Technical Specification for Plastic Housing of Outdoor Neck Lamp

Outdoor Wearable Lighting Series

1. Product Overview

This document defines systematic technical requirements for the plastic housing of outdoor neck lamps, covering material selection principles, structural design specifications, injection molding process standards and quality verification methods. As a lightweight, ergonomic plastic structural component tailored for wearable outdoor lighting devices, the housing is widely applicable to night running, hiking, camping, night fishing, emergency maintenance, reading assistance and other scenarios.

While providing reliable physical protection for internal electronic components, the housing system must ensure wearing comfort during long-time use, robust resistance to accidental daily impact, and durability under complex outdoor environments. The product adopts an open U-shaped wrap-around profile. With rationally designed radian and opening angle, it relies on the material's inherent elasticity to gently fit the neck, enabling quick donning and doffing without extra fasteners, and adapts to most adults' neck circumferences.

The entire shell contains a compact yet adequate cavity layout accommodating LED aluminum substrates, 18650 lithium battery packs, Type-C charging interface modules, tactile switches, driving circuit boards and other components. Mass production is realized via professional injection molding. Design for Manufacture and Assembly (DFMA) concept is fully integrated in the early design phase to guarantee high consistency and high yield throughout mold development to mass delivery.

2. Material Technical Specifications

Different grades of engineering plastics are available for the housing according to product definition, cost targets and application differences. Custom modified plastic formulas are offered to satisfy clients' specific demands for outdoor weather resistance, impact resistance, surface decoration or structural performance. Technical benchmarks of three recommended materials are listed below.

2.1 General-Grade ABS Housing

Material Type: High-flow, high-impact Acrylonitrile Butadiene Styrene (ABS) or modified ABS

Technical Performance Benchmarks

- **Surface Quality & Processability:** The material features excellent fluidity with a melt flow index (MFI, 220°C/10kg) ≥ 18 g/10min. It precisely replicates mold surface textures to deliver uniform matte or semi-gloss appearance, with good compatibility for subsequent spraying, electroplating and other post-processing.
- **Impact Resistance:** Notched Izod impact strength (23°C) ≥ 18 kJ/m², capable of withstanding repeated drop impact from 1.0m height and daily bumps without structural fracture.

- **Dimensional & Thermal Stability:** Linear molding shrinkage controlled at 0.4%~0.6% to ensure consistent critical assembly dimensions across batches. Heat Deflection Temperature (HDT/B) ≥ 85°C.

Application: Recommended for entry-level and mainstream consumer lighting products prioritizing premium appearance and cost performance, suitable for high-speed mass production.

2.2 Reinforced PC/ABS Alloy Housing

Material Type: Engineering-grade Polycarbonate/Acrylonitrile Butadiene Styrene (PC/ABS) alloy; PC content adjustable based on toughness requirements

Technical Performance Benchmarks

- **Ultra-High Impact Toughness:** Outstanding low-temperature impact resistance; notched Izod impact strength remains ≥ 30 kJ/m² at -20°C, meeting outdoor use requirements in frigid regions.
- **Heat Resistance & Structural Retention:** Heat Deflection Temperature (HDT/A, 1.8MPa) ≥ 105°C, resisting temperature rise from full-power LED operation and summer sunlight exposure with no obvious creep or stress relaxation after long-term service.
- **Balance of Rigidity & Toughness:** Flexural modulus ranges 2100–2500 MPa; tensile strength ≥ 48 MPa. It delivers sufficient structural support while retaining elastic resilience required for U-arm bending, with no obvious whitening or permanent deformation after repeated flexing.

Application: Top choice for high-end outdoor lighting housings passing stringent mechanical shock, high-low temperature cycling and bending fatigue tests. Custom formulas including toughened, weather-resistant and chemical-resistant grades are available for specialized outdoor environments.

2.3 Glass Fiber Reinforced Nylon Structural Housing / Bracket

Material Type: Polyamide 6 (PA6) or Polyamide 66 (PA66) reinforced with 25%~35% glass fiber (GF)

Technical Performance Benchmarks

- **Ultra-High Strength & Rigidity:** Tensile strength ≥ 160 MPa; flexural modulus ≥ 7000 MPa. Serves as the main internal load-bearing frame to firmly support batteries and circuit modules and prevent electronic damage caused by bending deformation.
- **Excellent Fatigue Resistance:** Mechanical property retention ≥ 80% after over 20,000 cycles of repeated bending or vibration loading, with no microcrack propagation.
- **Precision Dimension:** Isotropic and stable molding shrinkage, providing high-precision datum surfaces and fastening structures for precise positioning and assembly with ABS/PC/ABS outer cladding parts.

Application: Not directly used for skin-contacting outer casings; mainly applied to internal structural supports, battery compartment partitions, hinge reinforcements and other functional components. Glass fiber content and toughener proportion are adjustable to match customized rigidity-toughness balance demands.

