조절된 코팅구조상에서 옵셋인쇄광택의 발현: Part 2

전성재
한솔제지(주) 기술연구소

요 약

최근의 많은 연구로부터 인쇄광택에 대한 코팅구조의 영향이 보고되고, 거론되고 있다. 그러나, 다각적이고, 다양한 잉크량 범위에서 인쇄광택의 개별적 인자에 대한 독립적 영향은 보고된 바 없다. 본 고에서는 다양한 코팅재료와 이어진 캘린더링 공정을 조합하여 Full-factorial실험설계에 준한 모델시료를 제작하고, 특성화하였다. 더불어 공극이 없지만 넓은 범위의 거칠음 수준을 가진 필름을 포함하였다. 통계도구를 사용하여 각 인자의 독립적인 영향을 추출하므로써, 각 구조인자의 함수로서 인쇄광택의 정량적인 반응도를 얻을 수 있었다. 결과는 60도와 75도 광택으로 표현하였다.

잉크공급량의 증가는 코팅층 거칠음의 영향을 약화는 시키되 배제시킬 수는 없었다. Matte급의 코팅층에 대한 인쇄광택은 코팅거칠음이 가장 큰 영향인자로 나타났다. 이는, 잉크필름의 Leveling을 저해하는, 큰 잉크필름의 분열형태와 코팅면을 따라 흐르며 형성되는 잉크필름 때문으로 생각되었다. 공극구조의 영향은 전반적으로 높은 잉크량과 백지광택수준에서 가장 크게 나타났다. 전체적으로는 코팅거칠음이 인쇄광택에 가장 강한 인자였으며, 공극크기, 공극부피가 뒤를 이었다. 그러나, 광택지 영역에서는 공극크기가 가장 강한 영향인자로 구분되었으며, 거칠음, 공극부피가 뒤를 이었다. 이러한 결과는 인쇄품질 측면에서 코팅을 최적화하는데 활용될 수 있을 것이다.

1. 서 론

인쇄광택은 최종제품의 가장 중요한 광학적 품질의 하나로 간주된다. 인쇄광택은 오래

전부터 거칠음의 함수로 알려져 있다 (Chinmayanandam, 1919; Gate et al. 1973 Lee, 1974 Oittinen, 1980, 1983). 많은 인자와 공정이 인쇄물의 최종 표면에 영향을 하는데, 여기에는 인쇄조건, 잉크전이, 잉크종류와 유변특성, cavitations, 분열, 그리고 매체의 구조 등이 있다 (Zang et al. 1994; Glatter et al. 1997 Ercan et al. 1998). 최근에는 인쇄광택에 대한 코팅구조, 바인더종류 등의 영향에 대한 연구도 보고된 바 있다 (Donigian et al. 1997, Desjumaux et al. 2000). 잉크의 셋팅속도에 비교한 잉크필라먼트의 레벨링 속도로서 결과가 설명되는데, 빠른 셋팅속도는 잉크필라먼트가 레벨링하기에 충분한 시간을 제공하지 못하기 때문에 낮은 인쇄광택을 나타내는 것으로 이해되고 있다. Preston (2002)은 넓은 범위에 걸쳐 코팅구조와 잉크셋팅을 연구하여, 공극크기와 셋팅간의 매우 좋은 상관관계를 보고한 바 있으며, 긴 시간에 걸친 잉크셋팅공정동안 잉크필름내 구성성분의 재배열에 의해서도 인쇄광택이 결정될 수 있음을 보였다. 그러나, 인쇄광택에 영향하는 모든 기작이 명백한 것은 아니며, 잉크 필라먼트의 레벨링이 최종 인쇄광택을 결정하는데 주요 인자임은 분명한 것으로 생각된다. Jeon and Bousfield (2003)은 표면의 거칠음과 공극구조를 분리하여 각각의 측면에서 인쇄광택의 거동을 보고한 바 있다. 거칠음과 공극율은 짧은 시간에 인쇄광택에 영향하며, 잉크필름의 분열시에 관련하는 것으로 보였다. 그러나, 공극구조가 잉크필름의 분열과정에 영향할 수 있는 것 같으나, 잉크필라먼트의 크기, 분열, 그리고 레벨링사이의 연결관계는 충분히 나타나지 않고 있다.

