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Effect of Pigment Particle Size of Offset Inks on Printability

Madhura Mahajan[1],*, A. Arulmozhi[2]

Abstract

The pigment is the most expensive part of printing inks. The process of making ink involves physical processes that require even distribution of pigments in the surrounding vehicle. This process is known as "Dispersion". The quality of the final dispersion decides print parameters like dot gain, density, print contrast, and gloss. In this work, the aim was to study how the ink behaves on the printing press based on the ink particle size during printing trials. It is well known that pigment particle size controls ink optical properties like print density, specular gloss, and color characteristics. In our project, we prepared four process cyan inks with two varying levels of pigment particle size obtained by varying the number of milling passes/milling time, i.e., single pass and double pass. The agglomerate particle sizes used were 0.5 microns and 3.5 microns. Rheological analysis including parameters such as viscosity, hysteresis loop area, and index of thixotropy was conducted using a Physica MCR 301 rheometer to understand the interaction between the pigment and the vehicle, and the flow behavior. Press trials were conducted to evaluate the behavior of the prepared inks on Solid Bleached Sulphate and Folding Box Board paperboards. The results showed that ink pigment particles with small sizes showed better printability results. Particle Size Analyzer equipment works on the principle of light scattering and was used to measure the pigment particle size distribution of the developed inks. The maximum density obtained by the test chart with the wedge shape represents the target color density that the developed ink and thus achieves printability.

Keywords: Pigment, particle size, ink rheology, printability, paperboard

INTRODUCTION

Ink has dual characteristics: liquid and solid. The solid part of the ink is the pigment particles, and the liquid part is the vehicle comprising of resin, solvent, mineral oil, or vegetable-based oils and other additives. When printing, various deformations, flow, and fracture behavior occur on the ink. Pigments that impart color are insoluble and available as organic and inorganic. Pigments are the most expensive part of the ink [1]. The average diameter is 85 nm for an organic pigment and 700 nm for an inorganic pigment. Offset inks are a careful balance of organic and inorganic pigment dispersed in the vehicle to meet the printing process requirements. The particle size of the pigments controls various properties of the inks. The small particle size of pigments contributes to important printing and ink dispersion parameters, such as color strength, hiding power, and flow [2]. Printing inks require transparency and opacity during the print process and transfer on the substrate [3]. The opacity or the transparency can be achieved with

***Author for Correspondence**
Madhura Mahajan

[1]Research Scholar in Department of Printing Technology, School of Engineering, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, Tamil Nadu, India
[2]Associate Professor in Department of Printing Technology, School of Engineering, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, Tamil Nadu, India

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the help of the particle size of pigments [4]. Smaller particle-sized pigments give increased color strength as they give better bonding among the particles [5]. Smaller particle sizes are essential for better flow and suspension of particles into the vehicle [6]. The shape and size of the particle define the viscosity curve in the rheological measurements of inks [7]. To obtain the desired qualities of pigments, it is essential to reduce the particle size of pigments as much as possible [8]. Inks having smaller particle sizes were observed for time-dependence behavior. This resulted in particle-particle interactions [9].

Pigment particles can be divided into three classes: primary particles, crystallites, aggregates (primary particles having surface-to-surface contact), and agglomerates (primary particles touching each other via edges and corners). This research study explains the behavior of pigment particle size and its implications on printability. Pigment manufacturers supply pigments to ink manufacturers. The ink manufacturers prepare the inks and provide them to printers. Ink manufacturers may sometimes have problems with poor dispersion and flow of ink, which is reflected in ink transfer and print quality. The printers may encounter poor color strength, poor print contrast, and high dot gain. This study shall be useful to ink manufacturers and printers identify the problems and select the ideal combination of process parameters to enhance their print quality. Figure 1 explains the workflow of ink, rheology, flow properties affecting printability and primary structure of pigment affecting ink and print quality.