3. Structural Design Specifications

The housing adopts an asymmetric curved cavity design based on ergonomic neck scan data. 3D human neck scanning is used to build surface models for even pressure distribution and eliminate localized compression during wearing.

3.1 Lightweight Structural Optimization

The main body combines equal-wall-thickness shells with grid reinforcing ribs. Nominal main wall thickness = 2.0mm with allowable tolerance 1.8~2.3mm. Root thickness of reinforcing ribs shall not exceed 60% of main wall thickness (max. 1.2mm), with draft angle ≥ 1°.

Finite Element Analysis (FEA) simulates wearing deformation and 1.5m drop impact conditions. Redundant material in low-stress areas is removed, while stress-concentration zones are locally thickened with gradual transitions. Target single-side housing assembly weight ≤ 80g; total lamp weight (including all electronics) ≤ 180g to improve long-wearing comfort.

3.2 Uniform Wall Thickness Control

Uniform wall thickness is strictly implemented throughout the structure to avoid abrupt thickness changes. All corners adopt rounded transitions: inner fillet radius ≥ 0.5×wall thickness; outer fillet radius = inner radius + wall thickness to maintain consistent wall thickness across all contours.

This design ensures stable melt front advancement inside the mold cavity, effectively reducing sink marks, warpage and residual internal stress caused by uneven shrinkage. It guarantees mass-production dimensional stability with CPK ≥ 1.33 for critical dimensions.

3.3 Snap-Fit & Assembly System Design

- **Elastic Snap:** Integrated cantilever snaps with positioning guide pins utilizing material elasticity. Engagement depth = 0.7±0.1mm; full fillet R≥0.5mm at snap root to eliminate stress concentration. Insertion force < 3kgf; pull-out force > 8kgf for easy assembly and reliable locking.
- **Anti-Misassembly & Pre-Positioning:** Continuous male-female tongue-and-groove locating structure on mold parting line; groove depth = 1.0mm, fitting clearance = 0.1mm. It enables rapid pre-positioning and error-proof assembly while extending moisture ingress paths.
- **Auxiliary Fastening:** Hot-melt brass nut inserts or self-tapping screw bosses are designed at PCB fixing points and battery compartments as required. Screw boss outer diameter = 2.5~3×nominal screw diameter, with anti-cracking relief slots.
- **Environmental Protection:** Continuous triangular ultrasonic welding energy directors (height=0.5mm, included angle=60°) or silicone O-ring sealing grooves (25%~30% compression rate) can be machined on parting surfaces. Matched with rubber port plugs, the housing achieves IP54 splash-proof rating.

4. Injection Molding Process Specifications

Precision injection molding is adopted following Scientific Molding principles to establish robust process windows.

4.1 Mold Design & Manufacturing Standards

- **Mold Base & Cavity:** High-strength standard or customized hardened mold base. Cavity and core are fabricated from corrosion-resistant polished mold steel (e.g., S136 ESR) quenched to HRC 48~52 for burr-free long-run production. Cavity surface receives matte texture etching per VDI 24~27 as needed.
- **Gating System:** Hot runner with submarine gates or multi-point valve-gated hot nozzles. Gate locations are validated via Moldflow simulation, placed on non-cosmetic inner surfaces or low-stress zones to keep weld lines away from major load-bearing and high-visibility areas.
- **Temperature Control & Cooling:** Contoured cooling channels with uniform distance to cavity surfaces. Independent heating/cooling of fixed and moving halves via multi-circuit mold temperature controllers; mold temperature fluctuation controlled within ±1°C to minimize warpage of large curved parts.
- **Venting System:** Vent slots with depth 0.015~0.02mm are opened at fill endpoints and predicted weld line gas traps and connected to atmosphere to prevent burning and incomplete filling.

4.2 Key Process Window Control (PC/ABS Alloy Reference)

- **Raw Material Drying:** Dehumidifying dryer set at 95~105°C for 3~4 hours to strictly limit moisture content below 0.04%.
- **Melt Temperature:** Barrel temperature gradient from nozzle to feed zone set at 220~270°C to prevent thermal degradation.
- **Mold Temperature:** Recommended mold temperature 70~85°C to reduce residual stress, enhance weld line strength and achieve superior surface replication.
- **Injection & Packing:** Multi-speed injection control; medium-high speed during primary filling with velocity-to-pressure (V/P) switch triggered at 95%~98% fill volume based on absolute screw position. Gate seal time confirmed via part weighing; gradient packing pressure applied to compensate volumetric shrinkage.
- **Cooling:** Cooling time adjusted by wall thickness and mold temperature (typical range: 18~25s) to ensure complete solidification before ejection without ejection whitening or deformation.

