

Technical Document: Design of Plastic Five-Star Base for Office Chairs

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Contents

1. Introduction	3
2. Materials Selection and Performance Requirements	3
2.1 Material Options and Industry Standards	3
2.2 Mechanical and Thermal Properties	4
2.3 Chemical and Environmental Resistance	5
2.4 Electrical and Functional Properties	5
3. Core Structural Design Parameters and Engineering Optimization Principles	6
3.1 Geometric Configuration and Stability Analysis	6
3.2 Wall Thickness and Section Design	6
3.3 Reinforcement and Load Path Optimization	7
3.4 Interface Standardization and Assembly Features	7

3.5 Advanced Design Methodologies	8
4. Injection Molding Manufacturing Process and Key Control Points .	8
4.1 Pre-processing and Raw Material Preparation	8
4.2 Injection Molding Cycle Parameters	9
4.3 Post-Molding Treatments	10
4.4 Process Monitoring and Defect Mitigation	10
5. Product Quality Verification: Load and Durability Testing Standards	11
5.1 Static Load Testing	11
5.2 Dynamic Fatigue and Durability Testing	11
5.3 Impact and Environmental Resilience Testing	12
5.4 Dimensional and Functional Inspection	12
5.5 Additional Specialized Tests	13
6. Conclusion	13

1. Introduction

The plastic five-star base is a critical structural component in modern office chairs, providing primary support and stability for the seating system. This document outlines the comprehensive engineering framework for the design, manufacturing, and validation of high-performance plastic five-star bases used in ergonomic office furniture. The purpose of this technical report is to establish standardized guidelines covering material selection, structural design, injection molding processes, and quality verification protocols, ensuring product safety, durability, and compliance with international standards.

Office chair ergonomics demand robust mechanical performance under dynamic loading conditions, including vertical compression, rotational torque, lateral impact, and long-term fatigue. Safety requirements mandate that the base must withstand extreme static loads without structural failure while maintaining dimensional integrity over extended service life. This document addresses these demands through an integrated approach spanning materials science, mechanical engineering, process control, and reliability testing.

The key technical aspects covered include: (1) material selection criteria based on mechanical, thermal, and environmental performance; (2) core structural design parameters optimized for load distribution and stability; (3) injection molding process specifications with defined control points; and (4) standardized load and durability test methods for quality assurance. Material choice directly influences structural integrity, which is discussed in the following section.

2. Materials Selection and Performance Requirements

2.1 Material Options and Industry Standards

The primary material used for high-performance plastic five-star bases is glass-fiber reinforced polyamide, specifically PA6 or PA66 grades with 25–35%

by weight glass fiber reinforcement (designated as PA6-GF30 or PA66-GF30). This composite formulation provides superior strength-to-weight ratio, creep resistance, and dimensional stability compared to unfilled polymers or alternative plastics. The use of PA6/PA66-GF ensures compliance with international material standards such as ISO 1874-2 and ASTM D4066, which define property requirements for reinforced thermoplastics in structural applications.

For specific detachable components where lower stiffness is acceptable, polypropylene (PP) may be employed due to its excellent impact resistance and ease of processing. However, PP is not recommended for main structural elements due to its lower heat deflection temperature and higher coefficient of thermal expansion. All selected materials shall meet relevant regulatory frameworks including REACH, RoHS, and GB/T 26572 regarding restricted substances.

2.2 Mechanical and Thermal Properties

The selected material shall exhibit a minimum flexural modulus exceeding 8000 MPa to ensure adequate rigidity under operational loads. The Charpy notched impact strength shall be no less than 8 kJ/m² at 23°C, demonstrating sufficient toughness to resist fracture during accidental impacts or drops. These values are determined according to ISO 178 (flexural properties) and ISO 179-1 (impact properties).

Thermal performance requirements include a heat deflection temperature (HDT) at 1.8 MPa greater than 210°C and a Vicat softening point above 230°C, ensuring dimensional stability during prolonged exposure to elevated temperatures near heating vents or direct sunlight. The material shall maintain dimensional stability across a thermal cycling range from -40°C to +125°C, with linear thermal expansion coefficients below 3.5×10^{-5} /K in the flow direction. Crystallinity development shall be controlled via mold temperature management to achieve consistent mechanical behavior.

2.3 Chemical and Environmental Resistance

Plastic five-star bases offer inherent corrosion resistance advantages over metal counterparts, eliminating risks associated with rust or galvanic degradation. The material shall demonstrate low moisture absorption, not exceeding 2.5% mass gain after saturation in water at 23°C, minimizing hygroscopic swelling effects on fit and function. Hydrolysis resistance shall be verified through accelerated aging tests in humid environments (e.g., 85°C/85% RH for 1000 hours), with retention of $\geq 85\%$ of initial tensile strength post-exposure.

