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Effect of Electrostatic Assist and Gravure Process Parameters on Defect Reduction in Shrink PVC Film

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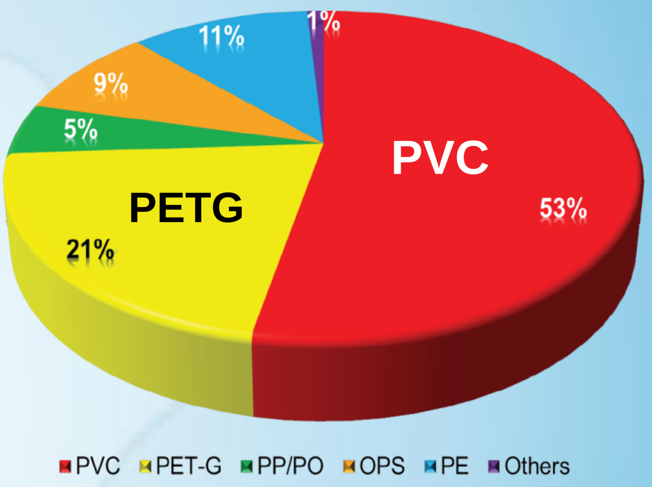
Introduction

- Global market for shrink sleeves is rising by 10%-15% per year.
- Major Share: PVC and PETG films.
- It is essential to obtain superior quality printability on shrink films.
- ***Printability*** is defined as an **optimal amalgamation of ink, substrate and process parameters**.



- **Printability Indicators:** Densitometry, Spectrophotometry and Print defects such as mottle and dot skips.

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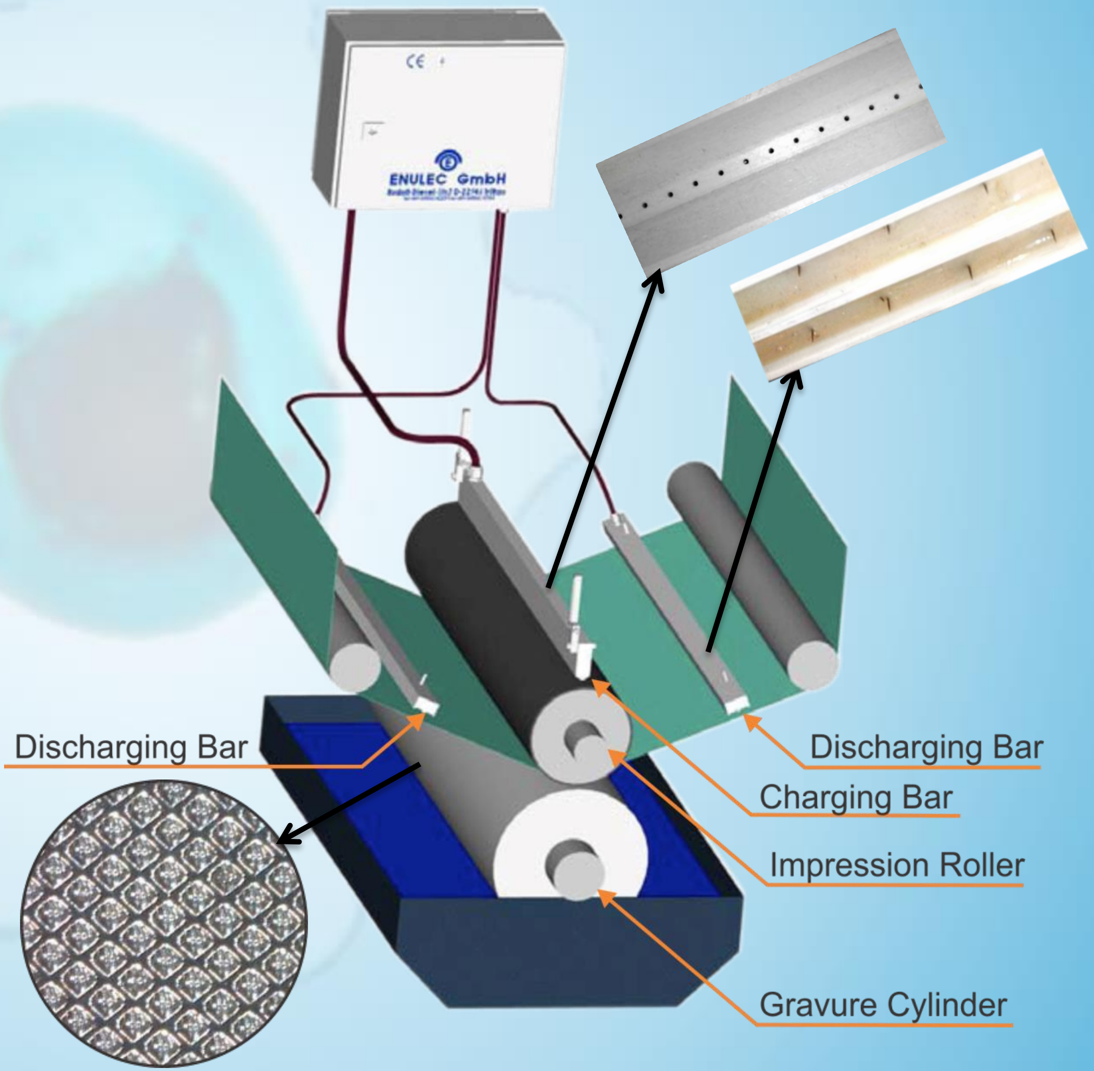
Introduction

