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Data Base System on the Fabric Structural Design and Mechanical Property of Woven Fabric

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1. Introduction

The structure of fabrics is very important, because fabric geometry gives considerable effects on their physical properties. Therefore, the studies for fabric structure have been carried out with following areas:

1. prediction of fabric physical and mechanical properties
2. education and understanding related to the fabric structural design
3. the area related to the fabric and garment CAD systems

Among them, the researches for the prediction of fabric physical and mechanical properties with fabric structure have been performed by many textile scientists. But the education and understanding related to the fabric structural design have been emphasized on the theoretical aspects. But the optimum fabric design plan is recently needed with the relevant fabric shrinkage in dyeing and finishing processes for making the various emotional fabrics for garment. For responding this need, the difference of fabric design plan such as fabric density, yarn count and finishing shrinkage has to be surveyed with weaving looms such as water jet, air-jet and rapier looms, and also has to be analyzed with weave patterns such as plain, twill and satin. On the other hand, recently, there are many commercial CAD systems such as fabric design CAD for fabric designers and pattern design CAD including visual wearing system for garment designers. But there is no fabric structural design system for weaving factories, so the data base system related to the fabric structural design for weaving factories is needed. Many fabric weaving manufacturers have some issue points about fabric structural design. The 1st issue point is that there is no tool about how to make fabric design according to various textile materials such as new synthetic fibers, composite yarns, and crossed woven fabrics made by these new fibres and yarns. As the 2nd issue point, they also don't have the data about what is the difference of fabric structural design such as fabric densities on warp and weft directions according to the weaving looms such as WJL, RPL and AJL. And 3rd issue point is that there is no data about how the difference of fabric structural design is among weaving factories even though they have same looms and they use same materials. Therefore, in this topic, a data base system which can easily decide warp and weft fabric densities according to the various yarn counts, weave construction and materials is surveyed by the analysis of design plan for synthetic fabrics such as nylon and PET and worsted and cotton fabrics. Furthermore, the analyses for easy deciding of fabric design from new materials and for making data base related to this fabric structural design are carried out as the objectives of this topic.

2. Background of fabric structural design

The first study for the fabric structural design was started in 1937 by Peirce paper(Peirce, 1937), which is the Peirce's model of plain-weave fabrics with circular yarn cross section. And he also proposed fabric model with an elliptic yarn cross section. In 1958, Kemp proposed a racetrack model(Kemp, 1958). Hearle and Shanahan proposed lenticular geometry (Hearle & Shanahan, 1978) for calculation in fabric mechanics by energy method in 1978. And many researches related to the fabric mechanical properties under the base of fabric structural model were carried out by Grosberg (Grosberg & Kedia, 1966), Backer (Backer, 1952) Postle(Postle et al., 1988). Lindberg(Lindberg et at., 1961) extensively studied fabric mechanical behavior related to the tailorability. Then the sophisticated measurement system of fabric mechanical properties was developed by Kawabata and Niwa(Kawabata et al., 1982) which is called KES-FB system. Another fabric mechanical measurement system called the FAST was developed by CSIRO in Australia(Ly et al., 1991). Recently new objective measurement systems(Hu, 2004) such as Virtual Image Display System(VIDS) and Fabric Surface Analysis System(FabricEye®) have been developed for the analysis of fabric geometrical properties. On the other hand, nowadays there are many CAD systems(i-Designer, Texpro) related to the fabrics design such as weave construction, color and pattern. And also there is pattern design CAD(Texpro, Harada & Saito, 1986) including visual wearing system(VWS) for garment designer. But there is no fabric structural design system related to the decision of the fabric density according to the fibre materials, yarn linear density, and weave pattern. Therefore, a data base system which can easily decide warp and weft densities according to the various yarn counts, weave constructions and materials is required through the analysis of design plan for worsted, cotton, nylon and polyester fabrics as shown in Figure 1(Kim, 2002).

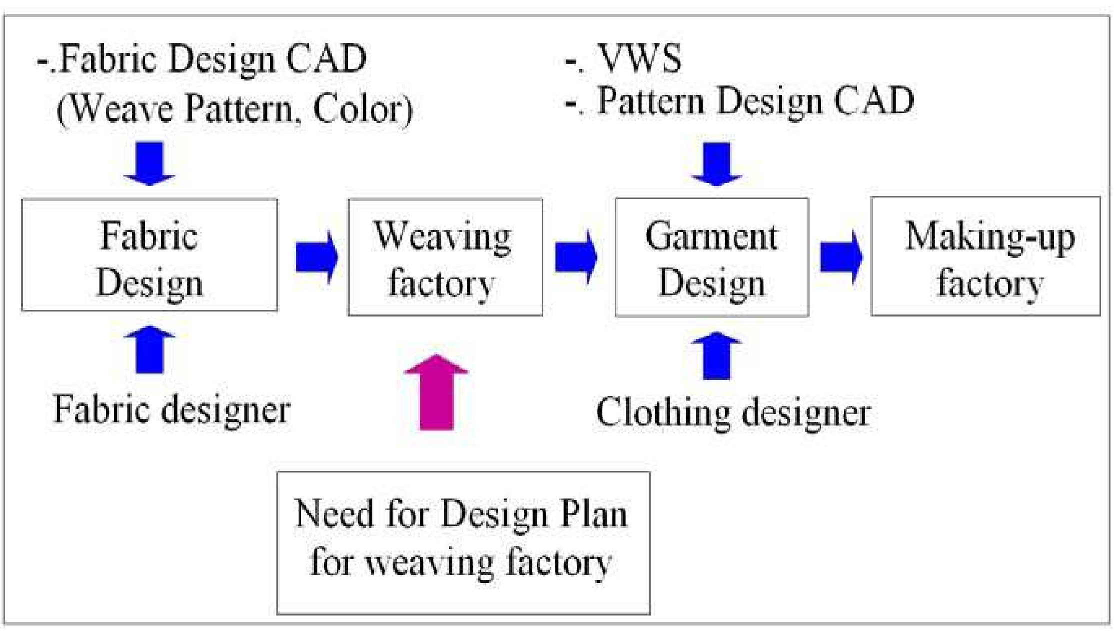


Fig. 1. Diagram for need of fabric structural design system for weaving factory

Figure 2 shows milestone of detail analysis steps related to the data-base system of the fabric structural design in relation with existing fabric design and wearing systems of garment(Kim, 2005). The final goal of this analysis is aiming to link with virtual wearing system, pattern design CAD and drape analyzer. As shown in Figure 2, in the 1st step, the data base of weave pattern and fabric factors has to be made using yarn count, fabric density and weave pattern from which weave density coefficient (WC) and warp and weft density distributions are calculated. And weave density coefficient can be analyzed according to weaving factories and loom types. Furthermore, weave density coefficient and yarn density coefficient (K) can be analyzed with cover factor of fabrics. In the 2nd step, the data base of various physical properties of fabrics is made with dyeing and finishing process factors, which affects fabric hand and garment properties measured by KES-FB and FAST systems. In the 3rd step, these data bases have to be linked with visual wearing system (VWS), pattern design CAD and drape analyzer. In this topic, the case study of data-base system of the fabric structural design in the 1st step shown in Figure 2 is introduced and analyzed with various kinds of fabric materials and structural factors.

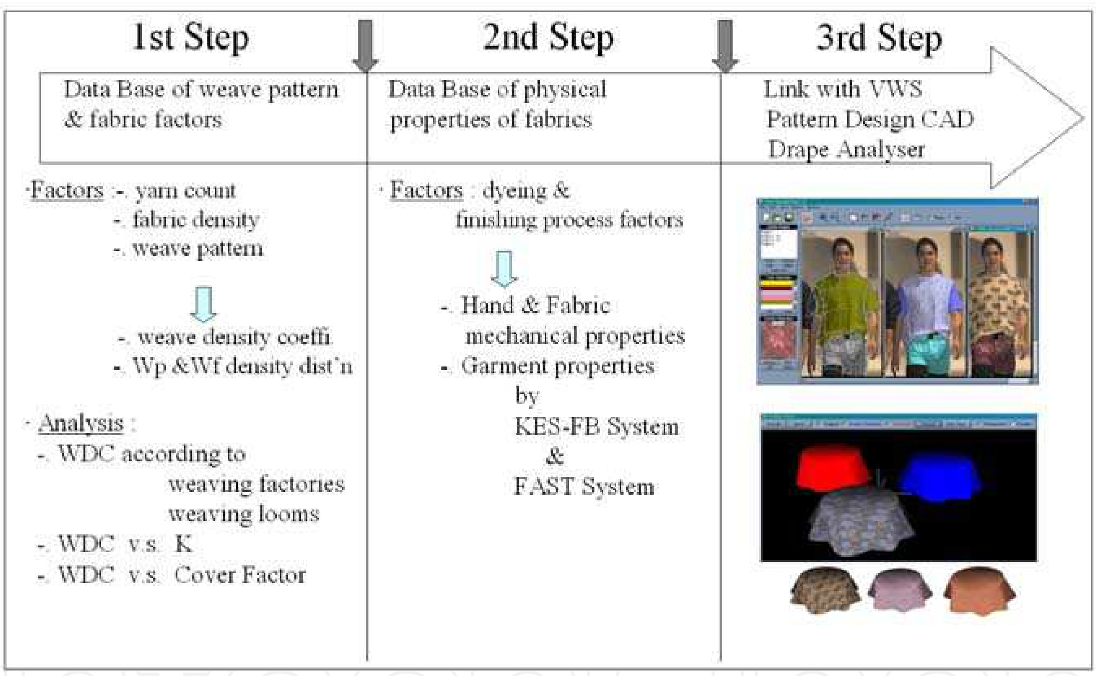


Fig. 2. Detail milestone of analysis steps in relation with existing fabric design and wearing systems of garment

3. Major issues of the mechanical property of the woven fabric related to the fabric structural design

Many researches about mechanical property of the woven fabric according to the yarn and fabric parameters were carried out using KE-FB and FAST systems (Oh & Kim,1993, 1994). Among them, the PET synthetic fabric mechanical properties according to weft filament yarn twists, yarn denier and fabric density were analysed and discussed with these yarn and fabric structural parameters. On the other hand, the worsted fabric mechanical properties according to the looms such as rapier and air jet were also analysed and discussed with weaving machine characteristics (Kim & Kang, 2004, Kim & Jung, 2005). Similar studies were also performed using the PET and PET/Tencel woven fabrics (Kim et al., 2004). The researches related to the fabric mechanical property according to the dyeing and finishing processes were also carried out (Kim et al., 1995, Oh et al., 1993). These are the discrete research results such as 1st and 2nd step shown in Figure 2. There are no informations about how these mechanical properties affect to the garment properties shown on step 3 in Figure 2. This is major issue point of the mechanical property of the woven fabric related to the fabric structural design. Fortunately, in i-designer CAD system, visual weaving performance is available by input the fabric mechanical properties measured by KES-FB system. So, the data base in 1st and 2nd step shown in Figure 2 is needed and these data bases have to be linked with existing visual wearing system, pattern design CAD and drape analyzer shown on 3rd step in Figure 2.