Environmental compliance requires adherence to heavy metal limits: lead (Pb) ≤ 100 mg/kg, cadmium (Cd) ≤ 20 mg/kg, hexavalent chromium (Cr^{VI}) ≤ 1000 mg/kg, and mercury (Hg) ≤ 1000 mg/kg, as specified in EU Directive 2011/65/EU. Formaldehyde emissions shall be limited to <0.11 mg/L when tested per chamber method EN 717-1, ensuring indoor air quality suitability.

2.4 Electrical and Functional Properties

Surface resistivity classification shall be provided based on application needs. Anti-static variants shall have surface resistivity between 10^4 and 10^9 Ω , suitable for general office environments. Conductive versions shall exhibit surface resistivity $\leq 10^4$ Ω , enabling electrostatic discharge (ESD) protection in sensitive electronic workspaces. The term surface resistivity refers to the electrical resistance measured across the surface of a material using concentric ring electrodes per IEC 61340-2-3.

Material formulations may incorporate carbon black or conductive fibers to achieve desired electrical characteristics. ESD-safe designs should provide continuous conductive pathways from contact points to grounding interfaces. Application-specific selection shall consider the operating environment, particularly in data centers, laboratories, or manufacturing facilities handling sensitive electronics.

3. Core Structural Design Parameters and Engineering Optimization Principles

3.1 Geometric Configuration and Stability Analysis

The five-point star layout is adopted as the optimal configuration balancing stability, usability, and material efficiency. Compared to four-leg designs, the five-arm geometry increases the effective footprint area by approximately 20%, significantly enhancing resistance to tipping under off-center loading. Six-leg configurations offer marginal stability improvements but increase tripping hazards and packaging complexity, making them impractical for most applications.

The typical radius from center hub to arm tip is standardized at 350 mm, aligning with industry benchmarks for mid-sized office chairs. This dimension provides adequate lateral support while maintaining compatibility with standard desk clearances. Adjacent arms are angularly distributed at 72° intervals around the central axis, ensuring uniform load distribution and rotational symmetry. The geometric arrangement maximizes the distance required for the center of gravity to move beyond the support polygon, delaying instability onset.

3.2 Wall Thickness and Section Design

A minimum nominal wall thickness of 8 mm shall be maintained throughout the primary load-bearing sections of the base, particularly at arm roots and hub junctions. Thinner sections may be utilized in non-critical areas, provided local stress concentrations remain within allowable limits. Cross-sectional profiles shall employ stiffened geometries such as I-beam or hollow rectangular shapes to enhance the stiffness-to-weight ratio.

Root thickening shall be implemented at arm-to-hub transitions, increasing local section modulus by up to 40%. Fillet radii of ≥ 3 mm shall be applied

at internal corners to reduce stress concentration factors (K_t) below 2.5. The transition zones shall follow smooth contour gradients to avoid abrupt changes in cross-section that could initiate crack propagation under cyclic loading.

3.3 Reinforcement and Load Path Optimization

Ribs and support blocks shall be strategically integrated at joint areas to reinforce connection points and guide load paths efficiently. Radial ribs extending from the central hub improve torsional rigidity, while axial reinforcements along the arm length enhance bending resistance. A dual radial-axial locking mechanism shall be incorporated for detachable leg assemblies, ensuring secure attachment without tools.

The locking interface shall consist of a square prism mating with a tetragonal cavity, providing positive engagement in both radial and axial directions. Interference fits of 0.1–0.3 mm shall be designed into the coupling features to prevent rattling during use. Secondary retention features such as snap-fit latches or spring-loaded pins may supplement the primary mechanical lock.

3.4 Interface Standardization and Assembly Features

The center hub bore diameter shall conform to standard dimensions: $\Phi 50$ mm for general-purpose models and $\Phi 60$ mm for heavy-duty or specialized applications (e.g., salon/barber chairs). Thread specifications for gas lift column attachment shall follow $M8 \times 1.25$ metric coarse thread profile, preferred over finer pitches (e.g., $M8 \times 1.0$) to minimize stripping risk during installation.

One leg shall be designed for tool-free removal to facilitate compact packaging and transportation. The quick-release mechanism shall allow full disengagement with ≤ 50 N of manual force and re-engagement without special tools. Alignment features such as tapered guides or chamfered edges shall ensure correct positioning during reassembly.

