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Improving Painting Process to Control Variable Dry Film Thickness (DFT) For Front Axle Beam

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Abstract:- *After the front axle beam is manufactured, there is a need for proper coating of paint in order to prevent rust and corrosion. The paint coating is provided for maximizing the life of axle beam. Dip paint process efficiency is dependent on paint consumption and dry film thickness. This paper represents the influence of temperature, controlling paint ethanol mixture with respect to DFT obtained. In this processing of axle beam after forging takes place. Grinding, shot blasting, straightening, sizing, crack removal and thereafter painting operation is done. There are coming numerous paint defects and flaws after a certain span of time. So in order to reduce them and enhance the process capability, we are implementing six sigma - DMAIC methodology. It is the aim of the author to address this issue by the use of discussion and case studies and to provide some useful guidelines and insights when performing capability analysis using Minitab.*

Keywords –DFT,Viscosity,Surface Roughness

I. INTRODUCTION

In forgingcompany the manufacturing of the Front axle beam is carried out. After manufacturing of the beam, it further proceeds for painting section. This section has dip painting section for performing painting operation. Two dipping tanks are provided for the dipping process. The vertical position of the axle is dipped in first tank. Then the axle is inverted vertically and again dipped in the second tank. After 2nd tank, the axle is passed to the oven where the paint is kept for drying. The problem issued was on the life span of the coating, so the designing of paint mixture and temperature conditions were studied and the readings were carried out for 3 weeks. The temperature, viscosity, DFT were measured at starting and ending shift. The paint characteristics depend on viscosity, adhesiveness, ambient temperature, dry film thickness, oven temperature and surface tension. The parameters were measured by Elcometer, viscosity cup, DFT meter and Adhesion kit. The results were tabulated by using Minitab software and the process capability analysis, linear regression analysis was carried out. The most efficient result was implemented.
So, in order to reduce the defects, decrease overall process parameters variation and to make process more effective DMAIC methodology is followed.

II. GAPS IN THE REVIEW

1. After our initial survey, I found that most of the life span of axle paint was decreasing.
2. Due to improper mixture of paint and ethanol, non-uniformity in the making the mixture when the tank paint gets low.

III. OBJECTIVE

Life span is directly proportional to viscosity, DFT of paint. Optimum range selection of the parameters helps in improving the paint life span. Especially, in this paper, viscosity, mixture of paint and temperature are observed and the optimized results are tabulated. In this project, the dry film thickness is improved for dip painting process of front axle beam by using MINITAB. The parameters are measured by Elcometer (surface roughness measurement instrument) and viscosity cup (viscosity measurement instrument)

IV. Methodology

Two parameters measured are-
1. Viscosity

The viscosity of paint is measured by viscosity cup. The standard viscosity cup is placed on the stand to avoid human interface, the paint is filled in the cup with closing the bottom hole of the cup (fig no 1). The cup is filled up to the orifice with no leakage. The finger is removed from the bottom and time is calculated for draining the paint from the cup. And the stop watch is stopped after complete draining from the cup. The process was carried out 3 times and the average was considered.

1.1 Process of measuring viscosity cup

Fig no 1. Filling the Viscosity cup

Fig no 2. Draining the viscosity cup.

