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Thermal and Cfd Analysis of Plastic Switch Box Base to Find Out the Optimum Shrinkage Value

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Abstract— *Injection Molding is a one of the most Conspicuous processes for producing the plastic Items. A contextual analysis on plastic Electrical switch box is considered to Research on the optimization of process parameters (temperature, pressure, and time). It is carried out for the Injection Molding machine. Quality of characteristic (shrinkage) of the injection molding product is made by Polycarbonate material is calculated by using L-9 Taguchi Array for Design of experiment. Signal-to-noise ratio and Analysis of variance (ANOVA) were used to calculate the influence of these parameters of the Shrinkage value. A multiple linear regression equation has been developed and through the finding predicted Shrinkage value. An Analytical approach is (Thermal and CFD analysis), component design, cooling profile, assembling, discussed to solving the Shrinkage problem. Experimental data and Analytical results are Discuss to investigate the significant Shrinkage value.*

Keywords–*ANOVA Analysis, Thermal and CFD Analysis, Injection molding, Taguchi method, Shrinkage.*

I. INTRODUCTION

Injection molding is a manufacturing process used to produce the plastic components. The process is by means of foaming a shape by forcing molten plastic material under pressure into the mould. Where it is then cooled, solidified and subsequently released by opening of the two halves of the mould. For efficient use of machine control parameters such as injection speed, injection pressure, holding pressure, melting temperature, holding time and cooling time which are need to be optimized in order to produce the finished plastic component with good quality and low be shrinkage. The Present work is to find out the suitable conditions of injection molding process and to optimize the injection molding process parameters for the optimum shrinkage value of the plastic switch box. The polycarbonate material is used for the manufacturing of plastic switch box.

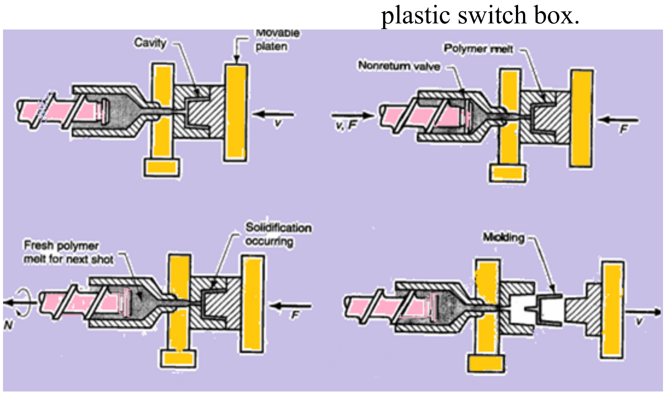

Fig 1 -Injection Molding Machine process

Thermal analysis is done on the plastic switch box to determine variation in temperature distribution to analyze the thermal properties by varying molten material and thickness of the component. Transient thermal analysis used to determine the temperature, molten material behavior and thermal quantities with respect to time. Computational fluid dynamics is used to Numerical analysis and data structure to solve and analyze problems that involve in the particular problem. CFD analysis is used to calculate material filling time, pressure and liquid fraction values. In Taguchi Method, the word "optimization" implies "determination of best levels of control factors". This log functions of desired output characteristics. This method is used to keep the variance in the output very low even in the presence of noise inputs. "L-9 Orthogonal Array" is used to design the experiment. Further optimization is achieved by using Signal-to-Noise ratio factor are smaller-is-better, larger-is-better and nominal-is-better. It is a measure of performance aimed at developing quality products and processes insensitive to noise factors. In the present work, a statistical approach based on Taguchi and ANOVA techniques was adopted to determine the degree of importance of each process parameter on the variance of Shrinkage value using in the Polycarbonate material.The Signal to Noise (S/N) ratio, mean value and Regression Experiment, were used to optimize the

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levels and to point out the impact of the process parameters on shrinkage.

