Sink Marks Around Reinforced Bosses in PA6/PA66 Injection-Molded Parts: Root Causes and Mold Corrections

Engineering analysis of thick-section shrinkage, fiber orientation, packing limitations, and tooling response

Scope and engineering context. Mounting bosses are common in brackets, housings, covers, and structural injection-molded parts. They provide locations for screws, inserts, standoffs, and assembly interfaces. In glass-fiber-reinforced PA6 or PA66 components, a boss may need enough local section to resist screw loading while remaining compatible with the surrounding nominal wall. When the boss base becomes a concentrated mass, the part can develop a visible depression on the opposite surface or an internal void within the thicker region.

The defect is often treated as a cosmetic sink mark, but the underlying mechanism can be more significant. A surface depression indicates that the material beneath the surface has contracted while the outer skin was already sufficiently solid to resist the same movement. An internal void is a cavity formed within the shrinking core when the surrounding material can no longer feed the volume loss. The two defects may occur together, but one does not prove the presence of the other.

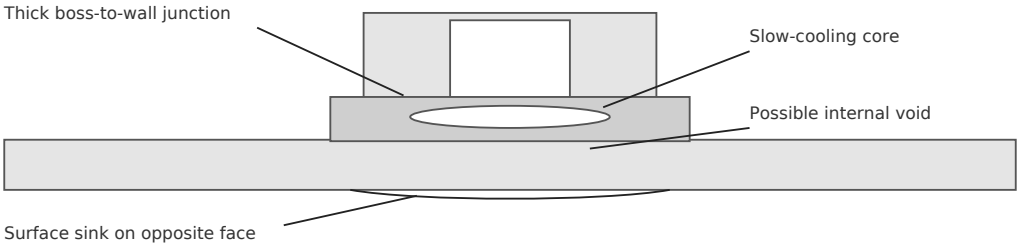


Figure 1. Conceptual cross-section of a thick boss-to-wall junction. The sketch illustrates a slow-cooling core, a possible internal void, and a surface depression; it is not a scale drawing of a specific component.

PA6 and PA66 are semi-crystalline polyamides. Their shrinkage is influenced by cooling and crystallization as well as by the pressure and material available during packing. Glass fiber can reduce overall molding shrinkage, but it also makes shrinkage direction-dependent because fibers tend to align with local melt flow. A reinforced grade therefore does not eliminate sink risk, particularly where geometry creates a thick junction and the cavity can no longer be packed effectively.

Key distinction: do not assume that a higher glass-fiber content or a higher holding-pressure setting will automatically remove a boss sink. The result depends on local section mass, gate freeze, pressure transmission, fiber orientation, cooling balance, and the mechanical function that the boss must retain.

1. Why Boss Roots Become Local Shrinkage Hot Spots

1.1 Thick-section cooling and volumetric contraction

A mounting boss is usually thicker than the wall to which it is attached. The most critical region is often not the cylindrical boss wall itself, but the junction where the boss base merges into the panel, rib, or bracket wall. If the boss is solid, has an oversized root fillet, or is reinforced by a heavy gusset, the local volume can become much greater than the nominal wall section. The surface layer cools and stiffens first, while the material in the center remains hot and continues to contract.

As the core cools, it needs additional molten material from the runner and gate to compensate for volume reduction. If the flow path has become highly resistant or the gate has frozen, the cavity can no longer supply enough material. The outer surface may then be pulled inward, producing a sink mark. If the skin and surrounding material constrain the core before it can be replenished, a void may form inside the thick section instead.

This is why a sink located opposite a boss root should not be diagnosed only by changing the machine settings. The local section geometry determines how long the core remains molten and how much material is needed to compensate for shrinkage. Process adjustments can reduce the visible effect, but they cannot always overcome a large, poorly fed mass of polymer.

1.2 Visible sink marks and internal voids are different observations

A sink mark is a surface displacement. It can be shallow and visible only under reflected light, or deep enough to be detected by touch or profile measurement. An internal void is a cavity within the shrinking core and may not create an obvious surface depression. A part can show a pronounced sink with no large internal void, or contain a void while the outer surface appears acceptable. Visual inspection alone is therefore insufficient when the boss carries a screw, insert, or structural load.

Where the boss is functionally important, cross-sectioning or suitable non-destructive imaging can help establish whether the defect is limited to the surface or extends into the load-bearing material. The location and size of a void matter: a cavity near the boss root or insert interface can reduce the effective section and alter stress distribution even if the cosmetic surface is acceptable.