4. Current trends of the data base system of the fabric structural design

4.1 Procedure of data base system of the fabric structural design

Figure 3 shows the procedure of data base system of the fabric structural design. In Figure 3, yarn diameter is calculated using yarn count and weave factor is also calculated by weave structure using number of interlacing point and number of yarn in one repeat weave pattern. Then the weave density coefficient is decided using yarn diameter, weave factor and warp and weft densities. And conversely the warp and weft density distribution is made by yarn diameter, weave factor and weave density coefficient. Peirce(Peirce, 1937) proposed equation 1 as a fabric cover factor which is recommended to weaving factories by Picanol weaving machinery company(Picanol, 2005). In equation 1, yarn and fabric correction factors are shown in Table 1 and 2, respectively.

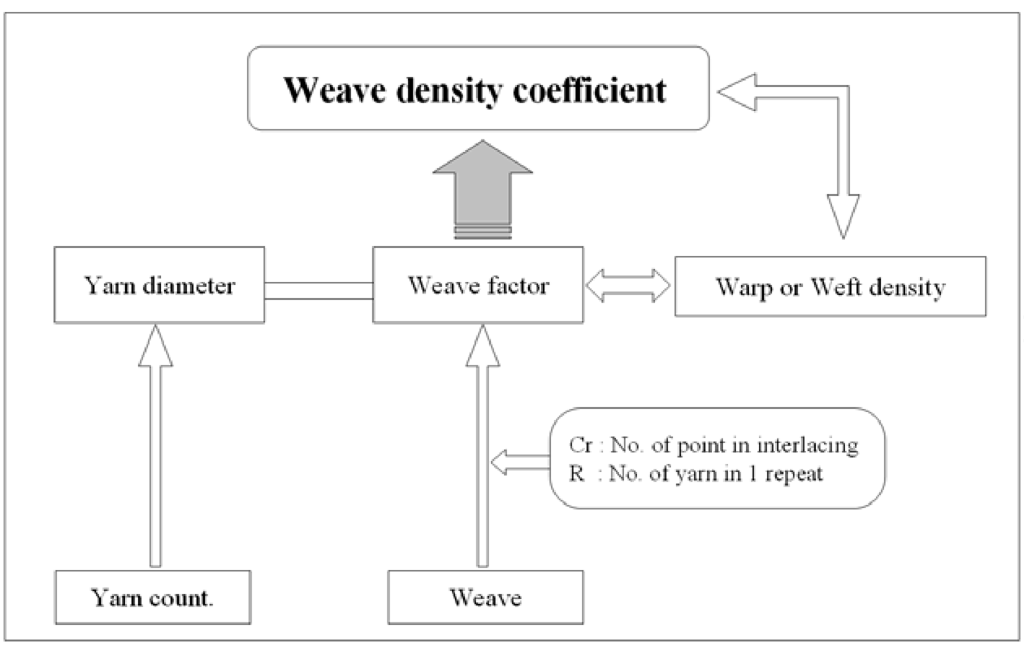


Fig. 3. Procedure diagram of data base system of the fabric structural design

$$\left(\frac{\text{ends/in}}{\sqrt{\text{Ne}}}+\frac{\text{picks/in}}{\sqrt{\text{Ne}}}\right)\times \text{yarn correction factor}\times \text{fabric correction factor} \tag{1}$$

Type of yarn	Correction factor
metallic	0.3
glass	0.6
carbon	0.9
cotton, flax, jute, viscose, polyester	1.0
acetate, wool	1.1
polyamide	1.2
polypropylene	1.4

Table 1. Yarn correction factor

Drill/twill weave		Satin weave	
Pattern	Peirce	Pattern	Peirce
2/1	0.819	1/4	0.709
3/1	0.769	1/5	0.662
2/2	0.746	1/6	0.629
4/1	0.763	1/7	0.599
5/1	0.714	1/8	0.578
6/1	0.694		
7/1	0.689		
4/4	0.671		

Table 2. Fabric correction factor

On the other hand, Prof. M. Walz(Park et al., 2000) proposed equation 2 as a little different equation form, but which is applicable to the various fabrics made by all kinds of textile materials. In equation 2, yarn and fabric correction factors are also shown in Table 3 and 4, respectively.

$$C(\%) = (\mathrm{dw} + \mathrm{df})^2 \times \mathrm{Dw} \times \mathrm{Df} \times b \tag{2}$$

$$where, \quad d_{w,f} = \frac{a}{\sqrt{Nm}} = \frac{a\sqrt{dtex}}{100} \text{: yarn diameter(warp, weft)}$$

where

C(%): cover factor
Dw: warp density (ends/inch)
Df: weft density (picks/inch)
a: yarn correction factor (Table 3)
b: fabric correction factor (Table 4)

Basilio Bona (Park et al., 2000) in Italy proposed empirical equation 3 for deciding fabric density on the worsted fabrics.

$$D = K \times \sqrt{Nm} \times C_f \tag{3}$$

where, D: fabric density (ends/m)
K: density coefficient
Nm: metric yarn count
C_f: weave coefficient

Type of yarn	Correction factor
metallic	0.39
glass	0.71
carbon	0.86
cotton, flax, jute, viscose	0.95
polyester	0.92
acetate, wool	0.98
polyamide	1.05
polypropylene	1.17

Table 3. Yarn correction factor

Drill/twill weave		Satin weave	
Pattern	Walz	Pattern	Walz
2/1	0.69	1/4	0.50
3/1	0.58	1/5	0.45
2/2	0.56	1/6	0.42
4/1	0.49	1/7	0.39
5/1	0.43	1/8	0.38
6/1	0.41		
7/1	0.40		
4/4	0.39		

Table 4. Fabric correction factor

$$\left(\mathrm{C_f} = \frac{R}{R + C_r} \times f_c \times f_f \times f_j \right)$$

f_c: cover factor
f_f: floating factor
f_j: jumping factor

Equation 3 is modified as equation 4 for the cotton fabrics.

$$D = K_c \times 0.0254 \times \sqrt{Ne \times 1.694} \times C_f \tag{4}$$

where, Ne: English cotton count
Kc: Yarn density coefficient (cotton)
where:
- Comber yarns : 425~350 (12 ~17 MICRONAIRE)
- Sea & Island cotton : 425, American cotton : 375
- Card yarns : 350~290 (14 ~22 MICRONAIRE)

But, in synthetic filament yarn fabrics such as nylon and polyester, more effective parameter is needed. So, weave density coefficient, WC is made by equation 5.

$$WC = \left[\frac{d_w + d_f}{25.4} \right]^2 \times D_w \times D_f \times WF \tag{5}$$

where, $d_{w,f}$: yarn diameter (warp, weft)

WF : weave factor

$D_{w,\,f}$: warp, weft density

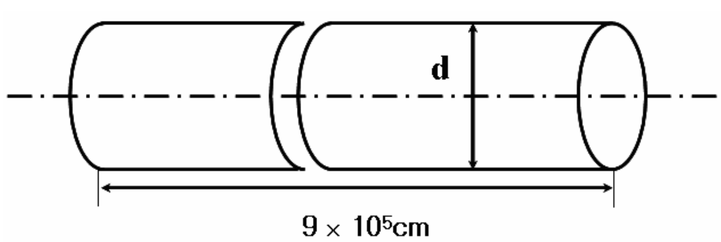
In equation 5, assuming that $D_w \times D_f$ is constant, it becomes as equation 6.

$$D_w \times D_f = \frac{WC}{WF} \times \left[\frac{25.4}{d_w \times d_f} \right]^2 = const. \tag{6}$$

WC in equation 5 can be converted to K and Kc in equation 3 and 4, conversely K is converted to WC and also WC in equation 5 can be compared with cover factor, C given in equation 1 and 2, which is shown in next case study.

4.2 Calculation of fabric structural parameters

In equation 6, d_w and d_f are calculated by yarn linear density, equation 7 as shown in Figure 4. WF is calculated by equation 8 as shown in Figure 5. In Figure 4, calculated yarn diameter by equation 7 is shown in polyester, nylon and rayon yarns, respectively. As shown in Figure 5, calculated weave factors by equation 8 are shown according to the various weave patterns. For plain weave, weave factor (WF) is calculated as 1 using R=2 and Cr = 2. In a little complicated weave pattern as a derivative weave, weave factor (WF) is calculated as 0.76 using R=4 and Cr=3 as an average value by two types of repeat pattern in the weft direction. And in a very complicated weave pattern, Moss crepe, weave factor is calculated as 0.538 using R=120 and Cr=56.06.



Yarn	Density	Yarn diameter (mm)
PET	1.38	$0.01246\sqrt{Den.}$
Nylon	1.14	$0.01371\sqrt{Den.}$
Rayon	1.52	$0.01189\sqrt{Den.}$

$$Den.(g) = \rho_f (g / cm^3) \times V(cm^3) = \rho_f \times \frac{\pi d^2}{4} \times 9 \times 10^5 \tag{7}$$

where, d: yarn diameter

ρ_f: fibre density

Den: denier

V: volume

Fig. 4. Diagram between yarn count and diameter

$$WF = \left[\frac{R + C_r}{2R} \right]^2 \tag{8}$$

where, WF: weave factor

R: No. of yarn in 1 repeat

Cr: No. of point in interlacing

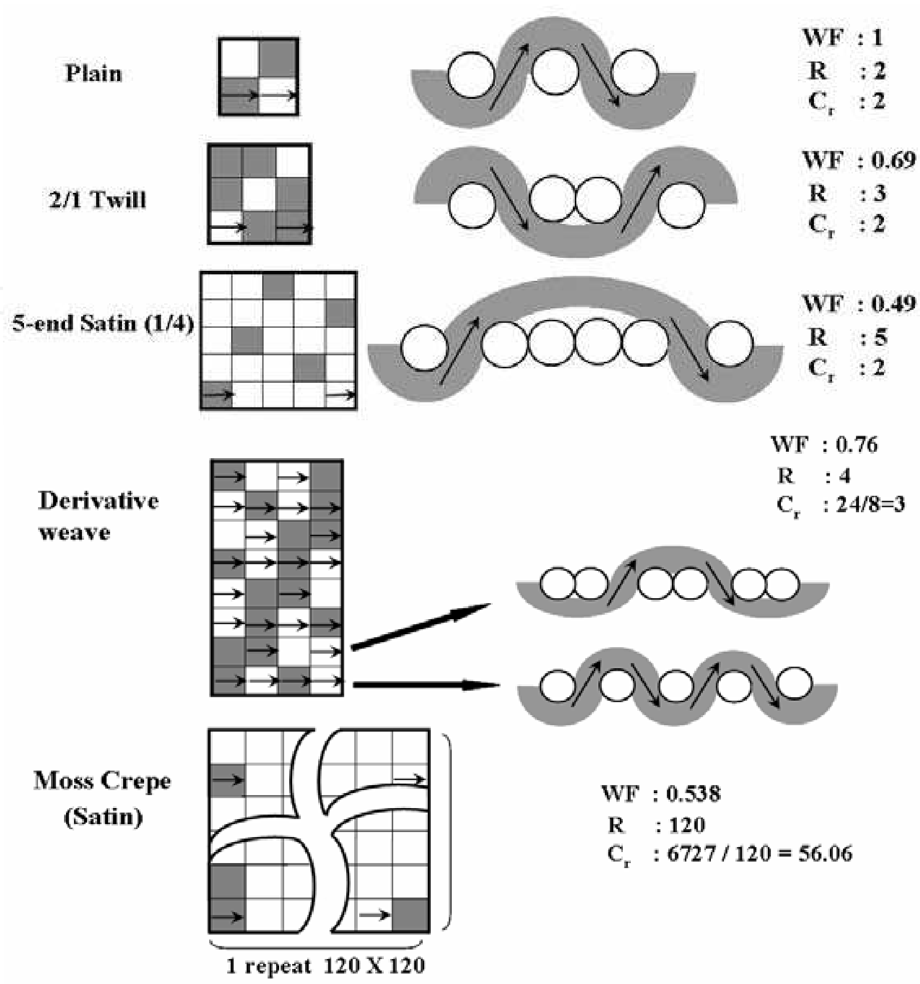


Fig. 5. Diagram of various weave constructions.