II. DESIGN REQUIREMENT AND USES

The 3D model of component Electrical Switch Box Base model is designed in the parametric software UNIGRAPHICS. The component is one of the main parts used in the PCB controlling and monitoring of the switches. This device system is devolved to reduce the House hold power waste and Consequent accidents. Addition channels are designed to Adjustment of the Material filling (wall thickness is 2.5mm) and cool the molten Plastic material.

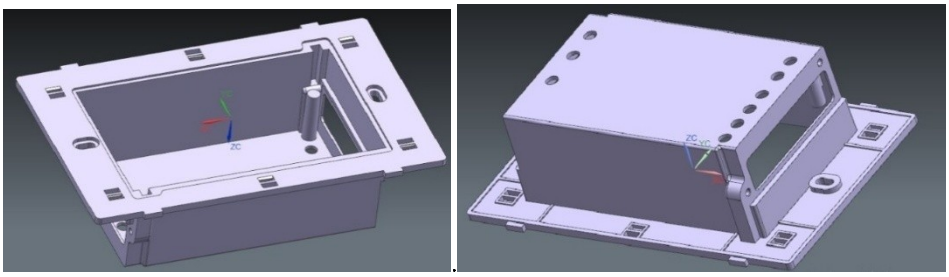

Fig 2 - Top view and Bottom view of model

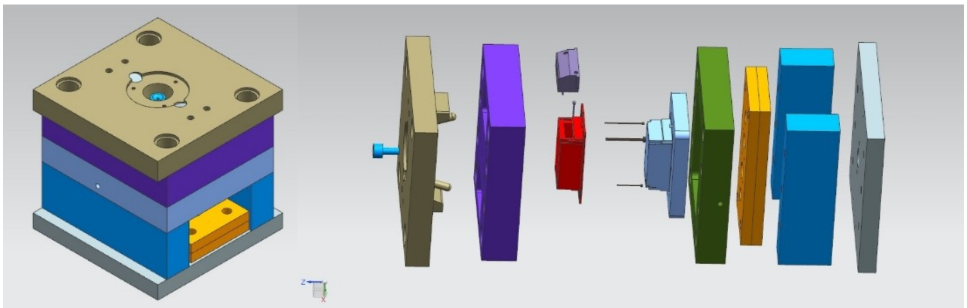

Fig 3- Mould assembled and Explode View

III. THERMAL ANALYSIS OF HEAT TRANSFER RATE

Thermal Analysis is used to determining the Temperature profile and computer fluid simulation values of existing model. Transient thermal analysis Conducted to the four different types of materials (Polyvinylchloride, Nylon, ABS and polycarbonate) using Melting temperature is 300°c (A), normal water Temperature 30°c (B) and Atmospheric air temperature is 22°c (C), used to finding the heat flux and temperature distribution profiles. Results were provided to verify the best material, better understanding and developing a good product to having better life.

Table1 – Material Properties

Material name	Density (p) – g/cm^3	Thermal conductivity (K) - W/mk	Spefic Heat (Cp) - J/K kg
Polycarbonate	1.2-1.22	0.19-0.22	1200
ABS	1.0-1.05	0.14	1300
PVC	1.3-1.45	0.12-0.25	1000-1500
Nylon	1.15	0.24-0.28	1700

3.1 Specific Capabilities on Analysis

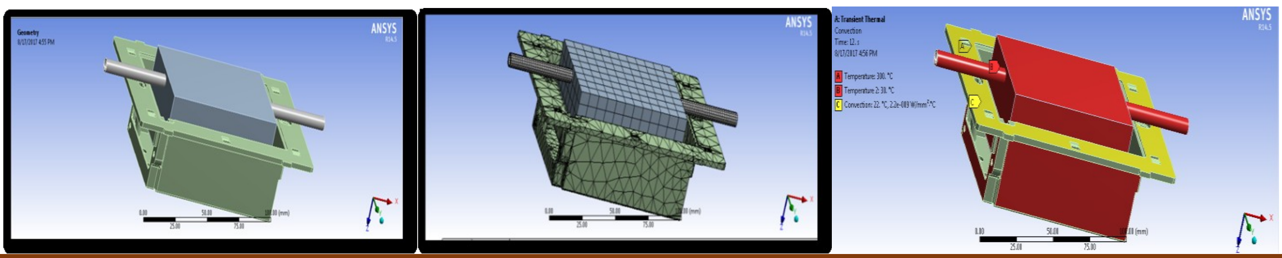

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Fig 4- Imported, Meshed and Boundary conditions model