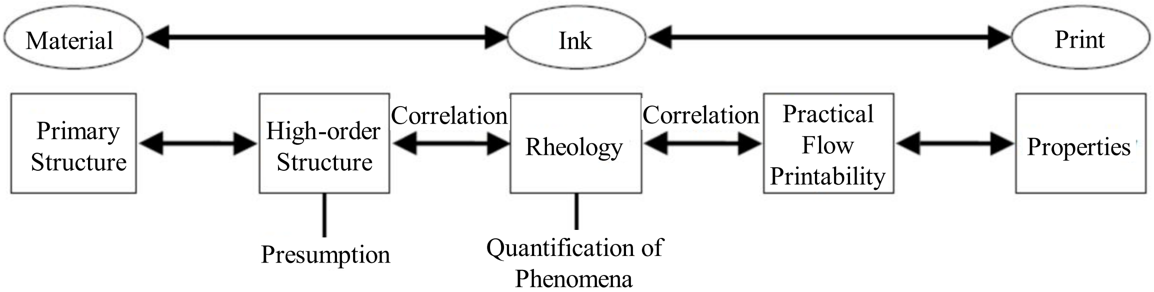

Figure 1. Brief Workflow of the Work Done in this Experimental Research.

MATERIALS AND METHODS

Ink

The batch of inks was being formulated considering breaking down the agglomerate structure of pigment during the dispersion process using a three-roll mill whose complete measurement of the particle size distribution gives conclusions down to much finer sizes, allowing optimization of the ink formulation and the manufacturing process serving as an excellent predictor of final product performance. The particle size of pigment particles in ink is a critical parameter that affects the surface finish of the ink after printing. The experiments were conducted using cyan base ink. Physical properties of organic and inorganic pigments such as specific density (ρ), specific surface (A), and volume fraction (ø) are measured. The particle size and shape of the pigment govern the intensity of color and affect rheological properties like thixotropy. Therefore, it is essential to reduce the particle size of the pigments to the primary particle size [10]. The resin component of the ink is measured in terms of its molecular weight and imbibes viscoelastic properties to an ink. The interactions between pigment particles and the continuous phase form a network of particles and aggregates within the ink, which can proceed with time to form a continuous network structure. Phthalocyanine Blue pigment was selected as a base color for the ink. Products of Phthalocyanine Blue Pigment with different Primary particle sizes from Sudarshan chemicals, as given in Tables 1 and 2, are selected as follows:

1. Blue 2680 has a mean diameter of 0.52 µm
2. Blue 2695 has a mean diameter of 3.74 µm

Formulation of ink

All four inks were prepared with the same formulation; only the Pigment Particle size was different for each ink.

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Huber Group India provided us with the base ink; its composition is in Table 3. We prepared four types of inks by adding the pigment particle size of two kinds. The particle size of the pigment particles was measured using a Cilas 990 liquid particle size analyzer. The liquid used was water to mix the pigment particles. The particle size of the agglomerate obtained is mentioned in Table 4. We then analyzed and compared the rheology and print performance of the inks. A three- or triple-roll mill was used to dispersion of ink pigment into the varnish. It is a machine that uses shear force created by three horizontally positioned rolls rotating in opposite directions and at different speeds relative to each other to mix, refine, disperse, or homogenize viscous materials fed into it, as given in Figure 2.

Table 1. Specifications of Blue 2680.

Product name	**Blue 2680**
Chemical type	Phthalocyanine Blue Pigment
Color index Name	Pigment Blue 15:3
Physical form	Greenish Blue powder
General Applications	Recommended for Offset Ink (I001), Aqueous Flexo Ink (I003), Gravure Inks (Vinyl–I006, Maleic-I007, NC\PA-I008), Plastics LDPE (A001), HDPE (A002), PVC & PVC Leather (A010), Leather Paste (L001) and Textile (T001) applications.

Table 2. Specifications of Blue 2695

Product name	Blue 2695
Chemical type	Phthalocyanine Blue Pigment
Color index Name	Pigment Blue 15:4
Physical form	Blue powder
General Applications	Recommended for Air Drying Enamel Paint (P001) and Industrial Paint (P003) applications.

Table 3. Composition of Base Ink.

