

Choosing the Right Plastic Materials for Marine Applications: UV Resistance, Saltwater Durability, and Mechanical Performance

By GEMS-MFG Team

I. Introduction

Selecting the right plastic material is critical for any product destined for marine environments. Whether it's a fishing accessory, a buoyant device, or a component of a seafaring vessel, the material must withstand intense environmental stressors over time. Prolonged exposure to ultraviolet (UV) radiation, constant contact with saltwater, high humidity, and physical handling pose serious challenges for polymers.

In addition to resisting corrosion and weathering, the material must also maintain mechanical strength and be compatible with industrial manufacturing methods such as injection molding or extrusion. This article explores key performance criteria and identifies the best-suited plastic materials for harsh marine applications.



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II. Environmental Challenges in Marine Applications

Marine environments are among the harshest for material performance. Understanding these conditions is the first step in effective material selection:

- **UV Radiation:** Continuous sunlight exposure accelerates degradation in many polymers, leading to brittleness, discoloration, and loss of mechanical strength. UV-resistant polymers or those with stabilizing additives are essential.
- **Saltwater Exposure:** Salt accelerates corrosion and can attack polymer chains, especially in moisture-absorbing materials. Resistance to hydrolysis and low water absorption are key traits.
- **Humidity and Temperature Fluctuations:** Materials must maintain dimensional stability despite fluctuating conditions, particularly in tropical or coastal regions.
- **Mechanical Stress:** Impact, abrasion, and flexural loads from waves, handling, and equipment contact necessitate toughness and resilience.
- **Biological and Chemical Exposure:** Algae, barnacles, and chemicals like oils or fuels in marine settings can degrade materials if they are not chemically resistant.

Successful material selection balances all of these factors without compromising manufacturability or cost.

III. Key Material Properties to Consider

To thrive in marine environments, a plastic material should demonstrate the following core attributes:

- **UV Resistance:** Look for polymers with inherently stable backbones (like ASA) or those with effective UV stabilizers.
- **Saltwater Resistance:** Choose materials with low moisture absorption and chemical resistance. Polymers like polypropylene or certain nylons (PA12) perform well here.
- **Mechanical Robustness:** High impact strength and resistance to cracking, especially under repeated loading or low temperatures, are essential for durability.
- **Dimensional Stability:** Materials should resist warping or swelling due to water absorption or thermal changes.
- **Processability:** Injection molding and extrusion are standard for marine product production. The selected material must flow well and have thermal stability during processing.

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Understanding these properties allows engineers and designers to make informed choices and tailor solutions to specific product requirements.

Material	UV Resistance	Saltwater Resistance	Impact Strength	Processability
ASA	★★★★★	★★★★	★★★★	★★★★
PP-C	★★ (UV stabilized)	★★★★	★★★	★★★★
PA12	★★★	★★★★	★★★★	★★★
HDPE	★★ (UV treated)	★★★★★	★★★★	★★★★
POM	★ (UV treated)	★★★★	★★★★	★★★
TPU/TPE	★★★ (stabilized)	★★★★	★★★★★	★★★★
PC+ABS	★★ (UV stabilized)	★★	★★★★	★★★★

IV. Recommended Plastic Materials for Marine Use

1. ASA (Acrylonitrile Styrene Acrylate)

ASA is one of the most UV-stable thermoplastics available. Its acrylic component offers excellent resistance to sunlight, color fading, and weathering. With good impact resistance and low water absorption, ASA is widely used for outdoor equipment, automotive trims, and marine housings. Materials like **KIBILAC® PW-957** are specifically formulated for high-gloss and marine applications.

- *Pros:* Outstanding UV resistance, stable mechanical performance, excellent surface finish
- *Cons:* Moderate heat resistance, lower chemical resistance compared to high-performance polymers

2. Polypropylene Copolymers (PP-C)

PP-C is valued for its lightweight nature and chemical resistance, including to saltwater and marine chemicals. When UV-stabilized, it performs well in marine applications like battery casings, floats, and containers.

- *Pros:* Chemically inert, low density, economical
- *Cons:* Poor UV resistance unless stabilized, lower impact strength at low temperatures

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3. **Polyamide 6/12 (Nylon)**

Certain nylon grades, especially PA12, absorb less moisture and retain better dimensional stability in marine environments. Glass-filled variants offer increased strength, but require UV stabilizers for long-term exposure.