각 인자가 연계되고, 경쟁적인 영향의 결과로 나타나는 인쇄광택에 대한 연구는 시스템적으로 연구된 바가 드물다. 본 고에서는 넓은 범위의 코팅 거칠음, 공극크기, 공극율을 갖는 모델시료가 제작되었다. 이들 시료들은 다양한 잉크량으로 인쇄되었고, 인쇄광택은 2개의 각도에서 보고되었다. 각인자의 유의성은 통계도구를 사용하였다. 이러한 결과는 각 인자의 영향도를 구분하고 개선하는데 도움이 될 것이다.

2. 실험재료와 방법

- Coatings: laboratory draw-down coater.
- Base substrate: polyester (PE) film, matte type (75 gloss of 4.3%),
  basis weight of 173.7 g/m^2

– Each set of coated samples are calendered with five different PE films with different roughness values: the roughness is transferred to the coating layer by the process. Details of the calendering step are in Jeon (2002).

– Sample codes are represented here as 'Pigment–Binder–Roughness', e.g. 'G1B06R1' means pigment G1, binder of 6 pph and roughness level '1'.

Table 1. A summary of pigments used.

Pigment code	Type	Particle size, mm
G1	Ground calcium carbonate (GCC), 96% < 2㎛	0.32
G2	GCC, 60% < 2㎛)	1.5
P1	Precipitated calcium carbonate (PCC) – Rhombo	0.3
P2	Prismatic	0.6
P3	Prismatic	2.2
PP	Plastic pigment	0.13

Table 3.Coating formulation for full–scale sample preparation.

Components		Particle Size*	SAMPLE CODE				
Generic	Class or type	(㎛)	G1 Series***	G2 Series	P1 Series	P2 Series	P3 Series
GCC	G1 (96%<2um)	0.32	100				
	G2 (60%<2um)	1.50		100			
PCC	P1 (Rhombo)	0.30			100		
	P2 (Prismatic)	0.60				100	
	P3 (Prismatic)	2.20					100
PP	Polystyrene	0.13	5**	5	5	5	5
Binder	SB Latex	0.17	6,10,15,20**	6,10,15,20	10,15,20,30,40	10,20,30,40	10,20,30,40
Lubricant	Calcium stearate	-	0.5**	0.5	0.5	0.5	0.5
pH control	NaOH	-	targetted to pH 8.5				
PVC level (%)			88,81,74,68	88,81,74,68	81,74,68,59,52	81,68,59,52	81,68,59,52

* From manufacturers, **Parts per hundred to pigment, ***Each series has 5 levels in roughness.

- Seasoning and measurements: standard room at 23℃, 50RH%
- Gloss : 75 gloss (T 480 om-92).

  60 gloss (ISO 2813)
- A stylus profilometer: Alpha-Step 200TM, Tencor Instruments.

  The scan lengths of 400㎛, force of 7 mg.
- The pore size distribution: mercury porosimetry. Surface tension of 485 dyne/cm and contact angle of 130°
- The printing test: laboratory printability tester (KRK™ print tester).
- The ink: commercial cyan quickset ink, 1.5~3.0 g/m^2

  (Capiplus III Process Cyan, Flint Ink Co.).

3. 실험결과 및 토론

The pore size distributions of the samples are presented in [Figure 1]. Each pigment series has almost the same pore size while their porosities varied with binder content. Relationships between roughness and gloss can be found in Jeon (2002) as well as details of the structural measurements and electron microscope pictures of the coatings.

