To Study the Effect of Process Parameters and Die Design Parameters on the Coating Thickness and Bonding Quality of the Wire Coating

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ABSTRACT

Progress Analysis of Wire Coating Process is review in the term of die design parameter and quality test of wire bonding which are depended on the process parameters of the Wire Coating Process. By using Taguchi and ANOVA method, getting comparison of practical, software and numerical analysis values. In this article we got the best bonding quality value and parameters of the die design from the process parameters of the Wire Coating Process.

Keyword: - *Wire coating, extrusion process, process parameters, bonding quality of wire, die design parameters, Taguchi Analysis, ANOVA method.*

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1. INTRODUCTION

The wire-coating process which is a continuous extrusion process used for primary insulation of conducting wires with molten polymers for increase the mechanical strength and environmental protection purposes. The molten plastic is extruded into a crosshead which passes the wire which is in forming of coated in a continuous manner. [7]

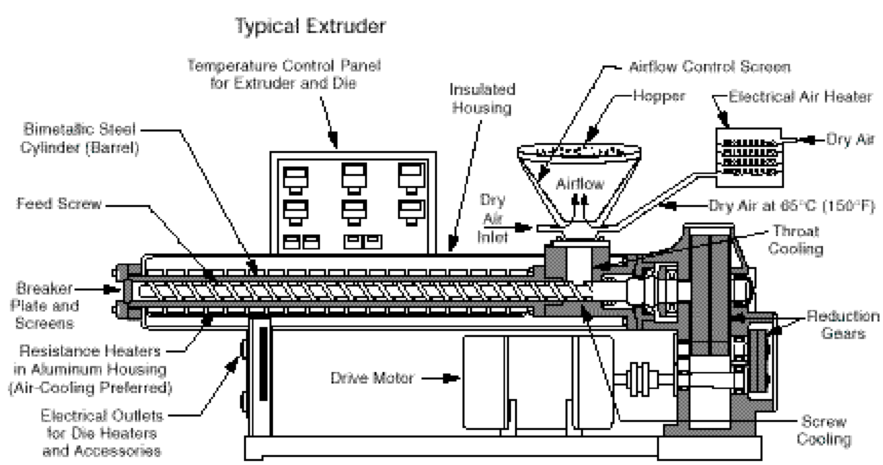


Fig -1: Wire Coating Machine

1.1 Experiment Procedure

The experimental set up of the wire coating machine consists of the drawing bench, the electrical installations, the wire feed mechanism, the drive system, the polymer feeding and melting unit and the pressure unit. The diagram of the wire coating process is shown in Fig. 3. In the wire coating machine the polymer granules are poured in the hopper which is fitted with a heater band and the hopper is connected to the melt chamber. Then it connected through a pressure line to the hopper which provides the back pressure in the polymer melt and we use the argon material which protects the polymer melt from thermal degradation and it also works against the irregularities of coated surface. During the wire coating process at first the wire enters the leakage control which is also acts as a wire preheating unit and it attached to the melt chamber. The wire passes through the melt chamber and enters the pressure unit where coating forms as the hydrodynamic pressure and the coated wire is wound on the bull block which is driven by a continuously variable speed motor. [19]

1.2 Material Specification

Polymer Characteristics
Polymer Type: Polyvinyl Chloride
Polymer Melt Temperature: 180 - 210°c
Wire Characteristics for Pressure Die
Wire Diameter: 4.5 mm
Wire Material: Aluminum
Wire Characteristics for Tubing Die:
Wire Diameter: 14.5 mm
Wire Material: Copper

1.3 Process Parameters Selection

Input Parameters: Temperatures (°c) {Die, Barrel and Head Temperatures}, Pressure (5-10 bar) {Constant value}, Screw Speed (rpm), Wire Speed (m/sec)
Output Parameter: Coating Thickness (mm)

Parameters	Screw Speed (rpm)	Temperature (° c)	Wire Speed (m/s)
Value Range	410-485-575	150-160-166	12-15-18

In this research Experiment is run as 3 Phases and each Phase have 3 levels so Total 9 Reading has been taken in this wire coating process.

