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# BLENDING VIRGIN WITH RECYCLED POLYPROPYLENE CHAIRS AND OPTIMIZATION OF INJECTION MOULDING PROCESS PARAMETERS

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Abstract:
There are several, diverse uses for chairs. Numerous commercial products, including chairs, stools, bags, containers, packaging films, and meshes, make extensive use of polypropylene. By its distinctive characteristics and attributes, polypropylene comprises as much as sixty per cent of the market for polymer chairs and stools. The discipline evaluates the variation of key qualities such as mechanical properties, lifetime, recyclability, lightweight, comfort, and so forth, given that chairs are considered cost-effective applications. Nevertheless, impact tests are generally regarded as effective forms of accelerated testing; thus, some effort has been devoted to the implementation of fatigue characteristics on chairs. The previously utilized chairs are subsequently recycled into second-grade chairs and stools that have an appearance incomparably similar to that of products manufactured from scratch. However, these products vary concerning their thermal properties and capabilities. The corresponding procedures for recycled chairs and virgin chairs differ. The investigation will focus on the static and long-term mechanical properties as a result of utilizing pre-consumer chair fragments. By employing a variety of methods, the degradation properties of virgin material mixed with pulverized pre-consumer and chair scraps are to be evaluated. The variation of static mechanical properties as a function of incorporating pre-consumer chairs and Stool scraps is to be investigated. In addition, impact tests are to be executed to evaluate the long-term durability of blending virgin chairs scrap and recycled chairs and fragments. The findings of this research are anticipated to provide valuable insights into the potential of blending virgin with recycled polypropylene in injection molding processes for furniture manufacturing. By optimizing the process parameters, manufacturers can contribute to sustainable practices without compromising product quality. The outcomes of this investigation will have implications for the broader field of plastic recycling and its application in the production of consumer goods.
Key words: Injection Molding, Blending, Recycled PVC, Virgin PVC, Mechanical Properties.

## 1. Introduction

Polypropylene chairs are a type of chair made from polypropylene, a thermoplastic polymer. They are known for their durability, lightweight, and stack ability. Polypropylene chairs were first invented in the 1950s, and they have since become one of the most popular types of chairs in the world. Polypropylene was invented by Italian scientist Giulio Natta in 1954. Natta discovered that polypropylene could be made into a strong, lightweight, and flexible material by using a special catalyst. This discovery led to the development of a wide range of polypropylene products, including chairs. The first polypropylene chairs were designed in the 1960s. One of the most famous early polypropylene chairs was the Universal chair, designed by Joe Colombo in 1965. The Universal chair was a simple, stackable chair that was made from one piece of polypropylene.

Fig 1.PVC chair

The global population has increased significantly over the past few decades. This has resulted in a notable rise in the demand for affordable housing, which partly drives a sharp rise in plastic consumption. According to historical data, over 100 million tons of plastic are produced annually worldwide. That produces about 3 million tons of plastic waste, of which environmental agencies estimate that about 80% ends up in landfills. Reusing or recycling the plastic that has already been made is the sensible course of action.

There are numerous benefits to recycling plastic
• Reducing or eliminating the quantity of waste that is dumped in landfills;
• Making use of a resource that would otherwise be wasted
• Lowering the price of waste disposal, which eventually saves the community money;
• Creating jobs;
• Safeguarding the environment; and
• Lowering pollution

The emphasis on plastic recycling has shifted in recent years. Prior to now, the emphasis was on informing and motivating businesses and the general public to recycle. Millions of pounds of plastic waste that were destined for the landfills now had some value as the public realized the need and incentives to reduce the amount of waste materials entering our landfills. The next concern was how to gather this material and turn it into a raw material that could be sold. Recycled materials, like polycarbonate, nylon, and PP, are more expensive engineering resins due to economic constraints. Because of the expenses associated with processing and transportation, recyclable materials can sometimes be more expensive than raw materials. Approximately 7% of post-consumer plastics were recovered in the United States in 2009. Therefore, it is ideal to find applications for recycled plastic material that make sense and are comparable in cost to the alternative solution involving virgin material.

