Technical Report: R+2304

Plastics in the Motorcycle Industry

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1 Summary

The use of plastics in the motorcycle industry has seen significant growth. Plastics are used in a wide range of applications, from aesthetic parts to structural components, offering benefits such as versatile design, lower cost, weight reduction, and ease of recycling. However, plastics have specific limitations and disadvantages for certain functionalities.

In this report, we explore the characteristics and performance of the main types of plastics used in the motorcycle industry and provide practical recommendations on selecting the best material for each application and testing the manufactured parts to ensure their performance. Finally, we provide specific examples of the use of each material, as well as a comparative table of the purchase costs of the most commonly used materials.

We hope you find this useful.

2 Introduction

In the automotive industry, the use of various plastics has become increasingly important throughout its historical evolution. Recently, there has been a significant increase in their use, attributed to the introduction of new types of plastics, innovative additives, pigments, and compounds that provide exceptional performance at a reasonable cost.

Vehicle manufacturers are constantly seeking innovations in design and efficiency improvements, covering both economic and environmental aspects. Plastics are no longer limited to aesthetic or auxiliary applications; they have become essential elements in motorcycle manufacturing. They have transitioned from being the first choice for components like fairings, windshields, luggage racks, grilles, supports, and accessories to being used in structural parts in some cases due to their increasingly favorable ratio of strength, weight, and cost compared to "traditional" alternatives like aluminum or steel.

The development of new types of plastics, driven by the automotive industry, and the introduction of additives that replace or combine with traditional materials like fiberglass and talc, have significantly expanded the field of applications for plastics in the production of motorcycle components.

In this document, we analyze in detail the most relevant plastics, their properties, advantages, and essential considerations for their correct specification and integration into any project in general, and specifically in motorcycle development.

3 Classification of Plastics

The most commonly accepted classification of plastics is based on how they react to temperature changes, according to which there are two categories: thermoplastics and thermosets.

3.1 Thermoplastics

The vast majority of plastics used in the manufacturing of vehicle bodies, whether two or four wheels, are thermoplastics. These plastics are hard at low temperatures but become malleable when heated, making them easier to mold and allowing for their joining or repair through heat (welding).

Generally, these materials have a high molecular density and consist of linear or branched macromolecules that are not interlinked. The mechanical properties of thermoplastics vary depending on the manufacturing process and their degree of polymerization.

These plastics are ideal for creating flexible parts designed to absorb impact and energy in minor collisions. In this report, we will detail several examples of parts designed to be manufactured with some of the materials we will describe.

An important characteristic (and advantage) of thermoplastics is that they can be recycled (as long as they haven't been painted).

(ABS) Acrylonitrile Butadiene Styrene

ABS is one of the most common thermoplastics. It is widely used in motorcycles and scooters due to its strength and flexibility. It combines the rigidity and strength of styrene and acrylonitrile with the flexibility of butadiene rubber. Additionally, it is a lightweight and versatile material that resists heat well. It is important to note that ABS requires painting to achieve good finishes (final piece gloss).

Characteristics:
- Rigid and dimensionally stable.
- High-quality surfaces and chemical resistance.
- Paintable (recommended).
- Opaque with a matte finish.

Costs:
The price of ABS, like the other materials we will discuss here, can vary significantly depending on the supplier, geographic location, quality, and batch size. Additionally, market price fluctuations, such as those observed after the COVID-19 pandemic, also influence costs.

Properties:
Described in the attached technical data sheet.

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ACRILONITRILO-BUTADIENO-ESTIRENO (ABS)

PROPIEDAD	UNIDAD	NORMA	ABS		
Densidad	gr/cm3	ISO 1183	1,03 – 1,08		
Contraccón de inyeccón	%	---	0,6 – 0,7		
Indice de fluidez MFI	gr/10min.	ISO 1133	5 - 12		
Impacto entalla	kJ/m2	ISO 180/1A A 23ºC/1A	>15		
Módulo de flexión	MPa	ISO 178	> 2200		
Temp. Inflexión bajo carga (HDT) 1,8Mpa	ºC	ISO 75	>95		
Temperatura màxima en continuo	ºC	---	90		
Resistencia a la luz y agentes atmosféricos	---	---	(A)		
Comportamiento a los agentes químicos	---	---	(B)		

Nota:

(A) Buena con pigmentación negra. Con otras pigmentaciones es necesaria una estabilización particular

(B) No es resistente a las gasolinas y a los liquidos de freno. Buena resistencia a liquidos refrigerantes (agua+glicol)

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R+ Datasheet: ABS (*)

(*) If you would like to receive a PDF copy of our three data sheets (ABS, PA, and PP), please send us an email with the subject line "Fichas_R+" to info@rothmans.es.

Examples of ABS applications in motorcycles:
Motorcycle/scooter fairings, headlight housing, spoilers, grilles, etc.

