A study on injection molding process for tensile strength of plastic components using optimization techniques

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Abstract: Tensile behaviour of plastics plays an important role in defining the quality of injection-molded products. Many studies have shown that the tensile behaviour of a product is influenced by the processing parameters governing injection-molding processes. This study employs Optimization technique, Design to systematically investigate the influence of injection molding processing parameters on the tensile strength of general purpose polystyrene (GPS). The results show that effect of each & every processing parameter has been discussed with the surface and contour plot on the response like Cycle time, GPS melt temperature significantly, affect tensile strength etc., while the room temperature noise-factor has no significant effect. The optimal conditions for the strongest tensile strength specimens are experimentally verified by the Taguchi Parameter Design. The match between the verification run and prediction from the optimal factor settings indicates that the Taguchi Parameter Design is very practical in optimizing the tensile properties of injection-molded products.

Keyword:-DOE, Injection molding, Optimization technique, Counter plot, surface plot, tensile strength.

1. Introduction

The Injection Molding the machine was invented by American inventor brother duo John Wesley Hyatt, along with his brother Isaiah in 1872. The machine was simple compared to the machine used today. It worked like a large hypodermic needle, using a plunger to inject plastic into a mold through a hot cylinder. Although the process of manufacture of injection molding is not in demand since 1978, plastic products have not been used in products of daily life. However, with time, plastic materials are replacing metals and non-metallic materials products. The popularity of this machine has increased tremendously in the three decades due to industrialization and development in society. As the injection molding process is found in everyday life, it includes toys, household products, automotive products, and consumer electronics products. Besides, container buckets, plastic toys, medical equipment products, small plastic bolts, a bottle are manufactured by an injection molding machine.

1.1 Injection molding machine

The central units of a specific injection molding machine are clamping units, plasticizing units, and drive units. The clamping unit has an injection mold. It can close, clamp and open the mold. Its main components are fixed and movable plates, tie rods and opening, closing and clamping mechanisms. The injection unit or the plasticizing unit melts the plastic and injects it into the mold. The drive unit feeds the plasticizing unit and the clamping unit. The injection molding machine is often classified according to the maximum clamping force that the machine can produce. This is the force that forces two molds to avoid opening the mold due to the internal pressure of the plastic melt in the mold. The schematic diagram of the injection molding machine is depicted in Fig.1.1. The process cycle can be categorized into three steps: Step 1: heating the plastic grains in the barrel after that injection of the molten plastic into the mold and Step 2: hold on the molten plastic into mold for some time after that Step 3: cooling of the molten plastic into the mold and ejection of product from the mold.

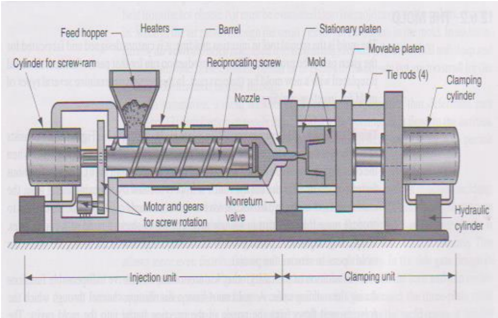

Fig. 1.1: Single screw injection molding machine [1]

1.2 Types of Injection Molding Machine

Molds for injection molding machines can be placed vertically and horizontally according to the needs of plastic products. However, most molds in the injection molding process are located horizontally. Many attachment tools are required to catch the mold so that nuts and bolts tighten both sides of the floor plates. However, the hydraulic clamp is used for the molding machine. Now a magnetic magnet is used to catch mold of the injection molding machine. Based on the drive unit, the injection molding machine into the following categories:

(1) Mechanical drive
(2) Hydraulic drive
(3) Pneumatic drive
(4) Electrical drive

Hydraulic driven, in-line screw machine is more frequently used in the industry. Usually, injection molding machines are electrically driven, and it will be more critical.