4.3 Case study of synthetic fabrics

Design plan sheets of polyester and nylon fabrics woven by various looms were selected as a specimens from various weaving manufacturers such as A, B, C, D, E and F as shown in Table 5, respectively, Table 5 shows the distribution of these specimens.

	PET fabrics						Nylon fabrics
	A company	B company	C company	D company	E company	Sub -total	F company
Loom	WJL	RPL	AJL+RPL	WJL+RPL	WJL+RPL		
Plain	26	4	14	46	5	95	516
Satin	10	41	20	4	8	83	24
Twill	60	28	33	4	9	134	113
Other	-	25	51	-	32	108	185
Sub-total	96	98	118	54	54	420	838

Table 5. Distribution of specimens

For calculation weave density coefficient as shown in equation 5, yarn diameter is first calculated using equation 7.

$$Den = \rho_f \times \frac{\pi d^2}{4} \times 9 \times 10^5 \tag{9}$$

where, ρ_f: fibre density (g/cm^3)
d: yarn diameter (mm)
Den: yarn count (denier)

For polyester filament, yarn diameter, d is $0.01246\sqrt{Den}$ and for nylon filament, that is $0.01371\sqrt{Den}$. On the other hand, weave factor, WF is also calculated using equation 8 and R, Cr in the one repeat weave pattern of fabrics. Through this procedure, yarn diameter, d and weave factor, WF are calculated for all the specimens of nylon and polyester fabrics. Finally weave density coefficient, WC is calculated using d, WF and warp and weft fabric densities, Dw and Df of the all the nylon and polyester fabrics. And WC is plotted against various yarn counts using equation 5 and conversely warp and weft density distribution is presented with various weave density coefficients and weave patterns using equation 6.

1. The distribution of weave density coefficient according to the looms

For four hundreds twenty polyester fabrics, the diameters of warp and weft yarns were calculated using deniers by equation 7, and weave factor was calculated by one repeat weave construction. The weave density coefficient was calculated using equation 5. Figure 6 shows the diagram between weave density coefficient and yarn count for the polyester fabrics woven by water jet loom. And Figure 7 shows that for rapier loom. As shown in Figure 6, the weave density coefficients of PET fabrics woven by WJL were widely ranged from 0.2 to 1.8, on the other hand, for rapier loom, was ranged from 0.4 to 1.4 as shown in Figure 7. And in Figure 6, the values for satin fabrics were ranged from 0.6 to 1.0, which were lower than those of the plain and twill fabrics. Around the yarn count 150d, 300d and

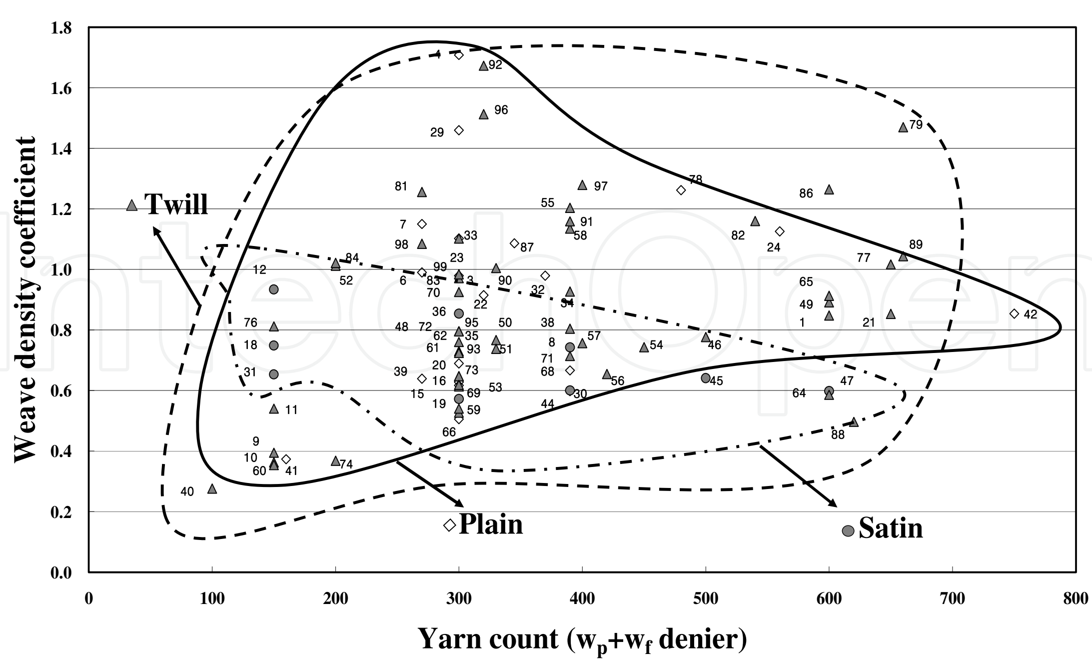


Fig. 6. The diagram between weave density coefficient and yarn count for PET fabrics (WJL).
(——— : Plain, ... : Twill, — · — · : Satin)

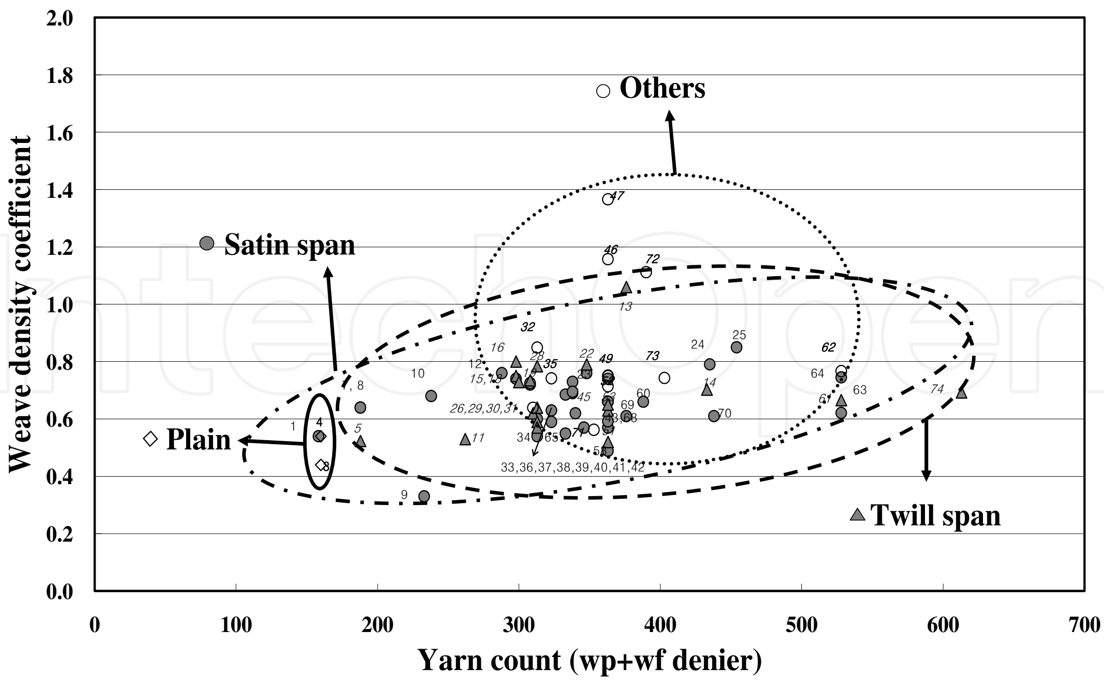


Fig. 7. The diagram between weave density coefficient and yarn count for PET fabrics (RPL). (——— : Plain, ... : Twill, – · – · : Satin, ... : Others)

400d for the twill fabrics, it is shown that the weave density coefficients are ranged from 0.4 to 1.0 for 150d, ranged from 0.5 to 1.7 for 300d and also from 0.6 to 1.3 for 400d. This demonstrates that the weave density coefficients of fabrics woven by water jet loom were widely distributed according to the end use of fabrics for garment.

2. The comparison of the weave density coefficient between polyester and nylon fabrics

Figure 8 shows the diagram between weave density coefficient and yarn count for polyester and nylon fabrics woven by water jet loom for the specimens of higher weft yarn count than warp. As shown in Figure 8, the weave density coefficient of nylon fabrics are widely ranged from 0.5 to 3.0, and comparing to polyester fabrics, the weave density coefficients of nylon fabrics are higher than those of PET fabrics. Especially, in polyester fabrics, plain, twill and satin weave patterns were widely divided to each other on weave density coefficient and yarn count, on the other hand, in nylon fabrics, it was shown that plain was most popular and many specimens were concentrated around yarn count 200d region. Figure 9 shows the weave density coefficients of polyester and nylon fabrics according to the weaving looms. As shown in Figure 9 (a), (b) and (c), the weave density coefficients of polyester fabrics woven by water jet loom were ranged from 0.4 to 1.5, those woven by air jet loom are ranged from 0.7 to 2.0 and woven by rapier loom was ranged from 0.5 to 2.8. And yarn count also showed wide distribution in water jet and rapier looms, but air jet loom showed a little narrow distribution. This phenomena demonstrate that the versatility of rapier loom was the highest comparing to the other weaving looms. On the other hand, comparing Figure 9 (a) with Figure 9 (d), the weave density coefficients of nylon fabrics were ranged from 0.5 to 3.0, while in polyester fabrics they were ranged from 0.4 to 1.5. Nylon fabric showed much wider distribution and much larger values of the weave density coefficient.