Case :1 material –polycarbonate

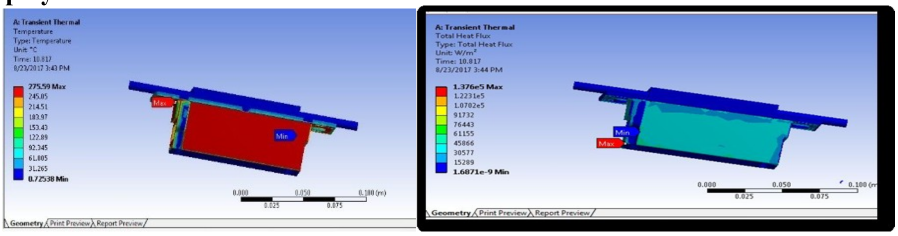

Fig 5 - Temaparature and Heat flux results from at 10,12,14 seconds

Case :2 material –ABS

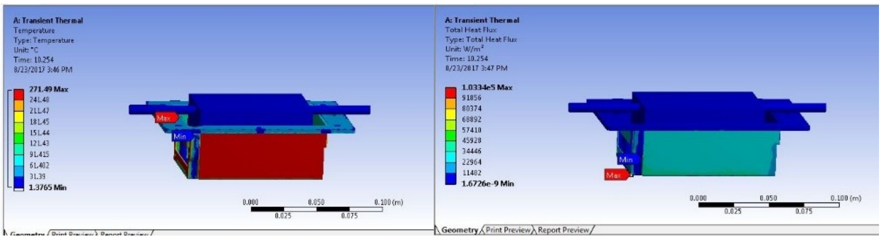

Fig 6 - Temaparature and Heat flux results at 10,12,14 seconds

Case : 3 material –Nylon

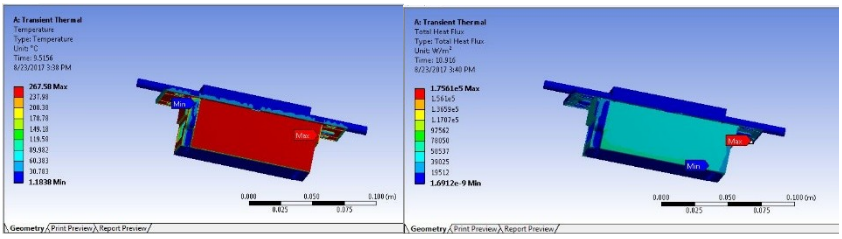

Fig 7- Temaparature and Heat flux results at 10,12,14 seconds

Case : 4 material –PVC

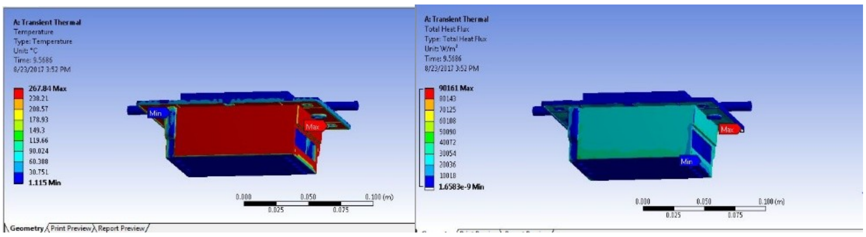

Fig 8 - Temaparature and Heat flux results at 10,12,14 seconds

Thermal analysis is done for the four materials. The material for the original model is consideration of their densities and thermal conductivity. By observing the thermal analysis results, thermal flux is more for Nylon than other three materials, but compare to polycarbonate it is having low shrinkage and stable for different atmospheric temperatures. So we can conclude that using Polycarbonatematerial and taking wall thickness thickness of 2.5mm is better.