1.3 What glass fiber changes near the boss

During filling, glass fibers tend to align with the local flow pattern. Around a boss core pin, the melt may divide, travel around the core, and reunite downstream. The resulting fiber orientation is not necessarily uniform through the boss wall or at the root. This can create directional differences in shrinkage and stiffness, and the meeting point of the flow fronts may form a weld line.

Fiber orientation is not, by itself, the primary explanation for every sink mark. The local thick section and the ability to pack it are usually central to the shrinkage mechanism. Reinforcement adds another layer: it changes how the region contracts, how the part distorts, and where the boss may be mechanically weakest. Gate location and flow around the core must therefore be reviewed together with section thickness and the intended screw-load direction.

2. Part Geometry: Reduce the Mass Without Losing Boss Function

2.1 Core out the boss instead of building a solid mass

A hollow or cored boss generally provides a more controllable wall section than a solid cylindrical projection. The core pin reduces the volume of polymer that must cool at the center and can shorten the distance over which heat must travel. The boss wall still needs enough thickness and support for the intended screw, insert, or locating function, but its dimensions should be established from the actual fastening method and load requirement rather than from appearance alone.

The transition from boss to panel should avoid a sudden increase in material thickness. A large fillet may improve stress distribution, but if it creates a heavy mass at the root it can worsen shrinkage. The correct solution is not to remove every radius; it is to balance the structural benefit of a smooth transition against the cooling and packing penalty of excess material. Use a controlled radius and evaluate the complete section through the boss base.

2.2 Use ribs to transfer load, not to create another thick junction

Ribs or gussets can support a boss against screw torque, bending, and pull-out loads without making the entire boss-to-wall junction solid. Their thickness and intersection with the nominal wall should be controlled so that the rib does not simply replace one thick section with another. Several well-positioned ribs may distribute load more effectively than one oversized gusset, but their arrangement must also account for flow direction, weld-line location, and the available ejection and cooling space.

A rib that terminates abruptly at the boss root can create a second local mass and a stress concentration. A gradual rib run-out, balanced support on the required sides, and a smooth connection to the nominal wall help make the structural load path more predictable. For glass-filled nylon, the orientation of fibers along the rib may improve stiffness in one direction while leaving transverse or weld-line regions less favorable. The boss should therefore be evaluated in its molded orientation, not only as an idealized CAD solid.

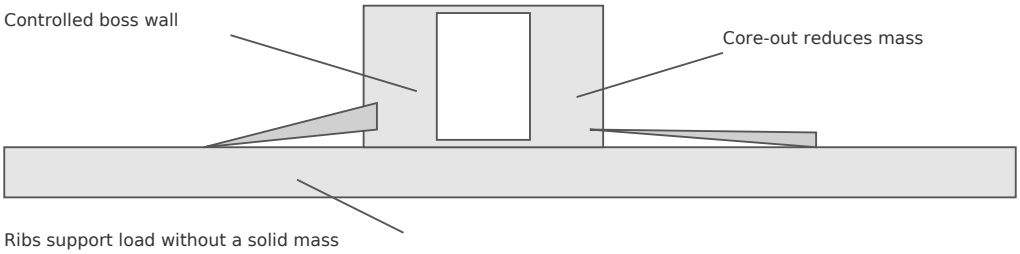


Figure 2. Conceptual geometry correction: a cored boss with a controlled wall and tapered ribs can preserve local support while reducing the solid material concentrated at the root.

2.3 Preserve the fastening requirement during cosmetic correction

Reducing boss wall thickness or removing material from the root can affect thread engagement, screw pull-out, insert retention, boss splitting, and local bearing stress. A geometry change that removes the sink but causes the fastener interface to fail is not a successful correction. Confirm the screw type, engagement length, insert design, installation torque, repeated assembly requirement, and the direction of service load before changing the boss.

For metal inserts, check the polymer support around the insert, the insert's retention features, and the local heat history during installation. The insert does not eliminate shrinkage around the boss, nor does it automatically compensate for an undersupported wall. If the boss is part of a load-bearing component, validate the revised geometry with representative hardware and the actual molded material grade.

Design principle: use the minimum local polymer mass that can reliably deliver the required fastening and structural function. Do not apply a single boss-to-wall ratio as a universal rule for every PA6/PA66 grade, glass content, surface requirement, and loading condition.