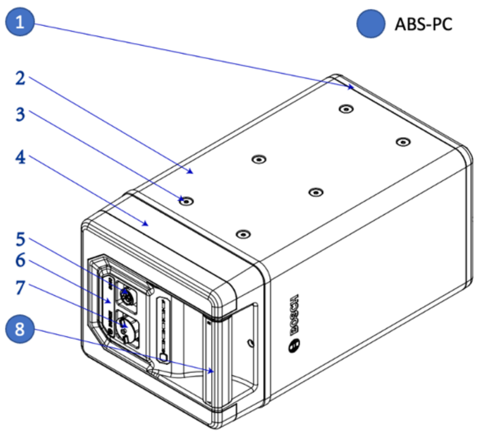
Photo Derbi Atlantis: Front, side panels, fender, handlebar cover

ABS PC (Alpha Polycarbonate ABS)
Its use is less common than standard ABS.

Characteristics:
- Offers greater rigidity and strength than conventional ABS.
- Performs well in traction and impact absorption.
- Not transparent in its standard form.

Cost:
The approximate industrial cost per kilogram (kg) of ABS-PC may vary, as mentioned earlier with ABS. However, in general, ABS-PC tends to be more expensive than ABS or PC separately due to its combined properties.

Examples of application:
Grilles, spoilers, windshields, exhaust protectors, battery housings, etc.



Upper and lower BOSCH battery covers for electric motorcycle

MPPA (Modified Maleic Anhydride Polyphenylene Ether)
Modified maleic anhydride polyphenylene ether is a thermoplastic containing ether and maleic anhydride groups in its structure. This polymer is known for its high chemical and thermal resistance. It is suitable for applications in corrosive environments. Some accessory manufacturers use it for windshields and wind deflectors.

Photo: Puig V-Tech windshield for Yamaha T-Max 560 2022/2023

PA (Polyamide)

Polyamide (PA) is an impact-resistant plastic, highly resistant to wear and various chemical agents. On the downside, PA is "hygroscopic," meaning it absorbs moisture from the environment, which can affect its physical and mechanical properties over time, especially during manufacturing and immediate storage. We always recommend "approving" your injector, ensuring they are familiar with this material before assigning them the production of a PA part to avoid problems.

The most commonly used PAs in motorcycles are PA6, PA6.6, and PA12. All of them can be reinforced with fiberglass from 5% to 35% to further increase their strength.

Technical Properties:

The physical properties of PA are listed in the attached technical sheet (*) below.

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POLIAMIDAS (PA)

PROPIEDAD	UNIDAD	NORMA	PA 6	PA 6 + 15% F.V	PA 6.6 + 30% F.V
Densidad	gr/cm3	ISO 1183	1,12 – 1,14	1,2 – 1,25	1,3 – 1,4
Contracción de inyección	%	---	0,8 – 1,5	0,4 – 0,7	0,3 – 0,6
Absorción de agua	%.	---	2,5 – 3,5	1,8 – 2,2	1,5 – 2,2
Impacto entalla	kJ/m2	ISO 180/1A	5 - 12	8 - 12	9 - 12
Módulo de flexión a 23ºC	MPa	ISO 178	2000 - 3000	4000 - 6000	6000 - 8000
Resistencia a la flexión a 23ºC	MPa	ISO 178	90	180	250
Temperatura máxima en continuo	ºC	---	105	120	140
Resistencia a la luz y agentes atmosféricos	---	---	(A)	(A)	(A)
Comportamiento a los agentes quimicos	---	---	(B)	(B)	(B)

Nota:

(A) Resistente solo si está estabilizado a los U.V.
(B) Buena resistencia a los aceites, al gasoil, gasolina.

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*Physical Properties of PA **

(*) If you would like to receive a PDF copy of the full technical sheets for ABS, PA, and PP, please request it by sending an email with the subject "Fichas_R+" to info@rothmans.es.

Types of PA:

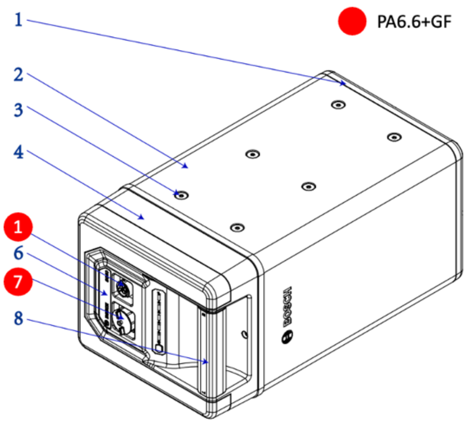
PA 4.6 (Polyamide 4.6)
Good heat and wear resistance.
Examples: Oil filter housing, chain tensioner.