Table 2 - Analytical results listed by using Transient analysis

Material	Time	Temperature		Heat Flux
		Min	Max	
PC	10	0.725	275.58	1.375e5
	12	1.223	285	1.4196 e5
	14	4.4409	303.51	1.5189 e5
ABS	10	1.376	271.69	1.033 e5
	12	0.842	279.45	1.061 e5
	14	0.339	302.16	1.1528 e05

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Nylon	10	1.1838	267.58	1.7976 e005
	12	1.8436	283.68	1.8053 e005
	14	2.9082	301.12	1.924 e005
PVC	10	1.115	267.84	90161
	12	1.8575	284.17	90466
	14	3.0726	300.99	96222

The material for the original model is consideration of their densities and thermal conductivity. By observing the thermal analysis results, thermal flux is more for Nylon than other three materials, but compare to polycarbonate, It is having a wide range of advantages such as high strength-to-weight ratio, high transparency, high flexibility, recyclability, corrosion resistance, and fast processing times, low shrinkage rate and stable for different atmospheric conditions. So it can be conclude to using Polycarbonate material and taking wall thickness of 2.5mm is better.

3.2CFD Analysis

An analytical approach is discussed by using in Ansys Fluent to analyze the behavior of molten metal at different stages of time by observing the results of temperature variations, pressure variations and liquid fractions by applying the input parameters.

Table 3 - Polycarbonate Material Properties and Using Parameters

Property	Value
Density (g/cm3)	1.20-1.22
Specific Heat (J/kg K)	1200
Thermal Conductivity (W/mK)	0.19 – 0.22
Viscosity (cm³/g)	49
Molten Meterial Temperature (K)	573
Velocity (m/s)	30
Fill Time (Secs)	10, 12, 14
Die Temperature (K)	70,90,120