- Gravure printing has always been widely accepted process for printing on shrink films.

- **Process Parameters:** Substrate, Ink Viscosity, Pressure, Press speed, Impression Hardness, Doctor blade, Screen Ruling.



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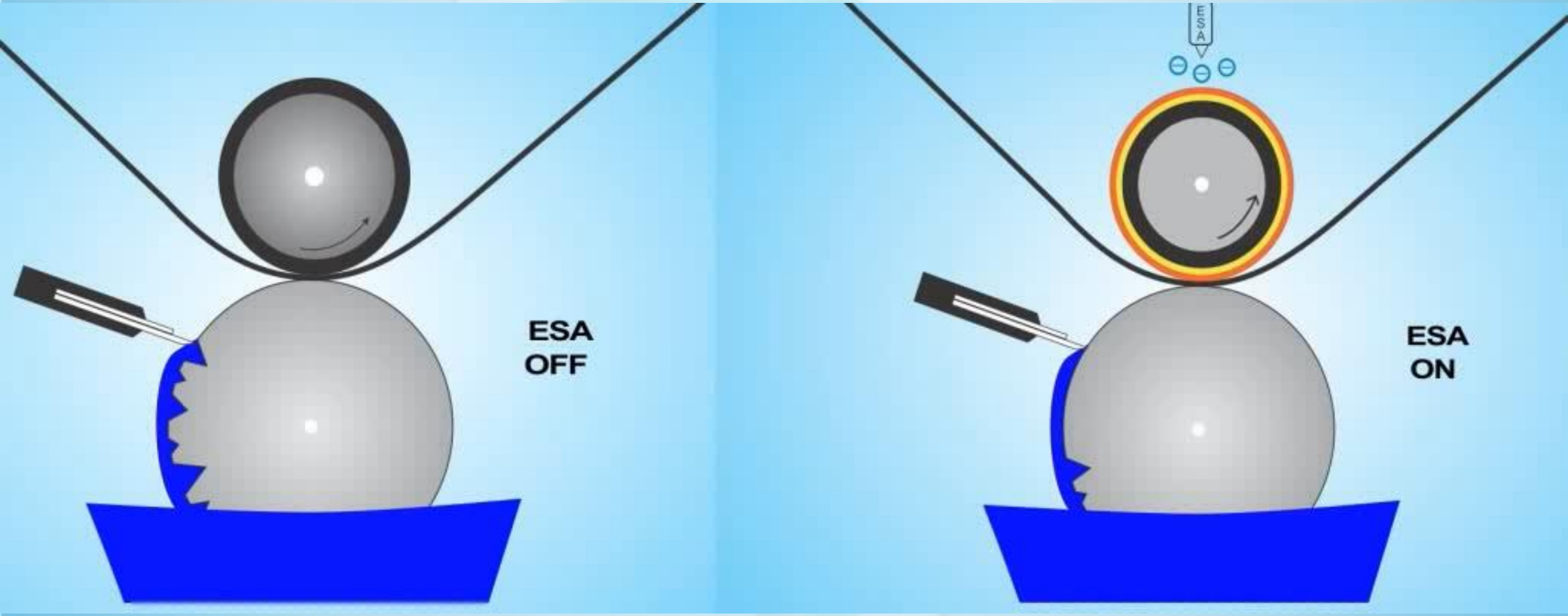
Problem Identification