PA 4.6 + GF (Polyamide 4.6 with fiberglass)
Reinforced with fiberglass for greater strength and rigidity.
Examples: Rollers, chain tensioner.

PA 6 (Polyamide 6)
Good combination of mechanical strength, stiffness, and toughness. Used in injection-molded parts, textile fibers, among others. Example: Clamps, covers, front wheel hubcaps for NUUK, control buttons, fan blades, etc.

Headlight mounting bracket for Bultaco Brinco

PA 6+GF (Polyamide 6.6 reinforced with fiberglass)
Reinforced with fiberglass for greater strength and rigidity.
Example: Covers, fans, connectors, clamps.



Charging and discharging connectors for an electric motorcycle battery

PA 6.6 (Polyamide 6.6)
Similar to PA6 but with greater heat and wear resistance.
Examples: Headlight housings, fans, springs, clamps, covers, contact supports, levers, switches, connectors,…

Guilera.com moped power inverter housing

PA 6.6+GF (Polyamide 6.6 reinforced with fiberglass)
Reinforced with fiberglass for greater strength.
Examples: Covers, fans, connectors, cable carriers, luggage racks, current protectors, suspension stops, underbody protectors.

Bultaco Brinco battery protection cover

PA 11 (Polyamide 11)
Corrosion-resistant, common in pipelines, fuel tubes, and cable coatings.

PA 12 (Polyamide 12)
Impact-resistant and low temperatures. Examples of use: Housings for electronic elements, dashboard housings in off-road motorcycles…

PA 12+GF (Polyamide 12 reinforced with fiberglass)
Reinforced with fiberglass typically in proportions ranging from 5% to 30%. Due to the hygroscopic nature of all PAs, these parts are usually painted externally.

PC (Polycarbonate)
PC is a material that exhibits high rigidity and hardness, in addition to being very impact-resistant. It has good weather resistance and is easier to repair than other types of plastics.
Characteristics:
- Capable of withstanding temperatures up to 120°C.
- It is an expensive material and absorbs moisture (slightly hygroscopic/not recommended for structural or support parts).
- In its natural state, it is transparent and resistant to UV degradation.

Examples of use:
Handlebar covers, decorative spoilers.

Aprilia Sportcity/Derbi Rambla windshield

PE (Polyethylene)

PE exhibits great elasticity against impact and the ability to recover its original shape. It resists a wide variety of chemical agents. It can begin to deform at around 87°C. The two most common types of polyethylene are high-density polyethylene (HDPE) and low-density polyethylene (LDPE). It is used in tubes, batteries, wheel arch linings, etc.

PP (Polypropylene)

PP is one of the most widely used plastic materials in the automotive industry for various parts and components. It clearly surpasses the performance of Polyethylene in traction, impact absorption, and heat resistance (up to 130°C). It also offers great elasticity and rigidity, and good behavior against chemical agents. For these reasons, PP is the most versatile material. Additionally, it can accept a large number of additives to change (improve) its structural and aesthetic properties.

There are two main types of PP: homopolymer and copolymer. PP “Homo” has greater rigidity and impact resistance compared to the copolymer and better fluidity during the injection process, making it easier to manufacture parts with intricate details. It is more economical compared to the copolymer, due to its simpler manufacturing process and greater availability.

The PP copolymer, on the other hand, is more flexible and has better impact resistance compared to the homopolymer, making it more suitable for applications where toughness and flexibility are more important than rigidity. PP “Copo” works better at low temperatures and requires higher injection temperatures and longer cooling times.

PP, in general, is widely used in off-road motorcycles (enduro, trial, cross), whose plastics are usually not painted (cost reduction, better recycling). For this, the molds where these parts are injected must have very fine surface finishes to achieve a high piece gloss.

PP can be mixed with colorants and glossing agents to achieve nearly any color, with finishes similar to painted parts. For the best results, I recommend consulting with a supplier specializing in additives and base materials. If you need assistance finding one, you can request a list of recommended suppliers from us by emailing info@rothmans.es.

Poliversal Colorant Additives Handbook

It should be noted that PP is a "soft" plastic - it can be easily scratched - when defining not only the functionality of the part but also its packaging and transportation to avoid rejections. PP can be painted, but it requires pre-preparation for good adhesion. However, it is preferable to opt for another material if you plan to paint the parts.

If you decide to use PP and prefer not to paint, keep in mind that dark colors show their defects more easily. Black, dark blue, or red PP parts may show visual signs of aging before light-colored parts.
To avoid or reduce scratches, protect susceptible areas with technical adhesives. If you plan to apply decals, inform the supplier of the material to adapt the type of adhesive, as PP has limited adhesion.