Plastic polymers that are set at room temperature are referred to as thermo-setting plastics. Polypropylene (PP), Melamine, Bakelite, and other common plastic polymers are examples of thermosetting polymers. If plastic material selection is not done correctly, it can be a very complex process for many materials (metals, plastics, etc.), especially when recycled plastics are involved. In certain areas, its methodology heavily relies on subjective intuition, while in other areas, it employs a sophisticated approach. When choosing an additive for a mixture, it's critical to take into account any possible negative effects on other properties. In certain instances, the system's cost may be decreased, but at the expense of other aspects, like mechanical characteristics that may affect how well the manufactured good performs. Any attempt to compare mixed plastic on a property-by-property or cost-by-cost basis with other conventional materials (metal, wood, glass, etc.) is bound to fail from the outset. Just too many distinct grades and formulations fall under the general category of "mixed plastic". Without a doubt, one of the thermosetting plastic polymers that are difficult to recycle and mould is polypropylene (PP). Post-consumer polypropylene (PP) is increasingly being recycled due to its widespread use, especially in the appliance and container industries, which has elevated PP to the top

of the plastic recycling hierarchy. The two sources of material used in this study are recycled post-consumer PP from different PP chairs and virgin PP. The PP scrap is in the form of flakes, but it is deposited in an uneven layer that is contaminated by 25 different kinds of PP chairs. Contamination by chance causes a number of issues, including chain cleavage, molecular weight loss, and a decrease in intrinsic viscosity, which all affect the material's mechanical properties. However, it is assumed that the PCR (post-consumer resin) has very little contamination, so how the material was purified (selected externally) is not taken into consideration in order to limit the scope of conducting research later developed. This study focuses on the process of injection molding, which has the advantage of intentionally stretching the molecular chains during the extrusion of melted plastic. This allows the inherent strengths of the chains to be more nearly realized than they would be in their relaxed configurations. Because thermal effects in processing determine the crystalline attained state, which is critical to strength, they are particularly significant.

The quality of the product should be taken into account even though producing products made from recycled plastic can lower the product's cost and environmental impact. The variability in mechanical properties and their alleged fluctuating processing characteristics make using these inexpensive (self-produced) raw materials problematic. Nowadays, a lot of businesses process either virgin material that is 100% pure or virgin material that contains a tiny amount of regrind from industrial processing. A large amount of regrind is either land filled or down cycled because the supply of regrind frequently surpasses set thresholds. A method that characterizes recycled plastic by both processing parameters and mixture state could significantly increase the supply of acceptable recycled plastic over the generic threshold approach, as it was previously discussed that both thermal processing conditions and mixture conditions affect quality characteristics.

## 2. Objective of work

The durability, affordability, and versatility of polypropylene have led to the widespread use of the material in chair construction. Nevertheless, improving the production procedures and resolving the environmental issues related to polypropylene chairs become more difficult as the need for sustainable practices grows. The purpose of this study is to identify and address important issues related to the lifetime of polypropylene chairs, including material selection, production efficiency, disposal of end-of-life products, and environmental effects. Through research into these issues, plans for improving the sustainability profile of polypropylene chairs will be developed, guaranteeing their market share in furniture production while reducing their environmental impact.

Today's polypropylene chairs can be found in homes, workplaces, public spaces, and educational institutions all around the world. Their distinctive blend of price, style, and durability contributes to their popularity. Nevertheless, while being widely used, polypropylene chairs have a number of drawbacks, such as:

Common challenges

- Environmental Impact: The main component of these chairs, polypropylene, is produced through an energy-intensive process that pollutes the environment and releases greenhouse gases. Furthermore, incorrect polypropylene chair disposal can damage ecosystems and result in micro plastic pollution.
- Limited Comfort: Although polypropylene chairs are strong and lightweight, they are frequently uncomfortable, particularly when sitting for long periods. Particularly for those with back issues or other physical restrictions, the harsh, unyielding surface of polypropylene can be uncomfortable and stressful.
- Design Aesthetics: Some polypropylene chairs have elegant, simple designs, but others could come off as impersonal and generic. The uniformity of design brought about by the mass production of these chairs has restricted the creative expression and uniqueness that furniture may provide.
- Sustainability: Create strategies, such as the use of recycled materials or bio-based polymers, to lessen the environmental impact of the production of polypropylene chairs.

- Comfort: Upgrade the ergonomic designs, add more cushioning, or use different materials that provide superior support and pressure relief to make polypropylene chairs more comfortable.
- Design aesthetics: Promote originality and creativity in the creation of polypropylene chairs by investigating novel shapes, materials, and coatings that improve chairs' visual attractiveness.

Additional Considerations

- Durability: Make sure that polypropylene chairs continue to be strong and long-lasting so that they can resist regular use and hard conditions.
- Virgin PP: This plastic was in pellet form, stored in a cabinet that was not temperature controlled, but was encased in its original packaging box in a near atmospherically separated condition with the help of its sealed plastic bag. PP's hygroscopic nature may have detrimental effects on processing due to unknown historical conditions.

