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Evaluation of Mechanical Properties and Optimization of Injection Moulding Process Parameters for Pvc Pedestal Fan Blade

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ABSTRACT

A Fan Blade is used in many wide ranges of applications where it forces the fluid flow to one direction that is concentrated to one particular area which results in a temperature change. Polyvinyl chloride (PVC) is commonly used in many commercial products such as fan blades, pipes, window profiles, rigid sheets, cables, etc. Due to its unique set of features and properties up to 40 percent of the polymer Fan Blade market is occupied by PVC. since PVC Pedestal Fan Blades are considered cost-efficient applications, the variation of some key properties such as mechanical properties, lifetime, etc. has not been properly evaluated in the field. However, impact tests are usually considered as one of the efficient accelerated tests, so there has been some use of efforts for the application of fatigue characteristics on PVC Pedestal Fan Blade. The PVC Pedestal Fan Blades which are already used are then recycled to produce new Pedestal Fan Blades which visually look incomparably similar to virgin-produced products. But these products differ in their strengths and thermal aspects. The procedures to be followed vary from a virgin PVC Fan Blade to a recycled PVC Fan Blade. The effect of using pre-consumer PVC Fan Blade scraps on static and long-term mechanical properties will be studied. The degradation characteristics of mixing virgin PVC with crushed pre-consumer and PVC Fan Blades scraps are to be analyzed using various techniques. The variation of static mechanical properties as a function of adding pre-consumer PVC Fan Blades scraps is to be investigated. In addition, impact tests are to be executed to evaluate the long-term durability of blending virgin PVC Fan Blades scrap and recycled PVC Fan Blades scraps.

KEYWORDS: POLYVINYL CHLORIDE (PVC), RECYCLE, POLYMER

I. INTRODUCTION

The Punkah (fan) was used in India in about 500 BCE. It was made from bamboo strips or other plants, that could be rotated or fanned to move air. During British rule, the word came to be used by Anglo-Indians to mean a large swinging flat fan, fixed to the ceiling and pulled by a servant.

Fig 1.1 Indian bungalow with Punkah

1.1 Pedestal fans

A fan is a powered machine used to create a flow of air. A fan consists of a rotating arrangement of vanes or blades, generally made of wood, plastic, or metal, which act on the air. The rotating assembly of blades and hub is known as an impeller, rotor, or runner. Usually, it is contained within some form of housing, or case. This may direct the airflow, or increase safety

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by preventing objects from contacting the fan blades. Most fans are powered by electric motors, but other sources of power may be used, including hydraulic motors, hand cranks, and internal combustion engines.

Fig 1.2 electrical pedestal fans

1.2 Electrical Fans

In 1882, Philip Diehl developed the world's first electric ceiling-mounted fan. During this intense period of innovation, fans powered by alcohol, oil, or kerosene were common around the turn of the 20th century. In 1909, KDK of Japan pioneered the invention of mass-produced electric fans for home use. In the 1920s, industrial advances allowed steel fans to be mass-produced in different shapes, bringing fan prices down and allowing more homeowners to afford them. In the 1930s, the first art deco fan (the "Silver Swan") was designed by Emerson. By the 1940s, Crompton Greaves of India became the world's largest manufacturer of electric ceiling fans mainly for sale in India, Asia, and the Middle East. By the 1950s, table, and stand fans were manufactured in bright colors and eye-catching.

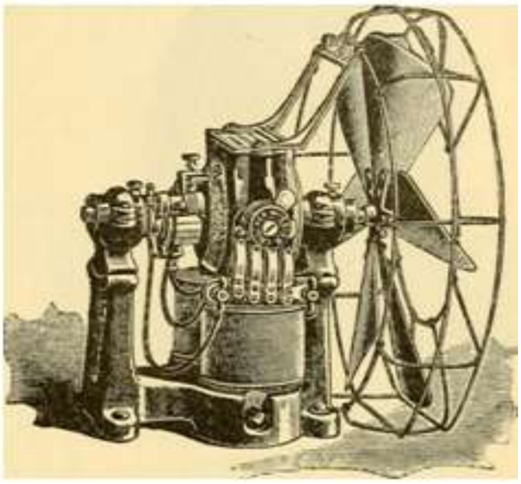

Fig 1.3 The first electrical fan

1.3 Movement of Airflow

There are three types of fans used for moving air, 1. Axial, 2. centrifugal (also called radial), and 3. cross-flow (also called tangential).