2. Experiment and Methodology

Experimental Name : Wire Coating Process (by using Pressure Die)

Measuring Parameters : Die Temperature and Coating Thickness

Wire Diameter : 3.5 mm

Wire Material : Aluminum

Coating Material : PVC

Time Interval : 5 min

SR. No	Screw Speed (rpm)	Head Temp Heating C°	Barrel : 1 Heating C°	Barrel : 2 Heating C°	Barrel : 3 Heating C°	Barrel : 4 Heating C°	Die Temp Heating C°	Wire Speed (m/s)	Coating Thickness (t in mm)
Value	410	162	164	166	167	165	150	12.68	0.75

Experimental Name : Wire Coating Process (by using Pressure Die)

Measuring Parameters : Die Temperature and Coating Thickness

Wire Diameter : 3 mm

Wire Material : Aluminum

Coating Material : PVC

Time Interval : 5 min

SR. No	Screw Speed (rpm)	Head Temp Heating C°	Barrel : 1 Heating C°	Barrel : 2 Heating C°	Barrel : 3 Heating C°	Barrel : 4 Heating C°	Die Temp Heating C°	Wire Speed (m/s)	Coating Thickness (t in mm)
Value	485	160	165	164	162	160	155	15.5	0.5

Experimental Name : Wire Coating Process (by using Pressure Die)

Measuring Parameters : Die Temperature and Coating Thickness

Wire Diameter : 2.5 mm

Wire Material : Aluminum

Coating Material : PVC

Time Interval : 5 min

SR. No	Screw Speed (rpm)	Head Temp Heating C°	Barrel : 1 Heating C°	Barrel : 2 Heating C°	Barrel : 3 Heating C°	Barrel : 4 Heating C°	Die Temp Heating C°	Wire Speed (m/s)	Coating Thickness (t in mm)
Value	575	165	164	166	167	166	160	17.78	0.3

2.1 Taguchi Method

Taguchi methods are statistical method which is developed by Dr. Genechi Taguchi to improve the quality of manufactured goods, marketing and advertising. Taguchi has empirically found that the stage optimization procedure involving S/N ratios indeed gives the parameter level mixture, where the standard deviation is least while keeping the mean on target. This implies that engineering system perform in such a way that the manipulated production factors can be divided into three categories:

1. Control factors, which affect process variability as measured by the S/N ratio.
2. Signal factors, which do not influences the S/N ratio or process mean.
3. Factors, which do not affect the S/N ratio or process mean.

2.2 Design of Experiment in MINITAB

MINITAB software provides the static and dynamic experiment quality characteristics of interest have fixed level. Main goal of Taguchi design is to find out optimal set of control factor against noise factors.

MINITAB calculates response tables and generates main effects for:-

1. Signal – to – Noise Ratios (S/N Ratio) vs. Control Factors
2. Means (Static Design) vs. Control Factors

2.3 Analysis of variance (ANOVA)

This method was developed by sir Renold fisher in the 1930s as a way to interpret the result from agricultural experiments. ANOVA is not a complicated method and has a lot of mathematical beauty associated with it. ANOVA is a statistically based, objective decision making tool for detecting any differences in average performance of groups of items tested. The decision, rather than using pure judgment takes variation into account. ANOVA will be applied to experimental situations utilizing orthogonal arrays, although this analysis method can be used and subsequent analysis is intrinsically tied to one another.