Fig 2 Virgin PP

- Recycled PP: This flake-form plastic was transported by train to a sizable off-campus commercial resin silo where it was left to its natural surroundings. 110°C. To reach a final moisture level rating of less than 50 m, the RPP mixture was sent to a compound mixing unit that operated at 150°C for four hours.

Fig.3 Pellets of Recycled PP

Fig.4 Recycled PP

3. Manufacturing process of PP chairs through Injection moulding machine:

Injection moulding is a manufacturing process for producing parts from both thermoplastic and thermosetting plastic materials. Material is fed into a heated barrel, mixed, and forced into a mold cavity where it cools and hardens to the configuration of the mold cavity. After a product is designed, usually by an industrial designer or an engineer, molds are made by a mold maker (or toolmaker) from metal, usually either steel or aluminum and precision-machined to form the features of the desired part. Injection molding is widely used for manufacturing a variety of parts, from the smallest component to entire body panels of cars.

Process Characteristics

- Utilizes a ram or screw-type plunger to force molten plastic material into a mold cavity.
- Produces a solid or open-ended shape that has conformed to the contour of the mold.
- Uses thermoplastic or thermoset materials.
- Produces a parting line, sprue, and gate marks.
- Ejector pin marks are usually present.

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Fig.5 Injection Molding Machine

Since polypropylene (PP) has certain advantages over other materials, it is frequently used in a wide range of commercial products like cables, rigid sheets, trays, and window profiles. Particularly, chairs and cowls are frequently made of PP; in fact, PP accounts for up to 40% of the polymer chair and cowl market. Commercial (consumer) uses for PP chairs are common.

Numerous process variables impact the quality of products produced through injection molding. To facilitate further analysis in DOE, it is necessary to identify the process parameters that will affect the experiment results before beginning the experiments. These parameters will both contribute to and influence the variations in results as a result of parameter adjustments. Four fundamental categories can be used to classify all the variables that are involved in the injection molding process: temperature, pressure, time, and distance. The order of importance for process parameters is temperature, pressure, time, and distance.

- Injection molding dies

The Dye Material used in the respective manufacturing of Chairs here is P20 Steel. It is a type of tool steel commonly employed in the manufacturing of molds for plastic injection molding and die-casting processes. P20 steel is known for its excellent machinability, good polishability, and wears resistance, making it suitable for use in molding applications. P20 steel is widely used to make injection molds for plastics. The molds are designed to shape molten plastic into specific forms, such as components for various products. P20 steel is also utilized in die-casting molds, where molten metal is injected into the mold cavity to create specific shapes for metal parts.

Fig: 6 Chair Die

3.1 Selections of process parameters

The following parameters were chosen in order to see how process parameters affected the tensile, compressive, and flexural strengths of plastic trays: Holding Pressure, Injection Time, Melting Temperature, and Holding Duration. Throughout the experiment, other variables like the mold's temperature (32°C), injection pressure (50 bars), cooling time (10 s), and stroke distance (140 mm) were maintained constant. The working range of each parameter was carefully selected to produce the PP chair of acceptable quality, given the significance of the primary process parameters and their

impact on the performance characteristics. Following careful selection of each parameter level, the experiments were carried out in accordance with the Taguchi L9 orthogonal array. Every level 3 parameter was taken into account. The injection molding parameters and their levels are displayed in Table 1.

| Factor | Parameter | Unit | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|---|
| A | Melting Temperature | $^{o}C$ | 170 | 172 | 167 |
| B | Injection Pressure | Bar | 90 | 100 | 110 |
| C | Injection Time | Sec | 6 | 8 | 10 |
| D | Cooling Time | Sec | 35 | 38 | 40 |

Table 1. Molding parameters

| Trial | Melting Temperature | Injection Pressure | Injection Time | Cooling Time |
|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 |
| 2 | 1 | 2 | 2 | 2 |
| 3 | 1 | 3 | 3 | 3 |
| 4 | 2 | 1 | 2 | 3 |
| 5 | 2 | 2 | 3 | 1 |
| 6 | 2 | 3 | 1 | 2 |
| 7 | 3 | 1 | 3 | 2 |
| 8 | 3 | 2 | 1 | 3 |
| 9 | 3 | 3 | 2 | 1 |

Table 2: L9 orthogonal array with the parameters and their levels

| Sample code | V100R0 | V80R20 | V75R25 |
|---|---|---|---|
| Virgin PP [wt.%] | 100 | 80 | 75 |
| Recycled PP [wt.%] | 0 | 20 | 25 |

Table 3: The composition of virgin PP and recycled PP scraps with sample codes (V: virgin PP, R: recycled PP)

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4. Experimentation

 Three mechanical tests—the tensile, compression, and flexural tests—were used to evaluate the quality of the injection-molded chairs. Nine chairs manufactured with V100R0, each with a different set of parameters based on L9 OA, were used for each test. The specifications for the virgin PP resins are as follows: melting temperature of 180 °C, density of 952 kg/m3, and melt flow rate of 18g/10 min. According to L9 OA, PP pellets—both virgin and recycled—were inserted into an OMEGA350 injection mold to create the PP Chair.