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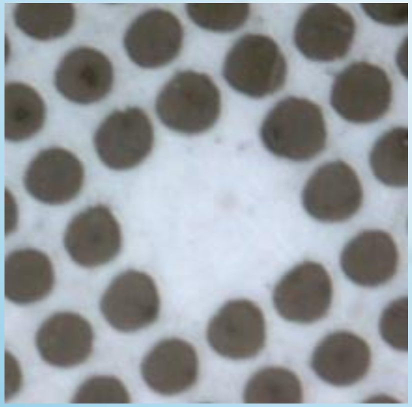
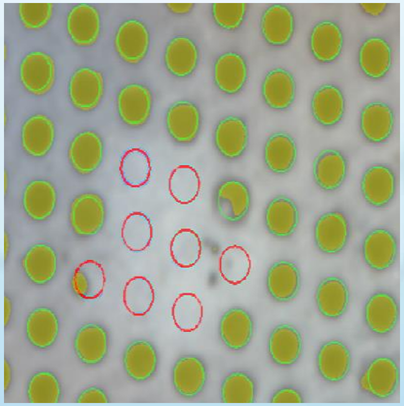
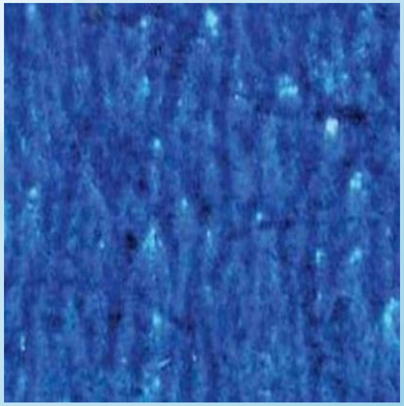
Introduction

- Printing on shrink PVC film is a major challenge for a printer.
- The surface imperfections in these films cannot be totally eliminated during their manufacturing.
- It results in print defects like mottle and dot skips, thereby leading to mounting wastage of ink, solvent, time and material.

Introduction

- This results in internal complaints and rejections, customer grievances, cost to company against claim value and environmental concerns.
- Efforts to prevent such defective prints from being shipped to the customer involve multiple inspection and added costs.
- Reduces the product margin.
- Hence, it is of utmost importance to study the various plausible factors that can affect print defects.

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Methodology

- Selection of Gravure Process Variables
- Layout Design and Cylinder Preparation
- Baseline Identification
- Design of Experiments
- Analysis
- Identifying the significant factors and optimal settings
- Verification of optimal settings
- Development and Validation of Model

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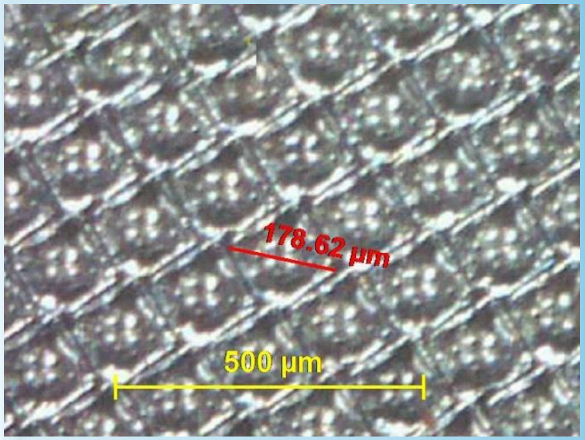
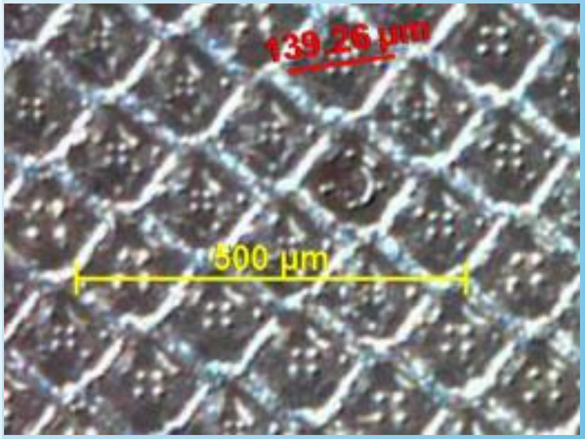
Methodology

Layout Design

- A monotone layout comprising of a skin tone, solid patches, step wedge, logo and surface/reverse text.

- Electronic Engraving with 70 and 80 lpcm with an opening of 178 µm and 139 µm.





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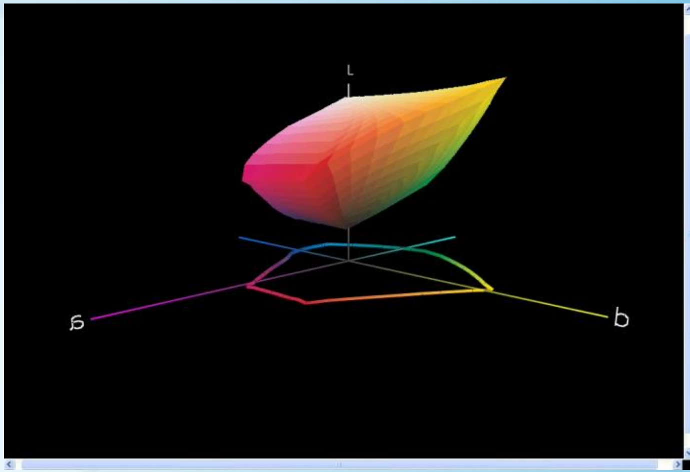
Methodology

Baseline Identification

- **Production Runs:** 70 lpcm, 19 sec, 1.667 m/s, 3.5 kg/cm^2 with **ESA OFF** for few days on a pilot gravure press.
- **Sample Size:** 10 and 25 sheets for mottle and dot skips.
- **Baseline for Mottle and Dot Skips:** 0.789 and 0.68.
- **Target:** To minimize from the baseline.