Properties

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POLIPROPILENOS (PP)

PROPIEDAD	UNIDAD	NORMA	PP COPOLIM.	PP + 15% F.V	PP + 30% F.V
Densidad	gr/cm3	ISO 1183	0,89 – 0,92	0,93 – 1,06	1,08 – 1,12
Contraccón de inyeccón	%	---	1,5 – 2,0	0,9 – 1,2	0,4 – 0,8
Indice de fluidez MFI	gr/10min.	ISO 1133	10 - 20	5 - 15	1 - 4
Impacto entalla	kJ/m2	ISO 180/1A A 23ºC/1A	4 - 12	7 - 17	10 - 20
Módulo de flexión	MPa	ISO 178	1000 - 2000	1800 - 3600	> 5000
Temp. Inflexión bajo carga (HDT) 1,8MPa	ºC	ISO 75	75 - 115	100 - 150	> 100
Temperatura màxima en continuo	ºC	---	90	115	120
Resistencia a la luz y agentes atmosféricos	---	---	(A)	(A)	(A)
Comportamiento a los agentes químicos	---	---	(B)	(B)	(B)

Nota:

(A) Resistente solo si està estabilizado a los U.V.
(B) Buena resistència al liquido de frenos, liquidos refrigerantes (glicol/agua), disoluciones acuosas con acidos y alcalines.
Resiste a la gasolina sin plomo en ataques poco prolongados

*Physical Properties of PP **

(*) If you would like to receive a PDF copy of the full technical sheets for ABS, PA, and PP, please request it by sending an email with the subject "Fichas_R+" to info@rothmans.es.

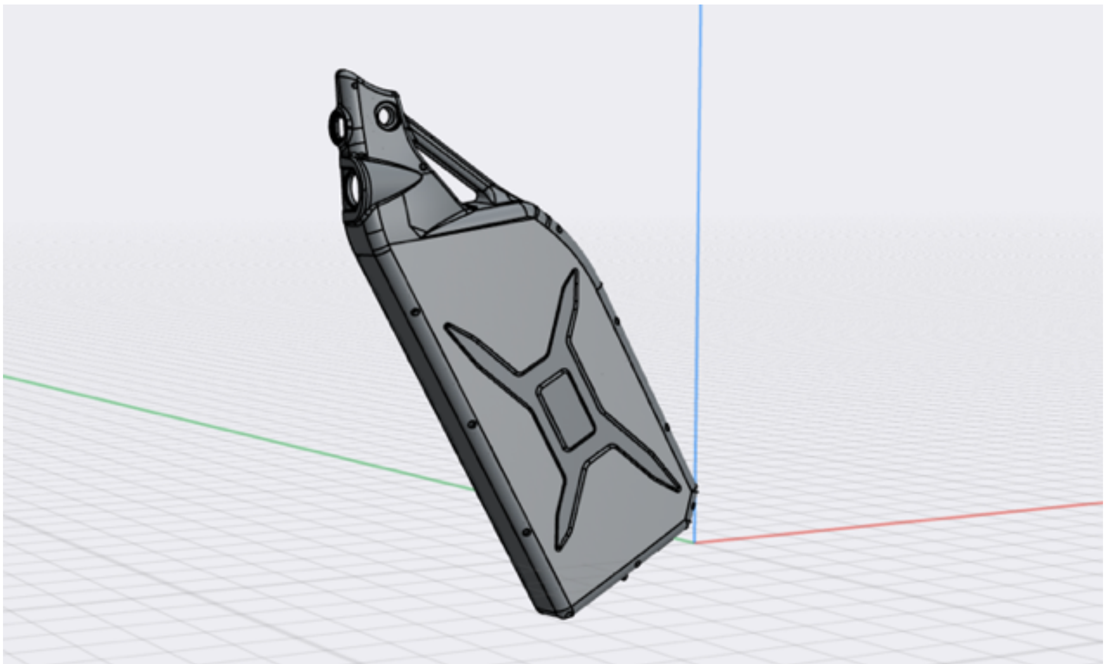
Examples of PP parts:
Mudguards, side panels, rear covers, fork protectors, number plates, headlight holders, hand protectors, and much more.

Rieju MRT radiator side cover

Reinforced PP

- PP+GF (Glass Fiber Reinforced Polypropylene)

