COST-EFFECTIVE AND ECO-FRIENDLY MOLD-IN-COLOUR (MIC) SOLUTION FOR AUTOMOTIVE AESTHETIC PLASTIC PARTS

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ABSTRACT

Vehicle Aesthetics strongly influence what people decide to buy. To achieve this, carmakers have used painting to create glossy surfaces; however, this process is expensive, harmful to the environment, and time-consuming due to VOC emissions and multiple steps. In this work, we look for more sustainable options by testing modified plastics—Polycarbonate (PC) and Acrylonitrile Butadiene Styrene (ABS)—as materials for decorative parts like bezels, interior trim, and pillar appliques. We focus on using these plastics in thin-walled injection molding, with wall thicknesses between 1.5 and 3 millimeters. These car parts need to handle heavy use and still look good in tough conditions. We checked how strong they are using engineering simulations and tested the surfaces for resistance to scratches and sunlight. The results show that production costs dropped by 35% and the carbon footprint shrank by 25%. Both ABS and PC matched or exceeded the usual standards for painted parts and offered better durability, scratch resistance, and weather protection. They also provided high-quality finishes, stability in heat, and lower weight and VOC emissions. Our findings highlight clear cost and environmental benefits. In addition, these findings can be applicable to other industrial sectors such as consumer electronics and medical technology, among others

KEYWORDS: *Mold-in-Colour (MIC), Polycarbonate (PC), Acrylonitrile Butadiene Styrene (ABS), Automotive Trim, Sustainable Manufacturing, VOC Emissions, High-Gloss Finishes, Injection Moulding, Material Testing, Thermal Aging, Cold Impact Resistance, Gloss Retention, Scratch Resistance, UV Weathering, Cost Reduction, Carbon Footprint.*

I. INTRODUCTION

Automotives are under growing pressure to cut costs and reduce environmental harm, especially when producing exterior parts with glossy finishes. In the past, these finishes relied on expensive and complicated painting methods that were wasteful and contributed to pollution from volatile organic compounds. Now, as companies focus more on sustainability, they are looking for new ways to achieve the same high-quality look without the drawbacks of traditional painting.

This paper looks at the viability of using high-temperature Polycarbonate (PC) and Acrylonitrile Butadiene Styrene (ABS) to make decorative car parts, like piano black appliques, bezels, and pillar trims, with a glossy look. These pieces need to look good and last a long time. We wanted to determine if ABS and PC can match or surpass the appearance of painted parts, while also saving money and being more environmentally friendly.

The core challenge addressed in this study is eliminating the need for painting without compromising the visual and functional qualities of these components. This paper will focus on the material selection, engineering design, and tooling optimization to develop a sustainable & high-performance manufacturing process. The primary objective is to minimize environmental impact, specifically by reducing VOC emissions, while simultaneously lowering costs and maintaining the high-quality standards required in the automotive industry. This study can be a game-changer in how components such as appliques, bezels, and pillar trims are finished.

The remainder of this paper is organized as follows. Section 2 presents a review of the existing literature on sustainable alternatives for decorative plastic components. Section 3 describes the experimental procedure, including material preparation, design optimization, and testing methods. Section 4 provides the comparisons between ABS with conventional painting and PC with Mold-in-Colour (MIC). Section 5 concludes the paper with key findings, implications, and potential applications

II. LITERATURE REVIEW

Automotive appliques and exterior trims, such as pillars, are manufactured using several well-known methods. One common technique uses polypropylene or nylon to make thermoplastic elastomers, then uses injection molding to shape the parts [1]. To improve life, some designs pair engineering plastics like nylon, polyacetal, or polycarbonate with sheet metal substrates [2]. Other approaches include making cosmetic resin appliques from polyplastic liquids, which are attached using acrylic-based double-sided tape [3].

Recent trends in automotive applique production highlight a trend towards more efficient and streamlined operations. Increasingly, manufacturers are integrating a thermoplastic base, long-lasting rubber gasket, and surface decoration into a single mould process [4]. Opaque bases covered with a clear protective coating are also being employed to both protect and give an attractive finish [5]. Plastic-tinted sheets have been covered and formed with transparent finishes for enhancing resistance to wear [6]. Companies that avoid the use of paint solvents are becoming increasingly popular to minimize their environmental impact [7]. Laminates applied in the automotive industry are increasingly being topped with shiny PVC finishes and bonded through pressure-sensitive adhesives [8].