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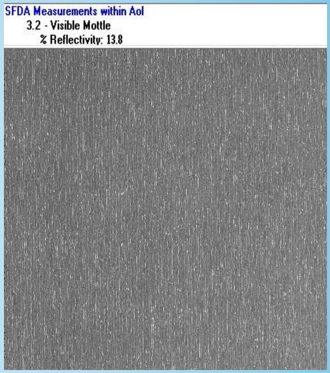
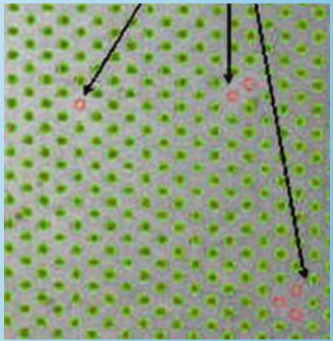
Methodology

- The samples were scanned at 600 ppi by Verity IA Print Target v3 software.



- AOI of 70x55 mm analyzed through SFDA algorithm to calculate mottle.

- Dot skips was measured at 30% patch of the step wedge (8 mm x 8 mm).



- The patch was captured by DPM Microscope at 50X and then measured in Fibro software to calculate the number of dot skips.

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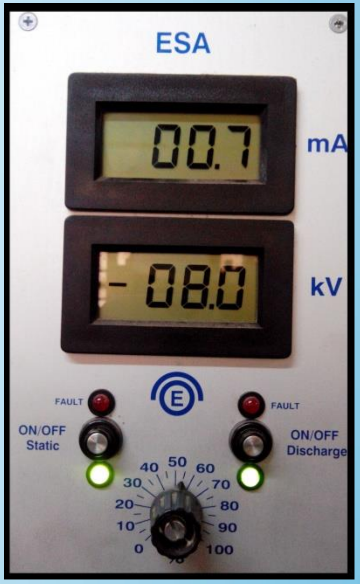
Methodology

- A general full factorial design with 54 runs and 2 replicates.

S. No.	Variables	Unit	Levels		
			Low	Mid	High
1	Line Screen	lpcm	70	-	80
2	Viscosity	sec.	17	19	21
3	Speed	m/s.	1.333	1.667	2.0
4	ESA Current	mA	0.4	0.7	1.0