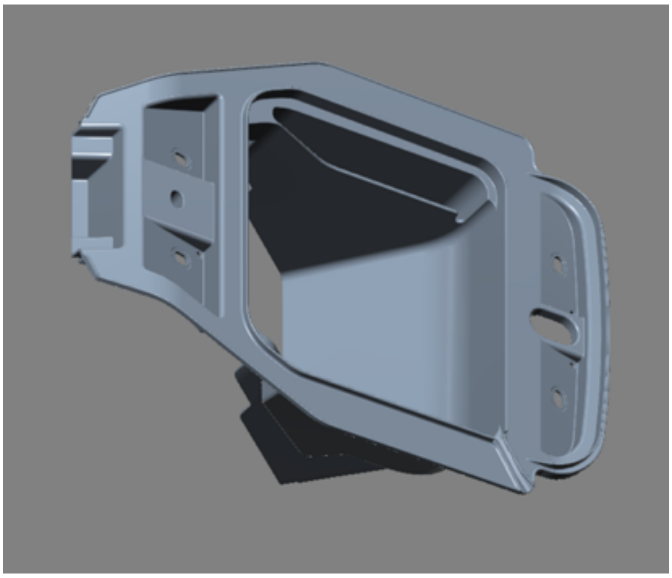
The use of glass fiber reinforcement in plastics can vary depending on the specific application and performance requirements. Both types of polypropylene (PP), both homopolymer and copolymer, can be used with glass fiber reinforcement, and the choice between them depends on the desired characteristics of the final product.



Render of Bultaco Brinco Battery enclosure (PP + 15% GF)]

- PP+Talc (Talc Reinforced Polypropylene)

Adding talc to PP increases its stiffness, impact resistance, and heat resistance. It reduces shrinkage during cooling. This material is slightly cheaper than glass-reinforced PP.



GOVECS FLEX seat base

- Special PPs

The materials industry offers a wide range of special PP formulations, including additives designed for highly demanding applications. If you're looking for a material with specific properties, it's likely already available.

Rothmans MRSpro racing steering wheel with removable and 'washable' grips

3.2 Thermosets

Thermosets are widely used in motorcycle engineering due to their stability under heat, pressure, and chemical exposure. Unlike thermoplastics, they don't soften when heated; instead, they form a strong, rigid structure that makes them suitable for high-temperature applications like engine covers, radiator supports, and electrical insulation components. Thermosets also have a "memory" effect, meaning they retain their shape even under stress and heat, which is important in areas like engine compartments. While they can't be welded, they can be repaired using adhesives or resins.

The most common thermosets used in the motorcycle industry include unsaturated polyester resins, epoxy resins (EP), and polyurethanes (PU). These materials are often reinforced with mineral or synthetic fillers to enhance their mechanical properties, such as strength, rigidity, and resistance to wear.

Epoxy Resins (EP):
Epoxy resins are widely used for applications requiring strong adhesive properties, chemical resistance, and high mechanical strength. They are commonly found in composite parts like carbon fiber-reinforced components, which offer a high strength-to-weight ratio. Epoxy resins are also used in the production of electrical components due to their insulating properties.

Examples:
- Bonding agents for composite materials in structural parts.
- Electrical insulation components, where high temperature and chemical resistance are important.

Polyurethanes (PU):
Polyurethane thermosets are versatile materials offering a wide range of hardness levels and elasticity. In the motorcycle industry, PU is used in applications requiring abrasion resistance, flexibility, and vibration damping. These properties make PU suitable for components like bushings, seals, and foam padding.

Examples:
- Engine mounts and bushings that reduce vibration and noise.
- Protective coatings for metal parts to prevent corrosion and wear.
- Flexible foams used in seats and padding for comfort and impact absorption.

Unsaturated Polyester Resins:
These resins are typically used in the production of fiberglass-reinforced plastics (FRP), which are lightweight yet strong materials. FRP is commonly used in structural and body components of motorcycles, such as fairings and fuel tanks, where a balance of weight and strength is important.

Examples:
- Fiberglass-reinforced fairings and body panels.

- Lightweight fuel tanks made from FRP for strength and reduced weight.

Silicone materials:
Silicone-based materials are often used in gaskets and seals that need to resist high temperatures and exposure to chemicals, ensuring reliable performance over time.

4 Bioplastics and Reinforced Biocomposites

The growing concern for sustainability has driven the development of bioplastics, which are polymers derived from renewable sources rather than petroleum. Among these materials, biopolymers and reinforced biocomposites, such as PLA (polylactic acid), produced from starch, stand out. These materials not only reduce dependence on fossil resources but also offer characteristics comparable to traditional plastics, making them ideal for applications in sectors like packaging and automotive.

4.1 Plastics with Special Properties

Another important aspect is the development of plastics with special properties, such as fire retardants and those with scratch-resistant coatings. These materials are increasingly being integrated into the interiors of automobiles and motorcycles, particularly in high-wear areas, where they offer superior durability.

4.2 Electronic Applications

Innovation in the electronics field continues unabated. Plastics with thermochromic properties, which change color with temperature, are beginning to be used in various applications, providing both aesthetic and functional benefits. Additionally, in electric vehicle (EV) batteries, the use of high-density solid polymer electrolytes (such as PEO, PAN, PMMA, polymethacrylate, among others) is achieving not only greater efficiency and safety but also weight reduction, contributing to the sustainability of EVs.