The literature has used olefin polymers for bumper fascia to achieve surface hardness and Mold flowability [9]. It uses polyolefin material for instrument panels and bumpers [10]. Manufacturing processes for soft bumper fascia which use RIM urethane, thermoplastic polyolefin, and thermoplastic polyester elastomers were discussed [11]. In addition, research was carried out on the materials used in car headlamps, lenses, and bezels with optical effects [12], and the size of bezels for rear-view mirrors made from several different polymers: ASA/PC, ABS/PC, PC, ABS, PA, PPO, strengthened polymers, and metal alloys [13]. This set of studies demonstrates high use of polymeric materials in automobile environments, particularly for ornamented bezels and appliques.

(PC), one of the toughest, impact-resistant, and optically transparent polymers, can be used as a substitute for painted finishes. In the automotive trim domain, this material has been successfully used to create piano black and silver surfaces, while being highly UV-resistant, thermally stable, and scratch-resistant. MIC processing of PC also saves energy and reduces VOC emissions, thereby helping the automotive industry meet its sustainability objectives [15].

III. EXPERIMENTAL PROCEDURE

A. Material (sample preparation)- This study focused on two of the most common plastic polymers cast as door appliques in the following way:

1. Sample 1: ABS with conventional painting, ABS (commercially known as CYCOLAC resin) is a terpolymer resulting by blending acrylonitrile (A), styrene (S), and polybutadiene (B)
2. Sample 2: PC with MIC, PC (commercially known as LEXAN SLX2776T resin) is a polycarbonate copolymer blend with extra low viscosity and enhanced UV stabilization. (Fig 1) (Source: Based on supplier datasheets such as SABIC LEXAN SLX2776T) (Reference: Supplier brochure for CYCOLAC/LEXAN resins.

FIG 1: Sample 2

The design was optimized to a thickness of 2.7 mm and the structural durability analysis confirmed that the design met the required stress and deflection criteria. Tooling was also optimized as seen in (Fig 2) focusing on gate design, cooling, and venting. The resulting improved design yielded a higher quality part free from common flaws such as warpage, fractures, or discoloration.

FIG 2: Apparatus

B. Material Testing (Mechanical properties)- Samples of each polymer grade were prepared and tested with a set of standardized tests for their properties. Melt flow index was measured by following the ASTM D1238; density evaluation was done by following the ASTM D792; tensile strength was based on the procedure provided by ASTM D638, and flexural property by following the procedure of ASTM D790. ASTM D256 was used to determine the effect strength, and heat distortion temperature testing was conducted in accordance with ASTM D648. Standard test methods per ASTM guidelines were followed as referenced in ASTM D1238, D638, D648, etc.,

C. Thermal Aging - To check how the outer appliques can sustain long periods of heat exposure, the parts were exposed to an oven at 85°C for 500 hours. The parts were mounted in a way that mimicked their use within vehicles so that the results would be relevant to real-world applications.

D. Cold Impact - The appliques conditioned at -30°C for five hours were subjected to impact testing by utilizing a falling ball apparatus to deliver some about 5J of energy. It was done right after the conditioning time to qualify the actual performance of the material in conditions of low temperatures.

E. Gloss Testing - Gloss levels of ABS, PC, and other samples were measured at different angles (20°, 60°, and 85°) to evaluate the quality of finish. These were compared with traditional painted surfaces, though these new materials performed almost equally or better.

F. Abrasion/Scratch Resistance - The wear resistance of the samples was evaluated as durability against wear by replicating standard surface degradation over time, using a Taber Abraser (Fig 3). In this method, a specified abrasive fabric and a rotating wheel simulates the conditions of wear and measures the cycles taken to leave a mark.

FIG 3: Taber Abraser (image © Taber Industries)

G. UV Testing (Weather test) - Xenon arc weathering is an accelerated test method which simulates long-term outdoor exposure damages for materials. Samples are prepared and tested in the Xenon arc chamber under the desired conditions of a simulated environment under ASTMG154 for some prescheduled time. After the test, the samples are withdrawn and physical properties in colour change, gloss loss, crack formation, chalking etc. are compared.

FIG 4: Weathering Test apparatus (image © Presto Group)

H. Cost Impact - A zero-based costing analysis that presents a comparison of the cost implications when PC-MIC is compared against traditional painting techniques based on such factors as Raw material, Moulding & painting, Direct material cost, overheads etc.,

I. Environmental Impact - Carbon footprint assessment as referenced by material costs, energy consumption, and VOC emissions indicated that the new materials offer not only significant reductions on the production costs but also on the environment. In light of these factors, they are considered new sustainable alternatives for automotive applications.