2.4 Level of Process Parameters and values

No	Factors	Levels	Values
1	Screw Speed	3	410 – 485 – 575
2	Temperature	3	150 – 160 – 166
3	Wire Speed	3	12.68 – 15.5 – 17.78

Table 1. Process Parameters Value Selection Table

3. Taguchi Method Analysis for Process Parameters:

3.1 Process Parameters and their Levels for conducting Experiments:

Parameters	Levels		
	1	2	3
Screw Speed (rpm)	410	485	575
Temp (º C)	150	160	166
Wire Speed (m/s)	12.68	15.50	17.78

Table 2. Process Parameters Level

3.2 Orthogonal Array:

Screw Speed	Temp	Wire Speed
410	150	12.68
410	160	15.50
410	166	17.78
485	150	15.50
485	160	17.78
485	166	12.68
575	150	17.78
575	160	12.68
575	166	15.50

Table 3. Orthogonal Array for Process Parameters

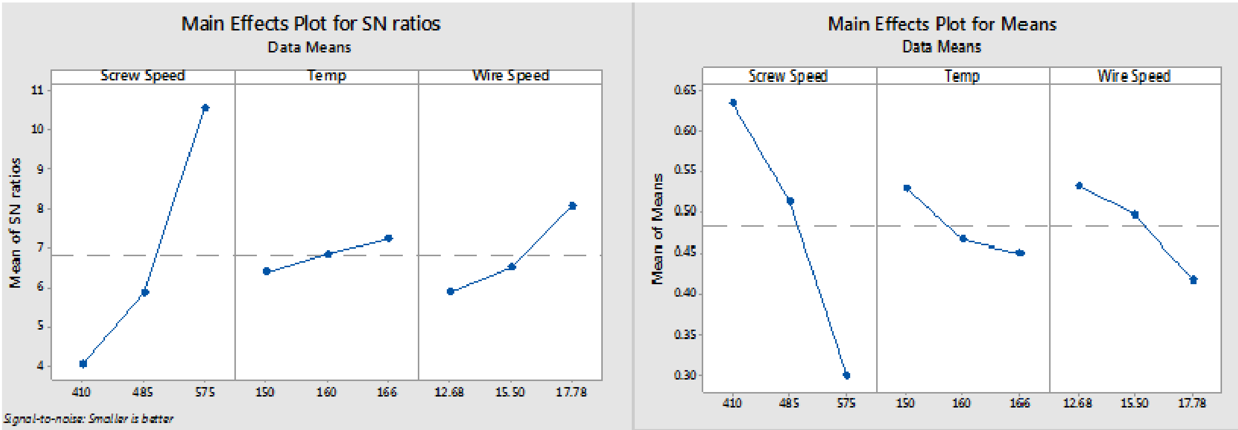
3.2 Taguchi Analysis for Coating Thickness versus Screw Speed, Temp, Wire Speed

Screw Speed	Temp	Wire Speed	Coating Thickness	SNRA	MEAN
410	150	12.68	0.75	2.498775	0.75
410	160	15.5	0.6	4.436975	0.6
410	166	17.78	0.55	5.192746	0.55
485	150	15.5	0.59	4.58296	0.59
485	160	17.78	0.45	6.93575	0.45
485	166	12.68	0.5	6.0206	0.5

575	150	17.78	0.25	12.0412	0.25
575	160	12.68	0.35	9.118639	0.35
575	166	15.5	0.3	10.45757	0.3

Table 4. Taguchi Analysis for Coating Thickness Parameter

3.3 Graphs of S/N Ratios and Mean for Coating Thickness



Graph 1 S/N Ratio and Mean for coating thickness

3.4 Response Table for Signal to Noise Ratios Smaller is better

Level	Screw Speed	Temp	Wire Speed
1	4.043	6.374	5.879
2	5.846	6.830	6.493
3	10.539	7.224	8.057
Delta	6.496	0.849	2.177
Rank	**1**	**3**	**2**

3.5 Response Table for Means

Level	Screw Speed	Temp	Wire Speed
1	0.6333	0.5300	0.5333
2	0.5133	0.4667	0.4967
3	0.3000	0.4500	0.4167
Delta	0.3333	0.0800	0.1167
Rank	**1**	**3**	**2**