3.5 Advanced Design Methodologies

Finite Element Analysis (FEA) shall be conducted to simulate stress distributions under static and dynamic loading scenarios defined by BIFMA X5.1 and EN 1335 standards. Linear elastic and nonlinear large-displacement analyses shall evaluate deformation, stress levels, and factor of safety across all critical regions. Simulations shall include worst-case loading conditions such as eccentric vertical loads, lateral impacts, and combined rotation-compression cycles.

Topology optimization techniques shall be applied to redistribute material based on actual load paths, achieving weight reductions of 10–15% while maintaining structural integrity. Pre-validation shall be performed using standardized loading profiles from ANSI/BIFMA X5.1, EN 1335-3, and GB/T 10357.3 to verify compliance prior to physical prototyping. Design iterations shall continue until the minimum safety factor reaches 2.5 under maximum rated load.

4. Injection Molding Manufacturing Process and Key Control Points

4.1 Pre-processing and Raw Material Preparation

Prior to molding, raw material pellets shall undergo drying in dehumidifying hoppers at temperatures between 80°C and 105°C for durations ranging from 16 to 24 hours, depending on ambient humidity exposure history. The target moisture content before processing shall be less than 0.2% by weight, verified using Karl Fischer titration or infrared moisture analyzers.

Stabilizer additives, typically comprising 5% by weight of the compound, shall be introduced to mitigate thermal degradation during melt processing. Virgin-grade resin shall be used exclusively for structural components to ensure consistency and traceability. Re-grind usage, if permitted, shall be limited to $\leq 20\%$ and only from clean, uncontaminated sprue systems.

4.2 Injection Molding Cycle Parameters

Temperature Control

The barrel heating zones shall follow a segmented profile: rear zone at 240°C, middle zone at 260°C, and front zone at 280°C, adjusted $\pm 5^\circ\text{C}$ based on melt viscosity measurements. The nozzle temperature shall be maintained slightly below the front barrel zone (approximately 270–275°C) to prevent drooling. Mold temperature shall be regulated between 60°C and 100°C, with an optimal range of 80–90°C to promote crystallinity development and minimize residual stresses.

Pressure and Speed Settings

Injection pressure shall be set between 100 and 180 MPa, determined by part geometry, wall thickness, and flow length. Holding pressure shall be applied at 50–80% of peak injection pressure for a duration of 15–25 seconds to compensate for volumetric shrinkage. Back pressure shall be maintained between 2 and 8 MPa to ensure homogeneous melt mixing and degassing.

Injection speed shall be controlled to achieve a high-speed filling rate of approximately 0.35 L/s, minimizing weld line formation and air entrapment. Flow rate modulation may be applied during fill to balance cavity pressure and reduce jetting tendencies.

Cooling and Ejection

Cooling time shall be calculated proportionally to the square of the maximum wall thickness, typically ranging from 25 to 35 seconds for 8 mm sections. Conformal cooling channels shall be designed to match the part contour, enabling uniform heat extraction and reducing cycle time by up to 20%. Demolding shall occur only after the core temperature has dropped below the heat

deflection temperature to prevent distortion.

4.3 Post-Molding Treatments

Annealing treatments shall be performed in oil or glycerin baths heated to 10–20°C above the intended service temperature for 10–30 minutes, followed by slow cooling to relieve internal stresses. Humidification conditioning shall be conducted in climate-controlled chambers at 65% relative humidity and 23°C for 48 hours to stabilize dimensions after molding-induced shrinkage.

Optional surface finishing operations may include vibratory tumbling or media blasting to remove minor flash or gate vestiges. Critical functional surfaces shall remain untouched unless specified.

4.4 Process Monitoring and Defect Mitigation

In-line quality checks shall include near-infrared (NIR) spectroscopy for monomer content analysis and X-ray fluorescence (XRF) spectrometry for heavy metal screening. Real-time monitoring of key process parameters (temperature, pressure, cycle time) shall be logged for traceability and statistical process control (SPC).

Common defects and corrective actions include:

- Sink marks: increase holding pressure or extend holding time
- Flash: reduce injection pressure or increase clamp force
- Warpage: optimize mold temperature gradient and ejection sequence
- Short shots: raise melt temperature or injection speed
- Weld lines: adjust gate location or modify local wall thickness

Process adjustments shall be validated through trial runs of 3–5 production cycles before full resumption.

5. Product Quality Verification: Load and Durability Testing Standards

5.1 Static Load Testing

Static load testing shall comply with ANSI/BIFMA X5.1 Clause 7 (“Base Test – Static”). A vertical load of 11,120 N (2500 lbf) shall be applied to the center hub for one minute per cycle, repeated twice. The load shall be transmitted through a hemispherical platen with a radius of 50 mm, ensuring no contact between the test fixture and individual legs.