- *Pros:* High strength and fatigue resistance, good wear properties
- *Cons:* Moisture absorption (PA6, PA66), needs UV protection

4. **HDPE and UHMWPE**

These polyethylenes are naturally hydrophobic and highly resistant to saltwater corrosion. UHMWPE is extremely tough and wear-resistant, used for docks, liners, and sliding components.

- *Pros:* Excellent chemical and moisture resistance, impact durability
- *Cons:* Limited UV stability unless treated, low rigidity for structural parts

5. **POM (Acetal)**

Also known as polyoxymethylene, POM offers high dimensional stability and resistance to water and fuel. However, it requires UV stabilizers for long-term sunlight exposure.

- *Pros:* Low friction, strong in wet environments, good fatigue resistance
- *Cons:* UV sensitivity, potential formaldehyde emissions during processing

6. **TPE/TPU (Thermoplastic Elastomers/Urethanes)**

Flexible and durable, TPEs and TPUs are ideal for seals, grips, and cushioning components on marine equipment. UV-stabilized grades can perform reliably in outdoor marine use.

- *Pros:* Elasticity, soft touch, excellent shock absorption
- *Cons:* Must be carefully selected for UV and chemical resistance

7. **PC+ABS (UV-Stabilized Grades)**

This blend combines the toughness of PC and processability of ABS. While not inherently UV-resistant, stabilized grades can offer adequate performance for covered or minimally exposed marine uses.

- *Pros:* High impact strength, moldability, aesthetic surface
- *Cons:* Poor saltwater and UV resistance unless specially treated

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8. Vinyl Esters & Marine-Grade Composites

For demanding structural applications like hulls or mounting brackets, marine-grade composites reinforced with fiberglass or carbon fiber deliver unmatched durability.

- *Pros:* Excellent mechanical and corrosion performance
- *Cons:* Higher cost, complex manufacturing, not suitable for all part sizes

V. Material Selection Strategy

Choosing the most appropriate plastic for a marine application involves more than selecting a single property. The process must consider the specific use case, budget, manufacturing capabilities, and expected lifecycle of the part. Here are key steps for an effective selection strategy:

1. **Define the Application Environment:** Determine the level of exposure to UV light, saltwater immersion, mechanical abuse, and temperature cycling. Outdoor surface parts need UV-stable polymers, while submerged components demand high chemical and water resistance.
2. **Rank Performance Priorities:** Identify the most critical requirements—such as impact strength, rigidity, or dimensional stability—and eliminate materials that fail to meet minimum thresholds.
3. **Assess Processing Compatibility:** Ensure the material is compatible with the planned manufacturing process, such as injection molding or extrusion. Evaluate melt temperature, shrinkage, and flow characteristics.
4. **Evaluate Cost and Availability:** Some high-performance polymers offer excellent marine durability but may be cost-prohibitive or have longer lead times. Balance performance with practical supply considerations.
5. **Prototype and Test:** Always validate your material choice under simulated or real marine conditions. Rapid prototyping, salt spray testing, and UV chamber aging help confirm long-term performance.
6. **Consider Regulatory and Environmental Compliance:** For certain applications—such as fishing gear or potable water components—verify compliance with environmental or safety standards like RoHS, REACH, or FDA.

A well-structured material selection strategy ensures product reliability and minimizes costly redesigns or failures after deployment.

VI. Field Applications and Case Studies

Real-world applications reveal how marine plastics perform under complex and demanding conditions. Below are two detailed case studies illustrating material selection, design challenges, and results.

Case Study 1: Floating Crab Trap Buoy — UV-Stabilized Polypropylene Copolymer

1.1. Background:

The client required a buoy for commercial crab traps designed to remain afloat and visible for extended periods in coastal saltwater environments. The buoy must withstand constant wave impact, exposure to direct sunlight, and harsh saline spray, while resisting biofouling that can add weight and reduce buoyancy.

