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Optimization of Process parameters in Injection Moulding of Cam Bush using DFA and ANOVA

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Abstract—*Injection Moulding is a versatile manufacturing technique for forming of plastics. Present work is focused on optimizing the process parameters to obtain the better quality for Cam bush. Polymer Matrix Composites were used tofabricate Cam Bush. Cam bush is used as an indexing device in ON/OFF Load Tap changer device of high voltage transformer and serves as the connector between the indexing head and the power changing gears. Injection pressure, Injection Speed, Holding pressure is the input parameters which influence the quality characteristics of Cam Bush such as Shrinkage,Warpage and Surface Roughness.Cam bushes are produced according to Taguchi's experimental design(L27) and the response values are recorded.Thisdata are analysed and optimized by DFA.*

Keywords—*Cambush, SiO_2, Parameters, Shrinkage, Warpage and Surface Roughness.*

I. INTRODUCTION

Plastic injection moulding is extremely versatile method of producing parts and products. It is one of the preferred methods for manufacturing parts because it has multiple advantages over other manufacturing methods. Intricate shapes can easily be designed and manufactured which otherwise would have been too complicated and expensive to manufacture and also the high production rates make plastic injection molding more cost effective and efficient. In fields where parts need to be strong and durable, plastic injection has an option that other molding processes do not offer which is Polymer Matrix Composites, which are either fibres or fillers as reinforcements.

II. LITERATURE REVIEW

WeiTai Huang et al. [1], investigated the effects of processing parameters and design of mould on the warpage of auto-lock parts. Optimization has been done by Taguchi's design and Grey Relation Analysis. Dr. S.A.Pande et al. [2], has been done the study on the effect of Zinc and Polyaniline fillers on the physical and mechanical properties of Nylon.Zuzana Mičicováa et al. [3],presented paper on using inorganic materials as filler in the polymeric rubber blend. The effect of quantity of filler was evaluated from result of optimum cure time, rate coefficient of cure and physical-mechanical properties were compared with properties reference blend.

Ali Mazahery et.al. [4]studies on usage of lignocellulosic materials as reinforcing fillers where PP as the matrix and rice-husk flour as the reinforcing filler. Four levels of filler loading (10, 20, 30 and 40 wt.%) were designed. Mechanical properties of the composite according to the filler loading have been measured and analysed. Tensile strengths slightly decreased and Tensile modulus improved with increasing filler loading. Notched and unnotchedIzod impact strengths were lowered by the addition of filler.

A.B. Humbeet al. [5] analyses input processing parameters like melt temperature, Injection pressure, holding pressure and cooling time. The cycle time and tensile strength are obtained through experiments according to Taguchi's L-9 Orthogonal Array. Experimental results are analyzed the effect of each parameter on the cycle time and tensile strength to achieve minimum cycle time and maximum tensile strength through RSM.

H. Radhwan et al. [6], studies optimization of shrinkage in injection molding part by using Taguchi Method. Process parameters selected which is the mold temperature, melt temperature, packing pressure, packing time, and cooling time. The number of simulation is based on the three level of L27 OA. The S/N ratio and ANOVA are utilized to identify the significant factors contribute to shrinkage. Mithun V Kulkarni et al. [7],investigates the influence of $Casio_3$ on the impact properties of Nylon6 and its composites. Reinforced with weight percentages (1%, 3% and 5%) of Casio3. The impact tests wereconducted on the samples at 3 different drop and 3 different drop. Results showed that $Casio_3$ significantly improves the impact strength of the polyamides.Wen-Chin Chen et al. [8], focuses on Melt temperature, injection velocity, packing pressure, packing time, and cooling time as initial process parameters in the experiment. Back-Propagation Neural Network (BPNN), Genetic Algorithm (GA), and combination of Particle Swarm Optimization and Genetic Algorithm (PSO-GA) are used in this study to find optimum parameter settings. ANOVA is used to determine significant factors of the control parameters.

LalitGuglani et al. [9] studies the Composites of Nylon 66 with different proportions of microparticle Al2O3. The sliding wear and mechanical properties of 2 to 8 wt.% Nylon 66–Al2O3 were investigated. Lowest wear is exhibited by 2 wt.% Al2O3–Nylon 66 composite. The lowest friction coefficient is also observed for 2 wt.% Al2O3-Nylon 66 composite.