IV. RESULTS AND DISCUSSION

A. Material Testing results- In Table 1, the physical, mechanical, and thermal properties of the investigated polymers in the form of ABS and PC are tabulated. Among the prepared samples, Sample 2, PC indicated higher tensile strength than Sample 1 which was prepared from ABS.

In terms of flexural properties. Although Sample 1 had the highest impact strength, Sample 2 still met the required toughness criteria. Sample 2's melt flow index falls within an intermediate range; therefore, it can likely be specified for developing thin-wall components. Its heat distortion temperature (HDT) was about 105°C.

TABLE 1 : PHYSICAL, MECHANICAL AND THERMAL PROPERTIES FROM TESTING

Table 1: Physical, mechanical and thermal properties

Properties	Units	Sample 1	Sample 2
MFI	g/10 min	min 21	min 9
Density	gm/ cc	max 1.06	max 1.35
Tensile strength	Mpa	min 40	min 63
Elongation at break	%	min 18	min 15
Flexural strength	Mpa	min 60	min 80
Flexural modulus	Mpa	min 2000	min 2150
Notched Izod impact strength at 23 ⁰ C	kg cm/ cm	min 20	min 15
Notched Izod impact strength at -30 ⁰ C	kg cm/ cm	min 9	min 8
HDT	⁰ C	max 90	max 105
CLTE	µm/ ⁰ C	max 90	max 90

B. Thermal Aging - Thermal aging test for samples shows a test at 85°C for 500 hours and retained its dimensional stability without any visible defect, thus proving it perfectly suitable for décor applications outdoors. Test on cold impact at -30°C proved that Sample 2's toughness was sufficient so as not to crack under impact.

C. Cold Impact - Vehicle-level durability testing was performed by driving the vehicle on a pave track for 100 cycles with the exterior trim appliques installed. Inspection after test revealed no cracks or looseness in components. The structural integrity and durability of the design from PC are validated as shown in Fig 5.

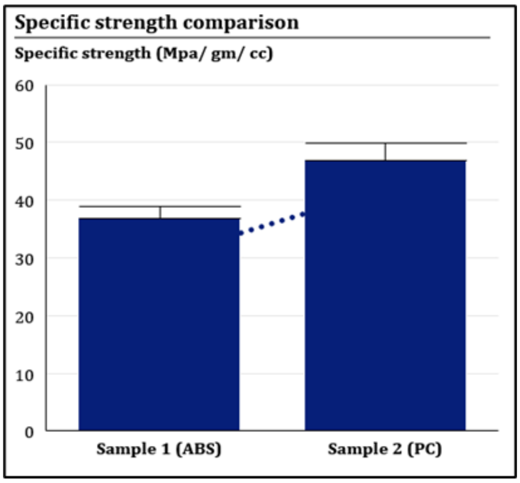

FIG 5: Specific strength comparison

D. Gloss Testing - Measurements for gloss testing demonstrated that Sample 2 acquired the same gloss finish to one that normally could be attained by traditional painting on Sample 1 as shown in Fig 6.

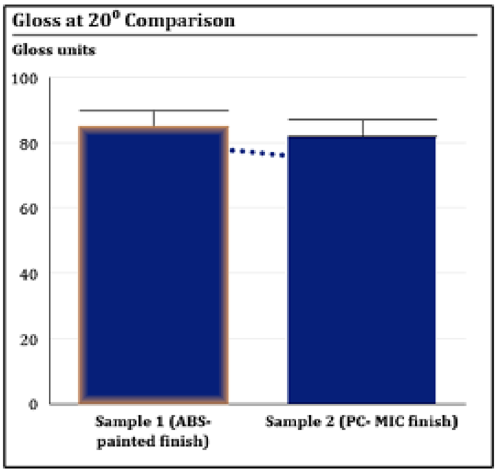

FIG 6: Gloss strength comparison

E. Abrasion/Scratch Testing - Scratch resistance tests revealed more surface damage resistance by Sample 2 than by Sample 1. This is reflected by a higher rating of the MIC finish on Sample 2 thus maintain long-term aesthetics.