Case a – Temperature – 573 K, Fill time – 14secs

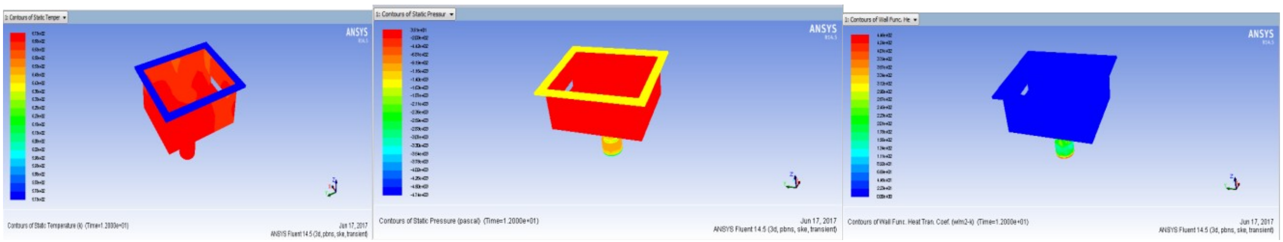

Fig 9 - Static Temperature, Pressure and Liquid Fraction at 14seconds

Case b – Die temperature – 573K, Fill time – 12secs

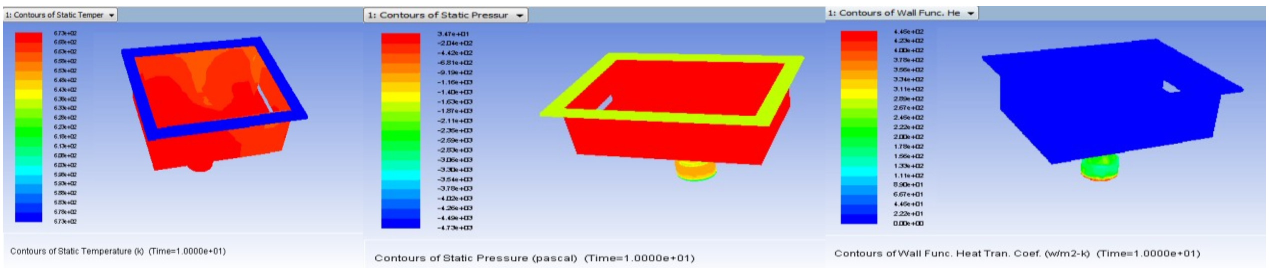

Fig 10- Static Temperatures, Pressure and Liquid Fraction at 12seconds

Case c – Die temperature – 573K, Fill time – 10secs

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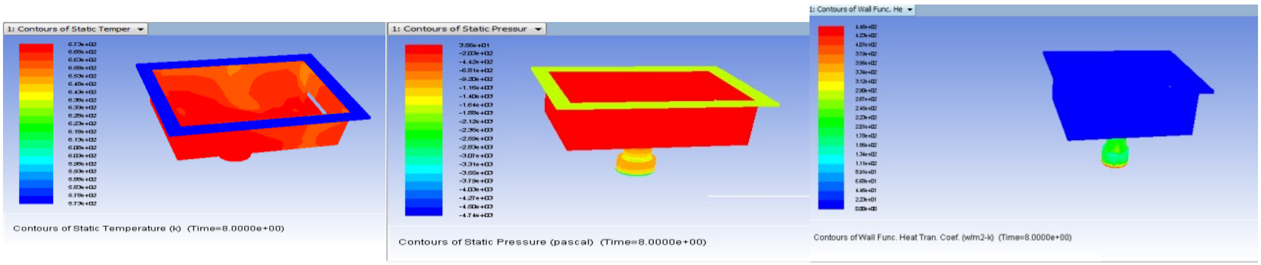

Fig 11- Static Temperature, Pressure and Liquid Fraction at 10seconds

Table 4 - Results of Pressure at different filling times and die temperatures

Filling time (secs)	Tempserature (K)	Pressure (Pa)
14	573	3.51 e+01
12	573	3.56 e+01
10	573	3.47 e+01

In this Results, the optimum filling time, injection pressure and die temperature for better solidification of the filling material are analyzed by taking the input parameters molten metal temperature, velocity at sprue , injection time and die temperature.Solidification analysis is done in Ansys CFD. From the results, the following conclusions can be made:
The better solidification occurs at 12secs injection time, 3.56 e^{+01} Pa pressure and 300^{0}C die temperature. Solidification of molten metal at high pressure and less die temperature

IV. TAGUCHI ANALYSIS

4.1 DOE of Taguchi Method

Nine setoff Experiment has been designed for selected process parameters to do this work- Pressure (A), Temperature (B) and Cycle time (C)as per the Taguchi L9 Array design system. The signal to noise ratio (S/N ratio) is used to measure the sensitivity of the quality characteristic being investigated in a control manner. In this Taguchi method the term Signal represents the desirable effect (Mean) and Noise Represents the Undesirable effect (Signal Disturbance). The equation of "smaller-the-better" was selected for the calculation of S/N ratio.

$$S/N = -10*\log10 (\Sigma (Y2)/n))\ldots\ldots\ldots\ldots (1)$$

Table 5 - The Shrinkage values measured from the experiments and their corresponding S/N ratio and, Mean value

S.no	Pressure	Temperature	Cycle time	Shrinkage-1	Shrinkage-2	S/N ration	Mean
1.	50	280	40	0.6116	0.6356	4.10027	0.6236
2.	50	290	45	0.6207	0.6247	4.11438	0.6227
3.	50	300	50	0.6457	0.6497	3.77248	0.6477
4.	55	280	45	0.6051	0.6041	4.37063	0.6046
5.	55	290	50	0.6418	0.6468	3.81817	0.6443
6.	55	300	40	0.8005	0.8095	1.88395	0.8050
7.	60	280	50	0.6622	0.6952	3.36388	0.6787
8.	60	290	40	0.6369	0.6869	3.57796	0.6619
9.	60	300	45	0.8094	0.8394	1.67580	0.8244

