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Optimization of Process Parameters in Extrusion of PVC Pipes, using Taguchi Method

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***Abstract* - In this experimental research work we have studied the major process parameters involved in PVC pipe manufacturing. After the extrusion Process Many defects have been observed like, Wall thickness, uneven diameter, rough surface and low tensile strength. Out of these, we focused on the wall thickness of pipes, Observed and analyzed all the relevant process parameter with the help of Taguchi method. With the help of statistical evolution software Minitab-18 and using L9 orthogonal array with 4 factors, studied and optimized process parameter has been obtained, which results higher productivity by lowering the defects.**

Key Words: Extrusion, PVC, Wall thickness, Design of experiments (DOE), Minitab, Orthogonal Array.

1.INTRODUCTION:-

The versatile applicability of Poly Vinyl Chloride (PVC) pipes in the field of agriculture, industries, building construction, and plumbing etc. for the transportation of water, slurry and sewage etc. from one place to another, under the variable environmental conditions are increasing day-by-day. PVC is a strong, lightweight and commonly available thermo-plastic; it is made softer and more flexible by the addition of plasticizer. It is of two type uPVC (Unplasticized PVC) and **CPVC** (Chlorinated PVC). The rigid form of PVC is used in the construction of PVC Pipes with the help of PVC pipe Extrusion Machine.

In the extrusion Process materials are allowed to pass through an orifice of desired shape. The materials have to gone through a bulk deformation. Thermoplastic (PVC), are first heated for the softening and then after extrusion it is chilled to set the desired shape. For the defect free extruded parts, machine needs to work on good condition. The process parameters that mainly affect the extrusion process are temperature, pressure, and feed rate. In extrusion process, Defects are mainly caused by improper machine settings or due to poor understanding of machine processing or lack of skill in staffs and inappropriate environment.

2. PROBLEM DEFINITION:-

Most of the Pipe manufacturing industry uses extrusion process for the pipe manufacturing. Bulk deformation of materials takes place with continuous flow of materials under variable internal or external conditions. These conditions depend on process parameters, so in this research work we focused ourselves to optimize the process parameter.

Table-1: shows the average number of defects and their frequencies in a pipe manufacturing industry.

S. No.	Major defects after extrusion	Frequency of defects
1.	Wall thickness	650
2.	Centering problem	550
3.	Surface cracks	340
4.	Diameter variation	480
Total		2020

After observing these statistics, we found the wall thickness of pipe is one of major reason of defected parts production. Therefore we focused on the parameters, which majorly affect the Wall Thickness of the Pipe, so that wastes can be reduced.

3. MAJOR PROCESS PARAMETERS:-

In extrusion process materials needs to be softened by heating and then pressurized through the orifice with some specified speed and then in chillers cooled down. The operator has to decide the input values for the process; he inputs the values with the help of a control panel powered by **Programmable logical controller** (PLC). It also helps in monitoring the Process parameter. Major process parameter

in the extrusion process, which affects the wall thickness are;

i. Barrel temperature,
ii. Extruder die temperature,
iii. Extruder pressure, and
iv. Feed Rate(Take off Speed)

4. METHODOLOGY USED FOR THE EXPERIMENT (TAGUCHI METHOD):-

In this experiment we need to deal with a number of factors (Process Parameters), which are combined to give a specific result; therefore it generates a huge number of possible combinations. To deal with this we took the Help of well known statistical evaluation technique i.e. **Taguchi Method**, Which uses an **orthogonal arrays** for the best possible

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combinations. We designed our experiment according to the Taguchi methodology. For this we followed the following procedure;

- ☑ Selected a PVC Pipe manufacturing industry.
- ☑ Look for the complete manufacturing processes, and identified the process parameters responsible for efficient working of machine. Here we found waste production and defined our problem.
- ☑ Collected data and information which directly or indirectly controls the product quality, and analysed them.
- ☑ According to the type of data, we go for the design of our experiment, and we found Taguchi approach most suited for such analysis.
- ☑ We set the levels of process parameters, it consist 4 factors, so we go for the **L9** orthogonal array. Here we got a set of possible experiments.
- ☑ Performed the experiments carefully under the supervision of corresponding authority, measured the wall-thickness of every output by using a micrometer and gauges. And then go for the statistical analysis.
- ☑ We have used Minitab-18 software for our analysis. Here we got the Means and signal to noise ratio (SN-ratio), for the **Nominal is the best** condition.
- ☑ Finally it gave us a Mean response table with optimized value of process parameters.

5. EXPERIMENTATION:-

5.1. Assigning the level of Process Parameters;

We have selected 4 controllable factors that control the production of pipe; these are Barrel temperature (T1), Die Temperature (T2), Extruder Speed (ES), and Extruder Pressure (EP).

After a deep discussion with relevant authority, Engineers and worker and the Study of the standard data book, we have decided the levels of the process parameters for the optimization.

Table-2: Levels of parameters.