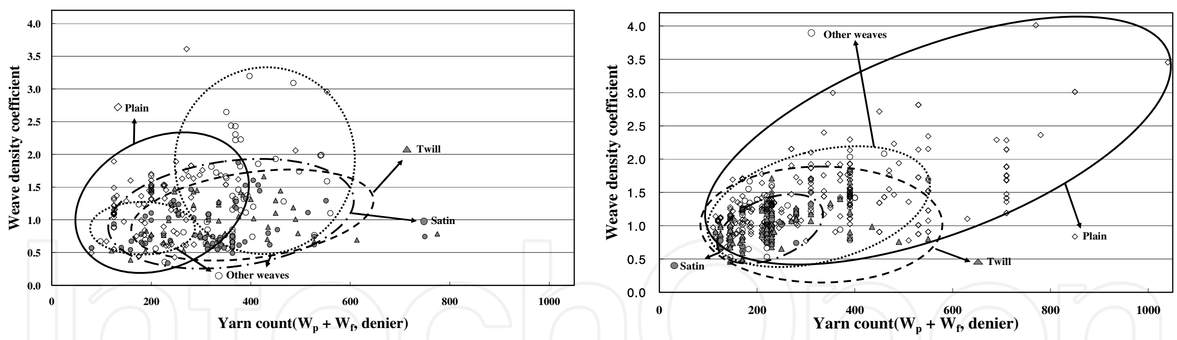
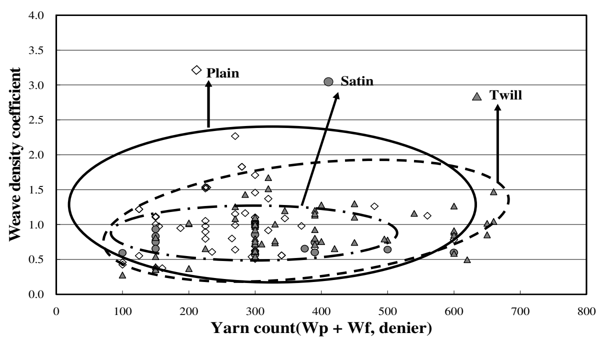
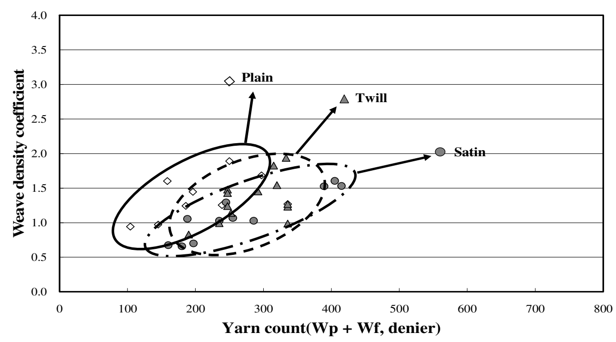


Fig. 8. Comparison of weave density coefficient between PET and Nylon fabrics (Wp<Wf).
(: Plain, : Twill, : Satin, : Others)

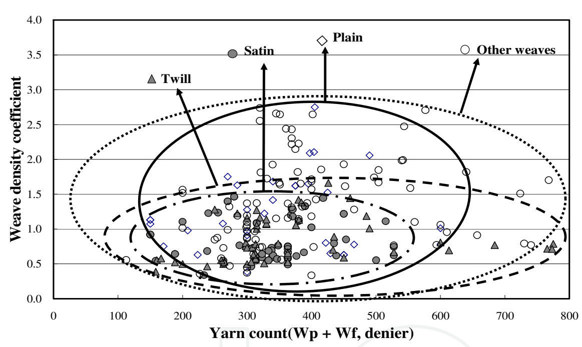
PET



(a) WJL

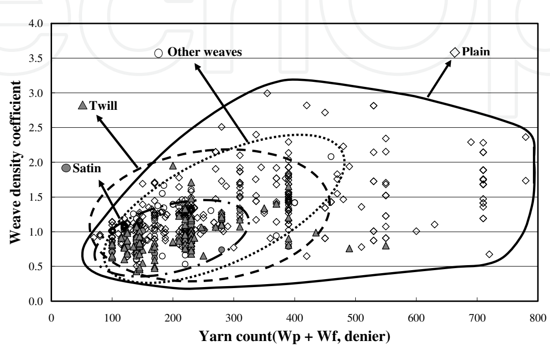


(b) AJL



(c) RPL

Nylon

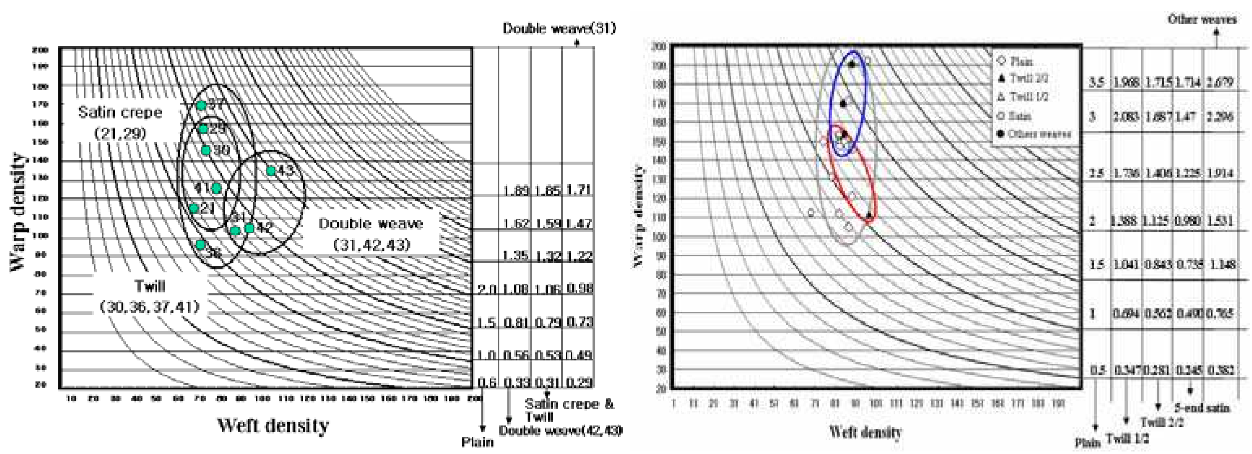


(d) WJL

Fig. 9. The weave density coefficients of polyester and nylon fabrics according to the weaving looms. (: Plain, : Twill, : Satin, : Others)

3. The density distribution

Figure 10 shows fabric density distribution calculated and simulated by equation 6 for polyester and nylon fabrics with 2 kinds of yarn counts. Figure 10 (a) shows warp and weft density distributions of polyester fabrics with various weave density coefficients and various weave patterns with warp and weft yarn counts 150 deniers. As shown in this Figure 10 (a), specimen no. 21 and 29, satin crepe fabrics, have almost same weft density of fabrics, but warp density of fabrics were different according to the end use of fabric for garment. And as shown in Figure 10 (b), many specimens of plain fabrics have same weave density coefficient, but it was shown that warp and weft densities were different one another according to the end use of fabric for garment. Then it was shown that it was very convenient to decide warp and weft fabric densities for good hand of fabrics.

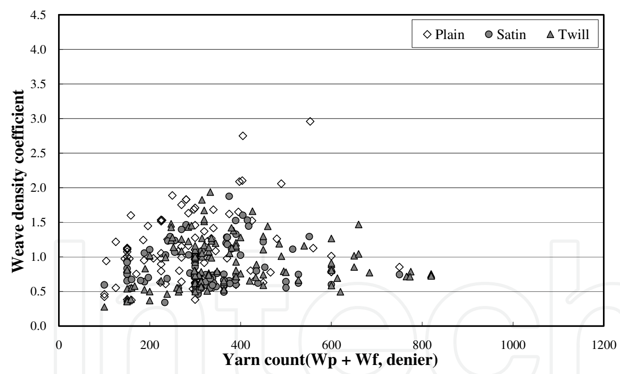


(a) PET (b) Nylon

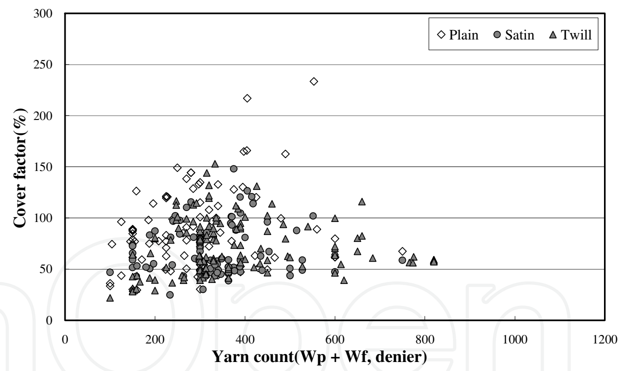
Fig. 10. The diagram between fabric density of PET and Nylon fabrics

4. Comparison between weave density coefficient and cover factor

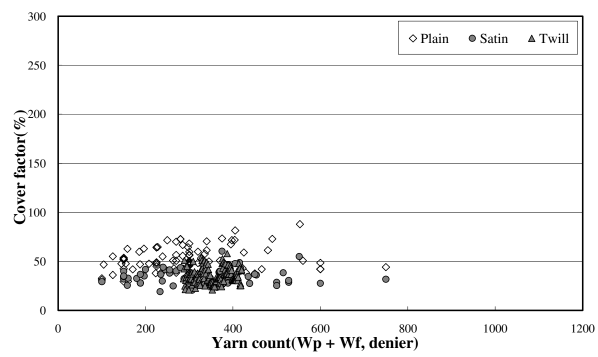
Figure 11 shows the diagram of weave density coefficient (WC), cover factors by Picanol and Prof. Walz which are calculated by equation 5, equation 1 and equation 2 using the specimens shown in Table 5, respectively. As shown in Figure 11(a), weave density coefficients of PET plain fabrics are widely ranged from 0.5 to 3.0. On the other hand, stain fabrics are distributed from 0.5 to 1.5, and for twill fabrics, ranged from 0.3 to 2.0. This phenomena demonstrate that plain fabrics show broad and wide distribution of weave pattern, and satin shows narrow distribution, which means the versatility of plain weave pattern. And also it is shown that 90% of all specimens' weave density coefficient is ranged from 0.5 to 1.5, which shows similar distribution to cover factor shown in Figure 11(b), proposed by Prof. Walz as equation 2. On the other hand, cover factors proposed by Picanol, which are calculated by equation 1, are distributed from 25% to 90% as shown in Figure 11(c). It is shown that Picanol's cover factor is much lower than those of WC and Prof. Walz equations, And comparing between WC and Prof. Walz equation, WC is about 30% higher than that of Prof. Walz equation. The reason seems to be due to the yarn correction factor 'a' and fabric weave correction factor 'b' in equation 2.
Figure 12 shows the same diagram for nylon fabrics. As shown in Figure 12(a), the weave density coefficients of all Nylon fabric specimens are distributed from 0.5 to 4.0 which are much wider than those of PET fabrics comparing with Figure 11(a). It is shown that weave



(a) Weave density coefficient



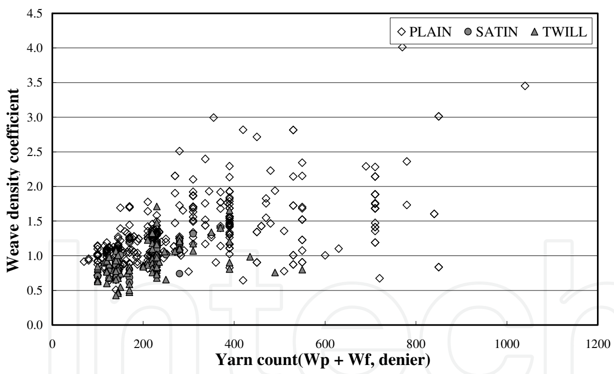
(b) Cover factor by Prof. Walz



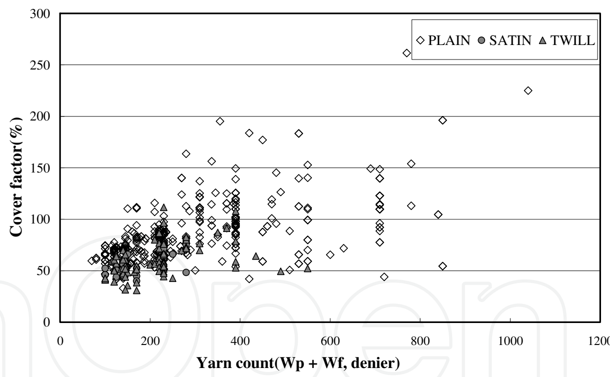
(c) Cover factor by Picanol

Fig. 11. Comparison among WC, cover factors of Picanol and Prof. Walz for PET fabrics

