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EVALUATION OF MECHANICAL PROPERTIES OF BLENDED PVC OVER VIRGIN PVC USED IN INJECTION BLOW MOLDING PROCESS

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Abstract
This paper discusses the mechanical properties of blended Polyvinyl Chloride (PVC) compared to virgin PVC in the manufacturing of storage containers for fertilizer through the injection blow molding process. The objective is to assess the viability of utilizing blended PVC, a potentially more environmentally friendly option, while maintaining the desired performance characteristics of the end product. The research method involved formulating different ratios of blended PVC and comparing them with virgin PVC in terms of mechanical properties The injection blow molding process parameters, including temperature, pressure, and cooling rate, were optimized for both materials. The study also considered the effects of weathering and exposure to harsh environmental conditions to evaluate the long-term durability of the containers. The findings of this study are significant for the plastics industry, offering insights into the use of blended PVC in injection blow molding processes, contributing to reduced environmental impact while ensuring the quality and durability of the end products. This research aligns with the global sustainability agenda and the drive to reduce the reliance on virgin plastics in manufacturing.

I. Introduction

POLYVINYLCHLORIDE(PVC)

Polyvinyl chloride (PVC) is a widely utilized polymer formed by combining monomer units of vinyl chloride. PVC stands out for its cost-effectiveness, versatility, chemical and electrical stability, as well as weather resistance, coupled with favorable flow characteristics. In numerous construction-related applications, PVC has taken the place of wood and concrete. Some notable applications of PVC encompass pipes, roofing sheets, cable insulation, packaging foils, bottles, and medical products (Doble & Kumar, 2005). By incorporating plasticizers like 2 phthalates, citrates, phosphates, adipates, etc., PVC can be transformed into materials offering a broad spectrum of flexibility. However, the incineration of PVC raises significant environmental concerns due to the emission of chlorine containing gases.

VIRGIN PVC

Virgin PVC is a polymer in its pure form, meaning that it has not been recycled or processed in any way. It is a versatile material with a wide range of properties, making it suitable for a variety of applications.

Properties of Virgin PVC:

High strength and toughness: Virgin PVC is a strong and durable material, resistant to impact and abrasion.

Good flexibility: Virgin PVC can be flexible or rigid, depending on the additives that are used.

Light weight: Virgin PVC is a light weight material, making it easy to transport and install.

Good dimensional stability: Virgin PVC has good dimensional stability, meaning that it does not shrink or swell significantly when exposed to changes in temperature or humidity.

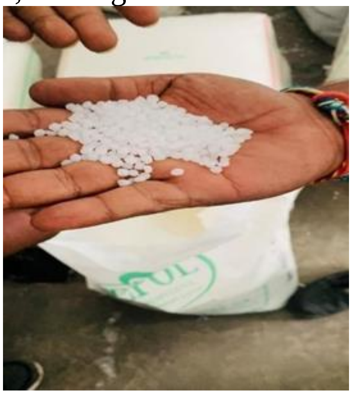
Good chemical resistance: Virgin PVC is resistant to a wide range of chemicals, including acids, alkalis, and oils.

Non-toxic: Virgin PVC is a non-toxic material, making it safe for use in food and beverage packaging and other applications where human contact is possible.

Flame retardant: Virgin PVC is naturally flame retardant, making it a good choice for applications where fire safety is a concern.

Good electrical insulation: Virgin PVC is a good electrical insulator, making it suitable for use in electrical applications.

Recyclable: Virgin PVC is recyclable, making it a sustainable material choice.