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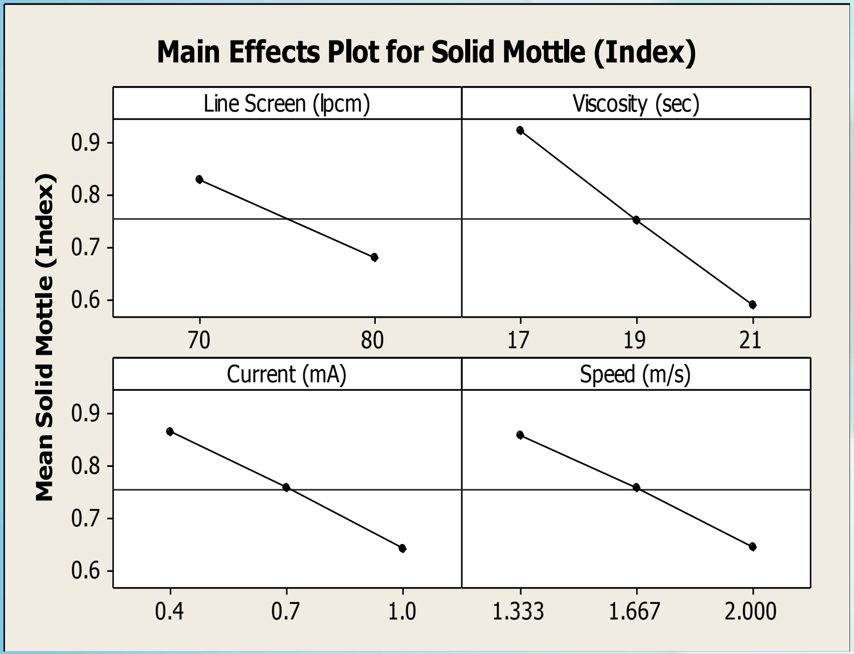
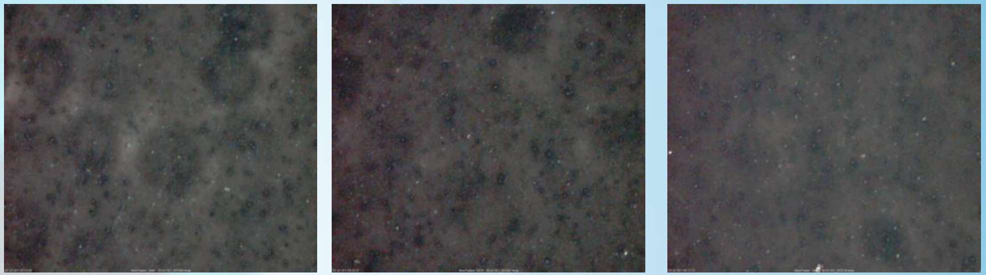
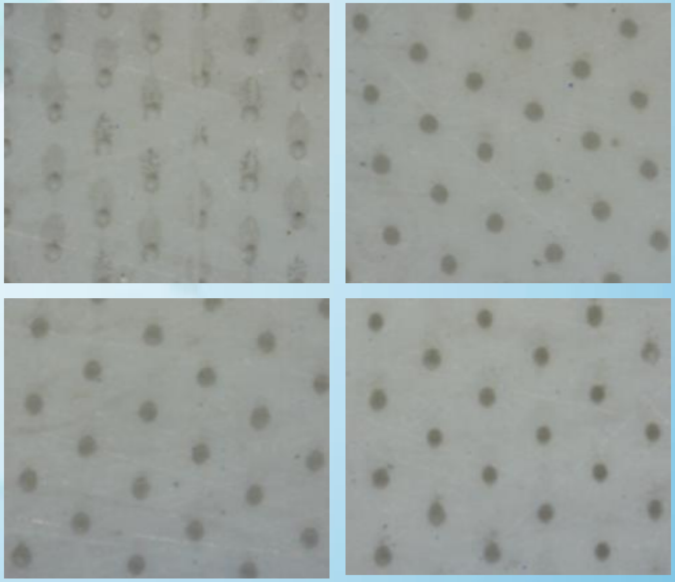
Methodology: Analysis_Mottle





17 sec　19 sec　21 sec



ESA OFF　17 sec

19 sec　21 sec

All factors show significance in minimizing solid mottle.

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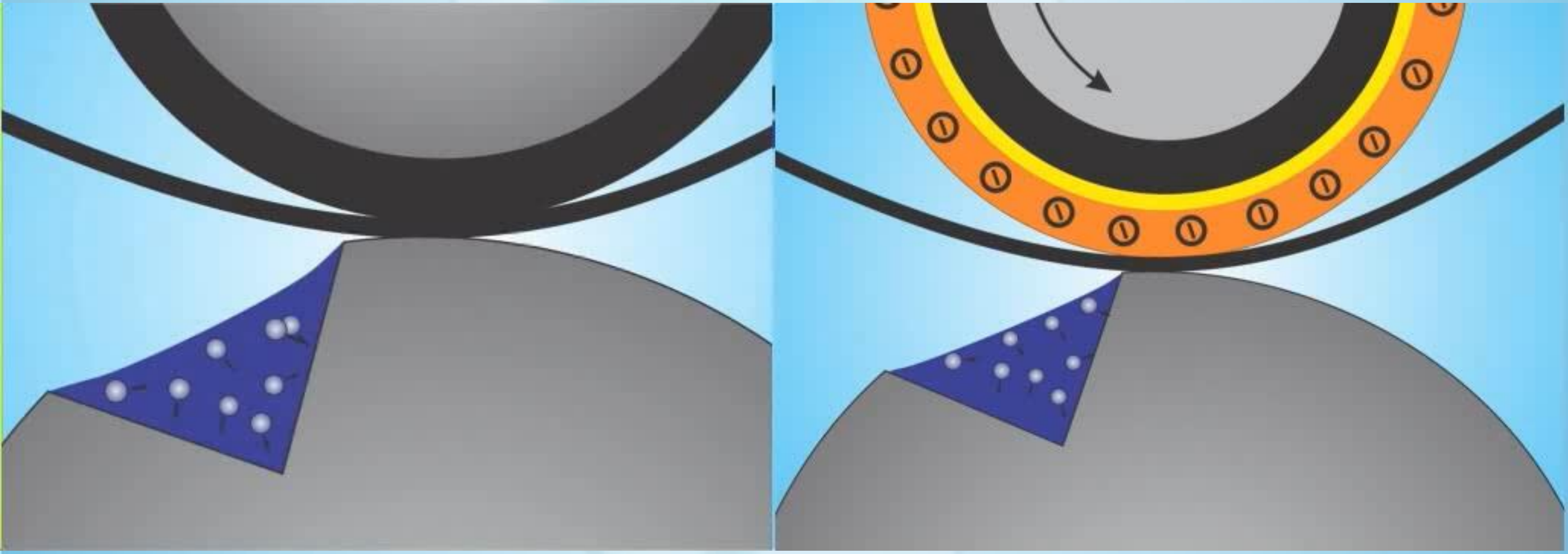
ESA OFF **ESA ON**