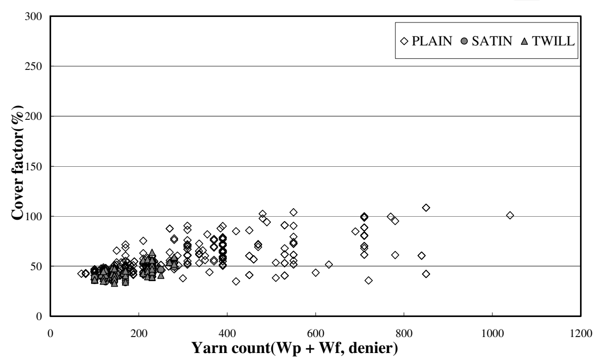
density coefficients of plain fabrics are widely distributed from 0.5 to 4.0. On the other hand, the weave density coefficients of twill and satin fabrics are ranged from 0.5 to 1.5, which is much lower and narrower than that of plain. As shown in Figure 12(b), cover factors by Prof. Walz are distributed from 50% to 200% which shows lower distribution than that of weave density coefficient as shown in Figure 12(a). It is shown that cover factor values by Picanol equation shown in equation 1 are distributed from 30% to 100% which is much lower than those of WC and Prof. Walz equations. And comparing between PET and nylon fabrics as shown in Figure 11(b) and Figure 12(b), in nylon fabrics, cover factors of satin and twill are distributed from 50% to 100%, but plain is widely distributed from 30% to 200% as shown in Figure 12(b). In PET fabrics shown in Figure 11(b), cover factors of all weave patterns such as plain, twill and satin are widely distributed from 30% to 150%. This phenomena demonstrate that plain weave patterns of nylon have higher density than those of satin and twill weave patterns, in one hand, the density of all weave patterns such as plain, twill and satin in the PET fabrics has almost same level. The cover factors of the nylon fabrics proposed by Picanol which are shown in Figure 12(c) ranged from 30% to 100% are much higher than those of PET fabrics which are shown in Figure 11(c).
Figure 13 shows density coefficient, K of the polyester and nylon fabrics calculated by equation 3. As shown in Figure 13, the density coefficient, K is distributed between 400 and 1600 both polyester and nylon fabrics. Mario Bona (Park et al., 2000) in Italy is recommending this value as 800 for synthetic fabrics. Comparing to this recommended value, both polyester and nylon fabrics show much higher values than recommended value,



(a) Weave density coefficient



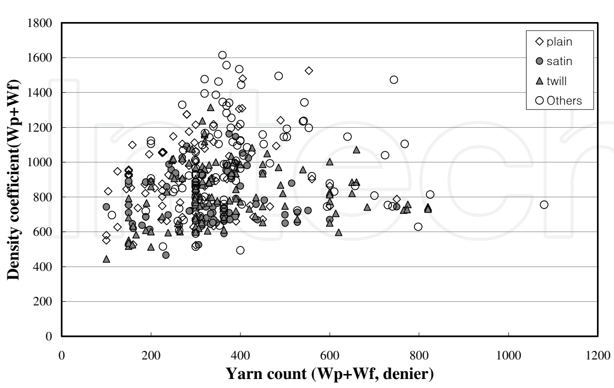
(b) Cover factor by Prof. Walz



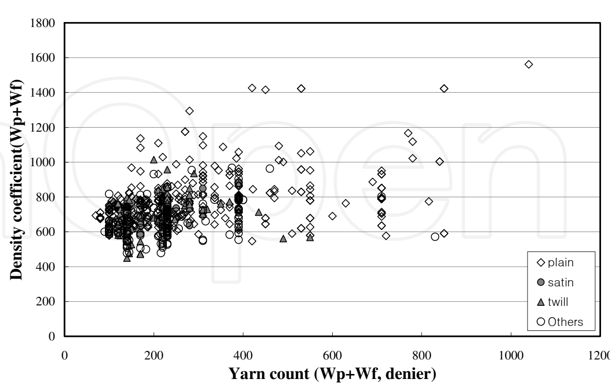
(c) Cover factor by Picanol

Fig. 12. Comparison among WC, cover factors of Picanol and Prof. Walz for nylon fabrics

800. As well known to us, the equation 3 proposed By M. Bona is based on density calculation of the worsted fabrics. Applying to synthetic fabrics as shown in Figure 13, the density coefficient distribution of the PET fabrics is mainly ranged between 600 and 1000 and for nylon fabrics, which is much more concentrated at this region. This results demonstrate the validity of the recommended value, 800 by M. Bona.



(a) PET



(b) Nylon

Fig. 13. Diagram of K against yarn count of polyester and nylon fabrics

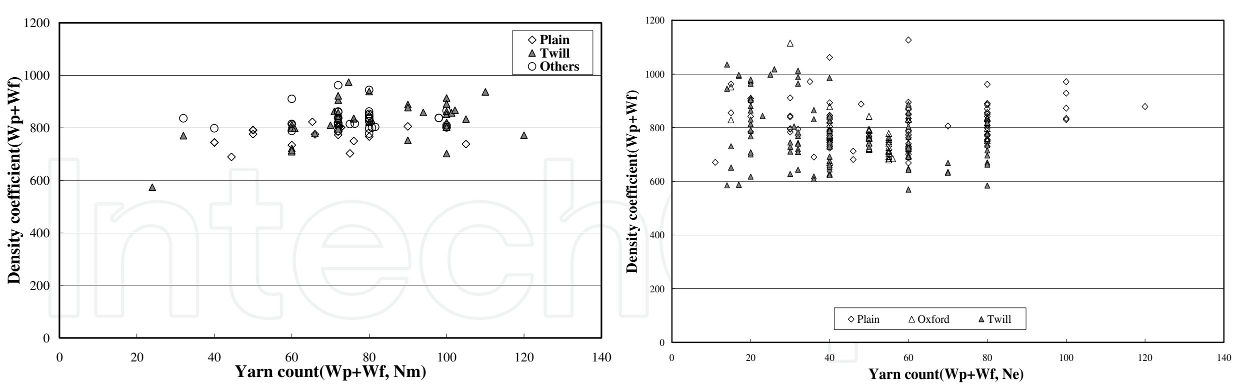
4.4 Case study of worsted and cotton fabrics

Various fabrics woven by worsted and cotton staple yarns were selected as specimens, respectively. Table 6 shows these specimens. For the worsted fabrics of one hundred thirteen, density coefficient, K was calculated using equation 3. For the cotton fabrics of four hundreds seventy nine, density coefficient Kc was calculated using equation 4.

Weave pattern \ Materials & Loom	Worsted fabrics	Cotton fabric
	Sulzer	Air-jet
Plain	35	243
Twill	48	156
Others	30	80
Total	113	479

Table 6. Specimens of worsted and cotton fabrics

Figure 14 shows the diagram between density coefficient and yarn count for worsted and cotton fabrics. It is shown that the density coefficient, K of worsted fabrics is ranged from 600 to 1000, for cotton fabrics, almost same distribution is shown. Comparing to synthetic fabrics such as polyester and nylon in which were ranged from 400 to 1600, as shown in Figure 14, natural fabrics such as worsted and cotton show lower values. Figure 15 shows weave density coefficients, WC calculated by equation 5, of worsted and cotton fabrics. As shown in Figure 15(a), the weave density coefficients of worsted fabrics are ranged from 0.4 to 0.8, for cotton fabrics, they are ranged from 0.2 to 1.0. Comparing to synthetic fabrics, which were shown in Figure 11(a) and 12(a) and ranged from 0.5 to 3.0, WC of the worsted and cotton fabrics show much lower values as below 1.0. Figure 16 shows weave density coefficient WC calculated by equation 5 and cover factors, calculated by equation 1 and 2 for worsted fabrics. As shown in Figure 16(a), weave density coefficients of worsted fabrics show the values below 1.0, and cover factors also show below 100%, especially the cover factor by Picanol shows lower values than Prof. Walz as below 50%. These values are much lower than those of synthetic fabrics shown in Figure 11(a) and 12(a). Figure 17 shows the diagram for cotton fabrics. The same phenomena are shown as worsted fabrics.

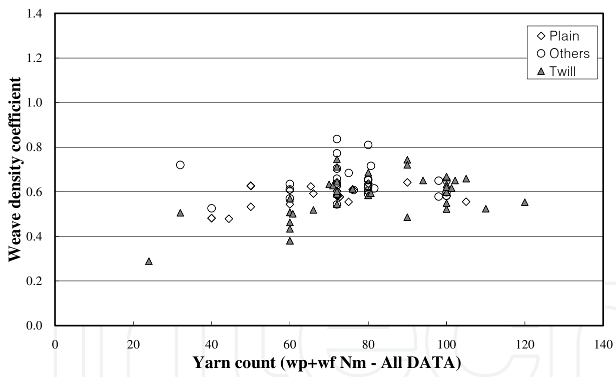


(a) Worsted (b) Cotton

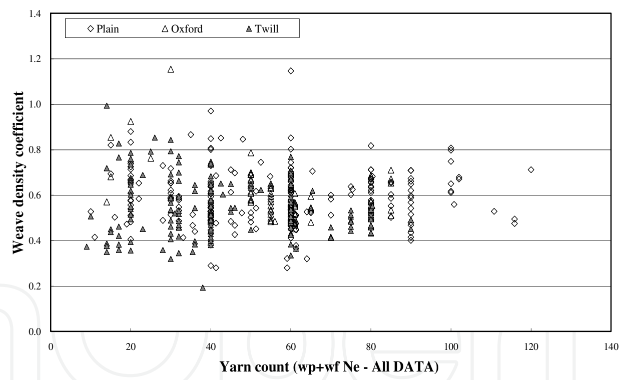
Fig. 14. Diagram between density coefficients and yarn counts for worsted and cotton fabrics

4.5 Relationship between weave density coefficient and shrinkage of dyeing and finishing processes

Figure 18 shows relationship between weave density coefficient and finishing shrinkage in dyeing and finishing processes of PET fabrics woven in the weaving company as shown in Table 5. The finishing shrinkages are distributed from 2% to 40% as shown in Figure 18. It is