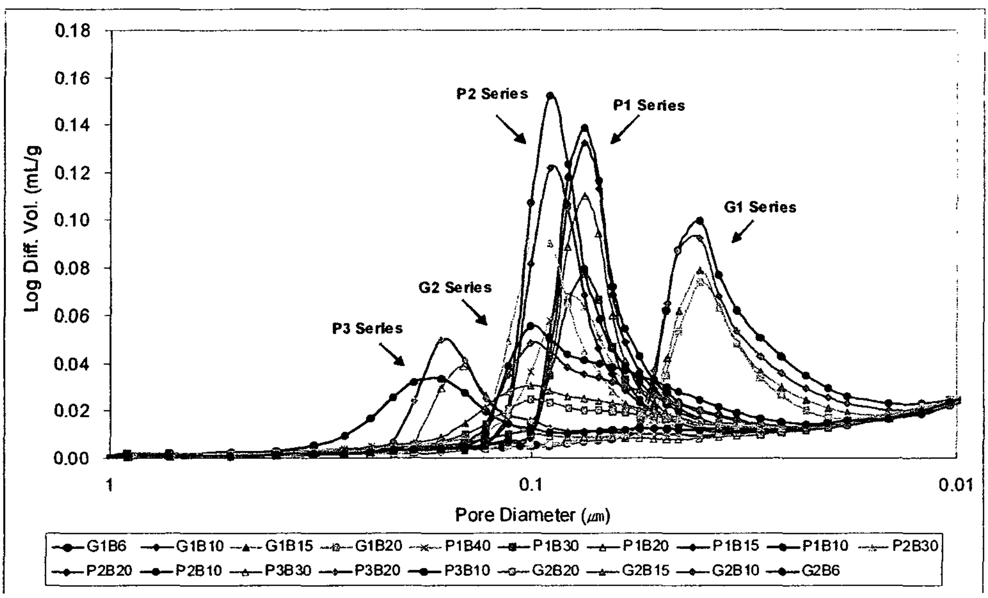

Figure 1. Pore size distribution of the different coatings.

[Figures 2] reports the print gloss for each sample series at 1.5 and 3.0 g/m^2 ink level. The effect of coating gloss is consistent all over the given range. The gaps between series are due to their different pore size and porosity. Though it may be hard to see the rank of the series in print gloss, it could be observed that the results are positioned depending on their pore size and porosity; a series with larger pore size and/or small porosity produces higher print gloss. As evidenced in [Figure 2], G1 series with the smallest pore size of 39 nm has the lowest gloss. The P3 series, with the largest pore size of 153 nm, produced the highest print gloss at a given roughness levels. Other pigment series, G2, P1, and P2, are close and crossed each other due to their small difference in pore size and porosity.

There is a steep drop in print gloss below 25 gloss units of polyester film. Most of coated samples also show a similar drastic change in print gloss in the low paper gloss region or the large roughness region. These results indicate that roughness can retard the ink film leveling process. In general, high inking levels increase the print gloss and reduce the roughness effect. The P3 series is almost flat at the ink level of 3.0 g/m^2, but the overall dependency of print gloss on roughness is still evident for the other samples.

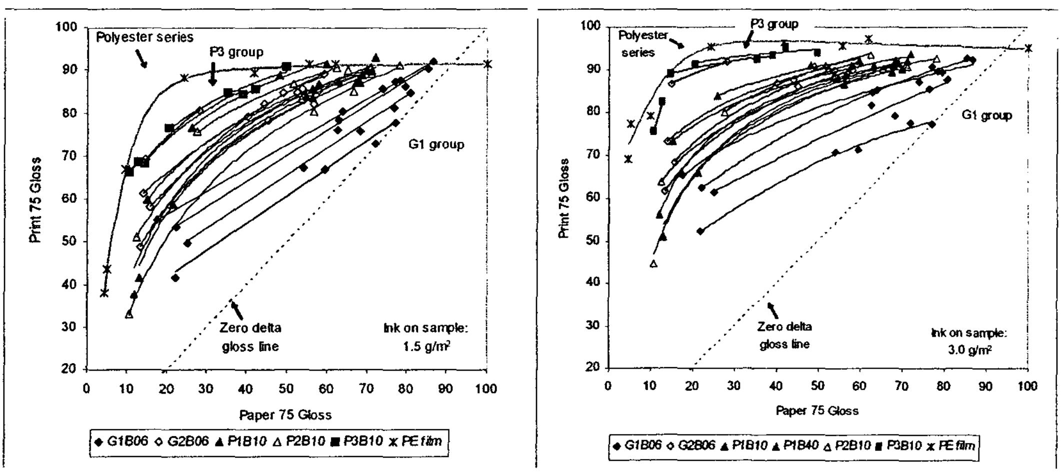

Figure 2. Print 75° gloss of coatings as a function of paper gloss at 1.5 g/m^2 and 3.0 g/m^2 ink on samples.