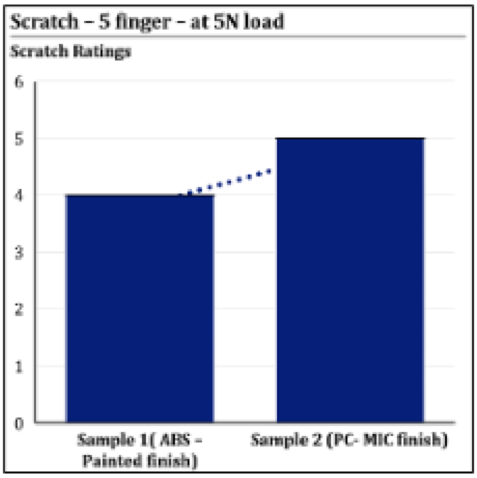

FIG 7: Scratch Test result comparison

F. UV Testing - Accelerated weathering tests showed that Sample 2 with mold-in-color (MIC) finish exhibited comparable weathering resistance to Sample 1 with a painted finish. Gloss retention was highest in Sample 2, demonstrating its durability and ability to maintain a new appearance over time.

TABLE 2 : WEATHERING TEST RESULT COMPARISON

Weathering Properties				
Properties	**Standard**	**Units**	**Sample 1**	**Sample 2**
Accelerated weathering up to 1500 h	SAE J2527	dE	≤3 at 2500 h	1.4 at 3000 h
		GSR	4-5 at 2500 h	4-5 at 3000 h
Gloss retention after artificial weathering	ASTM D523	%	Min 80% at 2500 h	Min 80% at 3000 h

G. Cost Impact - The cost analysis showed noteworthy savings that could be made from using PC-MIC over painting. Since the painting process could be eliminated, the manufacturers' production costs could be reduced by as much as 35%, mainly due to the shortening cycle times and reduced material waste, as depicted in Fig 8.

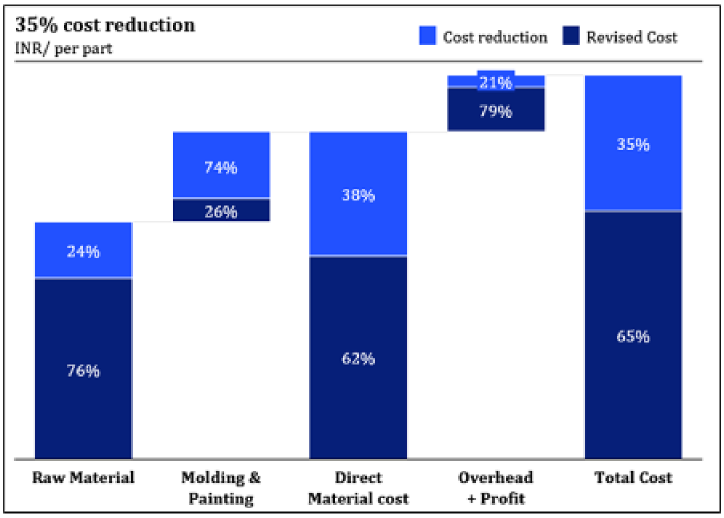

FIG 8: Cost reduction benefits in PC MIC parts

H. Environmental Impact - The carbon footprint assessment indicates that the new process has an overall saving of 25% based on environmental impact, as demonstrated in Fig 9. The reason for this is the improvement of production efficiency through the reduction of post-processing with paints and minimization of scrap rates.

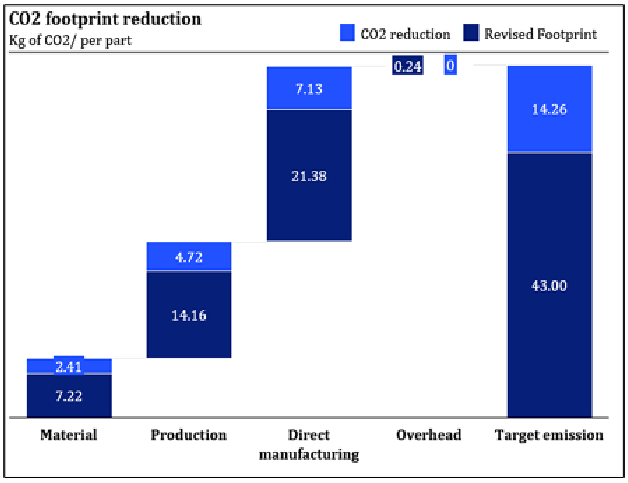

FIG 9: CO2 reduction benefits in PC MIC parts

V. Conclusions

The findings of this study revealed that high-temperature polycarbonate materials are an excellent alternative to the classic, painted finishes used in the car manufacturing industry. Glossy, durable, and cost-effective, these materials can meet or even surpass the performance of painted surfaces while saving costs by up to 35%. In addition to these benefits, the use of the above materials lowers VOC emissions, thereby leading to a 25% reduction in Carbon footprint. Achieving a high-gloss finish without painting is a significant advancement in materials science, promising numerous applications beyond the automotive sector, including home appliances & consumer electronics.

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