2. LITERATURE REVIEW

This chapter focuses on review of literature of the plastic Injection molding process primarily related to the processing of plastic material inside the mold, optimization of injection molding process parameters, weight assignment methods for responses of the injection molding process. Apart from this focus of the survey is based on self-mixing and blending of material.

2.1 Process parameters optimization and simulation methods

The quality of the part depends on the processing area of the injection molding process and the processing conditions. The processing condition of injection process depends on process parameters, such as temperature, time, pressure and environmental factors, which affect the response of the injection molding process, namely dimensional defects, mechanical properties and the cycle times for the production of the product. There has been a significant change over from the traditional injection molding process to the gas injection molding process, in terms of size, shape, and approach **[2].** Since the machine is properly inspected by inspection from time to time. However, a partial quality of the product remains necessary. Due to many hidden reasons, variation in physical properties (such as regrind resins are used), changes in ambient environment (e.g., humidity or temperature in the shop), and characteristics of the machine (especially using hydraulic power) occurs, the conditions of the procedure is re-read to reduce the quality of the part within the tolerance limit. Using specific control technologies to address the above problems and automated and adaptive quality control, various researchers have conducted an extensive research over the past two decades on appropriate process control systems. It is difficult to develop a possible control strategy without the full understanding of the relation and dependency between those variables **[3].** The effect of the parameters on the response is also the specific task to find the optimal location of the solution. If the molten temperature is too high, then the need for injection pressure should be high. The content of degradable material has a high melting temperature. If the pressure of the injection can be very low, there may be a short shot and much flash inside the material **[4].** So to reduce defects the interaction between the melting temperature and the injection pressure is higher than the interaction between holding pressure and injection pressure **[5].**

The temperature of the melting temperature of the barrel, the temperature of the mold and the cooling temperature of the mold inside the material, pressure like injection, pressure of packing, time, time of cooling, packing time, injection time and environment such as injection, Example of parameters factors air current, humidity, temperature is considerable factor **[6].** The condition of the product depends on the process parameters. Based on the conditions of the injection molding process parameters, various researchers have been carried out using various adaptation techniques **[7].** Various techniques are developed for such types of problems, which provide the best process areas for product development with the help of process parameters. Depending on its characteristics, advantages, disadvantages, and scope of the optimization approaches such as response surface model, bringing model, artificial neural network, genetic algorithm, and the previous researchers have addressed hybrid approach **[8])**. Numerical optimization techniques can be classified according to the method of improving the design point after each iteration step; there are three types of optimization techniques: non-gradient-based, gradient-based and hybrid optimization techniques.

2.2 Study based on Taguchi's Method

Tanel and Gangil [2020] Examined the sink marks, weld lines responses with the help of mold temperature, melt temperature, nozzle temperature and injection pressure as process parameters to study the headlight of the car as the product with the help of Taguchi's method. The study concludes that the clear light of the headlight can be control by nozzle temperature should be much less than the melt temperature to avoid the sink marks and vulnerability of the weld lines. **Abdullab and nair [2019]** Present Sink marks depth as response study with the help of melt temperature, mold temperature, packing pressure, packing time, Rib to wall ratio, Rib to gate system and injection time with the help of Taguchi's experimental method. Sink marks depth can be minimized by minimizing Rib distance from the feed point. **B Ozzollioc [2016]** studied the Warpage and sink marks responses with the help of rib cross-section, rib layout angle, melt temperature, mold temperature and packing pressure with the help of Taguchi's method. The study aim is to compare the Warpage and sink marks depth effect on different plastic materials Polycarbonate/ Acrylonitrile butadiene styrene, Polyoxymethylene, Nylon-66. Based on the resulting warpage is found to be minimum in the Poly Carbonate/ Acrylonitrile butadiene styrene and sink index is found to be minimum Nylon-66.
Mattvonond [2018] experimentally analyze tensile strength, Impact strength as the response of plastic material Acrylonitrile–Butadiene–Styrene by considering melt temperature, injection pressure, packing pressure and packing time as the process parameters. In their study of the experiment, they found that as packing pressure increases the tensile strength of material increased. In their study of the experiment, they found that as packing pressure improved the tensile strength of a material is increased.