When the print gloss is plotted in terms of coating surface roughness, as in [Figure 3], the steep drop in gloss is not seen. The change of print gloss of P3 series and G2 series is almost parallel with that of polyester series especially at high inking levels. Therefore, the ink film on those coatings may have a longer time to level. The 75° gloss becomes less sensitive over high gloss range. [Figure 4] reports the ink gloss in terms of 60° gloss. This now separates the high gloss results into different values.

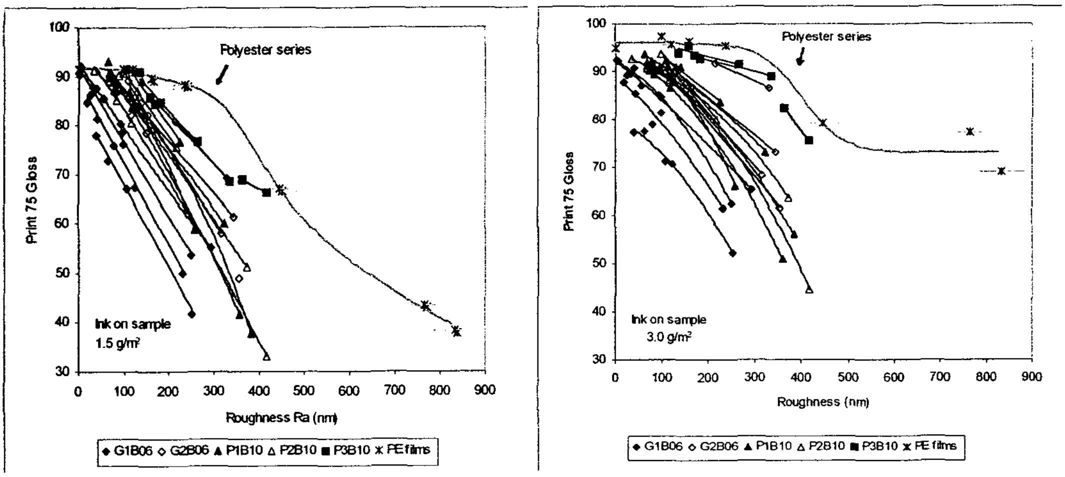

Figure 3. Print 75° gloss of coatings as a function of roughness at 1.5g/m² and 3.0g/m² ink on samples.

Other results at different inking conditions are in Jeon (2002), but the results follow these general trends. At low inking level, the 75° print gloss of coated samples reaches that of polyester films, but for the 60° print gloss, coated samples are greater than that of polyester films. The print gloss of P3 series, which is almost parallel to that of polyester films, shows a significant effect of roughness. Because of this clarity in differentiation between samples, the following analysis is done in terms of 60° gloss. The plots of 60° vs. 75° gloss is also given in the graph in order that the values can be converted.

Overall, the effect of roughness on print gloss extended over a wide range unless coating is non-porous. Even at ink film thicknesses much greater than the roughness, the influence of roughness on print gloss is seen.