1.3.1 Axial flow

Axial-inflow fans have blades that force air to move parallel to the shaft about which the blades rotate. This type of fan is used in a wide variety of operations, ranging from small cooling fans for electronics to the giant fans used in cooling towers. Axial inflow fans are applied in air exertion and artificial process operations. Standard axial inflow fans have diameters of 300 – 400 mm or,800 –,000 mm and work under pressures up to 800Pa.

Fig 1.4 Axial flow fan

1.3.2 Centrifugal flow

The centrifugal fan has a moving element (called an impeller) that consists of a central shaft about which a set of blades that form a helical, or caricatures, are positioned. Centrifugal fans blow air at right angles to the input of the fan and spin the air outwards to the outlet(by deviation and centrifugal force). A centrifugal fan produces further pressure for a given air volume and is used where this is desirable similar to leaf boasters, blow-dryers, air mattress inflators, inflatable structures, climate control in air running units, and colorful artificial purposes.

Fig 1.5 Centrifugal flow fan

1.3.3 Crossflow

The cross-flow or tangential fan, occasionally known as a tubular fan, was patented in 1893 by Paul Mortier and is used considerably in heating, ventilation, and air exertion (HVAC), especially in ductless split air conditioners. The fan is generally long relative to its periphery, so the inflow remains roughly two- dimensional down from the ends. The cross-flow fan uses an impeller with forward-twisted blades, placed in a casing conforming to a hinder wall and a whirlpool wall. Unlike radial machines, the main inflow moves obliquely across the impeller, passing the blading doubly.

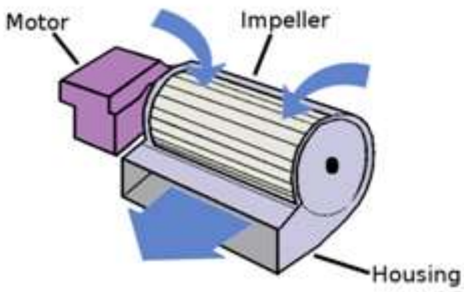

Fig 1.6 Cross-flow fan

II. LITERATURE REVIEW

One of the technical issues with the use of recycled PVC scraps for producing low-cost non-pressurized pedestal fan parts is that recycled PVC scraps impact the quality control of such pedestal fan blades because the control of recycled PVC scraps is not managed well. The separation of the scrap from the contaminants can be another issue while the regulation on the use of recycled PVC scraps is very limited, the details of the variation of long-term as well as static mechanical properties of PVC using recycled PVC scraps have scarcely been considered. Since PVC pedestal addict corridors are honored as low-cost operations, the variation of some crucial parcels is similar to mechanical l parcels, continuance, etc. has not been duly estimated in the field. Moreover, the long-term durability under fatigue and creep working conditions, in addition to the variation of static mechanical properties, are very important. Especially, fatigue tests are usually considered one of the efficient accelerated tests, so there have been some efforts to the application of fatigue characteristics to PVC fan designs previous research on the use of recycled PVC mainly focused on recycled PVC with different polymers, and the effect of aging due to the repeated use of PVC. However, most research focused on the variation of static mechanical properties, and investigations on long-term durability are very scarce.