3. RESEARCH GAP IN THE EXISTING STUDY

After extensive study of the literature, there are many gaps have been found out in the field of processing of injection molding process are:

1. The optimization of process responses cycle time of Injection molding process and Tensile strength of plastic components materials have been studied in the selected parameters range based on literature review with the help of Taguchi and advanced optimization techniques such as Desirability Function etc.

2. Since there are many studies have been done in the polypropylene plastic components materials, but a majority of researchers focused on the limited number of process parameters on the responses of an injection molding process, but none of them represented an optimization of input process parameters and factors with the advance hybridization techniques.

4. RESEARCH STATEMENT

Comparative and optimization study of Injection molding process parameters responses of polypropylene plastic components by using various hybridization techniques such as Desirability Function to the input process variables.

5 RESEARCH OBJECTIVES

The key features of an object of this paper are:

1. Investigation of working ranges and levels of process parameters of Injection molding process polypropylene components.
2.Multi-response optimization of process parameters of injection molding polypropylene components with the help of a combination of Design of experiment (Taguchi's) with desirability function and Utility concept.
3. Validation of the results by a confirmation test in conducting experiments

5. DESIGN OF EXPERIMENTS AND ITS ASSOCIATED OPTIMIZATION METHODS

In this chapter, the details of different tool which has been used in this research area are enlisted. At the outset experiments were planned using the Design of experiments, the Taguchi method was chosen due to its capability to provide the result in very less number of experiments. After conducting the experiments responses were measured and then optimized using Desirability Function and Utility concept. The dissimilar weight was assigned by using the objective weight methods like Principal Component analysis and entropy methods. The entire assessment tool is summarized in this chapter in detail.

A designed experiment is a test in which some useful changes are made to the input variable of a process or system so that changes in the response can be observed and identified according to output. Experimental design methods play a vital role in the development and improvement of processes. The design of an experiment is a powerful tool for "designing for value". Researchers always use the design of the experiment to answer specific questions, as a perspective in planning experiments, this design of experiments characteristics can be enlisted as:

1. Is a product a safe and effective use of a product for which it is made for a purpose?
2. What parameters of the manufacturing process affect the quality and accuracy of a product?
3. Changes to the process parameters will affect the manufacturing process.
4. Whether the manufacturing process can be improved with a short-term solution.
5. Does an interaction of process parameters affect the quality of the object?
6. under what circumstances a successful experiment can be conducted that provides the optimal solution in costs and minimum time.

To design a useful manufacturing process, perform related experiments that can improve product quality and reduce costs and time. To improve quality and design, ways are called process processing, which is controlled by the parameters of the manufacturing process, called processing of an object. A small experiment can be characterized by treatments and experimental units, which are assigned for treatment of the responses. The solution and method of treatment depend on the imposing of the units and the responses are measured.

6 COMPONENTS OF AN EXPERIMENT

The components of an experiment are the following.
Treatment: solution adopted for a reason
Experimental units: Process parameters responsible for causing
Methods of assignment: the method adopted for the given treatment
Experimental plan: allocation of treatment
When a user plans experiments to analyze the process, the analysis depends on the design of the method, because the design of experiments determines the appropriate analysis to a great extent.

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8. ALGORITHMS STEPS FOR MULTI-RESPONSE OPTIMIZATION TAGUCHI WITH DESIRABILITY FUNCTION

The following process, using the Taguchi and Desirability Function, is used to obtain multi-response optimization for the injection molding process.

1. Calculate the individual desirability index (di): Calculate the individual desirability index for the corresponding responses using the formula proposed by three forms of the desirability functions according to the response characteristics.