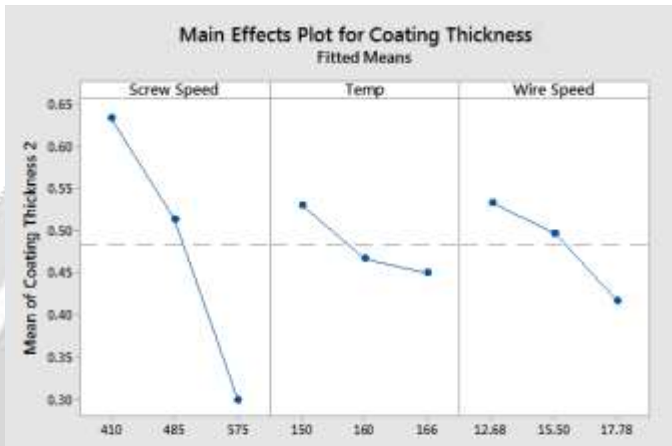
3.6 ANOVA for Coating Thickness versus Screw Speed, Temp, Wire Speed

Sources of Variation	Degree of Freedom (DOF)	Sum of Square (S)	Variance (mean square) MS	Variance Ratio (F)	Percentage Contribution (P)
Screw Speed Factor α	2	0.171023	0.088512	36.4808	0.823192

Temperature Factor β	2	0.010689	0.005345	2.2803	0.051449
Wire Speed Factor γ	2	0.021356	0.010678	4.5555	0.102794
Error E	2	0.004688	0.002343	1	0.022565
Total	8	0.207756			1

Table 5 Analysis of Variance for Coating Thickness

3.7 Graph of Main Plot for Coating Thickness



Graph 2. ANOVA of Main Plot for coating thickness

4. Taguchi Method for Bonding Quality Test

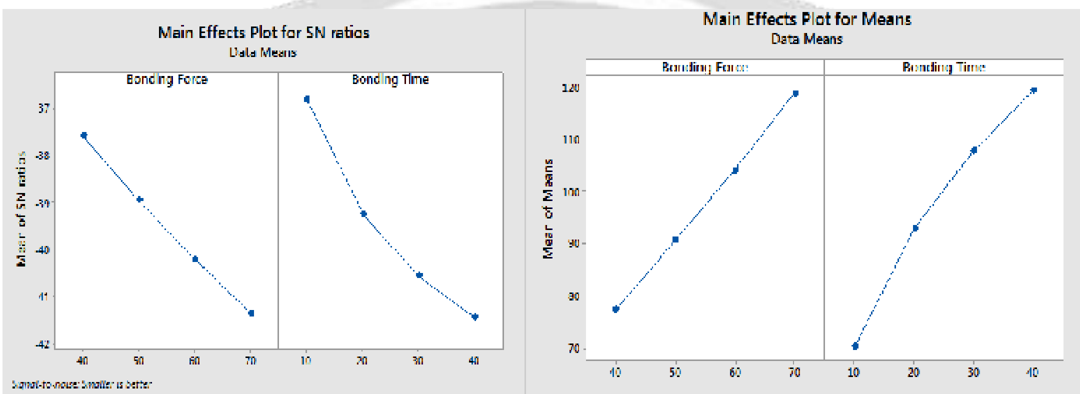
Bonding Force	Bonding Time			
	10	20	30	40
40	55.95	70.85	85.85	95.90
50	60.95	91.95	101.15	110.25
60	76.55	99.45	115.65	125.75
70	88.75	110.50	130.25	145.95

4.1 Orthogonal Array of Process Responses of Bonding Strength (Tensile Strength)

Bonding Force	Bonding Time	Bonding Strength
40	10	56
40	20	70.9
40	30	85.99
40	40	96
50	10	61
50	20	90.85
50	30	100.95

50	40	110.1
60	10	76.25
60	20	99.75
60	30	114.6
60	40	125.7
70	10	88.85
70	20	110.45
70	30	130.1
70	40	145.9

4.2 Graph for Main Effects Plot for SN ratios and Mean for Bonding Strength



Graph 3. Tauchi Analysis for Main Effect for S/N Ratio and Mean for Bonding Strength