3. Gate, Packing, and Cooling: Keep the Thick Region Feedable

3.1 Gate location and flow around the core

The gate determines how the cavity is filled and how long useful packing pressure can reach the boss region. If the boss is far from the gate, or if the melt must pass through a narrow or highly restrictive section before reaching it, the local cavity pressure may be substantially lower than the machine's displayed pressure. A gate that is too small can also freeze before the thick boss root has completed its contraction.

Moving the gate closer to the boss may improve pressure transmission, but it is not an automatic solution. The new flow path can change fiber orientation, create a weld line at a critical location, leave a gate vestige on a visible surface, or disturb filling balance elsewhere in the part. For a boss surrounding a core pin, review how the melt divides and rejoins. Where the boss carries a screw or insert load, avoid placing a weak weld line across the most highly stressed section unless the resulting strength has been validated.

Gate size, gate land, runner dimensions, and the location of the boss should be reviewed as one feeding system. The objective is to maintain sufficient pressure at the thick section until the gate seals, without creating flash, excessive residual stress, or an unacceptable cycle time.

3.2 Packing pressure and gate-freeze behavior

Holding pressure compensates for shrinkage while the material is still able to flow through the gate. Increasing the machine's holding-pressure setting does not guarantee that the boss receives more material: if the gate or an upstream section has already frozen, the extra setting cannot reach the isolated region. If the gate is still open but pressure is excessive, flash, parting-line damage, overpacking, or dimensional distortion may appear elsewhere.

A gate-freeze study is more informative than selecting a hold time by trial and error. Mold parts at progressively longer holding times while keeping the other conditions stable, then compare part weight. When additional hold time no longer produces a meaningful increase in weight, the gate has reached its effective freeze point under those conditions. The selected production hold time should be based on this result and then checked for dimensional stability and appearance.

Part weight is only a process indicator, not proof that every local area is adequately packed. If the machine and mold permit it, cavity-pressure measurement near the boss or along the flow path can show whether pressure is reaching the region and when it decays. Also verify shot size, cushion, non-return valve repeatability, and material consistency before attributing the defect to mold geometry.

3.3 Cooling balance around the boss

The boss root and the core pin can create a local thermal hot spot. Cooling channels that are effective for the main panel may not remove heat efficiently from a deep boss or a thick insert region. The result can be a longer local solidification time, increased shrinkage after the surrounding wall has stiffened, and a part that is still locally soft when ejected.

Review cooling access around both the cavity and core sides. Depending on the mold layout, a dedicated cooling circuit, baffle, bubbler, or improved contact to a core insert may be required. The aim is not simply to make the boss colder than the rest of the tool; it is to reduce the temperature imbalance while keeping the required crystallization, surface quality, dimensional stability, and cycle time within the grade-specific process window.

Mold temperature should not be lowered blindly to hide a sink. A colder surface can freeze the skin earlier and reduce the visible depression while leaving the thick core inadequately packed. It can also alter crystallization and final properties in semi-crystalline PA6/PA66. Uniform and repeatable thermal control is more useful than pursuing the lowest possible mold temperature.

4. Process Conditions and a Reliable Root-Cause Diagnosis

4.1 Separate material preparation from shrinkage control

PA6 and PA66 are moisture-sensitive. Pellets must be dried and handled according to the specific grade supplier's recommendations, and the moisture condition should be verified where the process is sensitive. Excessive moisture during melt processing can promote hydrolytic degradation and unstable melt behavior. This may contribute to inconsistent filling, surface defects, and loss of mechanical performance, but moisture should not be treated as the default explanation for a localized sink at a thick boss root.

Confirm the exact resin grade, glass-fiber content, color and additive package, lot traceability, and drying history before comparing trials. A change from one PA6 GF or PA66 GF grade to another can change viscosity, crystallization, shrinkage, and the pressure required to fill and pack the same cavity. Do not transfer a process window from a different grade solely because the nominal glass content is similar.

4.2 Adjust the process within the material supplier's window

Melt temperature, mold temperature, injection speed, transfer position, holding pressure, and hold time interact. A higher melt temperature may improve filling of a difficult boss region, but it can also extend cooling time and increase thermal exposure. A lower melt temperature may shorten the cooling burden but raise flow resistance and reduce pressure transmission. Faster filling may improve the flow front while changing fiber orientation and weld-line position. There is no single direction of adjustment that is correct for every part.