Testing Procedure of PP Chairs

i. A seat static load test involves pressing a large weight onto the seat for a predetermined amount of time. Next, the chair is inspected for any damage.

ii. A test of leg strength. If there are legs on the chair, the one that will get hurt is the weakest one. Each leg is subjected to prolonged weight application.

iii. Impact reduction. At a predetermined height, drop a weight onto the chair.

iv. Hairdrop. Drop the chair at different angles so that the standing mechanism's legs or other parts strike the ground first.

Performance Check of PP Chairs

i. Chairs ought to be sturdy and not prone to tipping over.

ii Chairs should not have any openings or areas where a person could snag their fingers, particularly if they have moving parts like movie seats. They must also lack easily accessible sharp edges.

iii Nearly all chairs in the UK and Europe are required to pass flammability tests and adhere to national fire regulations.

If the maximum weight on a chair must be sufficiently excess to support an individual's moving weight, which must be greater than their static weight. v The criteria used to test seating vary, I believe, depending on the country (home, offices, theaters, gardens, etc.). Testing procedures may change as a result (for example, office chairs must withstand an 8-hour workday with a 110 kg load and adhere to ergonomic standards for use with VDUs, outdoor furniture must withstand rain and freeze/thaw cycles, and public benches must be vandal-resistant with features to prevent people from sleeping on them or skateboarders from sliding on them).Long-term durability of chairs is tested, frequently by having a robot sit on them thousands of times. The frame and any related materials, like foam and padding, must be sturdy.

5. RESULTS

Virgin PP and recycled PP show very similar molecular weight distributions. In this study, the effect of using pre-consumer PP scraps (which can be collected during the chair manufacturing process), as an alternative to post-consumer recycling, mixed with virgin grade PP on static and long-term mechanical properties is studied. Samples were prepared by blending virgin PP with various contents of recycled PP.

| **Sample code** | **V100R0** | **V80R20** | **V75R25** |
|---|---|---|---|
| Impact strength (JOULES) | 19 | 18.23 | 17.9 |
| Injection Pressure (Bar) | 110 | 111 | 113 |
| Injection time (sec) | 12 | 13 | 15 |
| Cooling time (sec) | 40 | 40 | 40 |
| Refill time (sec) | 10 | 8 | 6 |
| Refill speed (RPM) | 72 | 69 | 65 |

Optimization:

The best solution (there are many solutions to gain these maximums) is rated as 0.556, responding with 80 % PP and 20 % RPP as the best mixture, processed at 18°C at the nozzle, 175 °C in the front of the barrel, and 167 °C at the rear of the barrel. The Impact strength is 18.23 J. It must be noted that maximizing both mechanical properties and the RPP content creates a severe bias towards the recycled content, hence it must also be understood that optimizing without that parameter will always have a prediction saying 100 % PP is favored.

| | Impact strength (JOULES) | Injection Pressure (Bar) | Injection time (sec) | Cooling time (sec) | Refill time (sec) | Refill speed (RPM) |
|---|---|---|---|---|---|---|
| **V80R20** | 18.23 | 111 | 13 | 40 | 8 | 69 |

Conclusions

The main objective of this work is to identify parameters that affect the performance of the pedestal chairs and determine an effective method to incorporate the critical performance factor into an equation to formulate a suitable performance rating method and recycling plastic can reduce the consumption of energy, non- renewable fossil fuels use, as well as global emissions of carbon dioxide. The effect of recycled PP and virgin PP on impact strength optimal values of process parameters was analyzed. The optimal amounts of mixture components to produce recycled plastic products are determined. As a result of doing systematic experimentation, using mixture experiments, the quality of recycled plastic products can be improved and becomes more robust to variations at the optimal operating settings. The results have proven that the manufacturer can use these settings of recycled PP and virgin PP to produce quality products at low cost (quality depends on the source as some recycled content qualities can be very high) and environmental impact reduction. In this work, the effect of using pre-consumer PP scraps (which can be collected during the chair production process), as an alternative to post-consumer recycling, mixed with virgin grade PP on static and long-term mechanical properties is studied. Samples were prepared by blending virgin PP with various contents of recycled PP.

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