4.3 Plastronics

Finally, we must mention plastronics, a technology that integrates electronic circuits directly into plastic parts. This innovation enables the creation of lightweight and multifunctional components, which is especially valuable in the development of electric vehicles, where weight reduction and function integration are primary goals for engineers.

5 Advantages and Disadvantages of Using Plastics

The performance offered by plastics in our industry gives them a clear advantage over other materials like steel or aluminum, thanks to their lower weight and cost, better adaptation to environmental regulations, and the ability to be recycled.

5.1 Advantages Over Other Materials

Plastics offer significant advantages in our industry compared to other materials, such as steel or aluminum:
- Lower Cost: Both in the calculation of motorcycle costs and in manufacturing and assembly times.
- Lighter Weight: Fundamental in a motorcycle, especially in electric motorcycles that already have a clear disadvantage due to the weight of their batteries compared to a full gasoline tank in conventional motorcycles.
- Reduced Consumption and/or Increased Range: This leads to a decrease in emissions, a crucial aspect for complying with current environmental regulations. Additionally, in many cases, plastics are recyclable, extending their lifespan.
- Environmental Impact: Lower consumption also leads to reduced emissions, a fundamental aspect today for complying with current regulations. Additionally, in many cases, they are materials that can be recycled, extending their use.
- More Complex Design Lines: They allow the design of parts with complex geometries, reducing the number of necessary parts.
- Good Thermal, Electrical, and Acoustic Insulation Properties: They facilitate comfort while driving and better absorption of low-speed impacts thanks to their greater flexibility.
- They Do Not Rust.

5.2 Disadvantages of Using Plastics

Despite the numerous advantages they offer, plastic parts have some drawbacks that should be considered before selecting a particular type of plastic:
- Lower Weather Resistance: Prolonged exposure to weather conditions can cause material degradation, resulting in loss of gloss and strength in exposed plastic. This is especially noticeable when parts are injected in fluorescent colors, reds, oranges, yellows, and some blues.
- Greater Sensitivity to Chemical Agents: Some plastics have lower chemical resistance to certain products, such as solvents, which can damage the plastic substrate.
- Lower Adhesion and Incompatibility with Some Paints and Adhesives: Due to the particular properties of some plastics (as mentioned earlier in the case of PP), it is advisable to use specific paints or adhesives to ensure better adhesion.

6 Recycling of Plastics

Thermoplastics like ABS, PP, and LDPE are easily recyclable. Polyamides PA 4.6, PA6, PA6.6, PA12, and MPPA are recycled to a lesser extent due to their chemical composition and require specialized facilities. Thermoplastics reinforced with glass fibers or other additives are generally more difficult and expensive to recycle due to the presence of reinforcement additives in variable proportions.

Thermoset plastics are not easily recyclable using traditional melting and remolding methods due to their chemical structure, which permanently hardens when molded and does not soften again with heat. Instead of being recycled through melting and remolding, thermoset plastics are often broken down or incinerated at the end of their life cycle.

No type of painted plastic is recyclable.

7 Specification of Plastic Components

So far, we have discussed theory combined with practical cases to help you select the best material for your application.

The following points will help you specify this material in the part's specifications, request for quotes, and drawings unambiguously.

7.1 Definition of Composition and Properties

We recommend incorporating a technical standard in the specifications of each component, where you explicitly define the expected composition and properties of the material to be used in the construction of your part. Define your own standard for each of the materials to be used, and mention them alongside the name of each part in your drawings.
Example: Material: ABS according to technical standard XXXXX.

7.2 Definition of Markings

Don't forget to incorporate markings in your molds for manufacturing plastic parts to facilitate traceability and recyclability of your parts. Analyze whether your plastic parts should incorporate any of the following markings:
- Part name and/or internal code
- Material identification for later recycling
- Homologation marking (if applicable)
- Manufacturer's logo or brand

8 Testing of Plastic Components

In another post, we will discuss in detail the testing plan for a motorcycle development project. In this chapter, we will list some specific tests for plastic materials and components that could be applied during the development of your project's plastic parts. Define a procedure that clearly outlines how to perform each test and how to present the results obtained.

8.1 Dimensional Tests
- Verification of control dimensions, mass, volume.
- Verification of plastic part markings.

8.2 Chemical Characterization
- Chemical analysis of the material (according to specification or Technical Standard).
- Determination of reinforcement filler content in thermoplastics.

8.3 Verification of Properties

Incorporate, if applicable, any of the following tests on plastic parts into your test plan:
- Determination of water absorption in plastic materials.
- Determination of melting temperature in plastic materials.
- Impact resistance test by ball drop.
- Detection of residual stresses in plastic components.
- Determination of brittleness in polyamides.
- Tensile test.
- Tensile test in flexible materials.
- Impact and thermal cycle resistance test for painted or unpainted parts.
- Color resistance test in plastic components.
- Moisture control for polyamides.
- Gloss measurement.
- Color measurement.
- Aging chamber.
- Impact test (material resilience measurement).