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Methodology: Analysis_Mottle

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	7	4.477	4.477	0.639	143.788	0.000
Line Screen (lpcm)	**1**	**0.606**	**0.297**	**0.297**	**66.882**	**0.000**
Viscosity (sec)	**1**	**2.030**	**0.069**	**0.069**	**15.575**	**0.000**
Current (mA)	1	0.889	0.037	0.037	8.245	0.004
Speed (m/s)	1	0.814	0.045	0.045	10.222	0.002
Line Screen* Current	**1**	**0.093**	**0.093**	**0.093**	**20.977**	**0.000**
Viscosity*Current	1	0.026	0.026	0.026	5.896	0.017
Viscosity*Speed	1	0.018	0.018	0.018	4.187	0.043
Error	100	0.444	0.444	0.004		
Lack of Fit	46	0.255	0.255	0.005	1.586	0.052
Pure Error	54	0.189	0.189	0.004		
Total	107	4.922				

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Methodology: Analysis_Mottle

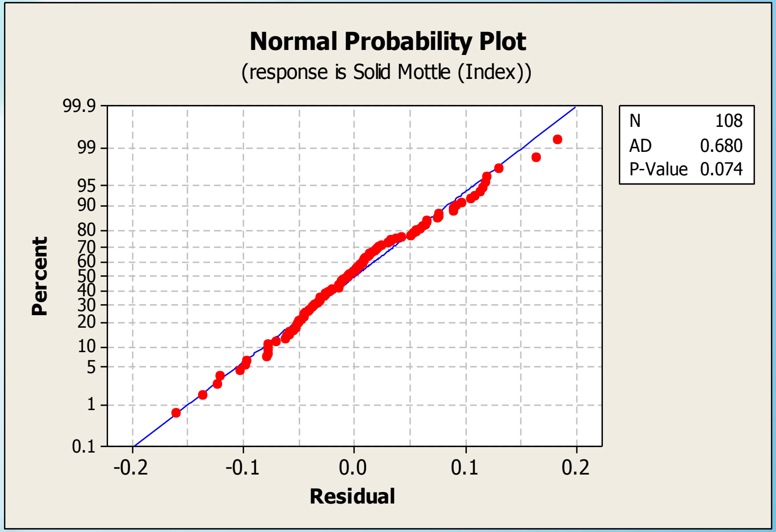
Summary of Model

S = 0.0666951 R-Sq = 90.96 % R-Sq(adj) = 90.33 %

PRESS = 0.522404 R-Sq(pred) = 89.39%

Regression Model

Solid Mottle (Index) = 5.94133 - 0.0317815 Line Screen (lpcm) - 0.105911 Viscosity (sec) - 1.43016 Current (mA) - 0.879981 Speed (m/s) + 0.024 Line Screen (lpcm)*Current (mA) - 0.0389583 Viscosity (sec)*Current (mA) + 0.0295341 Viscosity (sec)*Speed (m/s)



The residuals are normally distributed.