Ink formulation	
Pigment	16.5
Wetting Resin	6
Wetting Varnish	11
Structure Varnish	44
Veg. Oil	3
Min. oil	8.5
Anti-skinning Agent	1.5
Rub Improver	6
Dryer	2.5
Litho Improver	1
Total	*100*

Selection of Paperboard & Its Properties

Folding Box Board (FBB)

Coated virgin boards are one of the widely used duplex boards for various carton packaging applications in India. FBB is a folding box board with high bulk and superior stiffness and smoothness. It is designed to be the ideal substrate for all food, pharmacy, and FMCG brands.

Solid Bleached Sulphate

It is an eye-catching, premium-quality virgin fiber-based, fully coated Solid Bleached Sulphate board of medium density. Its unique high whiteness shade enhances the carton's shelf appeal. Fiber, pigment, shade, and quality are perfectly matched to create a surface with unparalleled definition and depth.

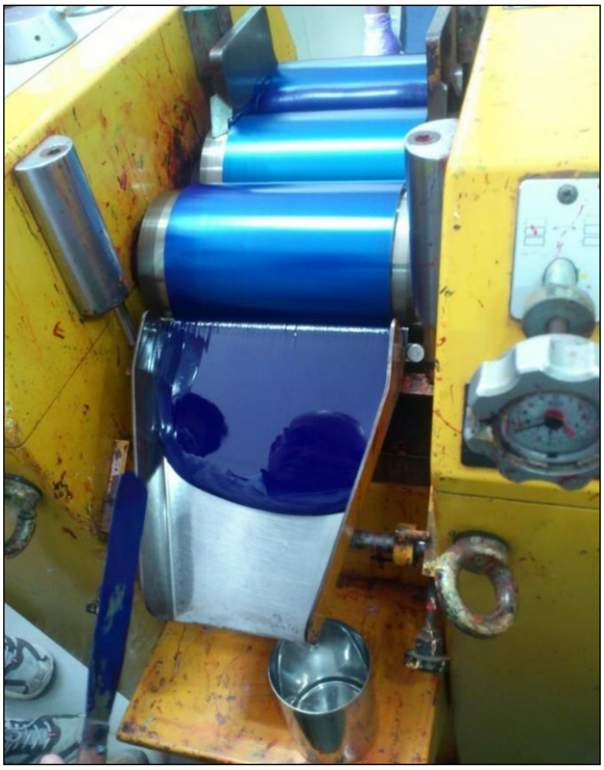

Figure 2. Three-Roll Mill (TRM) for Grinding and Dispersion of Ink Prepared by Mixing of Pigment Particles and Vehicle.

Table 4. Pigment Particle Size Modified in Base Ink.

S.N.	Samples	Particle aggregate size	Number of passes in Three-roll mill	Agglomerate size
1.	2680-10	0.52 microns	Single pass	10 microns
3.	2680-5		Double pass	5 microns
4.	2695-10	3.14 microns	Single pass	10 microns
5	2695-5		Double pass	5 microns

Offset Lithography press: Specifications of Press

- Machine Name – Graphica 771
- Speed – 8000 IPH
- Machine Size – 458 × 584 mm
- Plate Size – 650 × 510 mm
- Blanket Size – 675 × 575 mm
- Blanket type – 3 ply (compressible)

Computer-to-Plate and Pressroom Parameters

The plates were imaged using a computer-to-plate (CTP) process using a Thermal CTP plate of size 650 mm × 510 mm. The selected screen frequency was Amplitude Modulation with 150 lines per inch (lpi) screen ruling and 175 lines per inch (lpi) and three types of dot shape. The ambient temperature in the press room was 24 degrees Celsius, and the humidity was RH 52%. All the conditions in the press and press room were kept constant. A fount concentrate of 2% was added to the water to prepare a fountain solution with a pH of around 5.4.

Test Chart for Press Trials

A print layout design, as shown in Figure 3, was prepared to aim and study the ink starvation of developed inks to find out the maximum print contrast and density with minimum TVI that a particular ink can reproduce by adjusting uniform ink settings on the machine Graphica 771 ensuring a uniform ink flow throughout. Following is the list of elements used in the test chart:

1. Individual color wedge
2. Halftone patches (100, 05, 95, 25, 75 & 50)
3. Solid patches
4. Color control strip
5. Star target

From the gripper side: Individual color wedges for C are designed to relate and account for the ink coverage area from left to right. The halftone patches positioned above the color wedges consist of percentage patches for each color. The percentages are 100, 05, 95, 25, 75, and 50. During printing, the utilization of ink film on the roller for each revolution changes from left to right till the roller reaches halftone patches. A varying amount of ink is applied to the patches during printing. Thus, we obtain the above halftone percentage patches with varying ink film thickness, giving different densities and, thereby, different values of tone value increase. Above the tonal areas are solid patches in each row. The remaining elements are color control strips, trapping bars, star targets, and registration marks.