Acceptance criteria require no structural failure, cracking, or permanent deformation exceeding 1% of original dimensions upon unloading. Visual inspection and dimensional measurement shall confirm integrity of all joints, ribs, and locking mechanisms. Any visible damage or functional impairment constitutes a failure.

5.2 Dynamic Fatigue and Durability Testing

Caster Wheel Combination Test

The caster wheel combination test shall simulate real-world rolling conditions per BIFMA X5.1 Appendix C. A total load of 102 kg (225 lb) shall be applied to the assembled chair base equipped with standard casters. Reciprocating travel shall be executed over a 762 mm stroke at a frequency of 8–12 cycles per minute (CPM).

The test comprises 98,000 obstacle-free cycles plus 2,000 crossings over a 6.4 mm high obstacle, totaling 100,000 cycles. Pass/fail criteria include no rupture of wheels or mounting hardware, stable rolling resistance ($\pm 15\%$ of initial value), and continued functionality of locking mechanisms.

Rotational Durability Test

Rotational durability testing shall involve 120,000 full 360° rotations under a sustained load of 102 kg, simulating long-term swivel usage. The test apparatus shall constrain lateral movement while allowing free rotation about the vertical axis. The purpose is to evaluate the reliability of the gas lift interface and bearing surfaces.

Reference standard BIFMA X5.1 Clause 9 specifies that no structural damage, excessive play (>1 mm radial displacement), or binding shall occur during or after the test. Wear debris generation shall be minimal and not affect rotational smoothness.

5.3 Impact and Environmental Resilience Testing

Drop testing shall be conducted from a height of 1 m onto concrete flooring, with the base impacting edge-first. No brittle fracture or functional loss shall occur. Dynamic impact assessment shall also include pendulum impact tests per ISO 179-1 to quantify energy absorption capacity.

Thermal shock testing shall involve cycling between -40°C and $+125^{\circ}\text{C}$ for five complete cycles, with dwell times of 1 hour at each extreme. Cold impact testing shall verify functionality after 24-hour conditioning at $-20 \pm 2^{\circ}\text{C}$, confirming absence of embrittlement or seizure.

5.4 Dimensional and Functional Inspection

Critical dimensional tolerances shall be strictly enforced:

- Overall diameter tolerance: ± 1.5 mm
- Center hub bore diameter: ± 0.1 mm
- Assembly clearance between mating parts: ≤ 0.2 mm

Hardness shall be measured using Rockwell R-scale or Shore D durometer, with acceptance range of 110–120 HR R or 85–90 Shore D. Salt spray testing per ASTM B117 for 480 hours shall be performed if applicable, with no evidence of substrate corrosion observed after neutral salt fog exposure.

5.5 Additional Specialized Tests

Flammability rating shall meet UL94 V-0 classification when tested vertically with 20 mm flame application, indicating self-extinguishing behavior within 10 seconds and no flaming drips. Conductivity verification shall confirm surface resistance within specified ranges ($\leq 10^9 \Omega$ for conductive, $10^9\text{--}10^{12} \Omega$ for anti-static) using concentric ring probes.

Volatile organic compound (VOC) emissions shall be analyzed using headspace GC-MS methods, with total VOC levels below 0.5 mg/m^3 in 1 m^3 emission chambers after 28 days. Off-gassing analysis shall confirm absence of formaldehyde and other regulated compounds above threshold limit values.

6. Conclusion

This document has outlined the essential parameters governing the design, manufacture, and validation of plastic five-star bases for office chairs. The integration of high-strength glass-fiber reinforced polyamide materials, structurally optimized geometries, tightly controlled injection molding processes, and rigorous performance testing forms a closed-loop engineering methodology ensuring product reliability and user safety.

Key design considerations include the adoption of PA6/PA66-GF30 for its superior mechanical and thermal properties, implementation of a 350 mm radius five-arm configuration for optimal stability, and utilization of FEA-driven topology optimization for efficient load path management. Manufacturing excellence depends on precise control of drying, molding, and post-treatment processes, with real-time defect detection ensuring consistent output quality.

Product quality verification relies on standardized static and dynamic test protocols derived from ANSI/BIFMA X5.1, EN 1335, and GB/T 10357 series standards. Compliance with these benchmarks guarantees that products meet global market requirements for strength, durability, and environmental safety.

It is recommended that manufacturers adopt this integrated approach—linking material selection to structural design, process control, and final validation—to ensure conformance with international safety and performance expectations. Continuous improvement through data-driven feedback loops will further enhance product lifecycle performance and customer satisfaction.