2. Compute the composite desirability (D): The individual desirability index of all the responses can be combined to form a single value called composite desirability.

3. Determine the optimal parameter and the combination of its level: Higher combined overall desirability value means better product quality. Therefore, based on overall totality (D), the optimum levels for parameter effects and each uncontrolled parameter are estimated.

4. Calculate the estimated optimal condition: Once the optimum level of design parameters has been selected, the final stage is to predict and verify quality characteristics by using the optimal level of design parameters.

9 WEIGHT MEASUREMENT METHODS

The methodology that utilizes both Taguchi method with Principal component analysis and Grey entropy method is an entirely practical and useful procedure for tackling multi-response problems.

10 EXPERIMENTAL PERFORMANCE CHARACTERISTICS

The planning of experiments and method of conducting using the relevant data to find useful information and further conclusion. Taguchi approach should be planned and conducted relevant data according to the plan to find useful conclusions. It depends on how the experiment has been done. In Taguchi method, there are basic approaches to testing and error approaches and the use of design, planning, and experimentation. In the design of the experiment, statistical techniques are used, and it is used to study the effect of multiple variables simultaneously and determine the factor combination for optimal results. The following sections are devoted to providing some insight into experiments and conclusion.

10.1 Trial and error approach

Several experiments are conducted to reach an understanding of the phenomenon. it can be achieved by carefully observing the measurements after each experiment so that by analyzing the observed data, one can get able to decide which "which parameters should be regulate and how many" to achieve the desired result. The selection of such an approach will not be allowed the parameters that should be changed in the next experiment. In this situation, the available data is not enough to pull any critical conclusions. Therefore, this approach is not suitable for the above reason.

A designed experiment is a systematic approach with variable controllable input factors in the process and extremely helpful in finding a critical variable process affects the quality characteristics of interest. The design of the experiment is evaluated simultaneously for two or more factors for their ability to influence the resultant average or the variability of a particular product or process characteristics. A designed experiment is a systematic approach with variable controllable input factors in the process.

One of the major types of designs used is factorial design, in which factors differ in such a way that all possible combinations of factor levels are tested. The results of particular test combinations have been observed, and the full set of results is analyzed to determine effective factors and preferred levels. However, Taguchi treats optimization problems in two categories Static Problems and Dynamic Problems. Generally, there are several control factors in a process to be customized, which directly determine the target or output value of the output. Optimization involves determining the best control factor level so that the output target value is achieved. Such a problem is called a static problem. If the product to be adapted is a signal input which decides the output directly, then optimization involves setting the best control factor so that the input signal output ratio is closed for the desired relationship. Such a problem is called a dynamic problem.

10.2 Formulation of experimental layout

The method of Taguchi is designed to improve the quality of the product and the process where the performance depends on many factors. The experimental layout is designed by choosing the minimum possible number. But the number of possible combinations involving many factors for engineering projects is large. Apart from this, the high order interactions may be needed to influence factors for specific projects. Using a traditional method of reducing the number of test combinations of experiments, also known as partial factorial experiments. Taguchi created a particular set of general designs for factorial experiments. Use of these arrays helps to determine the least number of the experiments required for a given set of factors. When all factors involve a certain number of levels and conversations are insignificant, then standard orthogonal arrays will meet the needs of the most experimental processes. If there is a mixed level, an amendment of the Orthogonal Array becomes necessary, and instruments exist.