S. No.	Process parameters	Units	Level 1	Level 2	Level 3
1.	Barrel Temp. (T1)	^{0}C	180	195	205
2.	Die Temp. (T2)	^{0}C	160	170	185
3.	Extruder Speed (ES)	RPM	25	30	35
4.	Extruder Pressure (EP)	MPa	150	160	175

We applied the DOE according to the Taguchi Model and Obtain the Orthogonal array using Minitab-18. Here we have used 3-Level Design with 4-Factors and L9 orthogonal array. We performed the experiment and feed those data in Minitab to obtain the Means and SN-ratio.
The outcomes are as below;

Table –3: L9 Orthogonal array

S. No.	T1	T2	ES	EP
1	180	160	25	150
2	180	170	30	160
3	180	185	35	175
4	195	160	30	175
5	195	170	35	150
6	195	185	25	160
7	205	160	35	160
8	205	170	25	175
9	205	185	30	150

S. No.	T1	T2	ES	EP	WT1	WT2	WT3	SNRA	MEAN
1	180	160	25	150	4.15	4.25	4.10	22.3408	4.16667
2	180	170	30	160	3.95	4.15	4.05	20.0000	4.05000
3	180	185	35	175	4.25	4.30	4.05	17.5696	4.20000
4	195	160	30	175	3.75	3.85	3.95	20.0000	3.85000
5	195	170	35	150	4.10	3.95	4.15	19.6524	4.06667
6	195	185	25	160	3.70	3.90	3.75	19.6524	3.78333
7	205	160	35	160	3.95	4.10	3.90	19.6524	3.98333
8	205	170	25	175	3.90	4.00	3.95	26.0206	3.95000
9	205	185	30	150	3.80	3.95	3.90	22.3408	3.88333

Table- 4:- Wall thickness (WT) at different settings, the mean and SN-ratio.

WT1 :- Wall thickness on trail 1, WT2 :- wall thickness on trail 2, WT3 :- wall thickness on trail 3.

5.2. Performing the Experiments and testing:-

The Above data have been obtained by successive trails, and these data have been fed in the Minitab for further analysis. Main effects plot for means and SN-ratios have generated using the minitab-18, and they show the variation of process parameters and the desired output.

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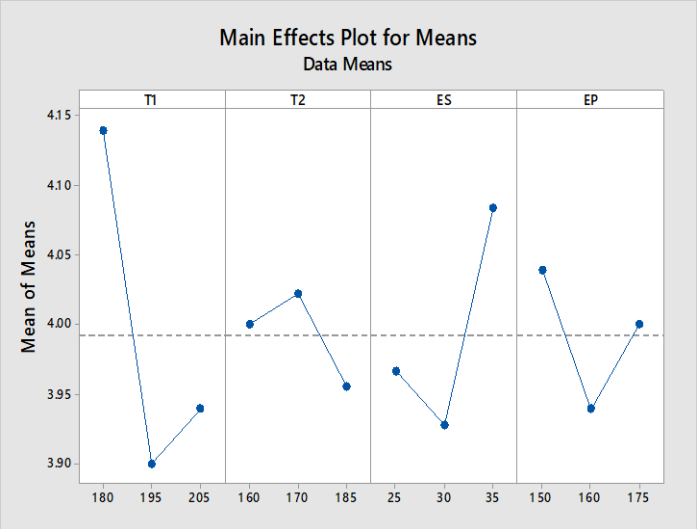
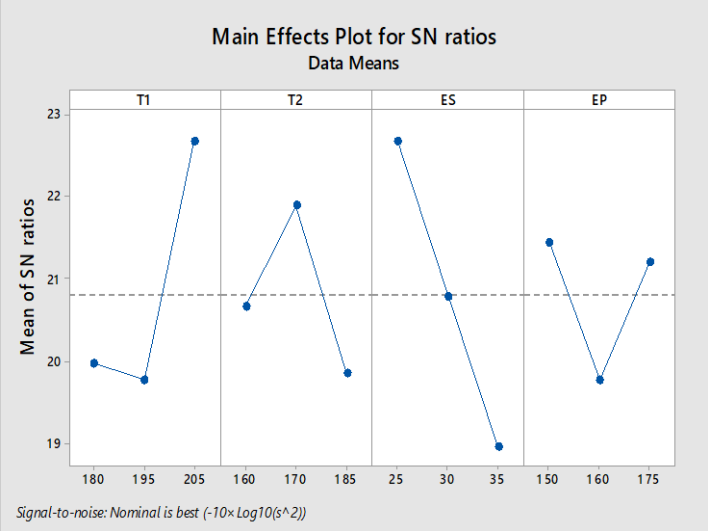
Graph- 1:- Plot for means



Graph-2:- Plot for SN-ratio



5.3. Formula Used:-

For a Pipe, neither a too much thick nor a less thick wall is preferable, we need a nominal wall thickness. So, here we used '**Nominal is best'** criterion for SN-ratio calculation with the help of Taguchi analysis.

SN-Ratio= $10 * log10(s^2)$

6. RESULT AND CONCLUSION:-

Response Table for Signal to Noise Ratios
Nominal is best (-10×Log10(s^2))

Level	T1	T2	ES	EP
1	19.97	20.66	22.67	21.44
2	19.77	21.89	20.78	19.77
3	22.67	19.85	18.96	21.20
Delta	2.90	2.04	3.71	1.68
Rank	2	3	1	4

The response table above shows the maximum delta 3.71, And the maximum SN- ratio is 26.02, which means the wall thickness has nominal value when the parameters are at the following setting;
Barrel temperature (T1) - 205 ^oC,
Die Temperature (T2) – 170 ^oC,
Extruder Speed (ES) – 25 Rpm, and,
Extruder Pressure (EP) - 175 Mpa.

The above results conclude that, the Process parameters can be optimized for the better result by using modern technologies and methodologies. We found Taguchi Method is very helpful tool in such analysis. Time to time inspection of machines working and accordingly setting the process parameters will be helpful in increasing the productivity of organization.

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