- C. Sarraf, H. Nouri, F. Ravelet, and F. Bakir (Elsevier Inc.) are the researchers who have researched the effect of blade thickness on a fan's overall performance. They analyzed an axial fan with two different thicknesses of blades and the conclusion is that the thick blade fan is preferable to a thin blade fan because with a thick blade wider range of flow can be achieved and fluctuations are less compared to a thin blade. So, on that basis blade thickness can be decided as per the requirement of the flow range. Though blade shape and thickness is important part so failure analysis of the blade must be considered while designing.
- WANG Yan-qing, JI Zhe, CUI Yong-li, CUI Chun-zhi, and SUN Zhi (Elsevier Inc.) are the researchers who have researched the failure analysis of air fan blades. The failure of all 12 blades of an air fan was investigated by metallurgical and mechanical experiments and an examination of the fracture surface. The experimental results show that the cast aluminum-silicon alloy without any modification had several material defects, such as coarse grains, a loose structure, a large number of shrinkage holes, a long and thin bold-pin shaped silicon-phase, poor material strength, and serious brittleness. In addition, installed on the spindle without elastic conjunction, blade No.10 vibrated and inevitably Spun off due to the large centrifugal force. Therefore, blade No.10 first cracked at the locking handle and then broke at the root, which caused all the other 11 blades to be broken by the crack of blade No.10. So, the experimental result says that while casting of blade proper method should be used and selection of material is also very important.
- Ma and La Mantia studied the variation of thermal stability and mechanical properties when using post-consumer PVC beverage bottles and recycled blade-grade PVC.

III. METHODOLOGIES

3.1 INJECTION MOULDING

Injection moluding 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

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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

Injection moulding is used to produce numerous effects similar to line spools, packaging, bottle caps, automotive dashboards, fund combs, and utmost other plastic products available moment. Injection moulding is the most common system of part manufacturing. It's ideal for producing high volumes of the same object. Some advantages of injection moulding are high product rates, unremarkable high tolerances, the capability to use a wide range of materials, low labor cost, minimum scrap losses, and little need to finish parts after moulding. Some disadvantages of this process are precious outfit investment, potentially high handling costs, and the need to design malleable corridors.

Fig.1.7 Injection Moulding machine

3.2 Injection process

With Injection Moulding, grainy plastic is fed by graveness from a hopper into a heated barrel. As the grains are sluggishly moved forward by a screw-type plunger, the plastic is forced into a heated chamber, where it's melted. As the plunger advances, the melted plastic is forced through a snoot that rests against the mold, allowing it to enter the mold depression through a gate and runner system. The mold remains cold so the plastic solidifies nearly as soon as the mold is filled.

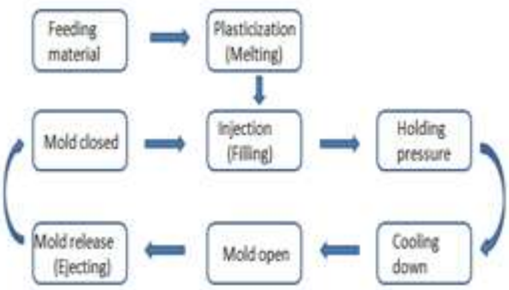

Fig 1.8 Injection Moulding process

Time Function

The time it takes to make a product using injection moulding can be calculated by adding:
Twice the Mold Open/Close Time (2M)
+
Injection Time (T)
+
Cooling Time (C)
+
Ejection Time (E)
Where T is found by dividing:
Mold Size (S) / Flow Rate (F)
Total time = 2M + T + C + E
T = V/R
V = Mold cavity size (in3)
R = Material flow rate (in3/min)

The closing and ejection times can last from a fraction of a second to a few seconds, depending on the size of the mold and machine. The cooling times, which dominate the process, depending on the maximum thickness of the part.

3.3 Necessity of Recycling of Plastics:

The last few decades have witnessed a significant increase in the n world population. This has caused a considerable increase in the demand for low-cost living conditions, which in part leads to a dramatic increase in the consumption of plastics. Past statistics show that the worldwide annual production of plastics is over 100 million tons per year.