Virgin PVC Pellets

PROPERTIESOFBLENDED PVC

- **Improved impact strength:** Blended PVC is generally more resistant to impact than pure PVC. This is due to the fact that the other polymer in the blend helps to absorb and dissipate energy on impact.
- **Improved flexibility:** Blended PVC can be more flexible than pure PVC, depending on the type and amount of polymer that is used in the blend. This is because the other polymer can help to soften the PVC matrix.
- **Improved thermal stability:** Blended PVC can have improved thermal stability compared to pure PVC. This is because the other polymer can help to stabilize the PVC chains and prevent them from breaking down at high temperatures.
- **Reduced cost:** Blended PVC can be less expensive than pure PVC, depending on the type and amount of polymer that is used in the blend. This is because the other polymer can be a filler material that replaces some of the more expensive PVC resin.
- **Improved resistance to chemicals and oils:** Blended PVC can have improved resistance to chemicals and oils compared to pure PVC. This is because the other polymer can help to create a barrier that prevents the chemicals and oils from penetrating the PVC matrix.
- **Improved process ability:** Blended PVC can be easier to process than pure PVC. This is because the other polymer in the blend can help to reduce the viscosity of the PVC melt and improve its flow properties.
- **Improved dimensional stability:** Blended PVC can have improved dimensional stability compared to pure PVC. This is because the other polymer can help to 11 reduce the shrinkage of the PVC matrix during processing and cooling**.**
- **Improved color ability:** Blended PVC can be easier to color than pure PVC. This is because the other polymer in the blend can help to disperse the pigments more evenly throughout the PVC matrix.
- **Improved surface properties:** Blended PVC can have improved surface properties compared to pure PVC. This is because the other polymer can help to create a smoother and more scratch-resistant

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surface.

• **Improved flame retardancy:** Blended PVC can have improved flame retardancy compared to pure PVC. This is because the other polymer in the blend can help to suppress the combustion of the PVC matrix.

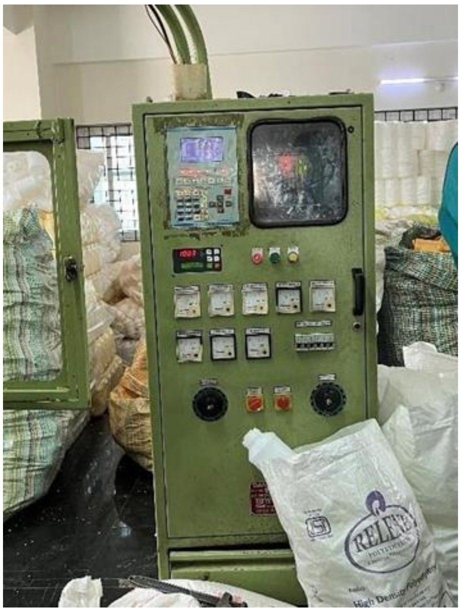
COMPARISONOFMATERIALPROPERTIES

ThefollowingisacomparisonofthematerialpropertiesofvirginPVCandblendedPVC:

Property	Virgin PVC	Blended PVC
Impact strength	Good	Excellent
Flexibility	Good	Excellent
Thermal stability	Good	Excellent
Cost	Moderate	Low to moderate
Resistance to Chemical sand oils	Good	Excellent
Process ability	Good	Excellent
Dimensional stability	Good	Excellent
Color ability	Good	Excellent
Surface properties	Good	Excellent
Flame retardancy	Good	Excellent
Wear resistance	Good	Excellent
Abrasion resistance	Good	Excellent
Electrical insulation	Good	Excellent
UV resistance	Good	Excellent
Weather resistance	Good	Excellent
Recyclability	Good	Excellent

Comparison of Material Properties

PROCESSPARAMETERSFORINJECTIONBLOWMOLDING



Injection Blow Molding Machine Control Panel.

The process parameters for injection blow molding (IBM) can be divided into three main categories:

1. Injection parameters:

• **Melt temperature:** The temperature of the molten plastic as it enters the mold. This is one of the most important parameters, as it affects the flow ability and viscosity of the plastic.

- **Injection pressure:** The pressure applied to force the molten plastic into the mold. This parameter affects the speed and completeness of the injection process.
- **Injection time:** The time it takes to inject the molten plastic into the mold. This parameter affects the wall thickness of the final product.

2. Blowing parameters:

- **Blowing pressure:** The pressure applied to force the preform to expand and fill the mold. This parameter affects the final wall thickness and dimensions of the product.
- **Blowing time:** The time it takes to blow the preform to the desired shape and size. This parameter affects the uniformity of the wall thickness and the clarity of the product.
- **Blowing ratio:** The ratio of the volume of the blown product to the volume of the preform. This parameter affects the wall thickness and stress distribution in the product.