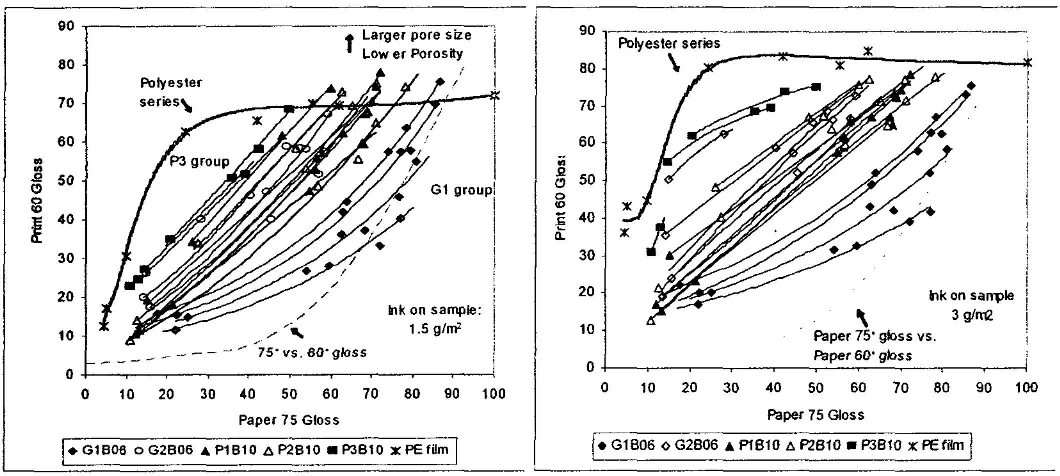

Figure 4. Print 60° gloss as a function of paper gloss at 1.5 g/m^2 and 3.0 g/m^2 ink on samples.

Overall Dependency of Print Gloss on Pore Structure

The print gloss at given roughness levels is extracted using interpolation from the fitted curves and the results are plotted as a function of porosity and coating gloss in [Figure 5]. Each series represents the print gloss at a certain base gloss level. Though the data in each series has scatter due to the difference in pore size, the trend lines show the overall dependency of print gloss on porosity. The gaps between the series indicates that the roughness effect produces a systematic change in print gloss. The porosity influence is strong in the high paper gloss region. The slope distribution should be interpreted with caution; relatively mild slope in low paper gloss series may have a significantly large change in 75° gloss. The increase in print gloss of low paper gloss series is noticeable to the similar parallel tracks of other series. Therefore, the effect of porosity seems to be strong as the ink film thickness increases.

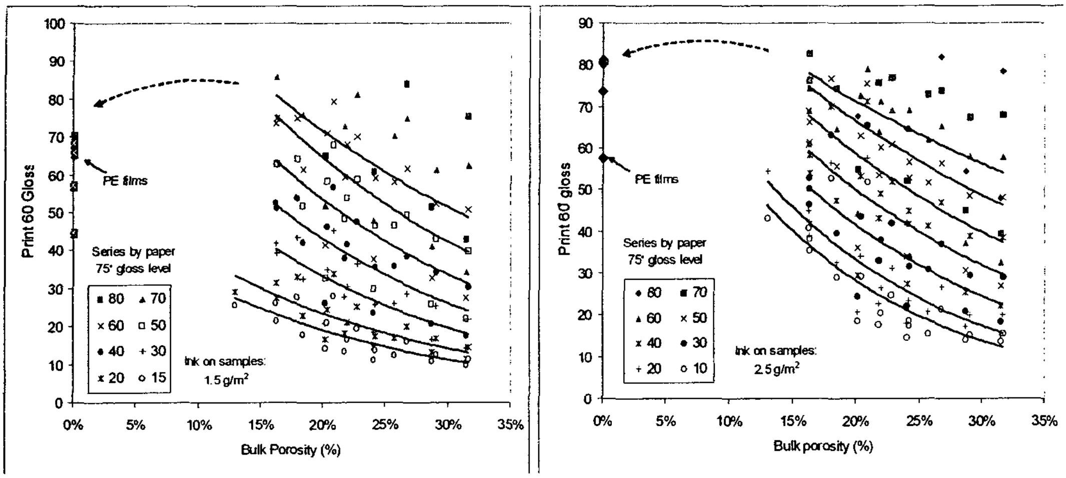

Figure 5. Overall trend of the relationship between print 60° gloss and porosity at 1.5 g/m^2 (left)) and 2.5 g/m^2 (right) ink on samples. No trend line given for '80' series due to missing data set.

Overall effect of pore size is found in a similar way. The results are presented in [Figure 6], at the ink levels of 1.5 and 2.5 g/m^2. The relation is rather convex shape and the change in print gloss is even larger than the case of pore volume within a given range of parameters. A coating with larger pore size often produces a higher print gloss regardless of paper roughness. As observed in porosity effect, influence of pore size also became stronger over the low print gloss series in the higher ink film thickness.