1.2 Viscosityreadings for tank 1, tank 2, temperature.

S.RNO	Date	Time	Viscosity		AMB Temp	Oven Temp
			Tank 1	Tank 2		
1	26/06/17	03.57pm	19.1	21.7	30.5	65
2	26/06/17	04.53pm	21.4	22.3	28.8	65
3	27/06/17	09.55am	22.37	24.14	28.7	68
4	27/06/17	11.05am	19.5	17.14	29.4	68
5	27/06/17	01.43pm	18.08	19.82	28.8	67
6	27/06/17	04.10pm	16.5	14.87	29.3	67
7	27/06/17	04.40pm	16.02	15.84	30.3	69
8	28/06/17	10.35am	15.93	19.19	30.7	66
9	28/06/17	11.35am	15.18	17.23	30.2	67
10	28/06/17	12.35pm	15.88	17.3	29.9	68
11	28/06/17	02.00pm	15.31	19.67	31.2	67
12	28/06/17	03.00pm	15.44	19.59	31.7	65
13	28/06/17	04.40pm	16.43	19.56	31.5	65
14	29/06/17	10.25am	15.18	18.95	28.9	67
15	29/06/17	11.15am	15.85	20.91	29.3	70
16	29/06/17	12.00pm	16.17	19.79	30.2	67
17	29/06/17	12.40pm	15.75	19.3	29.9	66
18	29/06/17	02.00pm	15.85	19.94	31	73
19	29/06/17	02.40pm	15.47	19.89	30.5	73
20	30/06/17	10.30am	15.31	19.04	28.8	63
21	30/06/17	11.00am	15.72	18.75	28.7	63

22	30/06/17	11.30am	15.44	19.58	29.4	66
23	30/06/17	12.00pm	15.465	19.93	28.8	66
24	30/06/17	12.35pm	15.07	20.18	29.3	67
25	30/06/17	01.45pm	15.23	20.69	30.3	67
26	30/06/17	02.15pm	15.34	20.34	30.7	64
27	30/06/17	02.50pm	14.78	20.55	30.2	65
28	30/06/17	03.20pm	15.24	20.06	29.9	67
29	1/7/2017	10.30am	15.97	22.8	28.1	66
30	1/7/2017	11.00am	16.31	23.27	28.2	64
31	1/7/2017	11.30am	15.96	23.45	28.6	64
32	1/7/2017	12.00pm	16.06	23.21	29.2	66
33	1/7/2017	01.45pm	16.82	20.2	30.8	64
34	1/7/2017	02.15pm	16.67	20.7	30.3	63
35	1/7/2017	02.45pm	16.17	20.65	30.4	64
36	1/7/2017	03.20pm	16.38	21.1	30.9	65
37	3/7/2017	10.30am	15.35	20.01	28.9	67
38	3/7/2017	11.00am	15.69	21.91	29.2	67
39	3/7/2017	11.30am	14.7	14.68	29.5	64
40	3/7/2017	12.00pm	15.35	19.76	30	68
41	3/7/2017	12.35pm	15.7	20.16	30.5	66
42	3/7/2017	01.45pm	15.73	19.93	31.2	68
43	3/7/2017	02.15pm	15.45	19.87	31.7	64
44	3/7/2017	02.40pm	15.95	19.99	31.5	66
45	3/7/2017	03.20pm	15.98	19.57	31.1	66
46	4/7/2017	10.30am	15.82	19.71	29	64
47	4/7/2017	11.00am	15.59	19.2	29.2	63
48	4/7/2017	11.30am	15.66	19.75	29.1	64
49	4/7/2017	12.00pm	16.1	20.07	29.4	62
50	4/7/2017	12.35pm	15.17	20.25	29.4	64
51	4/7/2017	01.45pm	16.04	21.89	30.3	65
52	4/7/2017	02.15pm	15.43	20.31	30.7	63
53	4/7/2017	02.45pm	15.59	19.97	29.9	62
54	4/7/2017	03.20pm	15.79	20.65	29.1	63
55	5/7/2017	10.30am	14.8	18.6	29.2	65
56	5/7/2017	11.00am	15.22	20.24	29.7	63
57	5/7/2017	11.30am	15.51	19.92	29.8	62
58	5/7/2017	12.00pm	15.09	19.64	30.1	64
59	5/7/2017	12.35pm	14.89	19.36	30.5	63
60	5/7/2017	01.45pm	15.85	16.13	30.8	65
61	5/7/2017	02.15pm	15.1	17.56	31	66
62	5/7/2017	02.45pm	15.55	17.86	31	65
63	5/7/2017	03.20pm	15	18.35	31.9	66
64			15.99	19.79	29.92	65.58

Table no 1- Viscosityreadings for tank 1, tank 2, and temperature.