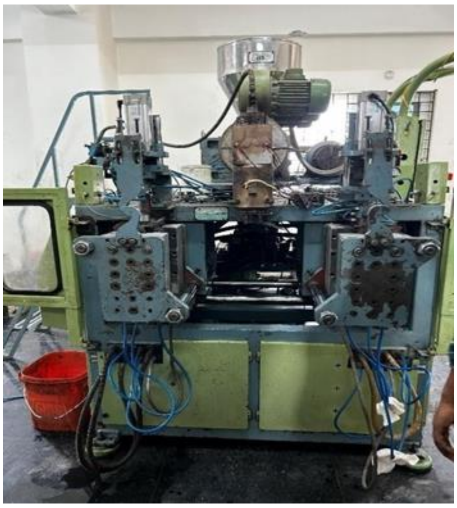
3. Mold parameters:

- Mold temperature: The temperature of the mold cavity. This parameter affects the cooling rate of the product and the final surface finish.
- **Mold design**: The design of the mold cavity affects the final shape and dimensions of the product. It is important to design the mold cavity carefully to ensure that the product has the desired wall thickness and stress distribution.
- **Preform temperature:** The temperature of the preform before it is blown. This parameter affects the flow ability and viscosity of the plastic during the blowing process.
- **Cooling time:** The time it takes for the blown product to cool and solidify in the mold. This parameter affects the final dimensions and properties of the product. The optimal process parameters will vary depending on the type of plastic being used, the shape and size of the product, and the desired properties of the product. It is important to carefully optimize the process parameters to achieve the desired results.

Process parameter	Range	Typical value
Melttemperature	140-220 °C	180 °C
Injection pressure	50-200 MPa	100 MPa
Injection time	0.5-10 s	1 s
Blowing pressure	0.5-5 MPa	2 MPa
Blowing time	1-10 s	2 s
Blowing ratio	1.5-4	2
Mold temperature	20-80 °C	50 °C
Preform temperature	40-80 °C	60 °C
Cooling time	1-10 s	2 s

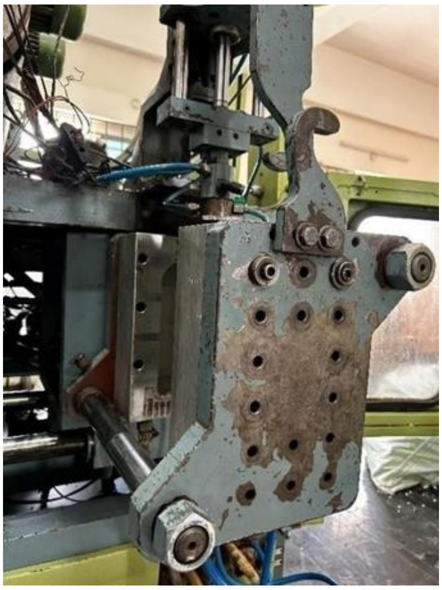
Process Parameters

The basic components of an injection molding setup include:



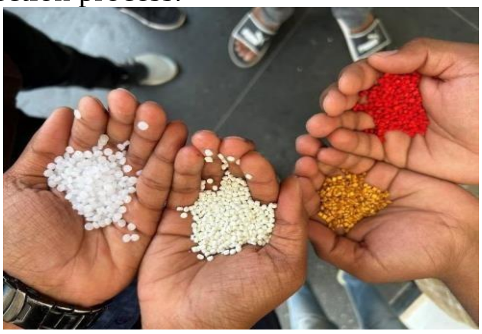
Injection Blow Molding Machine

- **Injection molding machine:** This machine consists of an injection unit, a mold clamping unit, And a control system.



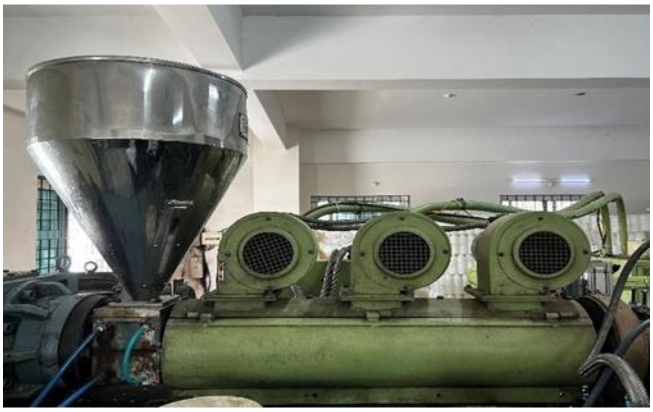
Fertilizer Container Die

- **Die:** This is the tool that gives the final shape to the plastic part. It is made of two halves that are clamped together during the injection process.