4.3 Response Table for S/N Ratios for Bonding Strength

Level	Bonding Force	Bonding Time
1	-37.58	-36.82
2	-38.95	-39.26
3	-40.20	-40.56
4	-41.35	-41.44
Delta	3.77	4.62
Rank	**2**	**1**

4.4 Response Table for Mean for Bonding Strength

Level	Bonding Force	Bonding Time
1	77.22	70.53
2	90.72	92.99
3	104.08	107.91
4	118.82	119.43
Delta	41.60	48.90

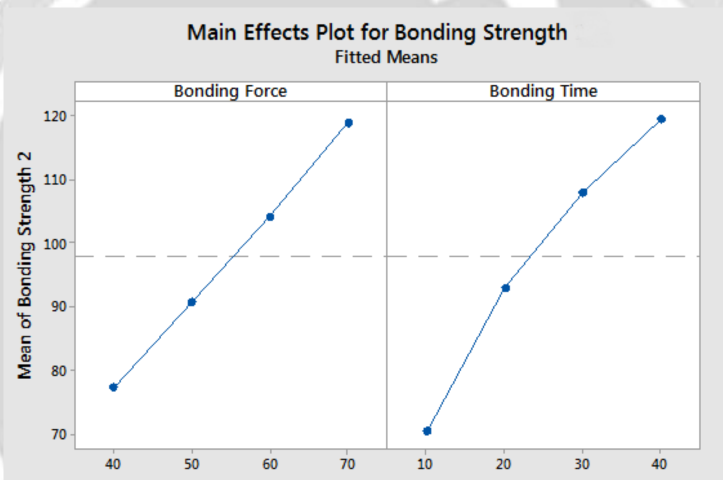
Rank	2	1

4.5 Analysis of Variance for Bonding Strength

Sources of Variation	Degree of Freedom (DOF)	Sum of Square (S)	Variance (mean square) MS	Variance Ratio (F)	Percentage Contribution (P)
Bonding Force Factor α	3	3819.5	1273.18	84.31	0.4106
Bonding Time Factor β	3	5347.6	1782.54	118.04	0.5748
Error E	9	135.9	15.10	1	0.0146
Total	15	9309.1			1

Table 6. ANOVA for Boanding Strength

4.6 Graph of Main Plot for Bonding Strength



Graph 4 ANOVA for Main Plot for Bonding Strength

5. Taguchi for Die Design Parameters

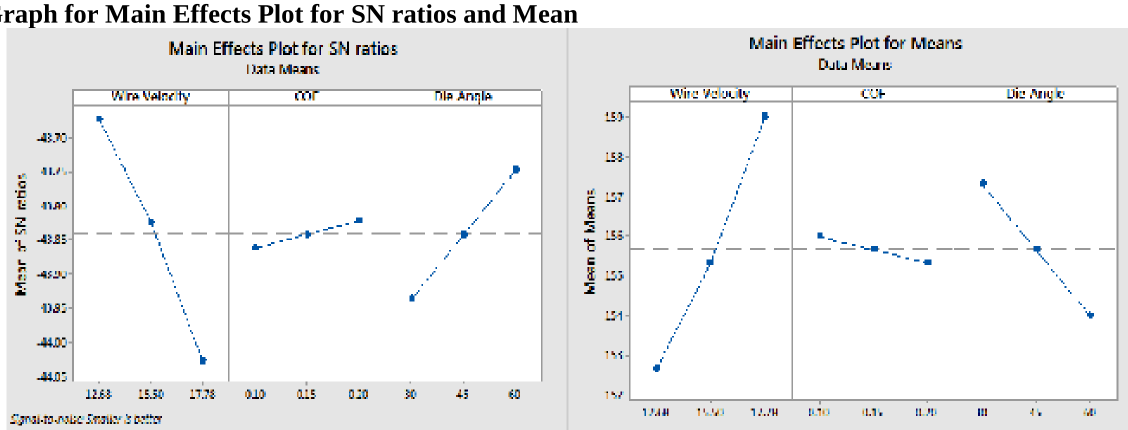
Parameters	Levels		
	1	2	3
Wire Velocity (m/s)	12.68	15.5	17.78
Coefficient of Friction	0.1	0.15	0.2
Die Angle (α)	30	45	60