Common Injection Defect Prevention

Defect Type	Root Causes	Countermeasures
Sink Mark	Local over-thickness, insufficient packing	Thin rib thickness, increase packing pressure/time, moderately lower mold temperature
Warpage	Uneven cooling, molecular orientation inconsistency	Optimize conformal cooling channels, adjust packing curve, extend cooling time
Weld Line	Low melt temperature, gas entrapment	Raise barrel/mold temperature, add vents, relocate gates
Flash	Insufficient clamp tonnage, worn parting line	Recalibrate clamping force, repair mold parting surface, lower injection pressure

Defect Type	Root Causes	Countermeasures
Gas Burn	Poor venting, excessive filling speed	Clean/deepen vents, reduce final-stage injection speed

5. Surface Finishing & Decoration Processes

All decorative options are based on molded mold textures with optional additional processes for branding customization:

- **Mold Texture:** Direct molded fine stone grain, leather grain or geometric brushed texture (VDI 24~36) delivering premium matte finish with optimal wear resistance and cost efficiency.
- **Soft-Touch Paint:** Two-component polyurethane rubber coating applied with thickness 30~50μm for velvet skin-friendly texture, covering minor surface imperfections.
- **High-Gloss Mirror Finish:** Mold polished to SPI A-1/A-2 paired with high-gloss resin for piano black appearance. Post UV hard coating improves scratch resistance.
- **Color Management:** Fast color matching via dedicated color masterbatch online dosing. Color difference complies with CIELAB standard: $\Delta E \leq 1.0$; batch-to-batch $\Delta E \leq 0.8$.
- **Marking:** Brand logos, switch icons and certification marks applied via laser engraving or pad printing on designated zones. Laser marking delivers permanent abrasion-proof identification.

6. Quality Inspection & Reliability Validation

A closed-loop full-process quality control system is implemented from incoming materials to shipment with sampling governed by AQL standards: Appearance C=0; Dimension AQL=0.65.

6.1 Incoming Quality Control (IQC)

- Verify material physical property reports for each batch; conduct melt flow index and moisture content testing.
- Color matching against master color swatches under standard light booth to guarantee batch consistency.

6.2 In-Process Quality Control (IPQC)

- Full dimensional inspection of first articles via CMM coordinate measuring machine; 3D comparison generates deviation rainbow plots to confirm all critical dimensions fall within tolerance midpoints.
- Visual appearance and key dimension measurement performed every 2 hours with X-bar-R control charts recorded for process stability monitoring.
- Online part weight monitoring triggers alarms for weight fluctuation exceeding ±0.3% to prevent short shot or flash.

6.3 Final Quality Control / Ongoing Reliability Test (OQC/ORT)

Periodic batch sampling for type testing verifying long-term outdoor reliability:

- **Mechanical Shock:** All housing surfaces withstand 0.5J spring hammer impact without cracking. Six-sided free drop from 1.5m onto concrete floor causes no battery displacement or structural rupture.
- **Bending Fatigue:** U-shaped housing repeatedly pried open to 180mm span for 20,000 cycles. No whitening/fracture; snap retention force declines ≤ 15%.
- **Environmental Aging:** 20 thermal shock cycles (-20℃/2h ↔ 70℃/2h) with no cracking/deformation. After 500h xenon arc aging, color fastness ≥ Grade 4 per gray scale; ΔE ≤ 3.
- **Skin Safety & Ergonomics:** All skin-contact surfaces are burr-free with sharp edges eliminated; parting line burr height < 0.1mm and smooth rounded transitions complying with skin-contact safety requirements.

7. Overall Performance Target Summary

Performance Index	Target Value / Description
Total Wearing Weight	≤ 180g (including battery and lamp head)
Material Identification	Material grade permanently engraved on inner non-cosmetic housing surface
Flame Resistance	UL94-HB or higher
Ingress Protection	Optional IP54 splash/dust resistance
Assembly Precision	Step offset ≤ 0.2mm after upper/lower shell closing
Long-Term Color Fastness	No obvious fading after 2 years of simulated outdoor sunlight exposure

8. Techinherit Manufacturing Capability

Leveraging profound expertise in engineering plastics, Techinherit delivers one-stop customized solutions covering material modification, industrial design optimization and mass delivery. Core capabilities are detailed below:

- **Material Engineering & Concurrent Design:** Early-stage technical participation providing material selection, custom formulation and DFM analysis. SLA 3D printed functional prototypes available within 3–5 days for rapid validation.
- **Precision Mold Engineering:** In-house design and fabrication of single/multi-cavity precision injection molds. Moldflow simulation minimizes shrinkage and warpage. Standard mold lead time: 25–35 days; rapid tooling options available.

- **Custom Mass Injection Molding:** 90T–380T servo injection molding machines with automated auxiliary systems stably process ABS, PC/ABS, glass fiber reinforced nylon and other engineering plastics. Scientific molding sustains overall production yield above 98%.
- **Vertical Integrated Service:** Post-molding downstream processes including ultrasonic welding, hot-melt nut insertion, laser engraving, spray painting and partial electronic assembly. Semi-finished modules or fully finished units can be supplied directly to streamline customer supply chains.