4.2 Analysis of Variance

Analysis of simulation results of shrinkage through design of experimental (DOE) are carried out with analysis of variance (ANOVA), it is used to determining the factor significantly affecting the shrinkage. The ANOVA contains a table consisting of degrees of freedom (DF), adjusted sum of squares (SS), adjusted mean of squares (MS), F-values (F), probability (P) values and percentage of contributions. Statistical significance to the response (here, shrinkage) is evaluated by the P-values and F-values of ANOVA shown in table 6.

Table 6 - Analysis of Variance for S/N Ratio, using Adjusted SS for Test

Source	DF	Adj SS	Adj MS	F-Value	P- Value
Regression	3	0.034149	0.011383	3.82	0.092
Pressure	1	0.008855	0.008855	2.97	0.145
Temperature	1	0.023650	0.023650	7.93	0.037
Cycle time	1	0.001643	0.001643	0.55	0.491
Error	5	0.014907	0.002981	-	-
Total	8	0.049056	-	-	-
Shrinkage 0.0546023, R2=69.61%, R2(Adj), =69.61%					

4.3 Linear Regression Model Analysis

Linear Regression uses Least Squares to calculate the minimum error between the actual values and the predicted values. The response variable is the shrinkage (S), while the predictors are mold Injection pressure (A), melt temperature (B) and Cycle time(C). Using multiple regression analysis, the correlation between the factors and the parametric characteristic is presented in equation (1),

Shrinkage(S) = -1.424+ 0.00768 x (A) +0.00628x (B) - 0.00331x (C)….…. (2)

V. RESULTS AND DISCUSSIONS

The response of the table 7 is give the best set of combination parameter can be determined by selecting the level with highest value for each factor. As the result the optimal process parameters of polycarbonate material is A1, B1and C3 i.e. 3.996,3.945 and 3.652.The graph represent to the Better performance of processes parameters are represent at pressure 50 Psi. Temperature 280 °C, and cycle time is 50 seconds.

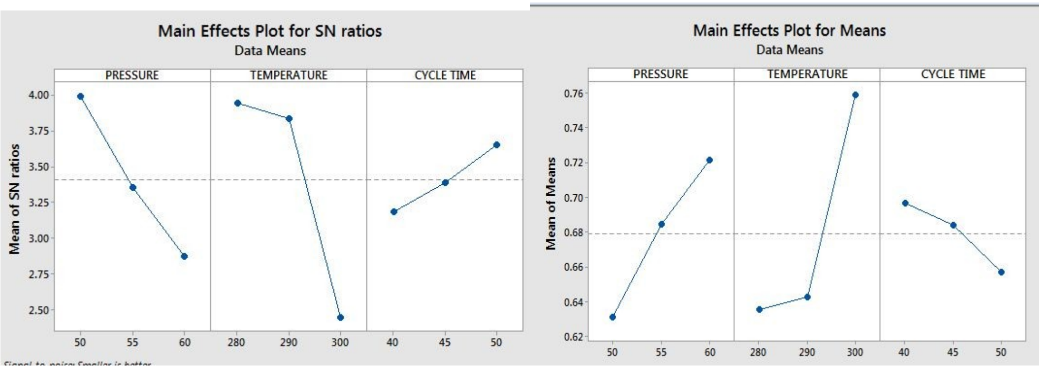

Fig 12 - Effect of Injection Molding machine parameters on force for S/N ratio and Means

Table 7 - S/N ratio process parameter

Level	Pressure	Temperature	Time
1	3.996	3.945	3.187
2	3.358	3.837	3.387
3	2.873	2.444	3.652
Delta	1.123	1.501	0.464
Rank	2	1	3

The response of the table 6.1 is give the the best set of combination parameter can be determined by selecting the level with highest value for each factor. As the result the optimal process parameters of polycarbonate material is A1, B1and C3 i.e. 3.996,3.945 and 3.652.The graph represent to the Better performance of processes parameters are represent at pressure 50 Psi. Temperature 280 °C, and cycle time is 50 seconds.