There are approximately 3 million tons of plastic waste produced from that, of which environmental agencies report around 80% reaching landfill sites. Recycling plastic has many advantages:

- Using a resource that would otherwise be wasted
- Reducing or preventing the amount of waste going to landfill

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- Reducing the costs involved in the disposal of waste, which ultimately leads to savings for the community
- Providing employment
- Protecting natural resources
- Reducing pollution

Over the last numerous times, the focus of plastic recycling has changed. before, the focus was on educating and encouraging the public and assiduity to recycle. As the necessity and impulse to reduce the volume of waste materials entering our tips sunk into the crowd 's minds, request forces came similar that millions of pounds of plastic waste heading for the tip now had some value. The question also turned to one of how to collect this material and convert it into marketable raw material. The economies mandate that recycled materials are the more precious engineering resins, similar to polycarbonate, nylon, and PVC. In some cases, the cost of recyclable materials also exceeds the cost of raw materials due to processing and transportation costs. In the United States, the recovery of post-consumer plastics for 2009 was roughly 7. So, it's desirable to find uses for recycled plastic material that can be justified by having an analogous cost to a virgin material's indispensable result.

3.4 Process Parameters

Selection of the Injection moulding Parameters and their levels:

A large number of process variables affect the quality of products made by the injection moulding process. The process parameters that will influence the results of the experiments have to be recognized before starting the experiments for further analysis in DOE as these parameters will contribute to the variations of results and influence the results due to the adjustments of parameters. All of the parameters involved during the injection moulding process can be grouped into four basic categories: temperature, pressure, time, and distance. Temperature is the most important of the process parameters, followed by pressure, time, and distance.

To visualize the effect of process parameters on the tensile, compressive, and flexural strengths of a plastic tray, the following parameters were selected: Melting Temperature; Holding Pressure; Injection Time; Holding Time. Other parameters such as mold temperature (32°C), injection pressure (50 bars), cooling time (10s), and stroke distance (140 mm) were kept constant during the experimentation. Keeping in view the importance of the main process parameters and their effect on the performance characteristics, the working range of each parameter was carefully chosen to produce the PVC fan blade of acceptable quality. Each parameter level was then selected carefully and the experiments were performed as per the Taguchi L_9 orthogonal array. Each parameter at level 3 was considered. The below table shows the moulding parameters and their levels.

Factor	Parameter	Unit	Level A	Level B	Level C
A	Melting Temperature	°c	170	172	177
B	Injection Pressure	Bar	90	100	110
C	Injection Time	Sec	6	8	10
D	Cooling Time	Sec	35	38	40

Table: Injection moulding parameters

IV. TESTING

4.1 Obtaining a steady state of fans

The fan should achieve a steady state before any experimental measurements are taken. Existing standards for fans such as the IEC 60879 define the steady based on the temperature of the motor where a steady state is achieved when the temperature change with time is 1℃/hour. The experiment was performed to analyze the temperature change over time from 0tthe h regulator position to each of the other regulator positions and to analyze the temperature change over time when switching between each regulator position. The time required to become steady from the room 0th regulator position to the 1st, 2nd, and 3rd regulator position was obtained as 50 minutes and the time required to become steady from the 1st regulator position to the 2nd regulator position and 2nd regulator position to the 3rd regulator position were obtained as 30 minutes.

4.2 Proposed test rig setup

The Figure shows the test rig setup obtained through the analysis of the flow around the fan. This setup is used to test the performance

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analysis. All the dimensions are defined in terms of the diameter (D) of the fan blade.

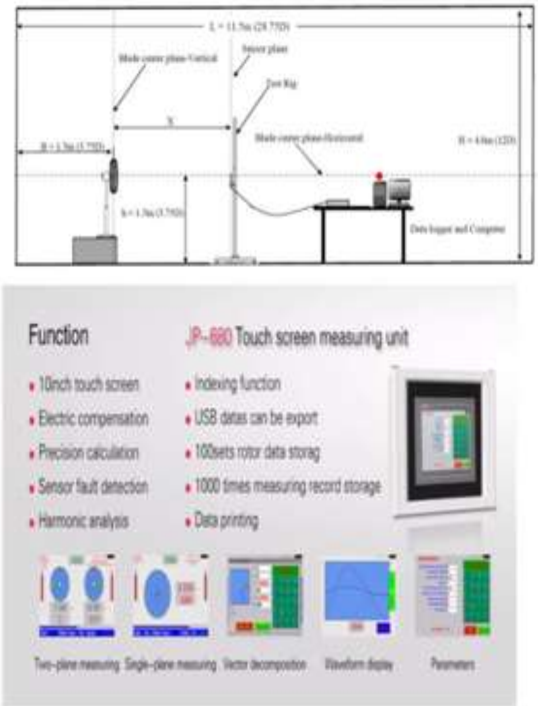

Fig 1.9 Defined test rig setup.