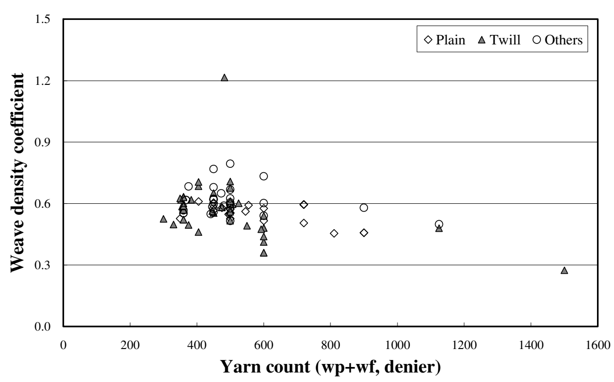


(a) Worsted

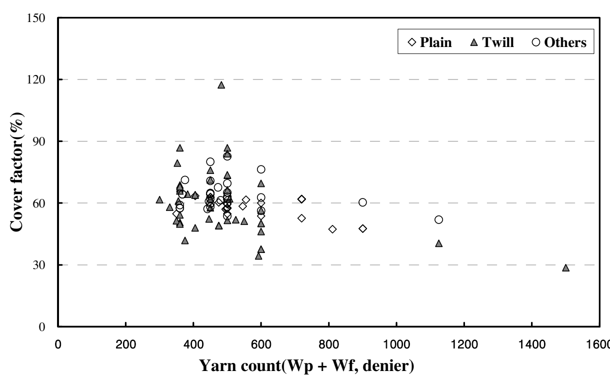


(b) Cotton

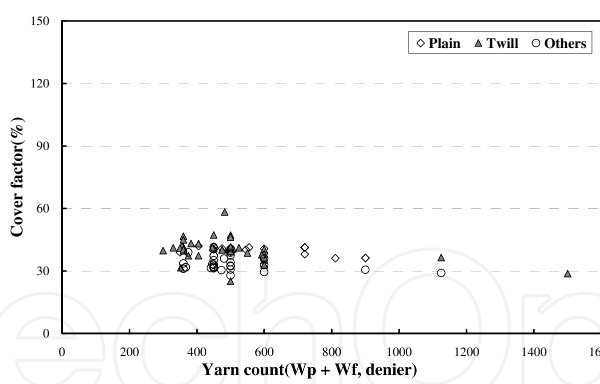
Fig. 15. Diagram of weave density coefficients of worsted and cotton fabrics



(a) Weave density coefficient



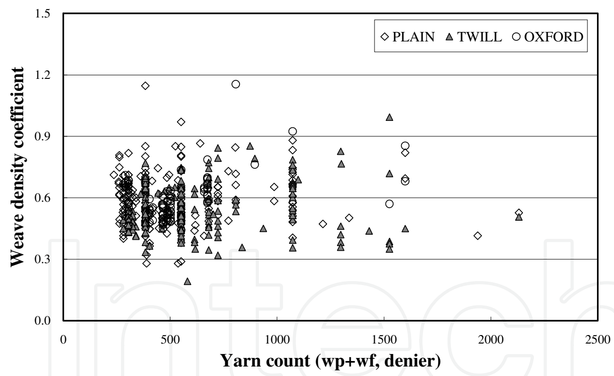
(b) Cover factor by Prof. Walz



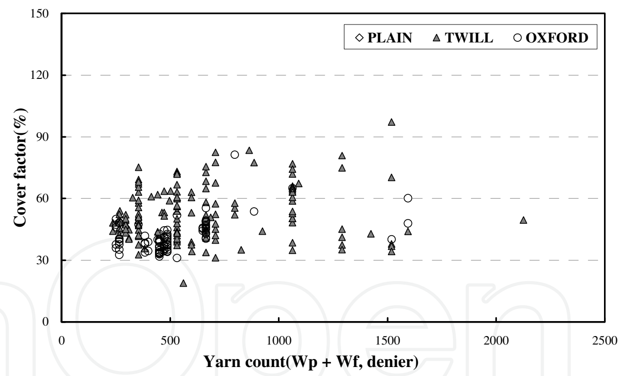
(c) Cover factor by Picanol

Fig. 16. Diagram of weave density coefficients and cover factors for the worsted fabrics.

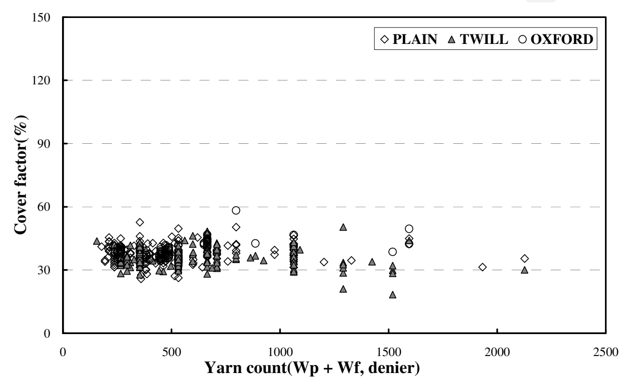
shown that finishing shrinkage varies according to the weave pattern such as plain, twill and satin. The shrinkages of plain fabric are ranged from 5% to 20%, for twill fabrics, three types of shrinkages levels are divided, one group is below 8%, 2nd group is ranged from 12% to 20%, 3rd group is ranged from 25% to 40%. The finishing shrinkages of the satin weaves are ranged from 12% to 23%(Kim et al., 2005). Figure 19 shows finishing shrinkages distributions from data-base of polyester plain fabrics manufactured by each company fabrics manufactured in A company is ranged from 5% to 20% and for C company, it is shown in the Table 5. As shown in Figure 19, the distribution of finishing shrinkage of PET



(a) Weave density coefficient



(b) Cover factor by Prof. Walz



(c) Cover factor by Picanol

Fig. 17. Comparison among WC cover factors by Picanol and Prof. Walz for cotton fabrics

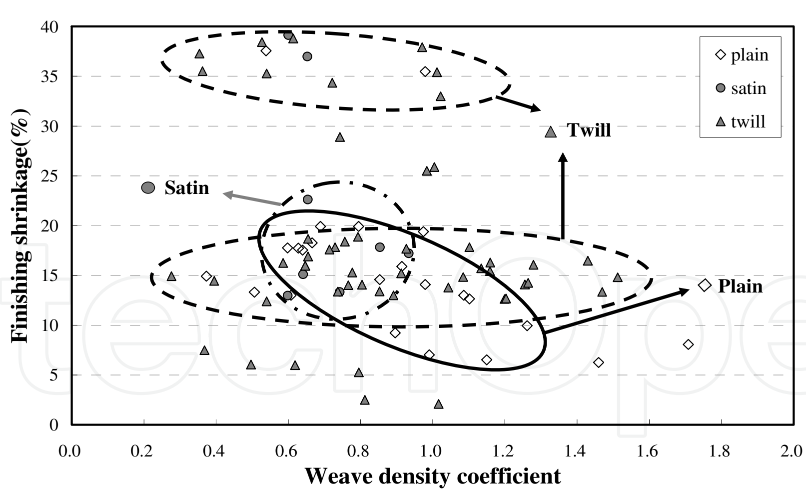


Fig. 18. Diagram between weave density coefficient and fabric shrinkage of PET fabrics woven in A company

ranged from 10% to 25%. This result gives us important information for fabric quality by getting finishing shrinkage according to the fabric manufacturers and weave density coefficients. Figure 20 shows weave shrinkages distributions of nylon fabrics manufactured by F company shown in Table 5. As shown in Figure 20, the weave shrinkages of nylon fabrics vary with weave patterns such as plain, satin and twill, which weave shrinkage values are shown as 7%, 8% and 10%. Figure 21 shows weave and finishing shrinkages of worsted fabrics shown in Table 6. As shown in Figure 21, the weave and finishing shrinkages of worsted fabrics are also distributed with weave patterns such as plain and twill, which are ranged from 2% to 10%.

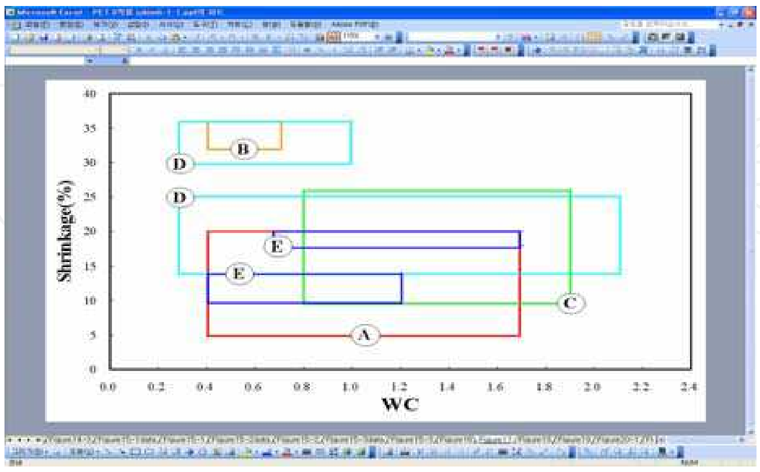


Fig. 19. Diagram between weave density coefficient and finishing shrinkage of PET fabrics woven by each company.

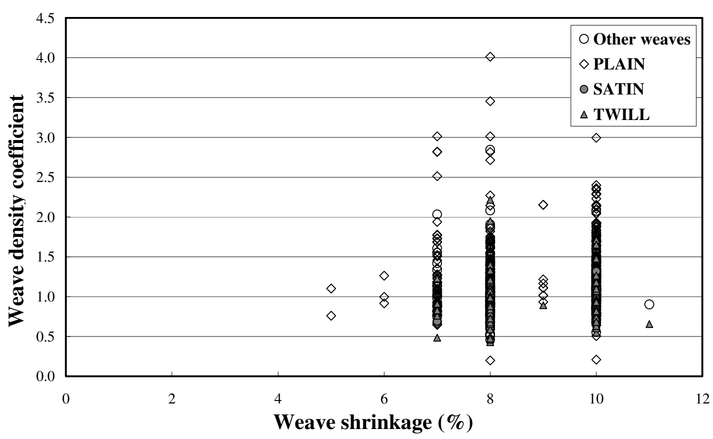


Fig. 20. Relationship between weave shrinkage and WC.