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Comparison was carried out between the Shrinkage values from the model developed in the present work (Equation 2) and, with the values obtained experimentally. From the analysis of the referred table we can observe that the calculated error varies from 1.83% to 12.22%.

Table8 - Predicted and Experimental Shrinkage values through Evaluate the Error factor

Predicted value	Experimental value	Error %
0.586	0.6 116	4.18
0.6323	0.6207	1.83
0.6785	0.6457	4.83
0.63345	0.6051	4.47
0.6541	0.6418	1.88
0.750	0.8005	6.30
0.6297	0.6622	4.90
0.7256	0.6369	12.22
0.7719	0.8094	4.63

A Small Difference between the Experimental and Analytical is 0.00116mm.this indicates that the experiment value is close to the Analytical value. Regression Equation is used to minimize the actual and predicted values to draw the best possible regression curve for the best prediction accuracy

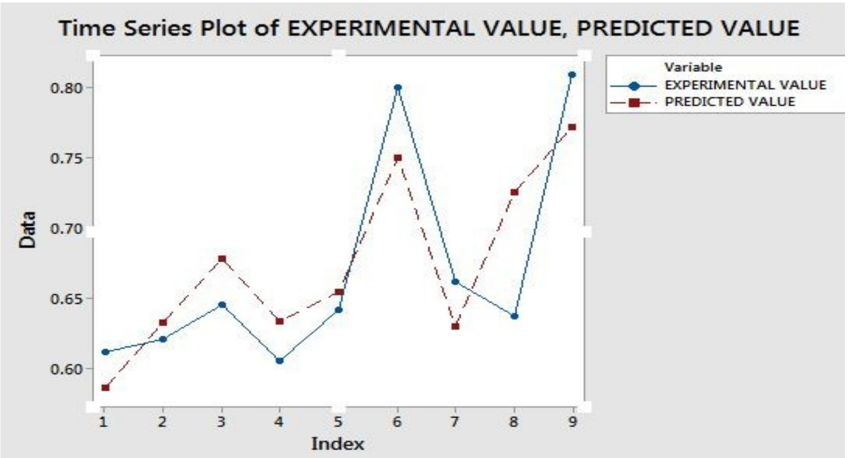

Figure13- Comparison test between Experimental values and predicted values

VI. CONCLUSION

The optimum filling time, injection pressure and die temperature for better solidification of the filling material are analyzed by taking the input parameters for molten metal (Pc) is consider to take temperature, Pressure, and Cycle time. Solidification analysis is done in Ansys based on result polycarbonate material is selected and optimum filling time (12 seconds) is calculated.

From the ANOVA and Taguchi L-9 results, the following conclusions can be made:

a. The better solidification occurs at 50 sec injection time, 50 Psi pressure and 280°C material melting temperature. Solidification of molten metal at high pressure and less die temperature and less cycle time.
b. The optimum shrinkage value is finding by using Regression Equation i.e. 0.6323mm.

These parameters can be applied practically to the experimental investigation. From this work, trial and error methods in manufacturing process of pressure injection molding can be avoided thereby reducing the total cycle time and also Minimize the material wastage in Production process.

VII. REFERENCES

[1] Prof.S.B.Khedkar, Prof.R.D.Thakre, “Study of Implementing 5S Techniques in Plastic Moulding”, International Journal of Modern Engineering Research (IJMER), Vol-2, Sep-2012.