2. Surface Roughness and DFT

Surface roughness is measured at 7 location and DFT is calculated for the top and bottom side of 7 locations. Dry Film Thickness directly proportional to product quality, process control, and cost control. The Correct amount of thickness ensures optimum product performance. The DFT is calculated by Elcometer DFT meter. To check the DFT the process is carried as followed-

1) The 7 Locations are selected on the axle beam and the paint coating is done on the axle.
2) The surface roughness is measured at the locations selected.
3) After surface roughness, the scratches are made on the selected locations after 24 hours of paint on axle beam by using the adhesion kit.
4) The adhesion strip is removed and the calculated DFT pattern is calibrating through standards.

1. Surface roughnessmeter

Check roughness on part as per locations selected beforeand after 24hrs of painting.

Fig no 3. Surface roughness instrument

1.3 SURFACE ROUGHNESS OF AXLE BEAM

The surface roughness at 7 different locations were measured and the mean average was calculated.

Sr.no	Location 1	Location 2	Location 3	Location 4	Location 5	Location 6	Location 7
1	132	124	66	152	70	114	90
2	170	123	130	107	82	131	73
3	51	98	117	133	83	50	83
4	106	87	126	89	83	117	54
5	116	150	106	89	91	74	74
6	43	77	103	110	57	69	80
7	107	149	145	94	80	69	72
8	125	171	109	98	49	63	85
9	103	152	161	292	56	67	73
10	138	86	131	91	96	49	39
11	54	81	72	83	72	148	77
12	131	141	106	134	23	43	89
13	130	99	113	71	107	67	68
14	160	113	108	91	30	67	75
15	95	127	70	90	80	27	67
16	133	103	95	156	156	125	114
17	81	65	75	57	112	69	38
18	158	76	78	152	119	142	100
19	199	74	81	135	119	108	67
20	106	85	90	116	64	93	35
21	103	126	140	66	53	63	66
22	177	96	108	113	65	84	59

23	51	74	120	132	72	74	30
24	60	91	107	113	57	69	80
25	129	141	69	74	80	69	72
26	76	133	113	104	49	63	85
27	110	125	87	92	56	67	73
28	119	93	72	171	96	49	39
29	94	151	102	100	71	53	48
30	76	118	125	128	64	44	53
31	70	128	124	133	51	80	103
32	72	114	92	46	129	47	42
33	92	82	83	69	45	73	45
34	125	156	80	69	72	112	88
35	108	149	114	172	81	96	57
36	72	62	87	91	100	66	37
37	92	97	131	122	99	105	104
38	102	127	85	113	99	98	75
39	106	105	157	88	140	73	74
40	147	102	116	135	125	70	74
41	116	107	121	73	90	36	102
42	167	128	101	290	92	87	125
43	76	70	101	78	77	78	87
44	161	98	122	55	90	86	76
45	123	134	96	59	95	125	114
46	62	94	86	77	74	100	96
47	136	127	120	40	93	94	76
48	92	105	63	189	71	209	89
49	153	104	67	133	78	44	65
50	124	166	112	150	125	135	80
51	134	99	107	62	37	14	59
52	131	129	118	219	87	75	55
53	134	95	131	158	110	59	91
54	235	126	117	98	52	38	92
55	167	197	78	174	100	120	73
56	219	178	161	158	78	64	78
57	152	150	188	125	64	81	62
58	116	159	154	184	140	64	75
59	99	106	113	100	32	101	132
60	172	112	109	126	40	91	52
61	125	113	90	68	48	94	96
62	137	126	225	139	46	93	106
63	126	182	156	140	62	75	85
64	128	113	51	97	66	47	41
65	133	98	101	101	85	49	71
66	111	99	129	83	83	40	109
67	150	161	94	105	73	54	69
68	176	78	104	71	66	64	50
69	91	109	261	121	76	71	73
70	154	58	111	127	43	63	102
	120	115	111	115	79	79	75