8.4 Functional Tests
On discrete plastic components:
- Fatigue test.
- Abrasion test.

On the complete vehicle:
- Durability test.
- Accelerated fatigue test (vibrations).
- Lateral drop test.
- Drop test.

9 Final Recommendations

Consider using plastics in motorcycle component manufacturing, as they offer advantages such as lower cost and weight, as well as recyclability. Choose the right type of plastic for each application based on its specific properties. Ensure that tests are conducted on the manufactured parts to guarantee their performance. Keep in mind the cost of plastics, which can vary depending on the supplier and geographic location. Avoid using painted plastics if you want to facilitate recycling.

10 Conclusion

In the motorcycle industry, plastics play a fundamental role in combining efficiency, performance, and economy. Their ability to adapt to complex designs, reduce weight, and comply with environmental regulations makes them highly valuable materials. To fully leverage the benefits of plastics and overcome challenges, it's essential to understand their characteristics and limitations when selecting them. Collaborating from the outset with mold makers, material suppliers, injectors, and even painters and decal manufacturers during the project specification phase allows you to anticipate problems, find solutions, and act before obstacles become costly or difficult to resolve. Ultimately, this collaboration drives innovation, ensures quality, and guarantees competitiveness in vehicle manufacturing. If you have any questions, don't hesitate to contact us at info@rothmans.es.

11 Annexes

11.1 Sources

R+Engineering Technical Standards:
NT-0106 ABS
NT-0107 Polyamides
NT-0108 Polypropylenes
NT-0109-Polyethylene
NT-0110-Polycarbonate
NT-0131 Painting on Polypropylenes

11.2 Material Selection Guide

A table for selecting materials based on specific applications, properties, and environmental conditions.

Material	Common Applications	Key Properties	Environmental Conditions	Comments
ABS	Fairings, headlight housings, spoilers, grilles	Rigid, dimensionally stable, chemically resistant, easy to paint	General use, good performance at high temperatures	Requires painting for high-quality finishes
ABS PC	Grilles, spoilers, windshields, exhaust protectors	Higher rigidity and strength than ABS, good performance in traction and impact absorption	General use, higher cost than ABS	Not transparent in its standard form, recommended for applications requiring greater strength
MPPA	Windshields, deflectors	High chemical and thermal resistance	Corrosive environments	Suitable for applications in extreme or corrosive conditions
PA	Oil filter housings, chain tensioners, clamps, covers	High impact resistance, wear-resistant, hygroscopic	Requires moisture control	Can be reinforced with fiberglass for increased strength
PA 6	Clamps, covers, control buttons	Good combination of mechanical strength, stiffness, and toughness	General use, good mechanical performance	Requires the manufacturer to be familiar with the material due to its hygroscopic nature
PA 6+GF	Covers, fans, connectors	Reinforced with fiberglass, high strength and rigidity	General use, demanding conditions	Recommended for parts requiring greater mechanical strength
PC	Handlebar covers, decorative spoilers	High rigidity and hardness, impact-resistant, weather-resistant, transparent	UV resistance and outdoor conditions	Not recommended for structural parts due to cost and slight moisture absorption
PE	Tubes, batteries, wheel arch linings	High elasticity against impact, chemically resistant	General use, chemical resistance	May deform at around 87°C, good shape recovery
PP	Mudguards, side panels, fork protectors, headlight holders	High elasticity and stiffness, heat-resistant (up to 130°C), good chemical resistance	General use, off-road, non-painted applications	Versatile and economical, can be enhanced with additives for specific properties
PP+GF	Housings, structural parts	Reinforced with fiberglass, greater rigidity and mechanical strength	Demanding conditions, structural use	Significantly increases mechanical strength, suitable for parts that bear mechanical stress
PP+Talc	Steering wheel housings, mudguards	Increased rigidity, impact and heat resistance, matte finish	General use, preferred for non-glossy finishes	Lower cost than PP+GF, good option for applications not requiring high gloss
PA 12+GF	Luggage racks, handles, grilles	High impact resistance and low-temperature performance, reinforced with fiberglass	Cold climates, structural applications	Requires external painting due to the hygroscopic nature of the material
TPU	Handlebar grips, steering wheel grips	High flexibility and resistance, impact absorption, chemical resistance	Environments requiring chemical resistance and flexibility	Higher cost than common thermoplastics, ideal for applications requiring high durability and comfort
PVC	Protective cable covers, wire jackets	High durability, moisture and chemical resistance, low cost	Moist conditions and chemical exposure	Not resistant to high temperatures, recommended for protective applications not exposed to extreme heat