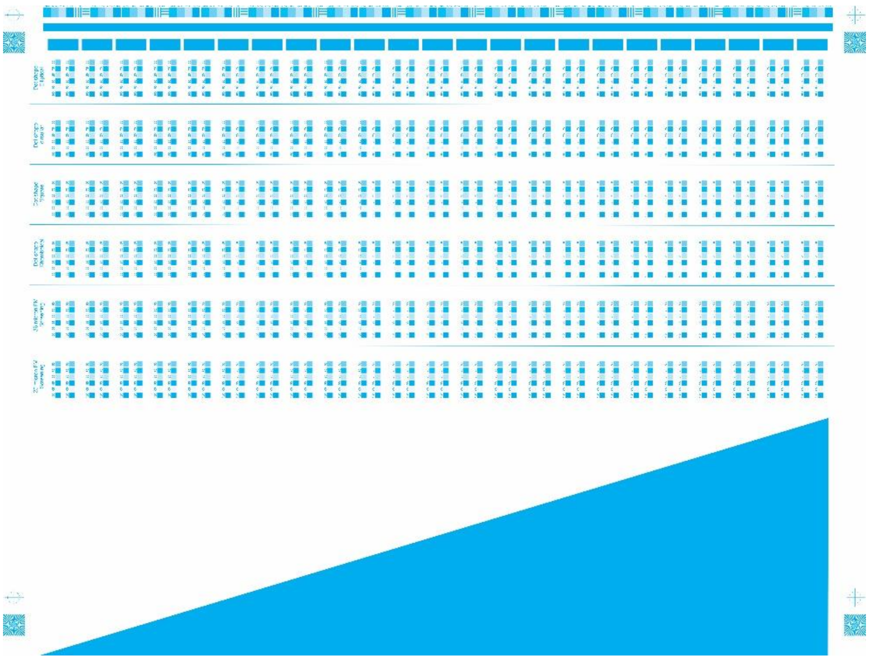

Figure 3. Layout of Test Chart.

Rheology Measurement and Particle Size Measurements

Rheological tests were conducted on Anton Par MCR 301, and the particle size distribution of the developed inks was analyzed on a Brookhaven 90 plus nanoparticle analyzer.

Experimentation

Table 5 displays a list of parameters, levels, and their respective variation range.

Table 5. Experiment Parameters and Their Levels.

Parameter	Unit	Levels
Particle size	microns	2680_5, 2680_10, 2695_5, 2695_10
Dot shape	-	Elliptical, Circular, Square, Rhomboidal
Substrate Type	-	SBS, FBB

Thirty-two trials were conducted on the Graphica 771 sheetfed press using the test chart shown in Figure 3. Coated paper boards were used in all trials. A design of experiments was generated to carry out the experiments with the help of parameters such as particle size of inks, dot shape and paper type and the data was analysed to identify the significant factors affecting Print contrast and Dot gain. Sample sheets were selected to measure print contrast, density, and dot gain.

RESULTS AND DISCUSSION

This section includes the results obtained from rheology measurements done on the rheometer for all four types of ink samples prepared using 2 different particle-sized pigments and 2 different passes on the Three-roll mill. The press results were measured using Techkon SpectroDens Spectro densitometer for Print Contrast (PC), Dot Gain, and Density.

Rheological Results

The apparent viscosity of inks decreases with the increase in shear rate. The rheology data was measured using the PHYSICA MCR 301 rheometer. All inks exhibit shear thinning behavior, and the degrees of shear thinning are different for all four inks. Table 6 summarizes all the rheological tests done.

Table 6. Comparison of Rheological Data.