11. SELECTION OF PROCESS PARAMETERS AND THEIR LEVEL SELECTION FOR THE STUDY

From the extensive literature review and specifically referring some paper viz**. [8]** etc., and also based on the discussion with experts of the field and form the personal experience some pilot experiments were conducted. Also considering the guide lines given in the operator's manual provided by the manufacturer of the Injection molding machine, range of process parameters the process parameters and their levels have been decided for the conduction of experiment. First pilot experiment is planned for the 4 Parameters and L_9 Orthogonal array to study the main process parameters melt temperature, injection pressure, packing pressure and packing time effect on mechanical properties of PP plastic product. Again Literature survey is done to include more main parameters and study main causes like Warpage dimensional defect, one more parameter is included cooling time based on the suggestion with a group of expert people and L_{27} experiment and also technical reason of selection is include finding possible answer, which is as below:

Since Injection molding process requires temperature control of barrel temperature, nozzle temperature, and dye temperature. The first two temperatures mainly influenced the flow of plastic and plastic, the later mainly affect the temperature of plastic flows and cooling. Each has a different plastic flow temperature, the same type of plastic because there is a difference in different source or brand, flow temperature, and decomposition temperature, it is caused by different molecular weight and molecular weight distribution, Plastic injection machine is caused by plasticization. The process is different, so the temperature of the barrel is not uniform. Nozzle temperature is usually slightly lower than the highest temperature in the barrel. This can be done in the "drooling phenomenon" to prevent melt through the tube. Nozzle temperature is not to very low. Otherwise, it will affect the performance of the products in the form of initial melt coagulation and feed in the mold cavity as the nozzle block or initial condensate. For all these factors the melt temperature of the plastic material is responsible. Back pressure using screw-type injection molding machine, the screw top of the melt in the screw by turning the pressure back when called plasticization pressure, also known as back pressure. The magnitude of this pressure is to be adjusted through the hydraulic system relief valve. In the injection phase, plasticization pressure, the size of the screw motion with all, the increase in pressure which will increase the plasticization temperature of the melt, but will reduce the rate of plasticizers. Besides, the increased pressure often make plastics melt temperature uniformity, pigment mixed evenly and melted in the gas discharge. Under the normal operation, the basis of plastic material dimension, plastic pressure to make sure to ensure right quality products. In the current production, almost all of the injection machine injection pressure is to screw the top on the plastic plunger or by the pressure (the pressure from the oil line conversion) to the yardstick. The injection pressure in injection molding is played by overcome barrel cavity flow resistance, by controlling the flow of plastic, given the rate of compaction of melting filling and melting. In the injection molding process gate, sprue and mold are fundamental design parameters. It affects polymer capacity, size of the part, mold structure, and position, selection of gate affect the way the plastic flows into the cavity. As the plastic material comes in the mold from the barrel, this is a hold for some time, in this stage, the change of plastic material starts inside the mold. After a particular time when extra material is supplied to compensate the material shrinkage after that cooling phase starts. Cooling time is a responsible factor in which plastic material transforms its state from liquid to solid.

Therefore, in this study, melt temperature, injection pressure, packing pressure, packing time and cooling time are used for study variables. So the range of these process parameters is selected based on literature review, expert's suggestion and pilot experiments conduction.

11. EXPERIMENT DATA ANALYSIS

This chapter focuses on the analysis of the experimental study of Tensile strength and Cycle time, polypropylene plastic products. Here the analysis is done with the help of hybridization of Taguchi with Desirability Function.

11.1 Virgin polypropylene is 100%

The use of the organization to carry out the experiments Taguchi orthogonal array and the process parameters are Melt temperature, packing pressure, injection pressure and packing time selected and three levels, Nine experiments are performed using the combination of virgin polypropylene as 100% each, which is shown in Table 11.1.

Table 11.1 Process Parameters and levels for Virgin polypropylene 100 %

Process Parameters	Abbreviation	Level 1	Level 2	Level 3
Packing pressure MPa	PP	40	50	60
Injection pressure MPa	IP	20	25	30
Melt temperature ^{0}C	MT	220	230	240
Packing time in Sec	PT	4	8	12

11.2 Multi-response optimization of 100% Virgin Polypropylene composition with hybridization of Taguchi with Desirability Function

Different Desirability index is calculated based on the type of quality characteristics for all reactions. In this study Tensile strength is Higher the better type characteristics and Cycle Time is Lower the better characteristics.