Establish a stable fill profile first, then optimize packing with the gate-freeze result as a reference. Confirm that the machine maintains a repeatable cushion and that the check ring is not allowing backflow. Once the process is repeatable, compare the boss appearance, part weight, critical dimensions, and—where needed—internal section quality. Avoid changing several parameters at once, because a cosmetic improvement can conceal a new dimensional or mechanical problem.

4.3 Diagnose the defect before changing the mold

Start by mapping the sink location against the boss geometry. Record whether the depression is directly opposite the boss root, around the boss circumference, or displaced along the flow direction. Compare parts from different cavities and production runs. A defect that follows one cavity may indicate a local cooling, gate, vent, or machining difference; a defect repeated across all cavities may point more strongly to part design, material behavior, or a common process limitation.

Use a controlled holding-time and part-weight study to establish whether the region responds to additional packing. If weight continues to rise and the sink improves, the existing process may be underpacking the cavity. If weight plateaus and the sink remains, investigate section mass, gate restriction, and local cooling rather than continuing to raise holding pressure. A cross-section or CT inspection can determine whether an internal void is present and whether it intersects the boss root or insert support.

Where available, cavity-pressure traces and mold-surface temperature measurements can help distinguish a pressure-loss problem from a cooling imbalance. Inspect the gate for premature freeze or wear, verify the cooling circuit for blockage or poor flow, and check machine repeatability. Material drying and lot changes should be reviewed in parallel, but they should not replace evidence from the cavity and the molded part.

A reliable correction follows the evidence: geometry changes address excess local mass; gate and runner changes improve pressure transmission; cooling changes reduce local thermal imbalance; and process changes stabilize filling and packing. A cosmetic adjustment alone is not enough if the boss must retain screw load or insert integrity.

5. Mold Corrections, Validation, and Production Release

5.1 Choose the correction that addresses the measured cause

If the boss root contains excessive material, the most durable correction is usually a geometry change: core out the boss, reduce an unnecessarily heavy junction, or replace a solid gusset with controlled ribs. A mold correction can implement the revised section by changing the relevant steel or core feature, but the part drawing, fastening function, and critical interfaces must be reviewed before steel is cut. Removing material from a boss root without checking screw pull-out or local stress can exchange a cosmetic defect for a structural failure.

If the geometry is already reasonable but the boss is not being packed, review gate size, gate land, runner pressure loss, and the flow path. A gate enlargement or relocation may extend effective packing, but the resulting fiber orientation and weld-line position must be assessed. If the defect tracks a local hot spot, revise the cooling arrangement around the boss core or insert. Do not use higher pressure as a substitute for a gate that has already frozen or a core region that cannot cool uniformly.

Where a process change is sufficient, lock the validated fill-to-pack transfer, holding profile, hold time, cushion, material preparation, and thermal conditions into the production setup. The final window should be robust to normal material and machine variation rather than tuned to one sample that barely meets the appearance requirement.

5.2 Validate both appearance and boss function

First-article validation should use parts molded from the intended PA6/PA66 grade and production-intent tooling. Inspect the sink area under agreed lighting and surface conditions, but also measure the boss position, wall geometry, mounting-face flatness, and other functional datums. Where the boss carries a screw or insert, test the actual fastening method and the required pull-out, torque, or assembly performance defined by the product specification.

If internal voids are a credible risk, use sectioning or suitable imaging on representative samples. Check more than one cavity and more than one production condition where the tool is multi-cavity or the process is sensitive. Repeat critical measurements after the conditioning state required for the application. A visually acceptable surface does not prove that the boss root is free of internal defects or that the fastener interface remains reliable.

After a gate, cooling, geometry, or process change, repeat the relevant dimensional, appearance, and mechanical checks. Record the material lot, cavity, mold revision, process settings, conditioning state, and inspection method so that future variation can be traced. Acceptance limits should come from the approved drawing and product requirements; no universal sink depth, void size, boss ratio, or process setting is valid for every reinforced nylon part.

Engineering conclusion

Sink marks around PA6/PA66 reinforced bosses are best understood as the visible result of a local section and feeding problem, often influenced by the directional behavior of glass-fiber reinforcement. The most effective solution begins with the boss-root geometry and continues through gate design, packing access, cooling balance, and controlled processing. A successful correction must improve the surface without compromising the fastening function, structural strength, or dimensional relationships that the boss is designed to provide.

Production release: approve the revised part only when the appearance requirement, boss geometry, internal integrity where relevant, fastening performance, and repeatability across the intended cavities have been verified under the agreed material and process conditions.