Effect of Injection Moulding Process Parameter on Tensile Strength Using Taguchi Method

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Abstract— ***The plastic industry plays very important role in the economy of any country. It is generally among the leading share of the economy of the country. Since metals and their alloys are very rarely available on the earth. Therefore, to produce plastic products and components, which finds application in many industrial as well as household consumer products is beneficial. Since 50% plastic products are manufactured by injection moulding process. For production of better quality product, we have to control quality characteristics and performance of the product. The process parameters plays a significant role in production of plastic, hence the control of process parameter is essential. In this paper the effect of the parameters selection on injection moulding process has been described. It is to define suitable parameters in producing plastic product. Selecting the process parameter by trial and error is neither desirable nor acceptable, as it is often tends to increase the cost and time. Hence, optimization of processing parameter of injection moulding process is essential. The experiments were designed with Taguchi's orthogonal array to achieve the result with least number of experiments. Plastic material polypropylene is studied. Tensile strength test of material is done on universal testing machine, which is produced by injection moulding machine. By using Taguchi technique with the help of MiniTab-14 software the best value of injection pressure, melt temperature, packing pressure and packing time is obtained. We found that process parameter packing pressure contribute more in production of good tensile plastic product.***

Keywords—*Injection moulding, tensile strength, Taguchi method, poly-propylene.*

I. INTRODUCTION

plastic industry is the largest industry in the world and providing significantly effect to the nation's economy. This sector is the fastest growing sector in the Indian economy similar to globe. Nowadays injection moulding bears the responsibility of mass producing plastic components to meet the rapidly rising market demand as a multitude of different types of consumer products including medical, electronics and automobile. To sustain in the market it is required to produce quality products at least price. The effective process for mass production of plastic products is injection moulding. Injection moulding has high efficiency, largest yield and highest dimensional accuracy among all the processing methods. More than 1/3 of all thermoplastic materials are injection moulded and more than half of all polymer processing equipments are for injection moulding.

The process starts with a selected plastic compound which is normally supplied as pellets. These pellets are put into a hopper on the injection moulding machine and the pellets are then transferred to the electrically heated barrel. Inside the barrel, a screw is located and when the screw is rotating, the pellets are melted due to the heat generated by the friction between the barrel wall and the screw. The rotation of the screw feeds the partly molten pellets forward, and the screw is at the same time moved backwards by the accumulation of the melt in front of the screw tip. Up to 70% of the heat needed to melt the pellets is provided by this shear-induced heating, while the rest is provided by the heaters on the outside of the barrel. When the injection chamber is full with molten plastic, the rotation of the screw stops, and a valve is opened into the mild. The screw is pushed forward, and the melt flows through the nozzle, the sprue, and the runner system into the cavity. The cavity is the inverse of the desired shape of the part to be manufactured. The process parameters such as cycle time, fill time, cooling time, injection time, injection pressure, packing time, packing pressure, holding pressure, melting temperature, mould temperature and so on need to be optimized in order to produce finished plastic parts with good quality. Amongst these parameters melting temperature, injection pressure, packing pressure, packing time are paid attention by the researchers due to its significant influence on the tensile strength.

Since, experimenting by changing the parameter level one at a time leads to increase the number of experiment lengthy, simultaneously the cost. In this research Taguchi method is adopted to minimize the number the experiment as well as cost. It has been widely used for product design and quality optimization worldwide. There are several studies have been conducted on optimization plastic manufacturing process. Reference [1] studies the effects of process parameters for injection moulding on surface quality of optical lenses. They consider warpage, waviness and other response on their research. Reference [4] studied effect of reprocessing cycle on shrinkage and mechanical properties of acrylonitrile-butadiene-styrene, they found that as reprocessing cycle increased, shrinkage decreased, and tensile and flexural ultimate strengths increased. So larger the tensile strength lesser will be the shrinkage in product. Reference [2] considers the tea plate of plastic product. On their analysis, they consider the tensile strength by taking process parameters melting temperature, injection pressure, cooling time and Polycarbonate as a material. They found that as the melt temperature increases tensile strength increases. Analysis of injection moulding considers the short shot defect by taking parameters injection pressure, mould closing speed mould pressure, back pressure [3]. Reference [5] studied the effects of processing parameters on the appearance of weldlines by Taguchi experimental design method. Weldlines are obtained by the right door of copy machine which is modelled with three gates. The pictures of moulding products are taken by digital camera. They consider the melt temperature, injection pressure, injection velocity as main factors which affect the strength of material polyproplylene. They showed that injection velocity is main