1.2. Challenges:

- Prolonged immersion and salt spray exposure causing chemical and mechanical degradation
- Intense UV radiation leading to polymer chain breakdown and discoloration
- Impact resistance needed due to collisions with rocks and boat hulls
- Manufacturing constraints demanding injection molding for scalable production

1.3. Material Selection:

UV-stabilized polypropylene copolymer (PP-C) was chosen for its excellent chemical resistance, low density, and cost-effectiveness. UV stabilizers were compounded to extend surface longevity under sunlight. The semi-crystalline nature of PP-C provided good impact resistance at ambient temperatures.

1.4. Design Considerations:

The buoy incorporated a thick outer shell to absorb impacts and a hollow interior for buoyancy. Surface textures and pigmentation were optimized to reduce biofouling and maintain visibility.

1.5. Outcome:

The buoy passed accelerated UV and salt spray testing simulating one year of continuous marine exposure. Field trials confirmed its resistance to cracking and fading. The production process achieved high throughput and consistent quality, meeting budget targets.

Case Study 2: Offshore Sensor Casing — Acrylonitrile Styrene Acrylate (ASA)

2.1. Background:

A manufacturer of offshore monitoring equipment needed a durable protective casing for sensitive electronic sensors mounted on buoys and submerged platforms. The casing must resist prolonged UV exposure, salt fog, temperature swings, and mechanical stresses caused by waves and debris impact.

2.2. Challenges:

- Surface chalking and brittleness due to UV degradation over multi-year deployment
- Salt mist corrosion affecting surface finish and potential ingress points
- Requirement for high dimensional stability to maintain tight seals around sensor interfaces
- Aesthetic demands for glossy, non-fading housing visible above water

2.3. Material Selection:

ASA was selected because of its superior UV resistance stemming from its acrylic component, which prevents color fading and chalking. Its low water absorption and excellent impact resistance protected internal electronics and ensured long-term dimensional integrity.

2.4. Manufacturing:

Injection molding enabled complex geometries with tight tolerances. The use of a marine-grade grade such as KIBILAC® PW-957 enhanced surface gloss and weathering resistance. UV stabilizers and anti-oxidants were incorporated during compounding.

2.5. Outcome:

The casings demonstrated exceptional surface retention and mechanical performance after 18 months of continuous marine exposure, verified by accelerated weathering tests (ASTM G154) and salt spray tests (ASTM B117). Field deployment confirmed robust protection for electronics with minimal maintenance requirements.

VII. Testing and Validation Methods for Marine Plastics

Rigorous testing is critical to ensure selected plastics can endure the multifaceted challenges of marine environments. The following test methods are industry standards used during material qualification and product development:

1. **UV Accelerated Weathering (ASTM G154, ISO 4892-3)**

These tests simulate long-term exposure to solar radiation using fluorescent UV lamps, combined with cyclic condensation or water spray to replicate dew and rain. They help evaluate changes in mechanical properties, color fastness, surface chalking, and cracking over time. UV stabilizers in plastics are validated based on performance in these accelerated conditions.

2. **Salt Spray (Fog) Testing (ASTM B117, ISO 9227)**

This method exposes samples to a continuous salt fog environment to simulate corrosive marine atmospheres. While polymers don't corrode like metals, salt spray testing reveals surface degradation, erosion, and loss of protective coatings or additives. It also helps identify moisture ingress pathways in composite or multi-material assemblies.

3. **Water Absorption Testing (ASTM D570)**

Moisture uptake can lead to swelling, dimensional instability, and hydrolytic degradation. This test immerses plastic specimens in water for specified durations and temperatures to quantify water absorption levels. Low water absorption materials like HDPE and ASA maintain better mechanical stability in marine conditions.

4. **Mechanical Testing under Marine Conditions**

- *Impact Resistance (ASTM D256, Izod or Charpy)*: Assesses toughness, especially critical for parts subject to wave or debris impact.
- *Fatigue Testing (ASTM D7791)*: Evaluates material endurance under cyclic loading, simulating repetitive stresses from waves and handling.
- *Flexural Strength and Modulus (ASTM D790)*: Ensures parts maintain rigidity and resist deformation in fluctuating loads and temperatures.

5. **Field Exposure Trials**

Ultimately, accelerated lab tests are complemented by long-term field trials in representative marine locations. Real-world data on weathering, biofouling, mechanical wear, and user feedback provide the most reliable validation.

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6. Chemical Resistance Testing

Testing against common marine chemicals such as oils, fuels, cleaning agents, and biological secretions ensures that the material maintains integrity and does not degrade prematurely.