[2] Mr.M.G.Rathi, Mr.Manoj Damodar Salunke,“Analysis of Injection Moulding Process Parameters”, International Journal of Engineering Research & Technology (IJERT), Vol-1, Oct- 2012.

[3] JohnVlachopoulos and David Strutt, “Basic heat transfer and some applications in polymer processing”, Vol- 2, Pages 21-33, Spet-2002.
[4] Allwin Arulanandan, K Ramesha.N,“Mould flow and structural analysis of injection mould tool for hooter body cover component”, International Journal of Research in Engineering and Technology (IJERT), Vol -04, May-2015.
[5] Alireza Akbarzadeh and Mohammad Sadeghi, “Parameter learn in Plastic Injection Molding approach utilizing Statistical approaches and IWO Algorithm”, Worldwide Journal of Modeling and Optimization, Vol-1, No- 2, June 2011.
[6] Prof. Patil Satish, Prof.Shinde, Prof. Borkar,“Design & analysis of plastic injection mould utilising nx-ug & delcam software”, international journal of strengthen in research in science and engineering, vol-5.
[7] H. Radhwan, M. T. Mustaffab, “An Optimization of Shrinkage in Injection Molding materials by using using Taguchi process”, Malaysia Journal of developed study in utilized Mechanics, Vol- 10, No- 1. 2015.
[8] Kalpesh s.Kamble and baliram jadhav,“Investigation and analysis of the energetic reasons to deal with the defect in plastic injection Molding procedure proceedings”,7th IRF international convention, Pune, India,April-2014.
[9] S. Kamaruddin, Zahid, A. Khan, S. H.Foong,“Application of Taguchi process within the Optimization of Injection Moulding Parameters for Manufacturing merchandise from Plastic mixtures”, IACSIT worldwide Journal of Engineering and technology, Vol-2, No-6, Dec- 2010.
[10] Z. Shayfull, M.F.Ghazali1, M. Azaman, S.M. Nasir,“Outcome of differences Core and Cavity Temperature on Injection Molded section and decreasing the Warpage by Taguchi system”, Worldwide Journal of Engineering & technological know-how IJET-IJENS Vol-10 No- 06, Dec- 2010.
[11] Vaatainen, pentti, “Effect of processing parameters on quality of injection molded parts using Taguchi parameter design method” plastic Rubber Compos1994:21:2117.
[12] Z.Shayfull,M.F.Ghazali,“Effect of Differences Core and Cavity Temperature on Injection Molded Part and Reducing the Warpage by Taguchi Method”, International Journal of Engineering & Technology IJET-IJENS Vol-10, No-06, Dec- 2010.
[13] Tom Kimerling,“Injection molding cooling time Reduction and thermal stress Analysis”, University of Massachusetts, Amherst MIE 605, Finite Element Analysis Spring 2002.
[14] K. Krishnaiah, P.Shahabudeen,“Applied design of experiment and Taguchi method”, PHI learning private limited, Delhi-110092. 2013.
[15] Alireza Akbarzadeh, Mohammad Sadeghi,“Parameter Study in Plastic Injection Moulding Process using Statistical Methods and IWO Algorithm”, International Journal of Modeling and Optimization, Vol-1, No. 2, June- 2011.
[16] K. Prashantha, J. Soulestin1, M. F. Lacrampe,“Taguchi analysis of shrinkage and warpage of Injection-moulded polypropylene/multiwall carbon nano-tubes nano-composites”, express Polymer Letters, Vol-3, No-10, (2009) 630–638.
[17]Kingsun Lee , Jui-Chang Lin,“Optimization of injection molding parameters for led lampshade”, Transactions of the Canadian Society for Mechanical Engineering, Vol. 37, No. 3, 2013.
[18] J.-R. Shie. “Optimization of injection-molding process for mechanical properties of polypropylene components via a generalized regression neural network”, Polymers for Advanced Technologies, vol-19, no- 1, pp. 73–83, 2008.