11.3 Draft Angles for Thermoplastic Materials

R+Engineering		Grados de Desmoldeo Recomendados	
Material		Mínimo	Máximo
LDPE	Polietileno de Baja Densidad	1°	3°
HDPE	Polietileno de Alta Densidad	1°	3°
PP homo	Polipropileno Homopolímero	1°	3°
PP copo	Polipropileno Copolímero	1°	3°
PP+Talco	Polipropileno Reforzado con Talco	2°	4°
PP+GF	Polipropileno Reforzado con Fibra de Vidrio	2°	5°
ABS	Acrilonitrilo-Butadieno-Estireno	2°	5°
PA 4.6	Poliamida 4.6	2°	5°
PA6	Poliamida 6	2°	5°
PA6.6	Poliamida 6.6	2°	5°
PA12	Poliamida 12	2°	5°
TPU	Poliuretano Termoplástico	2°	5°
MPPA	Polifenileno Éter con Anhídrido Maleico Modificado	2°	5°
PA6.6+GF	Poliamida 6.6 Reforzada con Fibra de Vidrio	2°	5°
PA12+GF	Poliamida 12 Reforzada con Fibra de Vidrio	2°	5°
ABS-PC	Policarbonato con Acrilonitrilo-Butadieno-Estireno	2°	5°
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Recommended draft angles for plastic part molds.

11.4 Comparative Cost of Thermoplastic Materials

The following table shows our comparative price study of the most commonly used thermoplastic materials in any motorcycle development project. Its purpose is to provide, for informational purposes, an approximate estimate of the price relationships between each of the thermoplastics described, emphasizing that we do not intend for it to serve as a selection criterion. Moreover, we believe that material cost should never be the first decision criterion but the last after considering the pros and cons of each material for the application in question.

R+Engineering	Delta VS																
Precio de / respecto a	PP homo	PP copo	LDPE	HDPE	PP+Talco	PP+GF	ABS	PA6	PA6+GF	PA6.6	PA6.6+GF	ABS-PC	PA12	PA12+GF	PA46	MPPA	TPU
PP homo	0%	-3%	-8%	-11%	-13%	-18%	-28%	-39%	-41%	-52%	-56%	-59%	-61%	-70%	-72%	-73%	-76%
PP copo	3%	0%	-6%	-8%	-11%	-15%	-26%	-37%	-39%	-51%	-55%	-58%	-60%	-69%	-71%	-72%	-76%
LDPE	9%	6%	0%	-3%	-5%	-10%	-22%	-33%	-36%	-48%	-52%	-56%	-58%	-67%	-69%	-70%	-74%
HDPE	12%	9%	3%	0%	-3%	-8%	-20%	-31%	-34%	-46%	-51%	-54%	-56%	-66%	-68%	-69%	-74%
PP+Talco	15%	12%	6%	3%	0%	-5%	-17%	-30%	-32%	-45%	-49%	-53%	-55%	-65%	-68%	-68%	-73%
PP+GF	21%	18%	11%	8%	5%	0%	-13%	-26%	-29%	-42%	-47%	-51%	-53%	-64%	-66%	-67%	-71%
ABS	39%	35%	28%	24%	21%	15%	0%	-15%	-18%	-33%	-39%	-43%	-46%	-58%	-61%	-62%	-67%
PA6	64%	59%	50%	46%	42%	35%	17%	0%	-4%	-22%	-28%	-33%	-36%	-51%	-54%	-55%	-61%
PA6+GF	70%	65%	56%	51%	47%	40%	22%	4%	0%	-19%	-25%	-31%	-34%	-49%	-52%	-53%	-60%
PA6.6	109%	103%	92%	86%	82%	73%	50%	28%	23%	0%	-8%	-15%	-19%	-37%	-41%	-43%	-51%
PA6.6+GF	127%	138%	108%	103%	97%	88%	63%	39%	34%	9%	0%	-7%	-12%	-32%	-36%	-38%	-46%
ABS-PC	145%	138%	125%	119%	113%	103%	76%	50%	45%	17%	8%	0%	-5%	-26%	-31%	-33%	-42%
PA12	158%	150%	136%	130%	124%	113%	85%	57%	52%	23%	13%	5%	0%	-23%	-27%	-29%	-39%
PA12+GF	233%	224%	206%	197%	189%	175%	139%	104%	96%	59%	47%	36%	29%	0%	-6%	-8%	-21%
PA46	255%	244%	225%	216%	208%	193%	154%	117%	109%	70%	56%	44%	38%	6%	0%	-3%	-16%
MPPA	264%	253%	233%	224%	216%	200%	161%	122%	114%	74%	60%	48%	41%	9%	3%	0%	-14%
TPU	324%	312%	289%	278%	268%	250%	204%	159%	150%	103%	87%	73%	65%	27%	20%	17%	0%
																	© I.Gonzalez, R+Engineering 2023

How to read this chart: ABS is approximately 39% more expensive than homopolymer PP.