PVC Pallets

- **Material:** The plastic material to be molded is typically supplied in the form of pellets.



Hopper

- **Auxiliary equipment:** This may include a material dryer, a hopper loader, and a temperature control unit.

Experimental Design:

The design of an injection molding experiment involves choosing the factors to be varied and the levels at which they will be studied. Some of the important factors to consider include:

- **Injection pressure:** This is the pressure at which the molten plastic is injected into the mold.
- **Injection speed:** This is the rate at which the molten plastic is injected into the mold.
- **Mold temperature:** This is the temperature of the mold cavity.
- **Cooling time:** This is the time that the plastic part is allowed to cooling the mold before being ejected.
- **Material properties:** The properties of the plastic material used can also affect the outcome of the injection molding process.

Once the factors and levels have been chosen, a statistical design of experiment(DOE) technique can be used to create an experimental plan. This will ensure that the experiment is statistically valid and that the results can be used to make accurate predictions about the behavior of the process.

Some commonly used DOE techniques for injection molding include:

- **Full factorial design:** This involves testing all possible combinations of the factors at all levels.
- **Fractional factorial design:** This is a more efficient way to test all possible combinations of the factors, but it requires making some assumptions about the interactions between the factors.
- **Central composite design:** This design includes a center point and a set of axial points, which allows for the estimation of the quadratic effects of the factors.
- **Taguchi method:** This method uses a smaller number of experiments than other methods, but it requires making some assumptions about the distribution of the responses.

DATAANALYSISANDCOMPARISON

- The mechanical properties of blended PVC can be significantly affected by the type and amount of each component in the blend.
- Comparing the properties of different blend compositions can help select the best material for a specific application.
- It is important to consider the entire range of properties, not just the most important one when selecting a material.

Property	**Units**	**Range**	**Factors Influencing**
Temperature	°C	150 - 230	Blend composition, Part Geometry

Pressure	MPa	50 - 150	Blend composition, part geometry
Tensile Strength	MPa	20 - 50	Blend composition, processing conditions
Flexural Strength	MPa	30 - 70	Blend composition, processing conditions
Impact Strength	kJ/m^2	10 - 40	Blend composition, presence of toughening agents
Hardness	Shore A	60 - 90	Blend composition, plasticizer content
Fatigue Resistance	MPa	10 - 30	Molecular weight, stress concentrations
GlassTransition Temperature(Tg)	°C	70 - 100	Blend composition, plasticizer content
Chemical Resistance	N/A	Varies	Blend composition, specific chemicals
Aging	N/A	Varies	UV exposure,

DESIGN AND MANUFACTURING OF BLENDED PVC CONTAINES

Fertilizer Container

Blended PVC is a popular material for the production of containers due to its versatility, affordability, and good performance properties. This material offers a good balance of mechanical properties, including:

- **High strength and stiffness:** PVC provides excellent rigidity and durability for the containers.
- **Good impact resistance:** Blended PVC can with stand moderate impacts without cracking or breaking.
- **Chemical resistance:** PVC is resistant to a wide range of chemicals, making it suitable for storing various products.
- **Light weight:** Compared to other materials like glass or metal, PVC offers significant Weight advantages, making it ideal for portable containers.
- **Process ability:** PVC can be easily molded into various shapes and sizes, making it versatile for a wide range of container designs.

Design Considerations:

When designing a blended PVC container, several factors need to be considered:

- **Intended use:** The container's purpose will determine its size, shape, and required properties. For example, a container for food storage will require different properties than one designed for hazardous materials.
- **Wall thickness:** The wall thickness must be sufficient to withstand the intended internal pressure and external loads.
- **Reinforcements:** Depending on the application, additional reinforcements like ribs or fibers might be needed to improve strength and rigidity.

- **Closures:** The type of closure system (e.g. screw cap, snap fit) needs to be chosen based on the desired level of security and ease of use.
- **Appearance:** Color, surface texture, and other aesthetic considerations can be incorporated into the design.