Table no 2- Mean average of surface roughness

1.4 ADHESIONKIT

Fig no 4. Adhesion kit

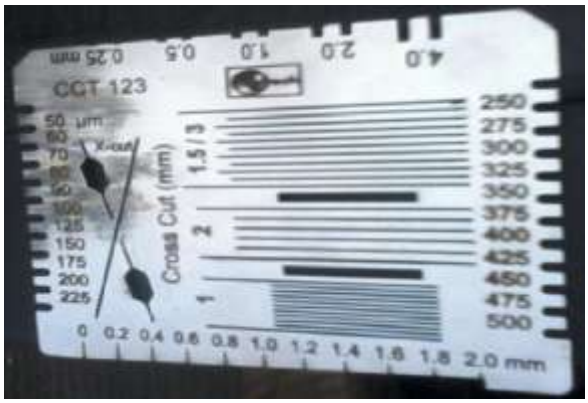


Fig no 5. Adhesion template

Fig no 6. Scratcher pen

Fig no 7. Adhesion strip

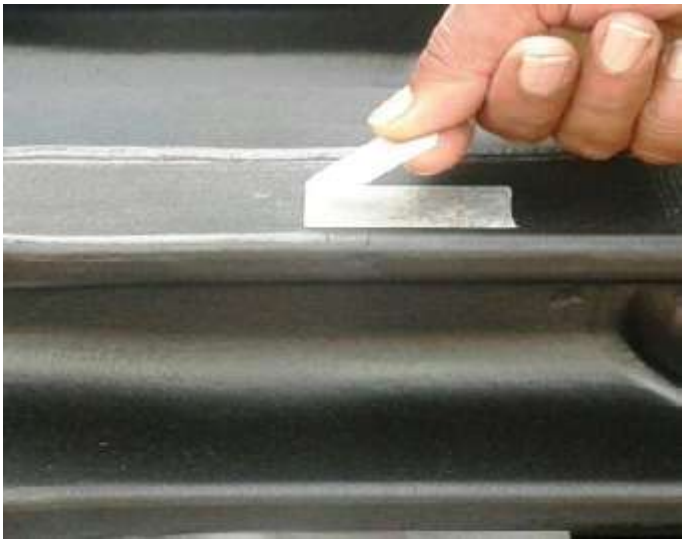


Fig no 8. Strip removal after 24 hours

Due to adhesion test, we are able to find the peeling off range which shows the poor adhesion of paint, blistering which is caused by the contamination in the environment, sinking, slow drying, and cracks which shows the difference in solubility between paint films.

1.5 CLASSIFICATION OF RESULTS

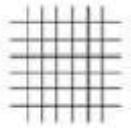
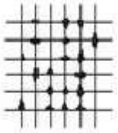
Classification	Description	Appearance of surface of cross-cut area from which flaking has occurred
1	The edges of the cuts are completely smooth; none of the square s of the lattice is detached.	
2	Detachment of small flakes of the coating at the inter-Sections of the cuts. A cross-cut not greater than 5 % is affected.	
3	The coating has flaked along the edges of the cuts at the intersections of the cuts. A cross-cut area greater than 5 %, but not greater than 15 % is affected.	
4	The coating has flaked along the edges of the cuts partly or wholly in large ribbons, and for it has flaked partly or wholly on different parts of the squares. A Cross-cut area greater than 15 %, but not greater than 35 % is affected.	
5	The coating has flaked along the edges of the cuts in large ribbons and/or some squares have detached partly or wholly. A cross-cut area greater than 35 %, but not greater than 65 %, is affected.	
6	Any degree of flaking that cannot even be classified by classification 4.	_

Table no 3- Classification of pattern

According to the standards the coating has flaked along the edges of the cuts at the intersections of the cuts. A cross-cut area greater than 5 %, but not greater than 15 % is affected (point 2).

1) DFTMETER-the DFT was measured on 7 locations both on top and bottom side of the axle beam.