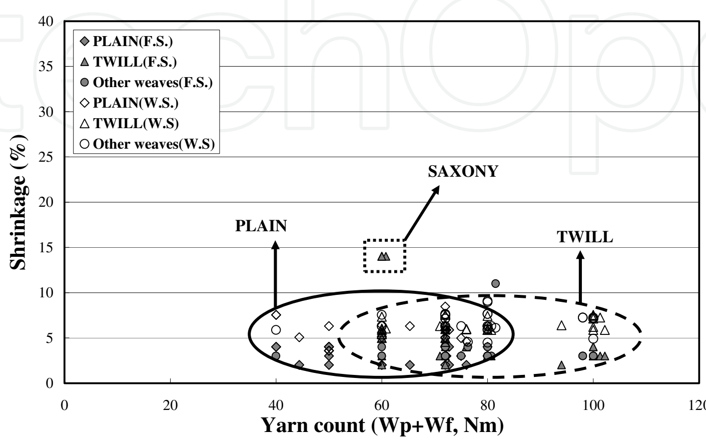
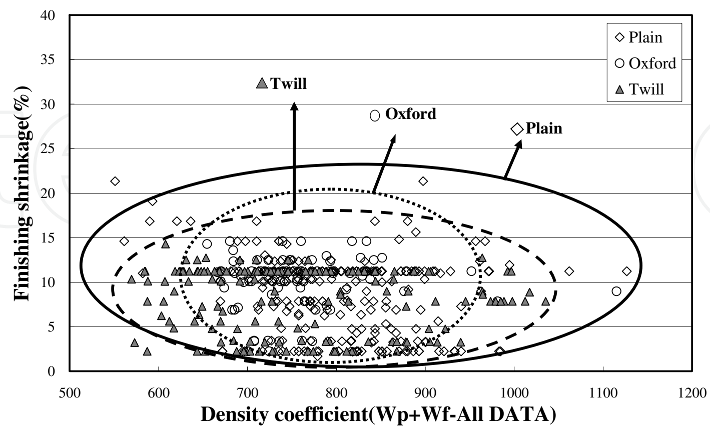
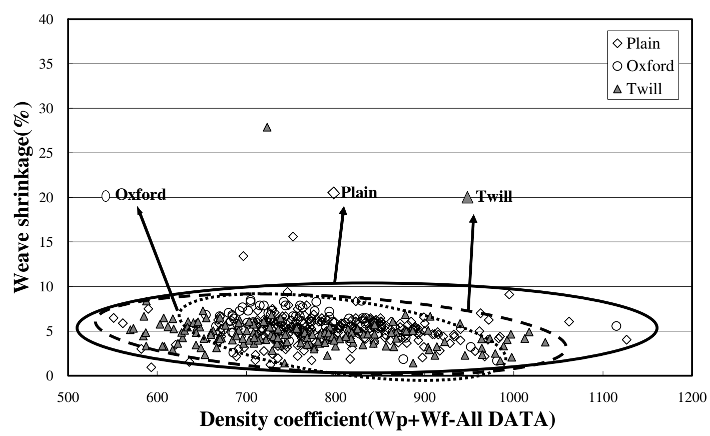


Fig. 21. Weave and finishing shrinkages according to the yarn count (F.S. : finishing shrinkage, W.S. : weave shrinkage)

Figure 22 shows finishing and weave shrinkages of cotton fabrics shown in Table 6. As shown in Figure 22, finishing shrinkages of cotton fabrics are distributed from 2% to 20%, on the one hand, weave shrinkages are ranged from 1% to 10%. It is shown that these shrinkages vary with weave patterns.



(a) Finishing shrinkage



(b) Weave shrinkage

Fig. 22. Diagram between density coefficient and shrinkage of cotton fabrics

5. Future challenges of the data base system for the fabric structural design

Even though a lot of commercial CAD systems(i-Designer, Texpro) for both fabric and pattern have been introduced, any system for weaving factories has not been developed. Therefore, a data base system related to the fabric structural design for weaving factory is needed to be explored. The yarn count, weave pattern and fabric density of 420 polyester fabrics and 838 nylon fabrics shown in Table 1 were used for making data base system, which were divided by weave patterns, weaving looms and weaving manufacturers. The reason why makes data base system according to the weaving manufacturers is explained as for examining the difference of fabric design according to each weaving factory. Figure 23 shows the diagram from data base between weave density coefficient and yarn count according to the weaving manufacturers. As shown in Figure 23, weave density coefficient is easily found according to the weaving manufacturers. It is shown that the distribution of weave density coefficients of PET fabrics manufactured in A company by water jet loom (WJL) is ranged from 0.2 to 1.8 according to the yarn linear density distributed between 100 and 800 denier. For the PET fabrics manufactured in C company by air-jet loom (AJL) and rapier loom (RPL), it is distributed between 0.6 and 2.4 according to the yarn linear density distributed between 100 and 850 denier. On the other hand, the weave density coefficients for the B, D and E fabric manufacturers are differently distributed with narrow distribution of the yarn linear density. This result from data base related to the fabric structural design gives us important information for the weave density coefficients according to the yarn denier and fabric manufacturers. Figure 24 shows the diagram from data base between weave density coefficient and yarn count according to the looms. It is shown that the distribution of weave density coefficients and yarn denier of PET fabrics woven by rapier

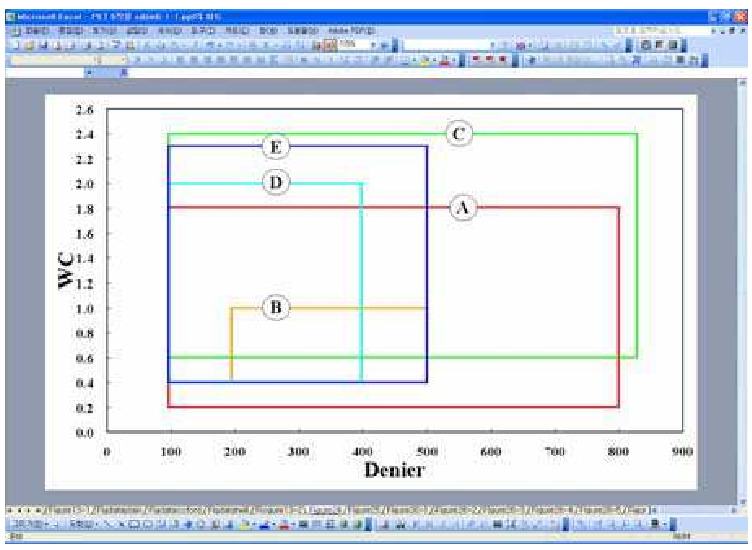


Fig. 23. Data base diagram between weave density coefficient and yarn count according to the weaving company. (PET)

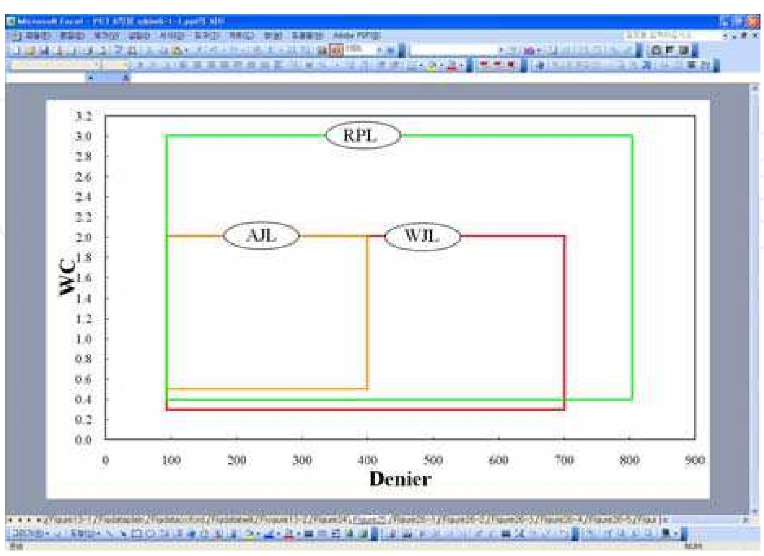
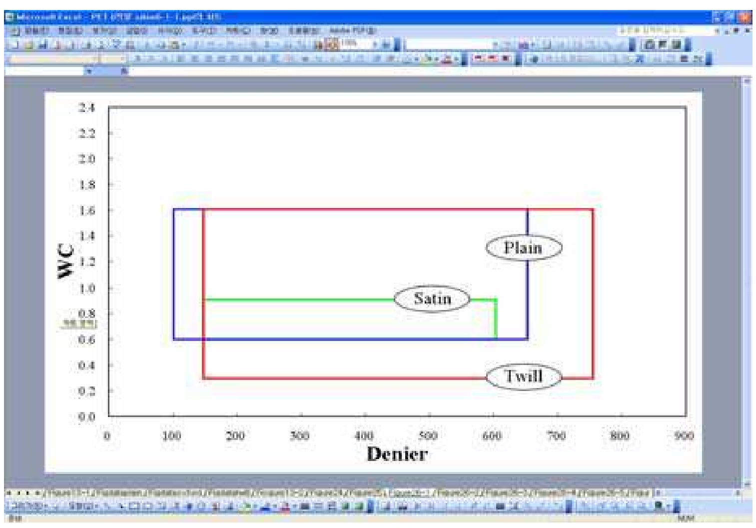
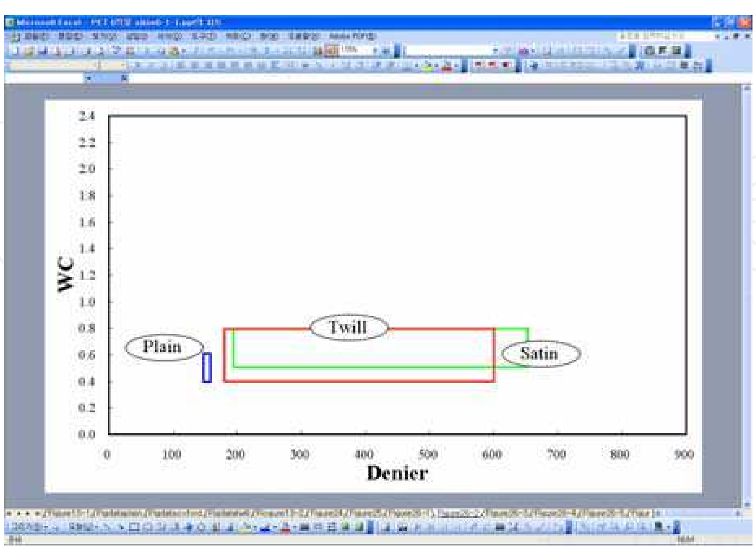


Fig. 24. Data base diagram between weave density coefficient and yarn count according to the looms. (PET)

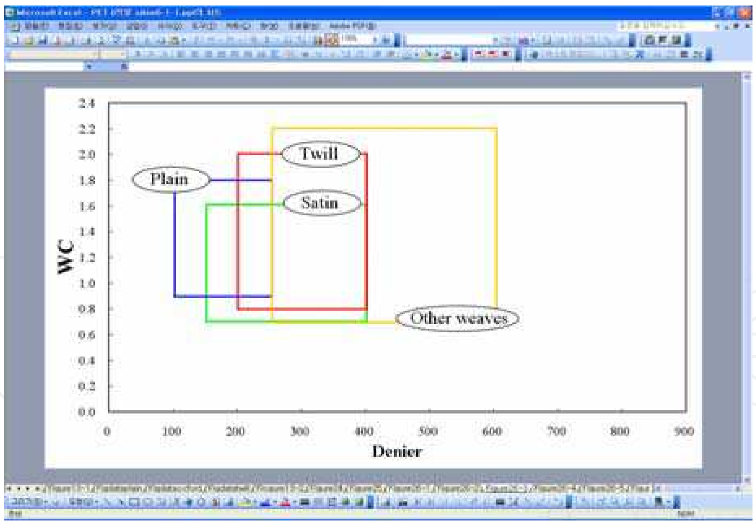
loom is the widest and air-jet loom is the narrowest. Figure 25 shows the diagram from data base between weave density coefficient and yarn count according to the weave pattern of each weaving manufacturers. It is shown that the distribution of weave density coefficient of twill fabrics of the A company is ranged from 0.3 to 1.6, and for plain weave pattern, it is ranged from 0.6 to 1.6, and the distribution of the satin is very narrow. These phenomena as shown in B, C, D and E company are differently distributed according to the weave pattern. Figure 26 shows the diagram of shrinkage of polyester fabrics according to the weaving companies (A, B, C, D and E) and weave patterns (plain, twill and satin) from data base. This result from data base related to the weave density coefficient gives us important information for the finishing shrinkage according to the fabric manufacturers and weave pattern.