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factor for the visibility of weld lines. Reference [6] studied two processing parameters injection velocity and injection pressure effect on tensile strength of plastic moulded part. They did their analysis on polyethylene material of plastic. They showed that injection pressure has significant factor which affect tensile strength of material and injection velocity has no effect on tensile strength. In the study of processing parameters on injection moulding process [7], they consider injection pressure, melting temperature, Cooling time, injection speed, mould temperature, holding pressure, holding time on tensile strength of injection moulded part. They found that holding pressure and melt temperature significantly affect the tensile strength of material. In the study of processing parameters on injection moulding process [8], they consider injection speed, injection pressure and melt temperature on tensile strength of Polypropylene material of plastic part. They found that melt temperature, injection pressure and injection speed affect tensile strength significantly. Reference [9] studied on micro injection moulding process. They consider injection pressure, injection temperature, holding time factor effect on the tensile properties of polypropylene material. They found as injection pressure increases tensile strength increases but as injection time increases tensile strength increases first then it decreases. Reference [10] studied holding pressure factor effect on tensile strength of metal injection moulding material part. They found that as holding pressure increases tensile strength of metal injection moulded part increases. Reference [11] studied of temperature effect on ABS material composites. They found that as the melting temperature, mould temperature increases tensile strength of composite material increases. Reference [12] studied of factor melt temperature, injection pressure, cooling time on tensile strength of polycarbonate material. They found that as melt temperature increases tensile strength of material increases.

Although numerous efforts have been made to map injection moulding process with Taguchi technique and the influence of the processing parameters on various responses have been studied. However, use of Taguchi technique on modelling of tensile strength of plastic product by injection moulding is rare. Moreover the use of this model on polypropylene material which has wide range of application in the plastic industry, make it special, is rare.

The scope of this study is focusing on the simulation of tensile strength on the raw materials including determination of the effective parameters that contribute to the response, the selection of the orthogonal arrays (OAs) and determination of the optimum parameter. The selection of the orthogonal arrays (OAs) depends on the level and parameter involved thus the 3 levels and 4 parameters were chosen. The chosen parameters and level influenced the type of orthogonal arrays and the Taguchi L27 orthogonal arrays were used. Finally, the optimum parameters were determined by exploiting S/N ratio..

II. METHODOLOGY

a. *Taguchi Method*

Taguchi method was developed by Dr. Genichi Taguchi of Japan. The objective of the method is to produce high quality product at low cost to the manufacturer. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters that affect process and the levels. Orthogonal Arrays (often referred to Taguchi Methods) are often employed in industrial experiments to study the effect ofseveral control factors.

b. *Signal-to-Noise Ratio (S/N Ratio)*

The experimental results are then transformed into a signal- to-noise (S/N) ratio. S/N ratio, which are 'Log' function of desired output serve as objective function for optimization, help in data analysis and prediction of optimal result. Taguchi recommends the use of S/N ratio to measure the quality characteristics deviating from the desired values. The S/N ratio for each level of process parameters is computed based on the S/N analysis. Generally, there are three categories of quality characteristic in the analysis of the S/N ratio, i.e. smaller-is-better, larger-is-better, and nominal-is-better. In the present experimental design, the higher-is-better type quality characteristics are used which is expressed as:

$$S/N = -10 \log_{10}(MSD) \quad (1)$$

For larger is better:

$$MSN = \frac{1}{n}\sum_{i=0}^{n}\frac{1}{y_i^2}$$

where; MSD = mean square deviation, y = observations, n=no. of tests in a trial.

Taguchi suggested a standard procedure for optimizing anyprocess parameters. The steps involved are

III. EXPERIMENTAL PLAN

A. Selection of Process Parameters and their Levels

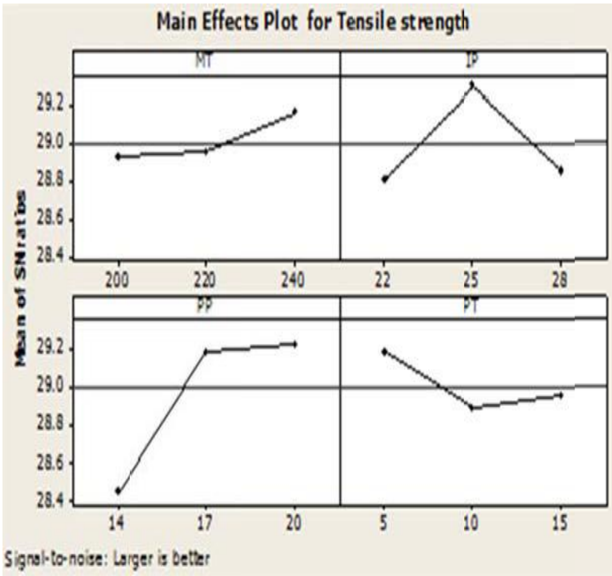

Fig. 1 Injection moulding machine

It is desirable to have three minimum levels of process parameters to reflect the true behaviour of output parameters of study. The process parameters are renamed as factors and they are given in the adjacent column. The levels of the individual process parameters/factors are given in Table 1:

Table.1 levels of the individual process parameters/factors

Parameter	Level 1	Level 2	Level 3
Melting Temperature (MT)	200	220	240
Injection Pressure (IP)	22	25	28
Packing Pressure (PP)	14	17	20
Packing Time (PT)	5	10	15

IV. EXPERIMENTAL RESULT AND DISCUSSION

As per experimental design a set of three levels assigned to each process parameter has two degrees of freedom (DOF). This gives a total of 8 DOF for four process parameters selected in this work. The nearest three level orthogonal array available satisfying the criterion of selecting the OA is L27 having 8 D

Fig. 2 Main effect plot for tensile strength

Four plots viz. normal probability plot, residuals vs fit, Histogram and residuals vs order. This layout is useful to determine whether the models meet the assumptions for analysis.

A. Response Effect for Signal-to-Noise Ratio of Tensile Strength

A greater value of S/N ratio is always considered for better performance irrespective of the category of the performance characteristics. The difference of maximum and minimum mean S/N ratio indicates the significance of process parameter, greater will be the difference, greater will be the

B. Effect on Tensile Strength

In order to see the effect of process parameter on tensile strength experiments were conducted using L27 orthogonal array .

Table .2 Response table for signal to noise ratio

Level	MT	IP	PP	PT
1	28.93	28.81	28.45	29.19
2	28.96	29.30	29.19	28.89
3	29.16	28.85	29.22	28.97
Delta	.23	.49	.77	.29
Rank	4	2	1	3

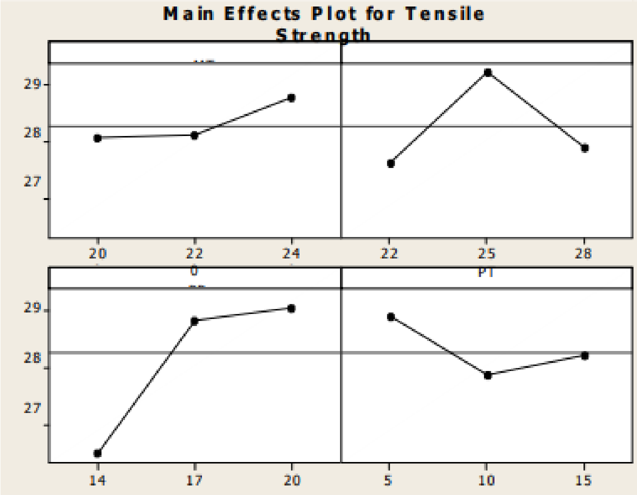

Fig. 3 Main Effect Plot for S/N ratio of Tensile strength

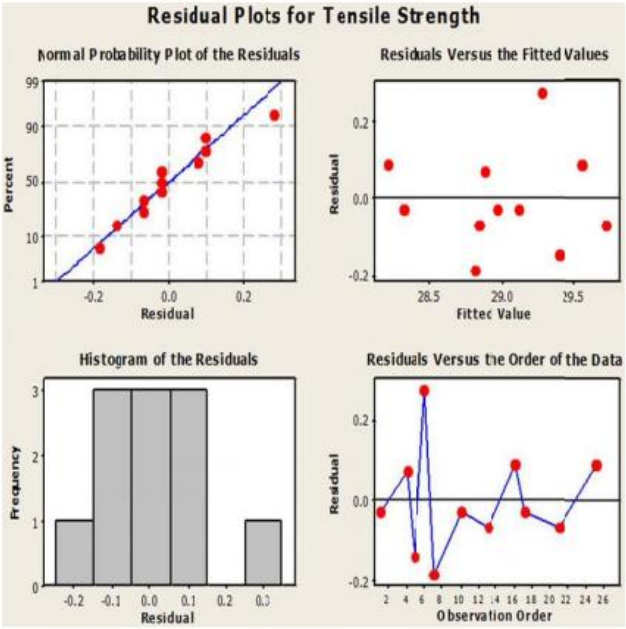

Fig. 4 Residual Plot of Tensile strength

V. CONCLUSION

Plastic injection moulding is a quite important field in manufacturing process. There are many plastic products that produced by the injection moulding process. The product that will produced will do experiment tensile strength. By using Taguchi method 27 trials have been run. The optimum parameter that can maximize the tensile strength are packing pressure etc. However, other factor are also have significant influence on the tensile strength.

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