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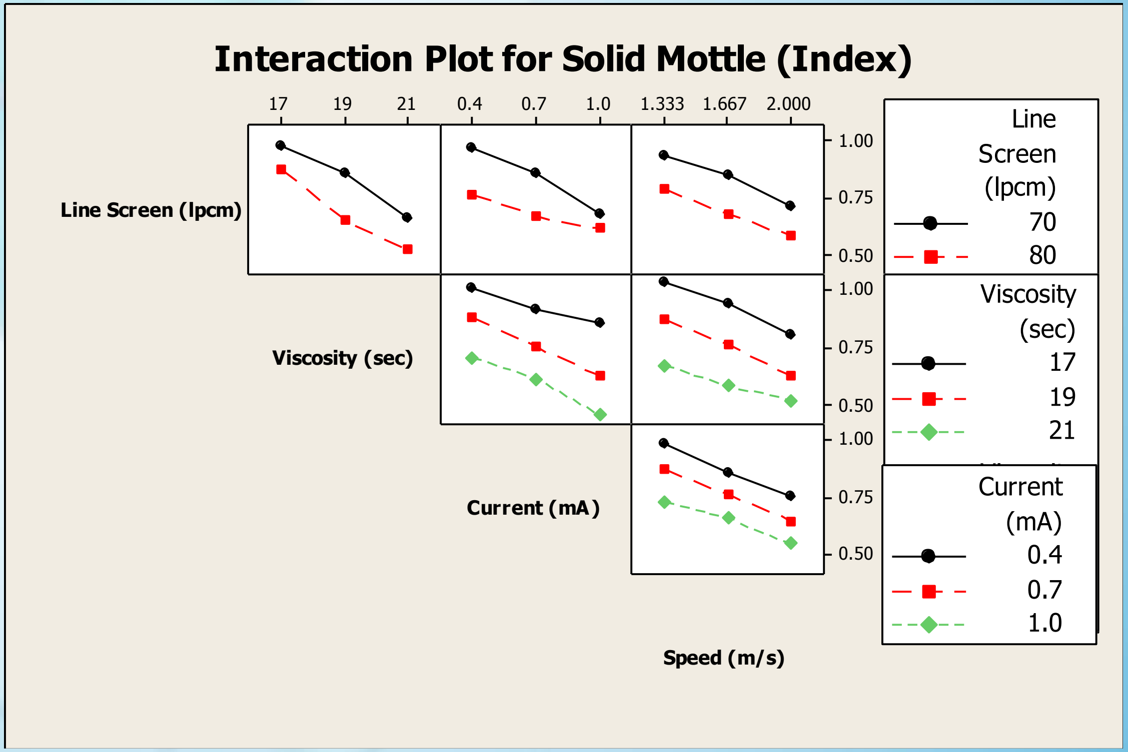
Methodology: Analysis_Mottle

- **Interactions:**
  Current with Line screen and Viscosity with Speed.

- **Best Settings:**
  80 lpcm, 21 sec, 1 mA and 2.0 m/s



Methodology: Analysis_Dot Skips

Test and Confidence Interval (CI) for one Proportion

Test of p = 0.05 vs p < 0.05

Sample	X	N	Sample p	95% Upper Bound	Exact P-Value
1	1	108	0.009	0.043	0.026

- The p-value (0.026) depicts that 97.4% of the data from 108 runs shall exhibit no dot skips for a predetermined 95% confidence interval (CI).
- As the p-value < 0.05, hence the null hypothesis ($p = 0.05$) is rejected.

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Methodology: Verification

- The best settings (80 lpcm, 21 sec, 2.0 m/s and 1 mA) was confirmed by conducting a press run.

Trails	Solid Mottle	Std. Dev.	Dot Skips/Sheet	Std. Dev.
Production Run	0.789	0.1534	0.68	0.8397
Verification Run	0.288	0.053	0.04	0.2

- A significant improvement is evident from production run to verification run in solid mottle and dot skips.

- The best settings revealed from the analysis showed minimization of solid mottle and dot skips by **64%** and **94%** on shrink PVC film.