Location 1		Location 2		Location 3		Location 4		Location 5		Location 6		Location 7	
T	B	T	B	T	B	T	B	T	B	T	B	T	B
98.8	62.6	45.9	47.4	85.4	82.8	56.2	79.8	94.8	61.6	46.4	103	119	101
45.8	52.4	46.2	56	58.4	74.5	108	75.9	75.2	71.4	60.7	66.7	107	112
56.3	61.2	51	53.8	78	87	85.7	55.3	66.9	99.6	87.4	71.9	84.3	80.1
133	127	62.4	54.9	79.7	62	66.1	81.7	53.6	73.9	67.5	68.3	85.4	95.36

92.6	90	89.5	88.3	87.4	67.4	80.7	65.4	70.7	62	65.6	69.3	73.2	79.9
107	93.4	47.7	33.9	72.4	53.3	76.12	83.8	60.2	60.7	99.7	84.3	66.8	68
65.1	88	56.2	51.9	83.8	107	62.1	65.9	69	56.5	94.5	71.4	92.1	91.5
65.1	59.5	78	51.6	100	110	64.3	76.3	60.9	54.7	100	97.1	87.5	78.7
49	56.3	49.9	51.2	79	83.2	69.9	73.9	70.7	68	78.3	54.5	102	82.7
98.1	87	46.6	40	66.2	53.7	63.3	92.2	57.4	49.8	59	73.6	54	47.6
84.1	92.3	39.8	69.2	52	55.7	85.4	84.3	52.8	64.6	57.6	68.2	55.4	49.1
56.6	143	51.1	51	78.8	69.4	88.2	76.6	58.5	54.3	81	92.3	83.3	91.6
93.8	71.5	49.9	33	64.7	55.1	70.4	76.4	61.3	55.3	83.1	65.2	62.4	57.8
82.4	56.4	48.6	49.5	72	83.7	81.4	56.5	63.9	56.8	94.2	58.2	110	68.3
68.4	75.1	57.4	58.2	50.4	50.4	73.6	78.4	53.2	61	92.4	103	86.8	106
84.1	87	53.3	48	62.8	59.9	74.5	78.3	59.8	53.4	54.2	57.4	98.3	92.6
82.3	72.3	51	47	71.9	81	80.1	82.5	51.2	54.6	97.5	105	105	68.4
57	56.8	82	63	61.8	49.5	72.3	76.5	57	62.6	62.1	64.5	110	95.1
78.8	63.3	71	64.4	72.3	68.8	78.9	83.6	78.9	54.6	85.2	59.4	63.7	54.5
103	98	67.3	58.8	55.1	50.4	79.5	72.6	79.5	72.6	103.4	72.5	96.1	91.5
73.1	64.3	62.5	54.6	83.2	63.7	91.4	70.7	99.5	84.5	126	99.5	70.7	82.6
95.2	63.1	66.7	55.7	64.3	61.7	88	76.9	73.1	104	96.1	109	103	85
62.7	47.8	73.2	55.2	70.2	63	73.8	75.9	87.7	77.5	106	104	50	99.6
89.1	75.2	67.4	63.2	70	53.1	78.8	78.1	90.5	73.5	106	110	78.6	78.6
21.7	83.4	71.1	65.2	69.4	61	67.7	94.5	78.3	85.1	104	91.4	91.2	91.1
68	47.3	53	65.5	84.8	77.4	123	81	85.5	88	99	119	70	93.5
82	117	64.4	71.3	73.9	59.6	68	88	62	78.7	96.9	124	99.4	106
62.9	62.3	74	63.3	70.6	63.6	68.9	91.8	83.7	70.2	114	110	121	80.9
62.7	84.4	64	53.7	96.2	66.2	84.3	82.3	60.9	75.6	111	83.4	84.7	89.1
55.8	82.3	53.3	51.7	52.2	66	82.1	87.8	80	89.5	126	96	98.5	73.7
75.81	77.37	59.81	55.68	72.23	68	78.09	78.096	69.89	69.15	88.49	85.07	86.98	83.062

Table no 4- DFT at 7 different locations.