11.2.1 Determination of desirability value

With the help of each attribute is converted into the preference scale between 0 and 1. The desirability value is calculated for the Tensile strength. For cycle time it is calculated from the Eq. and tensile Strength is higher the better type characteristics and Cycle time lower the better type characteristics. Then desirability value is calculated and listed in Table 11.2

Table 11.2 Normalized desirability value 100% Virgin Polypropylene composition

S. No.	MT (^{0}C)	IP (Mpa)	PP (Mpa)	PT (Sec)	Desirability for Tensile Strength (d_1)	Desirability for Cycle time (d_2)
1.	220	20	40	4	0.928571	0.112819
2.	220	25	50	8	0.785714	0
3.	220	30	60	12	0.571429	0.148197
4.	230	20	50	12	0	0.073098
5.	230	25	60	4	0.928571	0.043265
6.	230	30	40	8	0.714286	1
7.	240	20	60	8	0.714286	0.148197
8.	240	25	40	12	0.5	0
9.	240	30	50	4	1	0.060125

11.2 Weight assignment with the help of PCA analysis

By specifying the value of the weight with the Principal component analysis, changing the desirability value of the cycle time and tensile strength in the single response priority scale. The weight is calculated listed in Table 11.3.

Table 11.3 Eigenvectors and Weight Calculation for 100% Virgin Polypropylene composition

Responses	Eigenvectors		
	First principal component	Second principal component	Weight determination
Cycle time	0.707	0.707	0.5
Tensile Strength	0.707	-0.707	0.5

11.3 Weight assignment with the help of Grey entropy analysis

The objective weight of the Cycle time and Tensile strength is calculated with the help of Eq.3.31 to 3.38. It comes to be 0.5.

Based on generalized data, after determining the weight, the utility value of the responses is calculated by the product of the desirability value and weight. The value of Overall Desirability is listed in Table 11.4.

Table 11.4 Weight age Desirability value of 100% Virgin Polypropylene composition

S. No.	Weight age Desirability Value for Cycle Time	Weight age Desirability Value for Tensile Strength	Overall Desirability value
1.	0.963624	0.335886	0.568918
2.	0.886405	0	0
3.	0.755929	0.384963	0.539449
4.	0	0.270367	0
5.	0.963624	0.208001	0.4477
6.	0.845154	1	0.919323
7.	0.845154	0.384963	0.570398

8.	0.707107	0	0
9.	1	0.245203	0.49518

11.4 Response Parameters

11.4.1 Tensile strength of Plastic material

The response of a polymer when exhibiting deformation can be determined based on morphology, time of deformation, temperature, and humidity. This is due to the internal visco elastic properties of polymers, where the polymer behaves like a viscous liquid and an elastic liquid. Depending on the level of temperature and stress, the polymer performs different functions and for example, linear elastic behaviors, yield phenomenon or/and plastic deformation. Different stress (force) can be applied and measured separately for polymer material; Such as shear, tension or compression. If the solid is compressed or tensile strained, then the material reaction is known as the Young modulus. The Young modulus is the measure of a material's resistance to deformation, telling how stiff the material is. Modulus reflects the ability of the material to reproduce the deformation after retaining its shape and after it gets deformed. The deformation is instantaneous without time delay. Resilience is the ability to return to its original shape after being stretched or pulled.

A tensile test is carried out using a plastic piece shaped like a dog bone and stretching it using a constant force or a constant deformation rate according to ASTM D 638 tensile specimens to check the tensile strength of the material.