4.3 Rotation testing dynamic balancing machine for pedestal fan blade

Shanghai JP balancing machine manufactures a Single plane vertical balancing machine for disc rotors, wheel shapes, or small fans with up to 200 kg and 1000 mm diameter in a plate. The machine is widely equipped in multiple industries and not only for manufacturing, and balancing service providers, but also for machinery components repair shops. The machine can be installed with a pneumatic inflate clamp inside as the customer requested for rotors' immobilization. The rotor can be welded, milled, or drilled without disassembly from the balancing machine. The accessories of the vertical balancing machine include the milling machine setting on the table apart for rotor reprocessing. It is ensured that the rotor you take off from the balancing machine would be 100 % perfect.

V. DESIGN PROCESS

The design of the pedestal fan blade is done by using **Solid works 2020**. SolidWorks is a computer-aided engineering (CAE) and computer-aided design (CAD) program published by Dassault Systems. It is used to create three-dimensional models. It is one of the best 3D modeling software to design products with productivity and ease compared to other CAD software. From the first step of understanding a design, and execution of SolidWorks drawing until the product's manufacturing, SolidWorks software is capable of doing it all. This will help in creating innovative products at faster rates as the design cycle will be shortened.

The design process usually involves the following steps:

• Identify the model requirements.
• Conceptualize the model based on the identified needs.
• Develop the model based on the concepts.
• Analyze the model.
• Prototype the model.
• Construct the model.

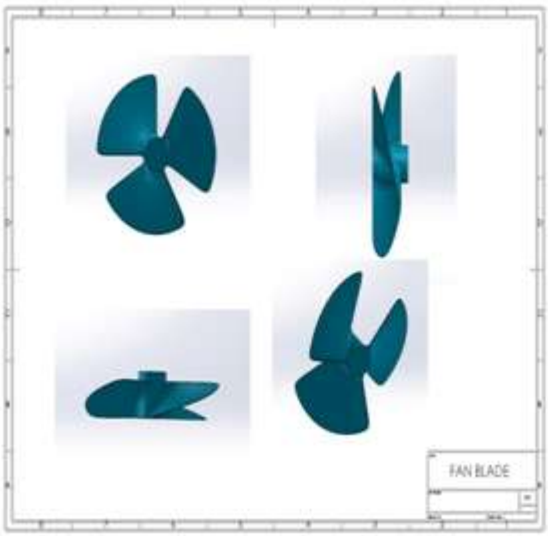

FIG 1.10 Design of Pedestal Fan Blade

Sample code	V100R0	V80R20	V60R40
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

	Impact strength (JOULES)	Injection Pressure (Bar)	Injection time (sec)	Cooling time (sec)	Refill time (sec)	Refill speed (RPM)
V80, R20	18.23	111	13	40	8	69

VI. RESULT

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

VII. OPTIMIZATIONS

The best solution (there are many solutions to gain these maximums) is rated as 0.556, responding with: 80% PVC and 20% RPVC as the best mixture, processed at 185°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 RPVC 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% PVC is favored.

VIII. CONCLUSIONS

The main objective of this research work is to identify parameters that affect the performance of the pedestal fan blades 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 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 become more robust to variations at the optimal operating settings. The results have proven that the manufacturer can use these settings of recycled PVC and virgin PVC 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 project, the effect of using pre-consumer PVC scraps (which can be collected during the fan blade production process), as an alternative to post-consumer recycling, mixed with virgin fan blade grade PVC on static and long-term mechanical properties is studied. Samples were prepared by blending virgin PVC with various contents of recycled PVC.

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