Note–Alltheinstrumentswereusedafterverifyingthemthrough measurement systemanalysis.

2. ANALYSE PHASE

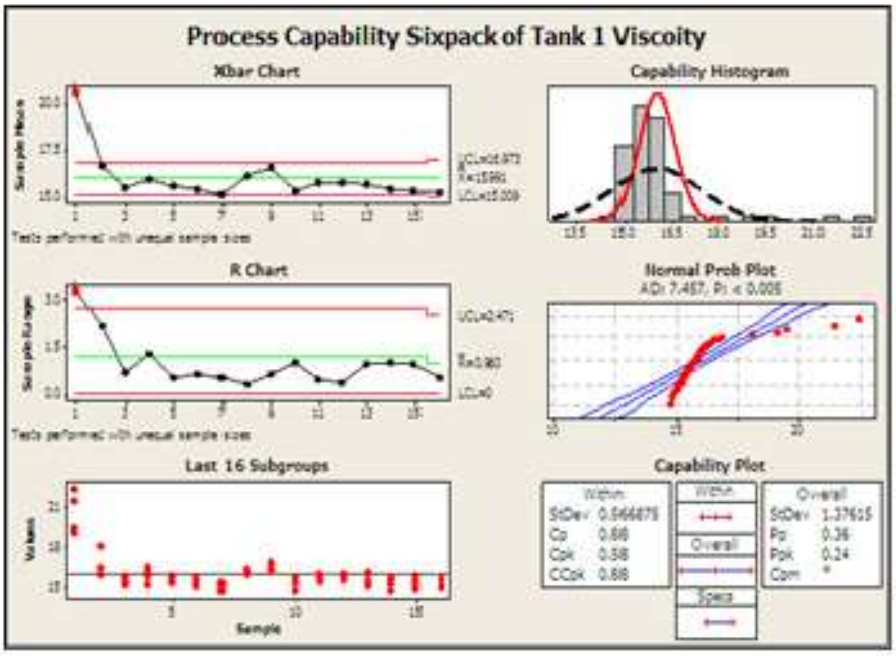
The results were calculated by two methods.

1. Process capability analysis
2. Regression analysis method

The results were tabulated by using MINITAB software Xbar chart, capability histogram, R chart, Normal Probability plot and sample subgroup were calculated for both tank differently. From the results obtained the tank 1 viscosity was low than desired, the improvement in tank 1 viscosity was needed. For tank 2 the viscosity was in range but temperature was slightly high than desired and the paint was getting contaminated so proper cover was required.
The results were tabulated by regression analysis and the tank 2 viscosity was low as same process capability analysis method.