11.4.2 Cycle time

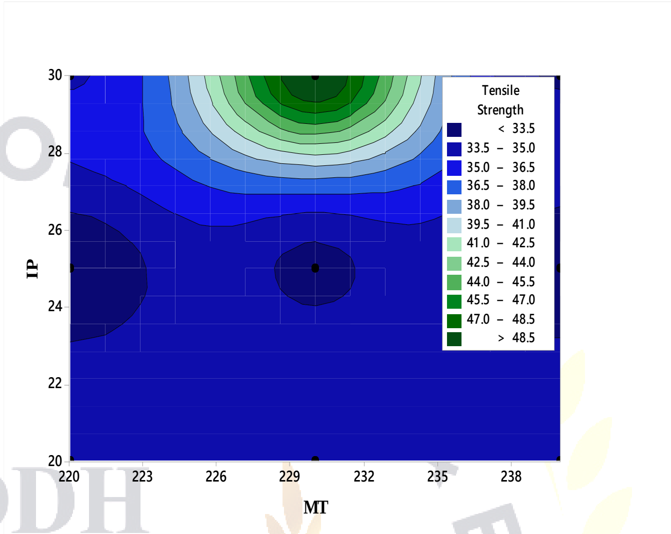
Mathivanan, D et al. [2017] defined cycle time as the summation of process parameters of injection time, packing time and cooling time. Due to the increase in the manufacture of these plastic products is due to weight is light, easy to handle, easy to produce, high stiffness and durability. The following steps of the injection molding process are Plasticization, injection, holding, cooling and finally ejection.

12 RESULTS AND DISCUSSION

This chapter discusses the result obtained from the experiments discussed in the chapter 5.The effect of each processing parameter has been discussed with the surface and contour plot on the response like Tensile strength and Cycle time, etc.

12.1 Polypropylene is 100%

Fig.12.1 (a) represents the contour plot, and Fig.12.1 (b) represents the surface plot of Tensile Strength in relation to the processing parameters IP and MT. From this figure, it can be observed that maximum Tensile Strength can be achieved at Injection Pressure, at a high level and Melt Temperature at, medium level for thin shell semi-crystalline plastic materials.



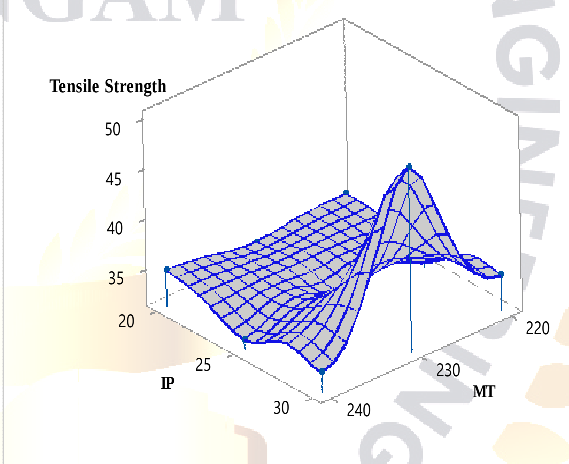
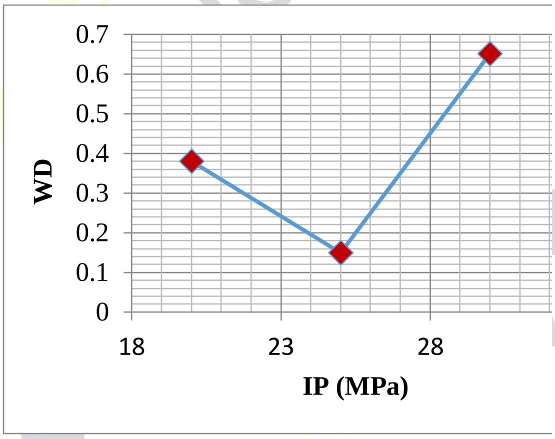