ShiboWang et al. [10], investigated Mechanical properties of nylon composites filled with zinc oxides. Influence of ZnO particles and ZnO whiskers filling on the friction and wear behavior of nylon 1010 (PA1010) composites under dry friction condition were observed. Experimental results show that Hardness, tensile strength and scratch coefficient of composites are increased by the addition of ZnO particles and ZnO whiskers. Filler shape has little effect on the friction coefficients of nylon-based composites. The wear rates of composites are strongly dependent on filler shape and filler content. Particle-filled composites exhibit the lower wear rates than whisker-filled compositeswhen the content of filler is lower than 10 wt.%.

Ramkumar Ramakrishnan1 et al. [11],did a study the effect of various injection molding process parameters on thevolumetric shrinkage of a acetal polymer gear part, optimizing the process parameters through Taguchi orthogonal array design and analysis of variance (ANOVA) method.. Taguchi optimization and ANOVA method were used in determining the most significant moldingprocess parameter that affect volumetric shrinkage and **o**ptimizingthe control parameters for achieving minimum part shrinkage.

The information is very helpful in finding the research gaps from the literature survey. There has been many types of fillers for Nylon has been studied. And there is much scope in analysing the responses like shrinkage & warpage. The Research can be extended to other types of Nylon. In this study, the material has been selected as GFN with SiO_2 as filler material.

Table 1. Influential parameters and their levels

Sl.No.	PARAMETERS	L 1	L 2	L 3
A	Size of Reinforcement particle	4	7.5	10
B	Percentage of Reinforcement	5	10	15
C	Injection Speed (mm/sec)	35	45	55
D	Injection Pressure (bar)	70	80	90
E	Holding Pressure (bar)	30	40	50
F	Injection time (sec)	2.5	3	3.5
G	Cooling time (sec)	20	30	40
H	Nozzle temperature (^{0}C)	250	270	290

III. METHODOLOGY

Mould for Cambush has been designed and fabricated by Selvaraj.S and P. Venkataramaiah, 2013 as shown in fig.1.a. The 3D model of Cambush is shown in fig.1.b.The influential process parameters and their levels are shown in table.1. Design of experimentation is based on Taguchi's L27 OA for the experimentation. Glass filled Nylon (33% GF) has been selected as base material and Silicon dioxide as reinforcement.

Fig.1:Mould for Cambush

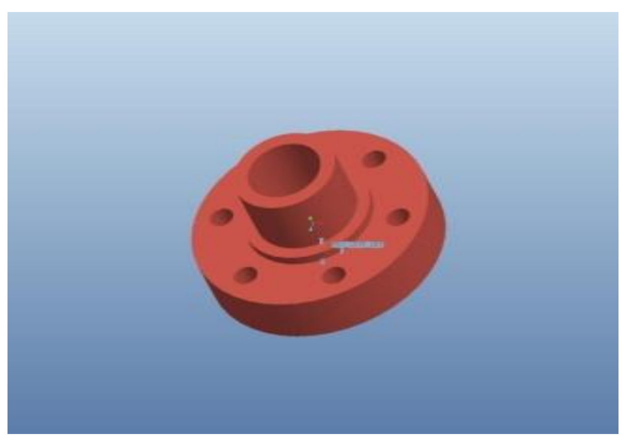


Fig.2: 3D drawing of Cambush

Injection moulding machine is used to fabricate the 27 components of Cambush (fig.2). The design of experiment for present study is depicted in Table 2. The output parameters known as Shrinkage is measured under 3D CMM and the volume is found on Pro-E design software. Warpage of Cambushes is measured by averaging the dimensional variation at thich section and thin section. Surface Roughness is measured using the Mitutoyo- Talysurf.

Table 2. Experimental Design

Exp.No.	A	B	C	D	E	F	G	H
1	1	1	1	1	1	1	1	1
2	1	1	1	1	2	2	2	2
3	1	1	1	1	3	3	3	3
4	1	2	2	2	1	1	1	2
5	1	2	2	2	2	2	2	3
6	1	2	2	2	3	3	3	1
7	1	3	3	3	1	1	1	3
8	1	3	3	3	2	2	2	1
9	1	3	3	3	3	3	3	2
10	2	1	2	3	1	2	3	1
11	2	1	2	3	2	3	1	2
12	2	1	2	3	3	1	2	3
13	2	2	3	1	1	2	3	2
14	2	2	3	1	2	3	1	3
15	2	2	3	1	3	1	2	1
16	2	3	1	2	1	2	3	3
17	2	3	1	2	2	3	1	1
18	2	3	1	2	3	1	2	2
19	3	1	3	2	1	3	2	1
20	3	1	3	2	2	1	3	2
21	3	1	3	2	3	2	1	3
22	3	2	1	3	1	3	2	2
23	3	2	1	3	2	1	3	3
24	3	2	1	3	3	2	1	1
25	3	3	2	1	1	3	2	3
26	3	3	2	1	2	1	3	1
27	3	3	2	1	3	2	1	2