5.1 Taguchi Analysis for Temperature versus Wire Velocity, COF, Die Angle

Wire Velocity	COF	Die Angle	Temperature	SNRA1	MEAN1
12.68	0.1	30	155	-43.8066	155
12.68	0.15	45	153	-43.6938	153
12.68	0.2	60	150	-43.5218	150

15.5	0.1	45	155	-43.8066	155
15.5	0.15	60	154	-43.7504	154
15.5	0.2	30	157	-43.918	157
17.78	0.1	60	158	-43.9731	158
17.78	0.15	30	160	-44.0824	160
17.78	0.2	45	159	-44.0279	159

5.2Graph for Main Effects Plot for SN ratios and Mean



Graph 5 Taguchi Analysis for Main Effects Plot For S/N Ratio and Mean

5.3 Response Table for Signal to Noise Ratios Smaller is better

Level	Wire Velocity	COF	Die Angle
1	-43.67	-43.86	-43.94
2	-43.83	-43.84	-43.84
3	-44.03	-43.82	-43.75
Delta	0.35	0.04	0.19
Rank	**1**	**3**	**2**

5.4 Response Table for Mean

Level	Wire Velocity	COF	Die Angle
1	152.7	156.0	157.3
2	155.3	155.7	155.7
3	159.0	155.3	154.0
Delta	6.3	0.7	3.3
Rank	**1**	**3**	**2**

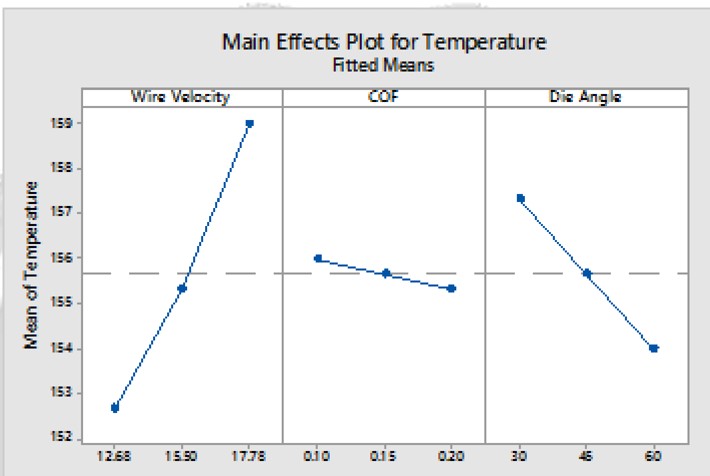
5.5. ANOVA for Temperature versus Wire Velocity, COF, Die Angle

Sources of Variation	Degree of Freedom (DOF)	Sum of Square (S)	Variance (mean square) MS	Variance Ratio (F)	Percentage Contribution (P)
Wire	2	60.6667	30.3333	30.33	0.75833

Velocity Factor α					
COF Factor β	2	0.6667	0.3333	0.33	0.00833
Die Angle Factor γ	2	16.6667	8.3333	8.33	0.20833
Error E	2	2.0000	1.0000	1	0.02501
Total	8	80.0001			1

Table 7. ANOVA for Die Design Parameter

5.6 Graph of Main Plot for Temperature



Graph 6 ANOVA for Main Effect for Temperature

6. CONCLUSIONS

From the Experiment and the software base performance we conclude that coating thickness is maximum depend on the screw and wire speed parameters which are got 82.32 % and 10.23 %. Also concluded that the Bonding Strength of the wire is mainly depend on the time duration of the pull force which we got 57.48 % and Die Design is mostly depend on wire velocity which is 75.83 %.

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