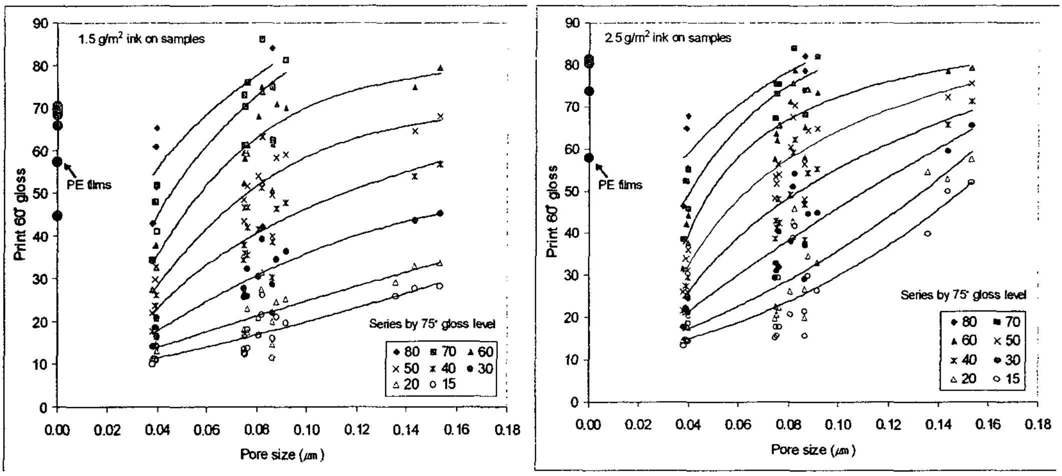

Figure 6. Overall trend of the relationship between print 60° gloss and pore size at 1.5 g/m^2 (Left) and 2.5 g/m^2 (Right) ink on samples.

Significance of Each Structural Factors by Statistical Analysis

The print gloss is extracted at given porosity levels to obtain a set of designed experimental data with three independent factors and analyzed the significance of the involved factors. The main effects are determined for the entire parameter range. The result is given in [Figure 7]; paper gloss ranged from 15~80 gloss units at 75° gloss, pore size from 39 to 86 nm, and porosity from 16 to 32%. The effect of roughness is larger than the other parameters. The pore size effect is second in significance. Visualized results of fitted response surface are given in Jeon (2002). Therefore, these results indicate that once the gloss level of paper is determined, the pore size is considered to be more important than porosity in determining print gloss.

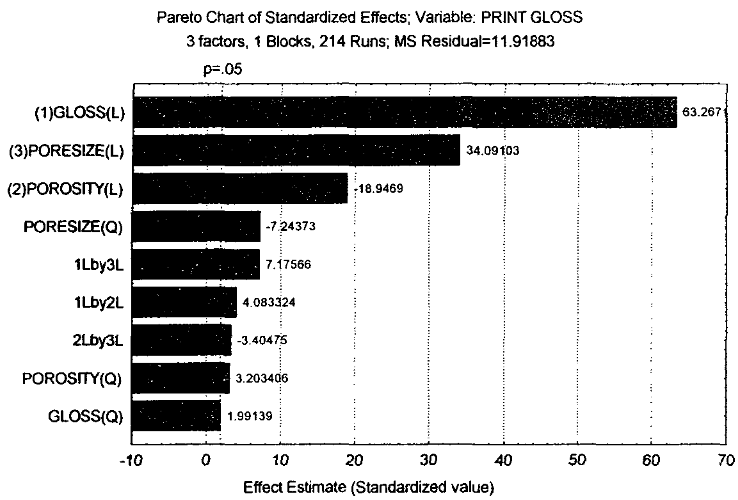

Figure 7. The result of main effects analysis for print gloss over all parameter ranges. The effects are from ANOVA estimates. The effects above p=0.05 are accepted as statistically significant. Here, 'p' is referred to reliability.