IV. TESTS AND RESULTS

A. Measurement of Shrinkage

Dimension of each specimen have been measured using 3D Coordinate Measuring Machine(700x1000x800mm)with a machine resolution of 0.1 micron at Unique Measurement Services. Based on the dimensions of the specimen, the Volume of each specimen has been calculated from the Pro-E 5.0 model. Percentage of Shrinkage of the each specimen has been calculated using the formula

$$\%\text{of shrinkage} = \frac{(volume\ \ of\ the\ mould\ - volume\ \ of\ the\ specimen\ )}{volume\ \ of\ the\ mould}$$

The calculated value of percentage of shrinkage is recorded for each experiment as in Table3.

Fig.3. Measuring under CMM

Fig.4.Measuring Roughness

V. MEASUREMENT OF WARPAGE

Dimension of outer diameter at thin section and thick section have been measured using 3D Coordinate Measuring Machine (700x1000x800mm) with a machine resolution of 0.1 micron at Unique Measurement Services, Chennai. Based on the dimensional variations of OD of the specimen, the warpage of each specimen has been calculated from averaging the above two variations.

VI. MEASUREMENT OF SURFACE ROUGHNESS

The measurement of Surface Roughness has been done by stylus type TalySurf (Mitutoyo made).The testing has been done as shown in fig 1.4. The calculated value of Ra is recorded for each experiment as given in Table 3.

VII. OPTIMIZATION

Optimization procedure using Desirability Function Analysis

a) Calculate the individual desirability index (d_i)for each response with the help of the formula proposed by Derringer and Suich(1980). There are usually three forms of desirability functions according to the nature of response characteristic. But, as the 3 response parameters considered here are must be minimised. Hence, Smaller-the-Better

$$d_i = \begin{cases} 1, & \hat{y} \le y_{min} \\ \left(\dfrac{\hat{y} - y_{max}}{y_{min} - y_{max}} \right), & y_{min} \le \hat{y} \le y_{max}, \quad r \ge 0 \\ 0, & \hat{y} \ge y_{max} \end{cases}$$

is used.

The Composite desirability (d_g) value is the combined form of all individual desirability indexes of all responses.

$$d_G = \sqrt[w]{\left(d_1^{w1} * d_2^{w2} \ldots\ldots\ldots * d_i^{wi} \right)}$$

d_i = individual desirability index of response $y_i w_i$ = the weight assigned to the response y_i

w = the sum of all individual weights.

b) Determine the optimum parameter and its level combination. The higher the composite desirability index denotes the better product quality. Hence, the parameter effect and the optimum level of each controllable parameter are estimated.

a) To identify the significance of parameters, ANOVA is to be performed as it measures the relative significance of parameters. The total sum of square values is used to measure the relative contribution of parameters.

Table 3. Experimental results and their Individual desirability values

S.No	**Warpage (mm)**	**Shrinkage (%)**	**Ra (µm)**	**d_i Warpage**	**d_i Shrinkage**	**d_i R_a**	**d_G**
1	0.26	4.032	0.45	0.62	0.47	0.28	0.444
2	0.17	3.863	0.48	0.76	0.52	0.21	0.446
3	0.32	4.098	0.27	0.55	0.45	0.76	0.561
4	0.02	4.011	0.45	0.98	0.47	0.28	0.510
5	0.20	4.100	0.48	0.72	0.45	0.21	0.413
6	0.04	4.266	0.56	0.94	0.39	**0.00**	**0.000**
7	0.04	4.362	0.35	0.95	0.36	0.55	0.553
8	0.03	4.512	0.37	0.96	0.32	0.50	0.510
9	0.01	4.506	0.35	0.98	0.32	0.55	0.531
10	0.01	4.407	0.38	0.99	0.35	0.47	0.527