Manufacturing Processes:

There are various manufacturing processes used to produce blended PVC containers:

- **Injection Molding:** This is the most common method, where molten PVC is injected into a mold cavity to form the desired container shape**.**
- **Blow Molding:** This process involves inflating a par is on (a pre-formed tube) to conform to the shape of the mold cavity.
- **Extrusion Blow Molding:** This combines extrusion and blow molding, where molten PVC is extruded into a par is on and then blown into the final container shape.

Each process has its advantages and disadvantages, and the choice depends on factors like:

- **Production volume:** Injection molding is more suitable for high-volume production, while blow molding is better for smaller batches.
- **Container size and shape:** Some shapes are easier to produce with one process than the other.
- **Material properties:** Different blend compositions might be better suited for specific manufacturing processes.

Additional Considerations:

- **Quality control:** Maintaining consistent quality throughout production is crucial to ensure the containers meet the required specifications.
- **Environmental regulations:** PVC manufacturing can potentially generate emissions and waste, so adhering to relevant environmental regulations is essential.
- **Cost optimization:** Balancing material costs, processing costs, and production efficiency is critical for maintaining competitive pricing.

STRENGTH AND DURABILITY TESTING

Tensile strength testing: This determines the maximum stress a container can with stand before breaking under tension.

- **Impact strength testing:** This assesses the container's ability to withstand sudden impacts without cracking or failing.
- **Drop testing:** This simulates real-world conditions by dropping the container from various heights on to different surfaces.
- **Pressure testing:** This checks the container's ability to withstand internal pressure without leaking or bursting.
- **Fatigue testing:** This evaluates the container's performance under repeated stress cycles to simulate long-term use.

ENVIRONMENTALFACTORS

- **UV exposure:** PVC is susceptible to degradation from UV light, causing discoloration and embrittlement. Adding UV stabilizers can mitigate this effect.
- **Heat exposure:** High temperatures can soften PVC, reducing its strength and rigidity. Choosing suitable blend compositions and designing for heat dissipation can prevent this.
- **Chemical resistance:** Blended PVC exhibits good resistance to a wide range of chemicals. However, specific chemicals might require additional testing and material selection considerations.

COST ANALYSIS

- **Material cost:** Blended PVC is relatively affordable compared to other container materials.

- **Processing cost:** Depending on the chosen manufacturing process and production volume, processing costs can vary.
- **Tooling cost:** Injection and blow molding require mold sand tooling, which can be a significant cost factor for small production runs.
- **Testing and certification:** Compliance with safety and quality standards might involve additional testing and certification costs.

Applications

Food and beverage:

- Bottles for water, juices, soft drinks, and other beverages
- Containers for food storage and packaging, such as yogurt cups, salad bowls, and meat trays
- Closures for bottles and jars

Household and personal care:

- Bottles for laundry detergent, dish washing liquid, and other cleaning products
- Containers for cosmetics, toiletries, and pharmaceuticals
- Dispensers for soap, lotion, and other personal care products

Industrial and agricultural:

- Drums and tanks for storing chemicals, liquids, and other materials
- Jugs and cans for paints, solvents, and lubricants
- Tubing and hoses for various industrial applications
- Irrigation pipes and agricultural containers

Medical and healthcare:

- Bottles and vials for medications and medical supplies
- Blood bags and trans fusion containers
- Disposable syringes and other medical equipment

Building and construction:

- Pipes and conduits for electrical and plumbing systems
- Roofing membranes and wall panels
- Flooring and window profiles

Conclusion

In conclusion, this study thoroughly explores the mechanical properties of blended Polyvinyl Chloride (PVC) in comparison to virgin PVC for the production of storage containers intended for fertilizer, employing the injection blow molding process. The primary objective is to assess the feasibility of adopting blended PVC, a potentially more environmentally friendly alternative, while preserving the desired performance characteristics of the end product. The research encompasses various ratios of blended PVC, optimizing injection blow molding process parameters for both blended and virgin PVC, including temperature, pressure, and cooling rate. Furthermore, the study extends its investigation to the impact of weathering and exposure to adverse environmental conditions, providing a comprehensive evaluation of the long-term durability of the containers. The outcomes of this research hold substantial implications for the plastics industry, offering valuable insights into the utilization of blended PVC in injection blow molding processes. This contributes to a reduction in environmental impact while ensuring the continued quality and durability of the manufactured products. The findings align with the global sustainability agenda, reflecting a commitment to decreasing reliance on virgin plastics in manufacturing practices.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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