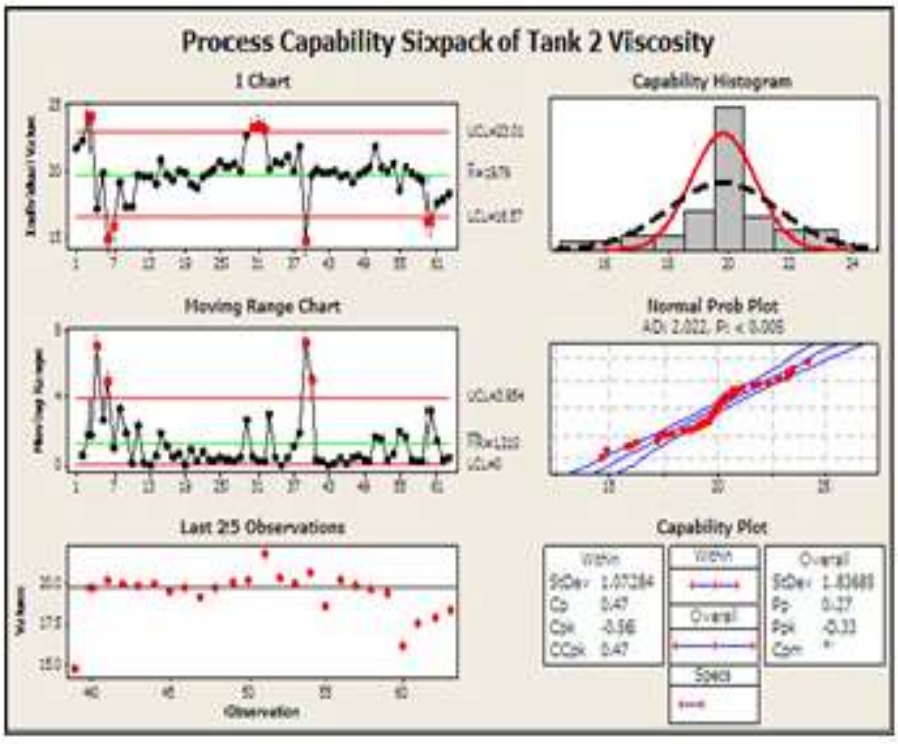
1. Process Capability Analysis

TANK 1



Graph no 1.

TANK 2



Graph no 2.

2.1 REGRESSION ANALYSIS

The results from MINITAB software are-

The analysis for dry film for top side with respect to Tank 1, Tank 2, Temp, SR1

Regression Analysis: DF3 T versus Tank 1, Tank 2, Temp, SR1

The regression equation is
DF3 T = - 6 - 0.9 Tank 1 - 3.91 Tank 2 + 6.45 Temp - 0.102 SR1

Predictor	Coef	SE Coef	T	P
Constant	-6.3	354.8	-0.02	0.987
Tank 1	-0.88	17.27	-0.05	0.961
Tank 2	-3.912	9.177	-0.43	0.688
Temp	6.452	9.584	0.67	0.531
SR1	-0.1020	0.1507	-0.68	0.528

S=14.1679 R-Sq=17.0% R-Sq(adj) =0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	4	205.2	51.3	0.26	0.895
Residual Error	5	1003.6	200.7	-	-
Total	9	1208.8	-	-	-

Source	DF	Seq SS
Tank 1	1	5.4
Tank 2	1	12.4
Temp	1	95.4
SR1	1	92.1

Residual Plots for DF3 T

MTB > Regress 'DF3 B' 4 'Tank 1' 'Tank 2' 'Temp"SR1';
SUBC> GFourpack;
SUBC> RType1;
SUBC> Constant;
SUBC> Brief

The analysis for dry film for bottom side with respect to Tank 1, Tank 2, Temp, SR1

Regression Analysis: DF3 B versus Tank 1, Tank 2, Temp, SR1

The regression equation is
DF3 B = - 200 + 2.6 Tank 1 - 22.1 Tank 2 + 23.6 Temp - 0.112 SR1

Predictor	Coef	SE Coef	T	P
Constant	-200.2	482.9	-0.41	0.696
Tank 1	2.63	23.51	0.11	0.915
Tank 2	-22.05	12.49	-1.77	0.138
Temp	23.57	13.05	1.81	0.131
SR1	-0.1118	0.2051	-0.55	0.609

S=19.2871 R-Sq=48.0% R-Sq(adj) =6.4%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	4	1717.2	429.3	1.15	0.429
Residual Error	5	1860.0	372.0	-	-
Total	9	3577.2	-	-	-

Source	DF	Seq SS
Tank 1	1	5.4
Tank 2	1	12.4
Temp	1	95.4
SR1	1	92.1

Residual Plots for DF3 B

MTB > Regress 'DF3 B' 4 'Tank 1' 'Tank 2' 'Temp"SR1';
SUBC> GFourpack;
SUBC> RType1;
SUBC> Constant;
SUBC> Brief2.

V. CONCLUSIONS

1. The paint in tank 2 is having less viscosity which needs to be improved.
2. The ambient conditions of the environment are not clean as impurities are found on the upper layer of the paint coating. The tank should have more closed area.
3. The temperature of the oven can be increased more up to 25°C.

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