Employing a combination of these methods during the design phase significantly reduces the risk of premature failure and costly recalls.

VIII. Surface Finishing and Protective Coatings

Surface treatment technologies play a pivotal role in enhancing marine plastic durability, aesthetics, and functionality:

1. Inherent UV Stabilization

UV absorbers and hindered amine light stabilizers (HALS) are compounded into polymers to intercept damaging UV rays and neutralize free radicals. These additives dramatically slow down photo-oxidative degradation, preserving color and mechanical strength.

2. Pigmentation and Masterbatches

Marine plastics often use specialized pigments that resist fading, chalking, and cracking. Darker and opaque colors typically perform better outdoors, but tailored formulations (e.g., KIBILAC® PW-957 in white or bright colors) enable high-gloss, color-stable finishes.

3. Hydrophobic and Anti-Fouling Coatings

Marine biofouling — accumulation of algae, barnacles, and microorganisms — accelerates surface wear and increases maintenance. Applying hydrophobic coatings or biocide-free fouling release coatings reduces organism adhesion and water uptake, preserving material performance and lowering cleaning frequency.

4. Surface Texturing and Patterning

Micro-texturing can improve grip for handles or reduce wet surface glare. Additionally, surface topographies engineered to discourage fouling and sediment buildup improve long-term usability.

5. Paints and Sealants

For complex assemblies or multi-material interfaces, protective paints and sealants provide additional barriers against moisture ingress and chemical attack. Marine-grade polyurethane or epoxy paints are common, but compatibility with the base plastic must be confirmed to avoid delamination.

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6. Plasma and Corona Treatments

Pre-treatment technologies improve surface energy, enabling stronger bonding of paints, adhesives, or coatings, critical in harsh marine conditions.

7. Maintenance of Treated Surfaces

Even with advanced coatings, regular inspection and cleaning protocols extend service life. Understanding coating wear characteristics guides maintenance scheduling.

In summary, surface finishing is not merely cosmetic but an essential part of marine plastic engineering, optimizing longevity, safety, and performance.

IX. Design and Manufacturing Considerations for Marine Plastic Components

For marine applications, material selection is only one part of ensuring performance. Proper design and manufacturing practices are equally important to achieve durability, efficiency, and cost control in production.

1. Material Processability

- Marine plastics like ASA, PC+ABS, and PP-C are suitable for injection molding, offering stable flow and dimensional control.
- Additives (UV stabilizers, glass fiber) can affect molding behavior—process settings should be adjusted accordingly.
- Hygroscopic materials (e.g., PC blends) require proper pre-drying to avoid defects during molding.

2. Part and Tooling Design

- Uniform wall thickness helps avoid warping or sink marks.
- Ribs, bosses, and fillets improve structural strength and moldability.
- Adequate draft angles, gate placement, and venting are essential for clean ejection and surface finish.

3. Assembly and Integration

- Use corrosion-resistant fasteners or molded inserts for long-term durability.
- Snap-fit designs should consider UV aging and mechanical fatigue over time.

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- Multi-material parts (e.g., PC+ABS with TPU overmold) must account for bonding, sealing, and differential expansion.

4. Surface and Aesthetic Considerations

- High-gloss or textured finishes should be matched with appropriate mold surface treatments.
- Color stability under sunlight requires UV-resistant pigments and proper dispersion during compounding.
- Weld lines and cosmetic defects can be minimized with balanced flow and optimized gate design.

5. Efficiency and Lifecycle Cost

- Select materials that balance environmental resistance with ease of processing and consistent cycle times.
- For high-volume production, invest in robust molds and maintain process stability to reduce scrap and rework.
- Design for ease of replacement or repair can extend product life and reduce long-term maintenance costs.

X. Conclusion

Marine applications place exceptional demands on plastic materials, combining mechanical abuse, chemical exposure, and extreme environmental conditions. The ideal material must withstand prolonged UV exposure, resist saltwater degradation, and retain mechanical integrity over time.

Ultimately, the right material choice depends on the specific application scenario, required lifespan, and manufacturing constraints. Early involvement of design engineers, material scientists, and production teams will ensure the selected plastic delivers the performance needed to endure the challenges of the marine environment.

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