

But to our point about the power of GD&T Profile Tolerance being powerful in casting producibility and First Article inspection success, look at the orange highlights where the gating system is cut off and the riser contacts for feeding solidification shrinkage are cut out with a MAPP gas torch.

To allow the as-cast hex socket features, there was no way to feed the low alloy steel solidification shrinkage without this crazy mold cavity design. The original drawing had no accommodating crazy Profile Tolerances, but the truck manufacturer allowed the Profile Tolerances in the 3D images in Figure 4 and sketches in Figure 5. (Profile Tolerances are indicated by blue arrows and orange lines in Figure 4 and orange lines and orange highlights in Figure 5.)

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Given these Profile Tolerance exceptions to the drawing, the First Article was approved on the first attempt, and hundreds of castings were produced each year with no rejections. The only machining needed was to drill the 6 smaller holes used to clamp the bracket to the truck's frame rail.

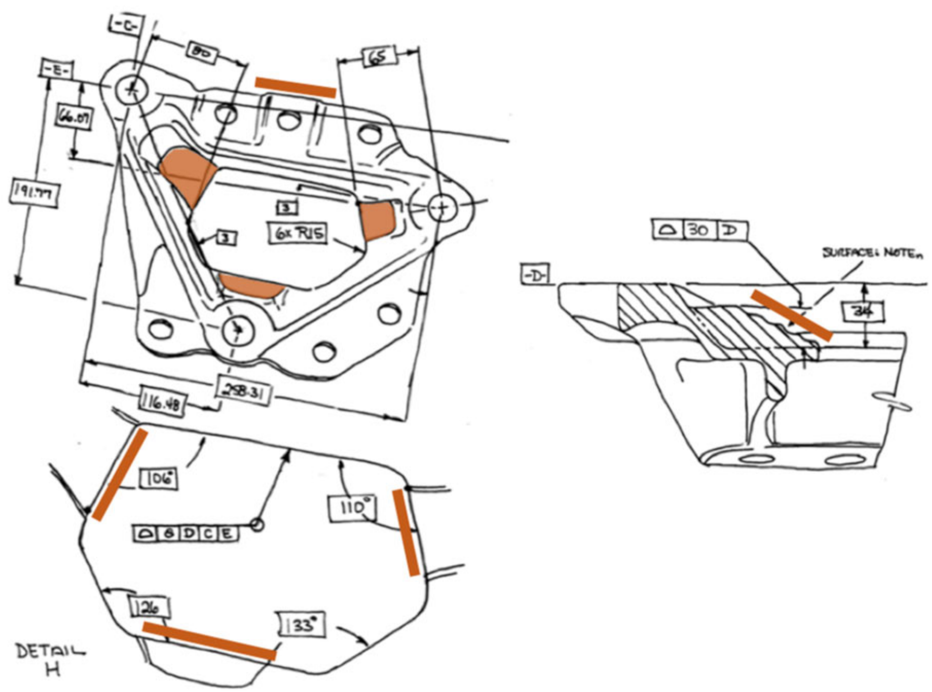

Figure 5

This Casting Quality Tip is sponsored by the DLA Troop Support, Philadelphia, PA, and the Defense Logistics Agency Information Operations, J68, Research and Development, Ft. Belvoir, VA.