DESIGN GUIDELINES: NEAR-NET-SHAPE CASTINGS FOR 5-AXIS CNC MACHINING

Optimizing Geometry for Advanced Manufacturing by ForceBeyond

In aerospace, defense, and high-performance industrial applications, components are frequently manufactured from work-hardening superalloys like Inconel, Titanium, and Cobalt-Chrome. Machining these geometries strictly from solid billet is economically unviable due to massive material waste and excruciatingly slow removal rates.

The solution is a hybrid manufacturing approach: producing a **Near-Net-Shape (NNS) investment casting**, followed by **5-Axis CNC machining** to achieve precision tolerances and critical surface finishes. However, successfully marrying these two processes requires intentional Design for Manufacturability (DFM) at the CAD stage.

1. Establishing Datums and Fixturing Strategy

The most common point of failure when machining castings is an inability to repeatedly locate the part in the CNC machine. Castings have inherent dimensional variations (shrinkage, shift); if datums are poorly chosen, the machined features will not align with the cast geometry.

- **Design Dedicated Tooling Tabs:** Whenever possible, design sacrificial "tooling tabs" or locating lugs into the non-functional areas of the casting. These tabs provide flat, stable surfaces for the 5-axis vise or fixture to grip.
- **Aim for Single-Setup Machining:** By designing a singular, robust fixturing point at the base of the part, you allow the machine to complete 90% of the work in one setup, drastically improving geometric true-position tolerances.

2. Machining Allowances (Stock Allocation)

Feature Size / Type	Recommended Machining Allowance (Per Face)
Small parts (< 100mm)	1.0 mm to 1.5 mm
Medium to Large parts (> 100mm)	1.5 mm to 3.0 mm
Holes to be Bored/Reamed	Cast solid if < 12mm. Leave 2.0 mm on radius if larger.
Critical Sealing Faces	Add an extra 0.5 mm to guarantee subsurface cleanup.

3. Mitigating Distortion & Residual Stress

When you cut into a casting, you release residual internal stresses trapped during the metal's solidification. In precision 5-axis machining, this can cause the part to physically spring or warp mid-cut.

- **Pre-Machining Heat Treatments:** Always specify a Stress Relief or Hot Isostatic Pressing (HIP) cycle on the casting drawing prior to machining. This normalizes the grain structure.
- **Ribbing for Rigidity:** Thin-walled cast sections will vibrate (chatter) against the milling cutter. Design temporary cast-in support ribs that stabilize the wall during machining.

4. Designing for 5-Axis Accessibility

- **Avoid Deep, Narrow Pockets:** If a machined pocket is too deep relative to its width (aspect ratio > 4:1), standard end mills will deflect. Cast the pocket closer to its net shape.
- **Standardize Corner Radii:** Match the internal radii of your machined features to standard tool diameters.

The Turnkey Advantage with ForceBeyond

Managing a foundry for the casting and a separate machine shop for the CNC work often leads to finger-pointing when tolerance issues arise. **ForceBeyond provides a unified, turnkey solution.**

Our engineers concurrently design your casting tooling and the 5-axis machining fixtures. By controlling both the raw material and the final precision cut under one roof, we guarantee optimal stock allowances, flawless datums, and zero manufacturing friction.

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