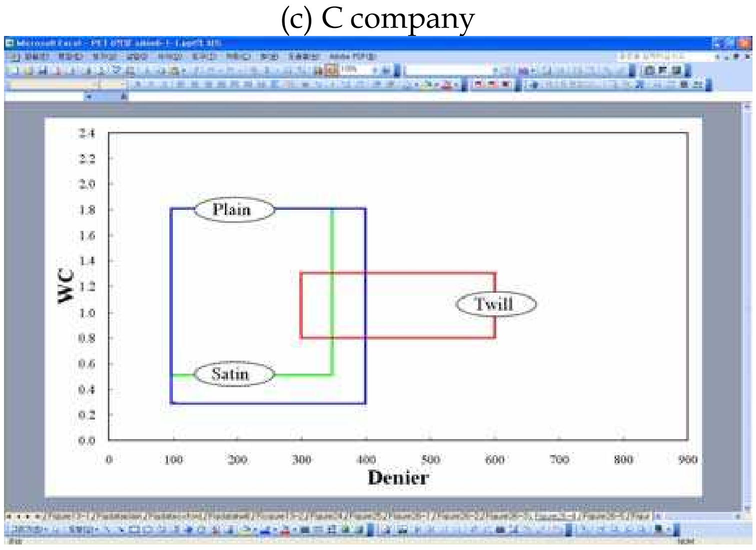
(a) A company



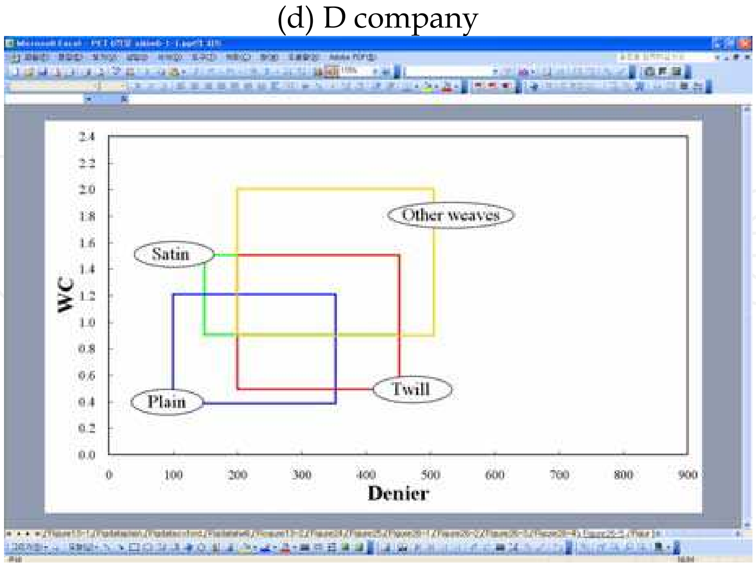
(b) B company



(c) C company



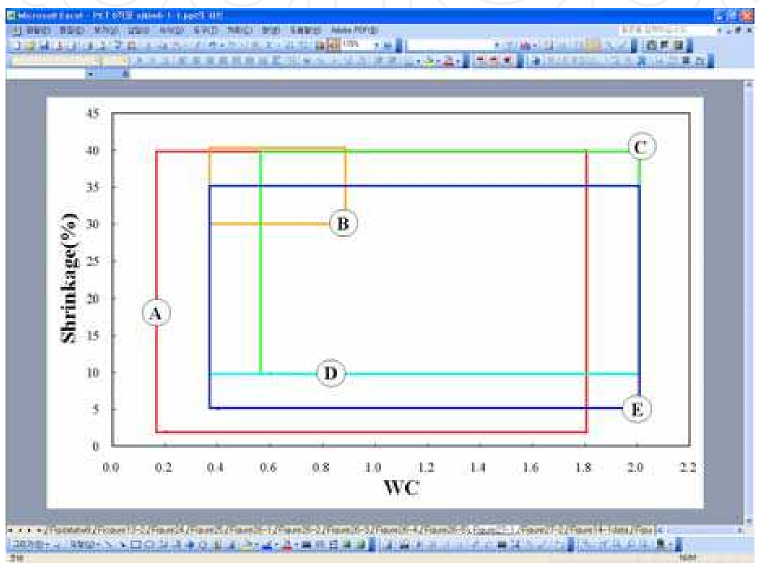
(d) D company



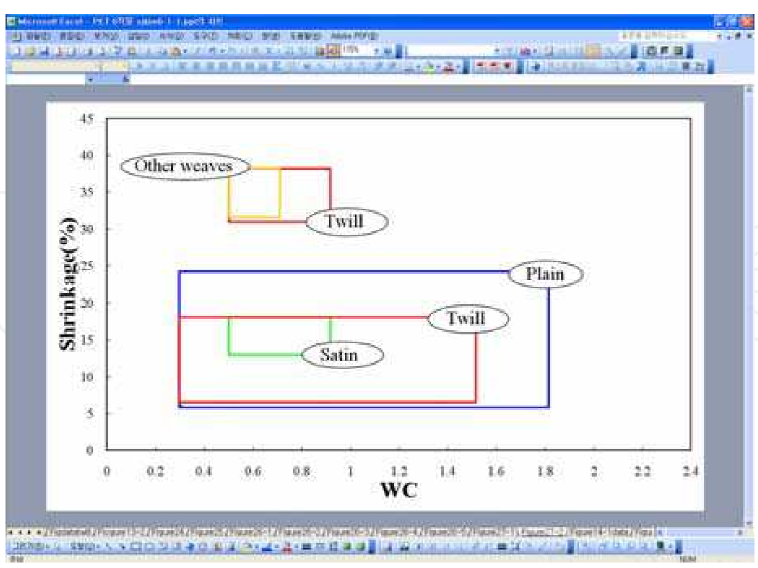
(e) E company

Fig. 25. Data base diagram between weave density coefficient and yarn count according to the weave patterns of each weaving manufacturers. (PET)

Figure 27 shows the application fields of fabric structural design data base system. As shown in Figure 27, final objectives of this topic is aiming to make a data base system with connection of the existing systems such as virtual wearing, pattern design CAD and drape analyzer, i.e. for getting some virtual wearing effect and some drape properties, this data base system is to give the answer about what is the best decision for woven fabric structural design component such as weave density coefficient, weave factor and yarn count. This topic is the first step for wide spreading this application fields to the existing woven fabric and clothing CAD systems.



(a) according to company



(b) according to weave pattern

Fig. 26. Data base diagram of shrinkage of polyester fabrics.

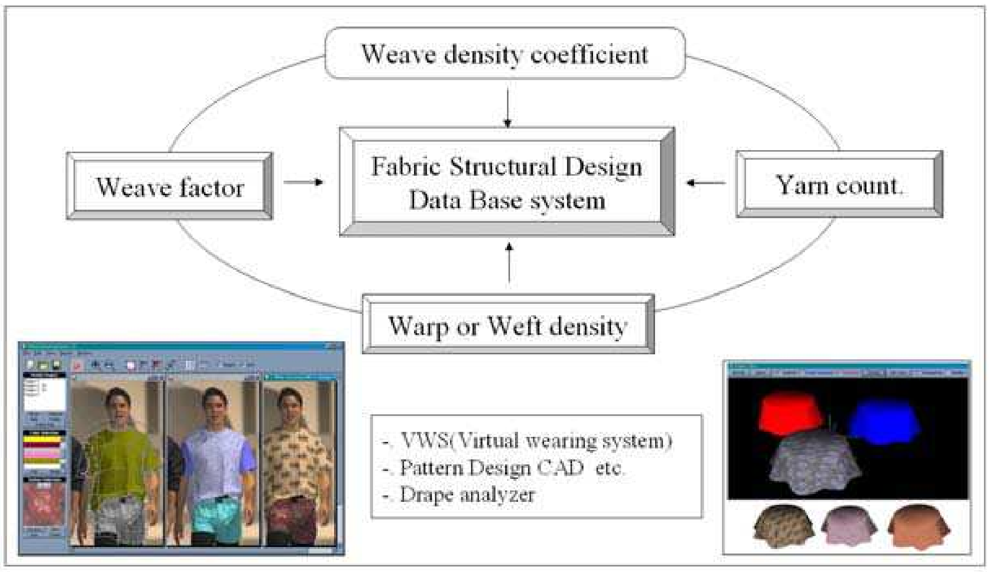


Fig. 27. The application fields of fabric structural design data base system

6. Summary

There were many tries for linking with visual wearing system of garment using fabric mechanical properties, and also there are many CAD systems such as fabric design CAD and pattern design CAD using many data bases on the computer. But there is no fabric structural design data base system linked with fabric physical properties and process conditions. The reason is due to too many factors considered for making such kind of data base system. As a 1st step for making data base system related to the fabric structural design, the data base between fabric structural parameters such as yarn count, fabric density, weave pattern and cover factor and process parameters such as weave and finishing shrinkages has to be constructed and analyzed using various kinds of fabric materials such as worsted, cotton, nylon and polyester fabrics. Through this procedure the estimation of the fabric density with given warp and weft yarn counts and weave construction seems to be possible. It makes easy application for new fabric design and also makes it possible to estimate the weavable fabric density according to the various types of looms for loom machinery maker. For getting the final goal of this topic, further study as follows is needed. 1st is to make data accumulation such as fabric structural design parameters and dyeing and finishing process parameters according to the various weaving companies and looms they are using. 2nd is to make data base for measurement of the physical properties of fabrics such as drape coefficient and mechanical properties. Finally, these have to be applied to the existing virtual wearing system and pattern design CAD.

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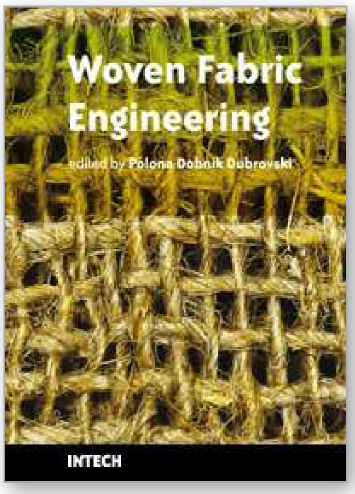

Woven Fabric Engineering
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The main goal in preparing this book was to publish contemporary concepts, new discoveries and innovative ideas in the field of woven fabric engineering, predominantly for the technical applications, as well as in the field of production engineering and to stress some problems connected with the use of woven fabrics in composites. The advantage of the book Woven Fabric Engineering is its open access fully searchable by anyone anywhere, and in this way it provides the forum for dissemination and exchange of the latest scientific information on theoretical as well as applied areas of knowledge in the field of woven fabric engineering. It is strongly recommended for all those who are connected with woven fabrics, for industrial engineers, researchers and graduate students.