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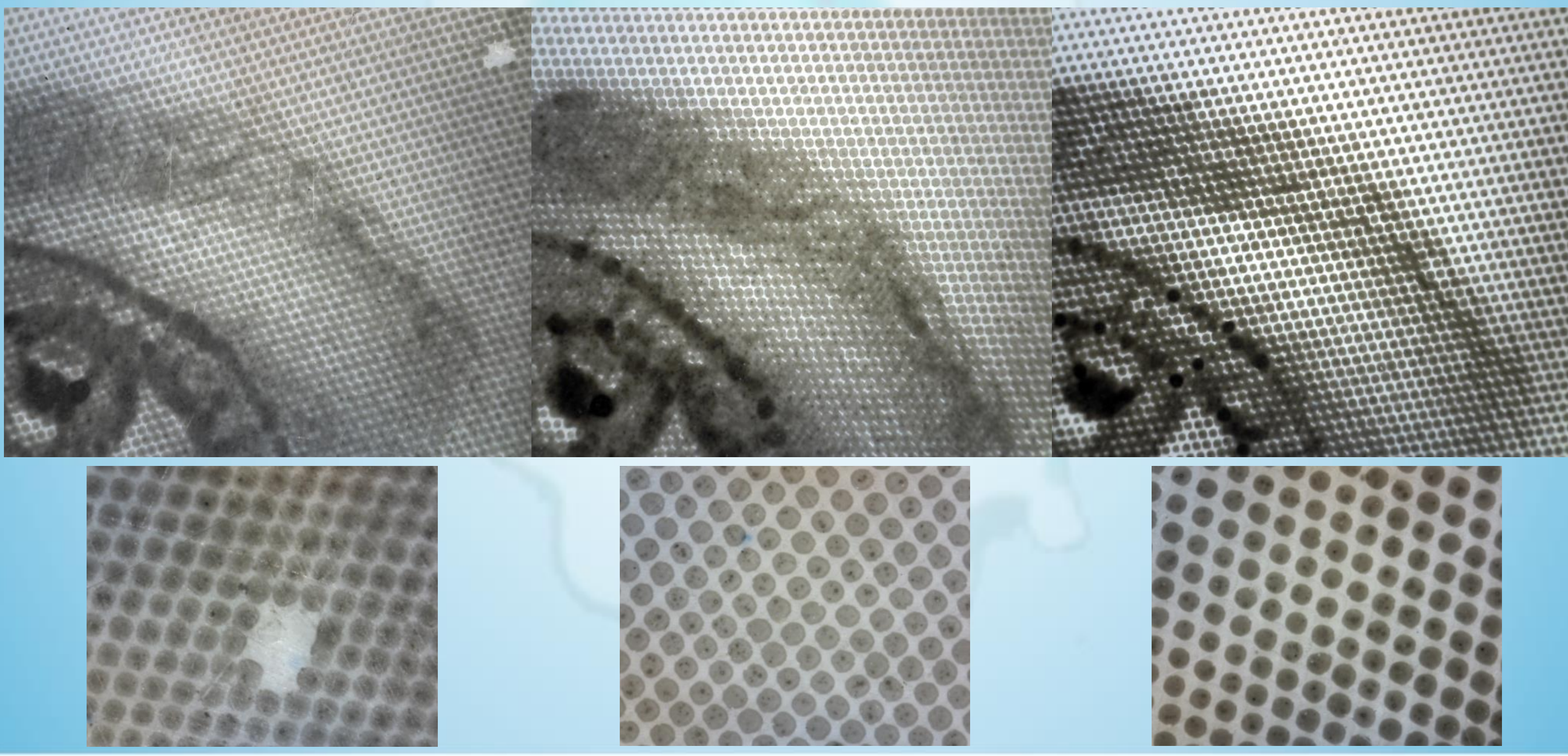
Methodology: Verification

ESA OFF **19 sec** **ESA ON** **21 sec**



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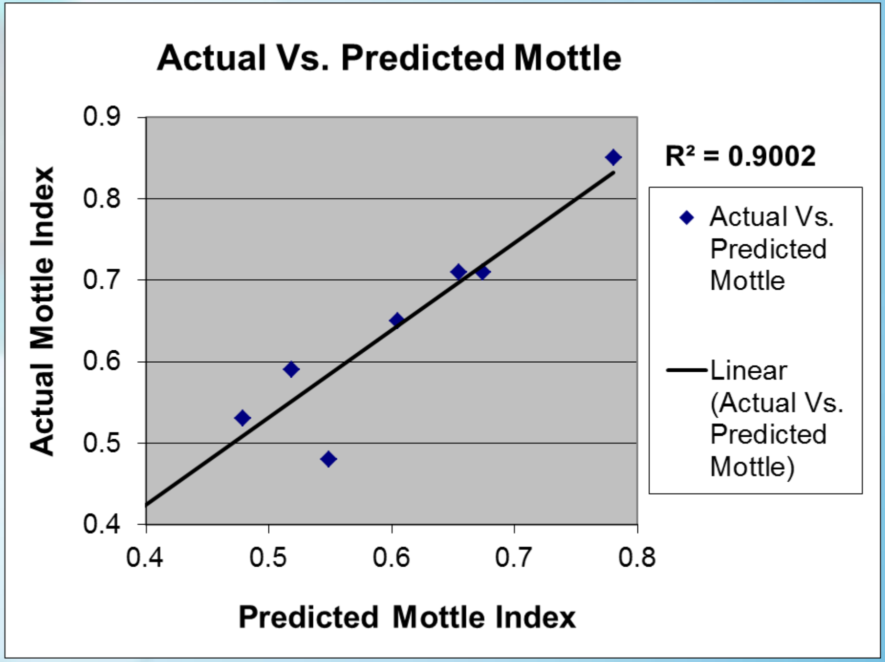
Methodology: Validation of Model

The model developed was validated by comparing the mottle calculated from experimental data and mottle predicted from the regression equation.

A correlation coefficient of **0.9002** for mottle prediction justifies the prediction ability of the model.



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Conclusion

- Optimization of the gravure process parameters itself has a solution to reduction in losses and wastage to a greater extent.
- The analysis revealed **line screen, current and viscosity** as the most influential factor in minimizing the mottle.
- The print mottle was minimized by **64%** and dot skips by **94%**.
- Regression Model showed a correlation coefficient of **90.02%**.
- Minimization of defects helps in controlling wastage and avoidable environmental damage.

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Thank You