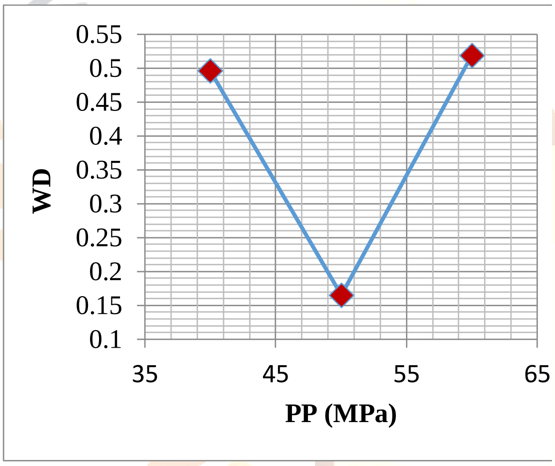
Fig.12.1: (a) Contour Plot and (b) Surface Plot for Injection Pressure (IP) Vs. Melt Temperature (MT) for Tensile Strength of Virgin Polypropylene

Fig.12.1 (a) represents the contour plot and Fig.12.1 (b) represents the surface plot of Tensile Strength in relation to the processing parameters PP and MT. From this figure, it can be observed that maximum Tensile Strength can be achieved at Packing Pressure, at a low level and Melt Temperature, at the medium level for thin shell semi-crystalline plastic material

12.2 Optimal combination of process parameters with the help of Taguchi with Desirability Function

Fig.6.8 is presented on the basis of overall desirability value calculation of chapter 5. It has Melt Temperature at Level 2, Packing Pressure at Level 3, and Injection Pressure at Level 3, Packing Time at Level 1 has higher the better desirability value.





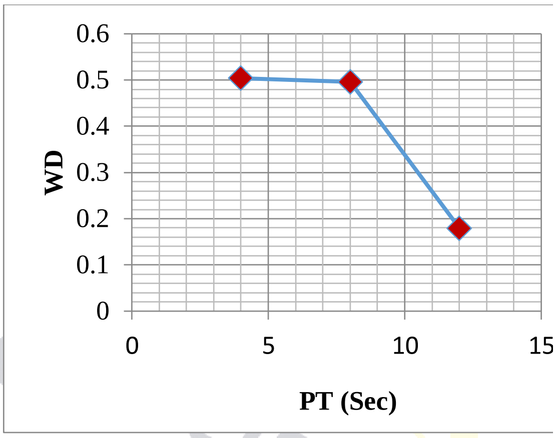


Fig.12.2 a, b, c Evaluation of optimal setting for overall desirability Value for Virgin Polypropylene

Table 12.1- Optimal setting for the 100% Virgin Polypropylene Composition by Desirability Function

Melt Temperature (^{0}C)	Injection Pressure (MPa)	Packing Pressure (MPa)	Packing Time (Sec)
230	30	60	4

12.2.3 Confirmation Test

For the conduction of the confirmation test based on higher the better desirability value from the Fig. 12.2 melt temperature at 230 ^{0}C, injection pressure at 30 MPa, packing pressure at 60 MPa, packing time at 4 sec has Tensile Strength 51.34 MPa and Cycle time 22 Sec. (Table 6.2).

Table 12.2 Optimal setting for the Tensile Strength and Cycle Time for Virgin Polypropylene

Melt Temperature (^{0}C)	Injection Pressure (MPa)	Packing Pressure (MPa)	Packing Time (Sec)	Tensile Strength (MPa)	Cycle time (Sec)
230	30	60	4	51.34	22

By confirmation test an experimental run, the error of experiment is found out to be 3%, which shows that this method is suitable for the maximization of Tensile strength and minimization of Cycle time of the plastic products. Based on analysis both methods are suitable for the process.

CONCLUSION

The following conclusions have been drawn from the study. To obtain optimal process parameter that could provide better Tensile Strength of the plastic products Tensile Strength can be maximum

- Melt temperature at 230^{0}C and 30 MPa injection pressure
- Melt temperature at 230^{0}C and packing Pressure at 40 MPa
- Melt temperature at 230^{0}C and 7.5 sec .packing time
- Injection pressure 30 MPa and 40 MPa packing pressure
- Injection pressure 30 MPa and 7.5 sec. packing time

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