S.N.	Rheological Parameters	Unit	Model used	Sample 2680-5	Sample 2680-10	Sample 2695-5	Sample 2695-10
1	Initial Shear Viscosity ($\eta 0$)	Pa·s	Carreau model I	490.86	281.41	211.05	160.92
2	Infinite Shear Viscosity ($\eta\infty$)	Pa·s	Carreau model I	3.1454	3.0819E-06	3.8593E-06	2.6836E-06
3	Yield Stress	Pa·s	Bingham model I	47.79	29.594	26.379	20.882
4	Hysteresis Loop Area	Pa·s	-	11755	8343.2	10419	104822.9
5	IT (Index of Thixotropy)	-	-	0.1989	0.1588	0.1482	0.155

Results of Density Obtained from Test Chart Using Print Contrast Method

The objective of the ink starvation chart is to study the performance of developed inks. It is done by determining the maximum print contrast and target density with minimum TVI that a particular ink can reproduce. Table 7 shows the results obtained for the four ink types, specific dot shapes, and paper types.

Table 7. Result of Density obtained from Maximum Print Contrast as Measured from Test Chart.

Type of Ink	Dot shape	Paper type	Highest contrast obtained	Density	Dot gain
2680-5	Elliptical	SBS	45.00	1.6	21
2680-10	Elliptical	FBB	47.00	1.54	20
2695-5	Round	SBS	36.00	1.33	25
2695-10	Rhomboidal	FBB	38.00	1.57	27

Analysis of DOE for Print Contrast and Dot gain

The main effect plot shown in Figures 4 and 5 suggests that the pigment particle size is the critical parameter affecting the Print contrast and dot gain. The particle size 2680-10 has shown the lowest dot gain, and 2695-5 has shown the highest dot gain and lowest print contrast. The elliptical dot shape has been printed with a higher print contrast and lower dot gain. These parameters are essential for printing any image with better sharpness. The two paper types, FBB and SBS show less significant differences in print contrast. Whereas FBB shows a higher dot gain than SBS. One of the contributing factors affecting the print contrast and dot gain is the viscosity of the four inks, as shown in the table. The Ink with less pigment particle size of 2680-5 has higher ink viscosity and yield stress, affecting ink transfer

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and resulting in less ink contrast with higher Dot gain. This is due to the higher viscosity of ink, which causes difficulty in ink transfer. The interaction plot in Figure 6 shows a strong interaction between particle size and dot shapes. The round dots are circular throughout the range of halftones used in all the halftone areas and are non-directional. The elliptical and the rhomboidal dots are directional. In the elliptical case, the dot starts almost circular in the highlight area and then becomes increasingly elliptical. When the dots join the first time at 44%, it takes on a rhombic shape. After the dots join the second time, at 61%, the rhomboidal shape is first created, followed by elliptical ones, and finally, round dots appear again in the shadows. This is the transition of elliptical dots. Rhomboidal dot shapes are oblong dots and get bigger as they begin to merge into one another on the same axis, forming a chain-like linear pattern.