In a practical sense, no single paper grade has the gloss range in this work. Therefore, the data are sectioned into two blocks based on the gloss level such that the gloss up to 40 gloss units may represent for matt and/or dull grade surface while the above for gloss and glossy grade. [Figure 8] describes the obtained result from the low paper gloss range data. The effects between roughness and pore structure remain in the same order as the overall results, but the gap became smaller. In summary for the low paper gloss range, the roughness effect is in the strongest position, but the competitiveness is high with pore size following by porosity. Therefore, even in the high roughness (low gloss) range, refined control of pore structure is important.

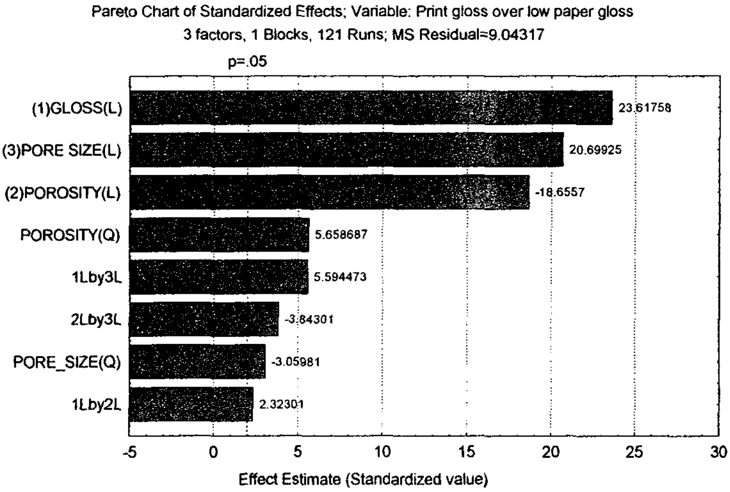

Figure 8. The result of main effect analysis for print gloss over low paper gloss ranges; (up to 40 gloss units at 75° geometry).

The second section of analysis is done for the above 40 gloss units up to 70 gloss units. The result of main effects is given in [Figure 9]. The pore size effect is equivalent or even larger than the paper gloss influence. Since porosity effect is relatively small and far below from these two factors, the significance is much on the pore size in the high paper gloss region. In a practical sense, the structural difference from various products may lie in the pore size rather than paper gloss since it is controlled for a specific grade.

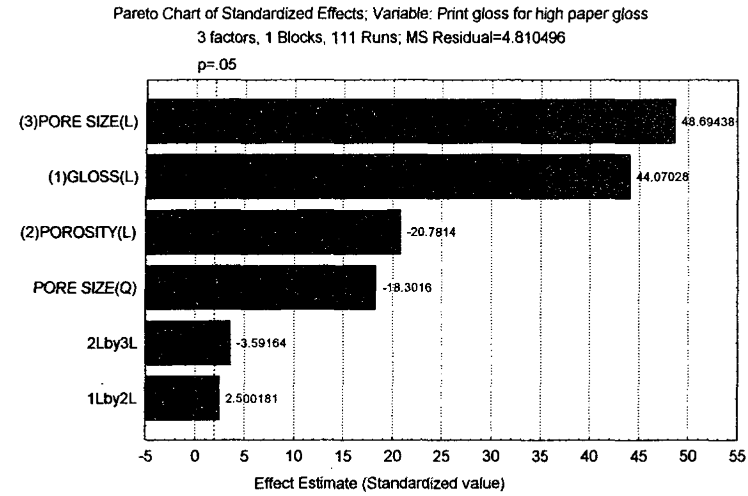

Figure 9. The result of main effect analysis for print gloss over high paper gloss ranges; (40 ~ 70 gloss units at 75° geometry).

4. 결 론

A well defined set of coatings with systematic change in roughness, pore size, and porosity is generated and analyzed with respect to the print gloss development for several ink layer thicknesses. Increasing ink levels increases the print gloss to a plateau for most surfaces. Coating surface roughness influences print gloss in all ranges, even when the ink thickness is virtually larger than the surface roughness. Print gloss of coatings with low porosity and large pores had a small dependency on roughness. Coating porosity had a strong influence on print gloss at low values of porosity, but at moderate levels, the influence is weak. The effect of pore size is stronger than porosity at a given roughness level and strongest at glossy region. The print gloss must be interpreted with setting and/or tack dynamics, which will be dealt in other paper.

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