11	0.02	4.237	0.41	0.98	0.40	0.39	0.526
12	0.04	4.857	0.37	0.95	0.21	0.50	0.432
13	0.32	4.815	0.4	0.54	0.22	0.42	0.354
14	0.01	3.498	0.43	**1.00**	0.63	0.34	0.606
15	0.51	4.234	0.4	0.26	0.40	0.42	0.361
16	0.12	2.961	0.43	0.83	0.80	0.34	0.629
17	0.25	2.702	0.38	0.65	0.88	0.47	0.669
18	0.62	4.296	0.45	0.10	0.38	0.28	0.241
19	0.26	3.973	0.46	0.63	0.48	0.26	0.438
20	0.34	4.178	0.37	0.51	0.42	0.50	0.473
21	0.54	2.340	0.46	0.22	**1.00**	0.26	0.425
22	0.70	5.538	0.38	**0.00**	**0.00**	0.47	**0.000**
23	0.53	4.245	0.18	0.24	0.40	**1.00**	0.457
24	0.54	4.409	0.23	0.22	0.35	0.86	0.404
25	0.61	4.195	0.51	0.12	0.42	0.13	0.206
26	0.68	4.324	0.28	0.01	0.38	0.73	0.186
27	0.32	2.384	0.32	0.55	0.98	0.63	0.725

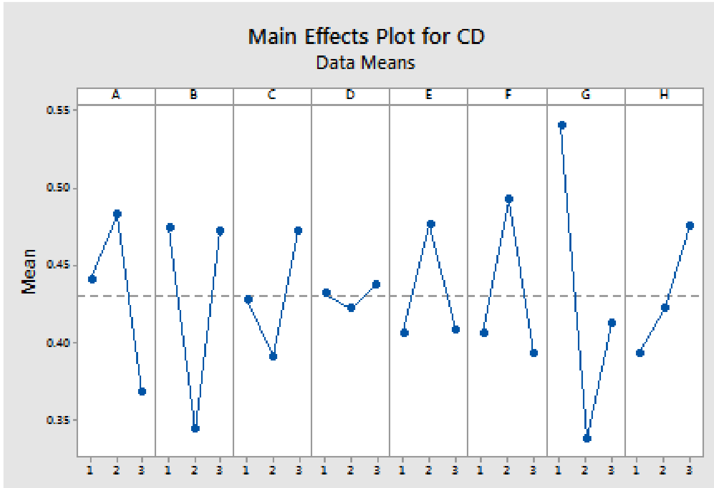
Table 4: Factor effects for composite desirability (DG)

	L1	**L2**	**L3**	**Optimum values**
A	0.441	**0.483**	0.368	A2
B	**0.475**	0.345	0.472	B1
C	0.428	0.392	**0.472**	C3
D	0.432	0.422	**0.438**	D3
E	0.407	**0.476**	0.409	E2
F	0.406	**0.493**	0.393	F2
G	**0.540**	0.339	0.413	G1
H	0.393	0.423	**0.476**	H3

Table 5. ANOVA for Composite desirability

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**	**Contribution (%)**
A	2	0.060363	0.030181	0.92	0.431	7.376
B	2	0.099366	0.049683	1.51	0.267	12.142
C	2	0.029454	0.014727	0.45	0.651	3.599
D	2	0.001111	0.000556	0.02	0.983	0.136
E	2	0.028218	0.014109	0.43	0.663	3.448
F	2	0.052677	0.026338	0.80	0.476	6.437
G	2	0.186910	0.093455	2.84	0.105	22.839
H	2	0.031372	0.015686	0.48	0.634	3.833
Error	10	0.328920	0.032892			
Total	26	0.818391				

Table 6: Main effects plot of Composite desirability



VIII. CONCLUSION

In the present work, Shrinkage, Warpage and Surface roughness has been calculated for each component of CamBush which is made from Poymer composite consisting GFN (33%) as base material and SiO2 as filler in proportions of (5, 10, 15wt%).

1. Direct mixing of Filler powder to base material has been flexible and simple.
2. From the mean values of composite desirability, the optimal combination of process parameters is: A2-B1-C3-D3-E2-F2-G1-H3.Composite Desirability value improved from 0.725 to 0.757
3. From ANOVA, Shrinkage has been effected mostly by Injection Pressure (28.98%) followed by Cooling time (25.77%) and Percentage of reinforcement (9.96%) with minimum value of 2.341%.
4. Warpage has been influenced mostly by Size of reinforcement particle (48.78%) followed by Injection Speed(11.46%) and Injection Pressure (6.47%) with minimum value of 0.0115mm.
5. From ANOVA, Surface Roughness has been effected mostly by Injection Pressure (30.50%) followed by Cooling time (13.80%) and Size of reinforcement particle (10.72%) with minimum value of 0.180.

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