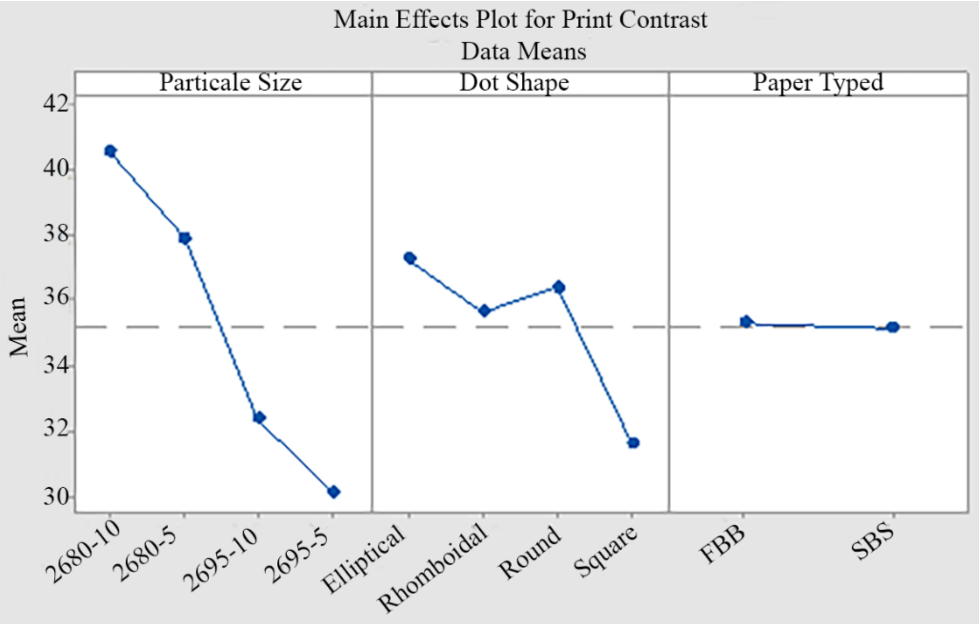

Figure 4. Main effect plot of Print contrast vs pigment particle size, dot shape and paper type.

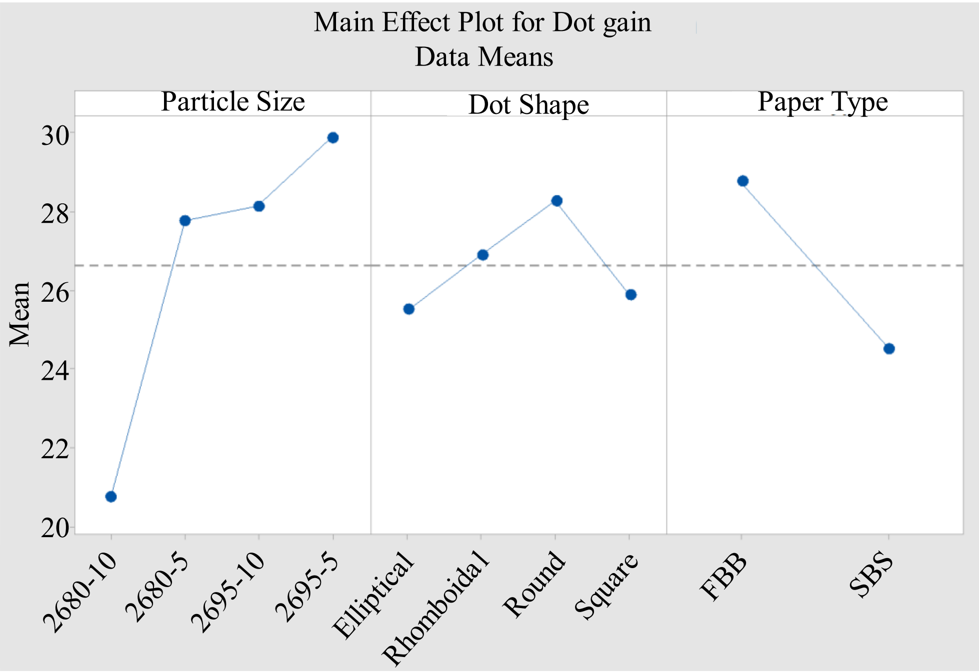

Figure 5. Main effect plot of dot gain vs pigment particle size, dot shape and paper type.

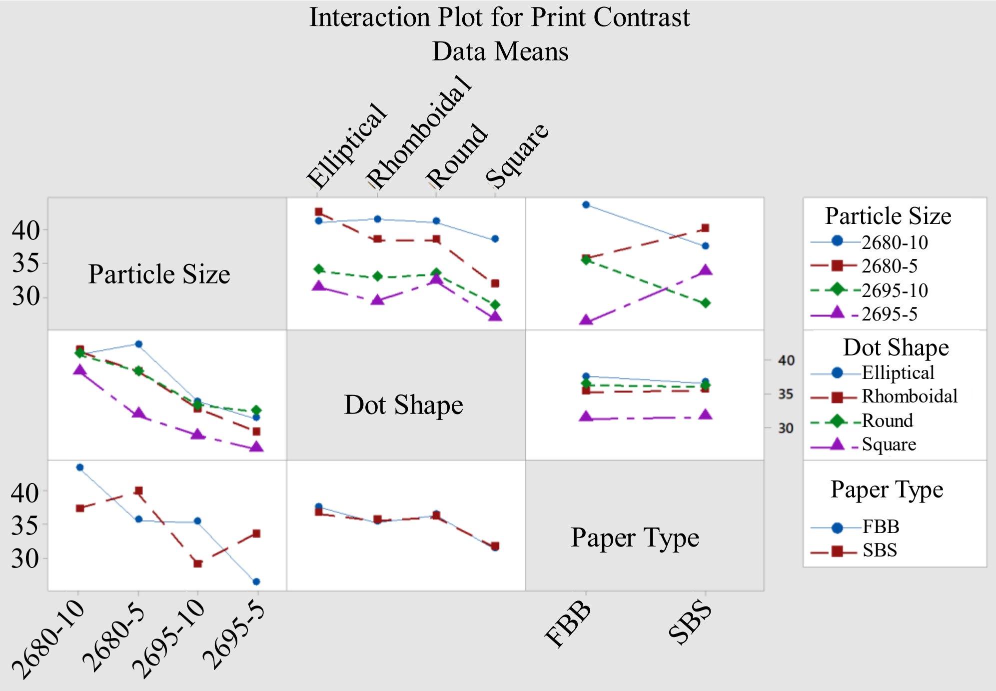

Figure 6. Interaction Effect Plot of Print Contrast Vs Pigment Particle Size, Dot Shape and Paper Type.

CONCLUSION

This study was carried out to study the factors affecting the printability in offset inks. Two pigments used had agglomerate sizes of 0.52 and 3.14 microns measured using a Cilas 990 liquid particle size analyzer. Pigments contribute to the color of ink, and the particle size of the pigments plays a key parameter in the print parameters, such as print contrast and dot gain. A high contrast of 45 and 47 was achieved by 2680-5 and 10 samples. However, the agglomerate size of 2680-10 microns printed with better print contrast and lower dot gain due to its rheology, such as viscosity. Sample 2680-5 showed a higher initial and infinite viscosity and yield stress as well, thus resulting in poor transfer compared to the ink particle sample 2680-10.

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REFERENCES

1. Parfitt GD. Dispersion of powders in liquids, with special reference to pigments. London, Applied Science Publishers; 1973.
2. Nobuoka S. The Relation between Particle Size and Shape of the Pigments and Optical Properties. Color Mater. 1982;55(10):758-65.
3. NOGUCHI N. Printing Ink/Offset Ink 2. Pigment Dispersion of Printing Ink. Journal of Printing Science and Technology. 2000;37(6):315-23.
4. Bermel AD, Bugner DE. Particle Size Effects in Pigmented Inkjet Inks. Journal of imaging science and technology. 1999;43(4):320-4.
5. Ferguson LD. Introduction to printing technology and ink chemistry. TAPPI DEINKING Seminar notes. Atlanta: TAPPI Press; 1996; p.19-28.
6. Seyed Saeid Hosseini, Arjomand Mehrabani-Zeinabad, Ali Zadhoush. The effect of carrier molecular weight and pigment particle concentration on the rheological properties of suspension systems in polymeric medium. In: An Introduction to Emulsions and Suspensions from Different Perspective [Internet]. Nordic Rheology Society; 2007. Available from: https://nordicrheologysociety.org/AnnualTransactions/ShowAllTransactions?selectedYear=2007

7. Hellinckx L, Mewis J. Rheological behaviour of pigment dispersions as related to roller passage. Rheologica Acta. 1969; 8:519-25.
8. Micale FJ, Sharma MK, editors. Surface phenomena and fine particles in water-based coatings and printing technology [Internet]. New York, NY: Springer; 2012. Available from: http://dx.doi.org/10.1007/978-1-4615-3812-7
9. Bastani S, Pishvaei MA, Jalili MO, Sorooshnia S. The Effect of Pigment Concentration and Particle Size Distribution on the Rheological Behavior of Lithography Inks. Journal of Color Science and Technology. 2010 Jun 22;4(2):91-103.
10. Frimova A, Pekarovicova A, Fleming PD, Pekarovic J. Ink stability during printing. TAGA J. 2005 Dec;2:122-31.

