Computer-Assisted Total Material Design of Woven Fabrics for Apparel Use

Part 3 : Methods for Determining Priority, Suitability, Conceptual Design Phase and Related Application Examples

M. N. Suresh*, T. Matsuo**, M. Nakajima**, M. Inoue***, S. Matshubara**** and T. Harada*****

Abstract

In our earlier works the fundamental structure of 'Total Material Design System' has been presented. The basic idea of the suitability judgement method to calculate the suitability of the designed parameter was dealt. Further, the detailed system development and its application example has been illustrated. This paper mainly deals with the methods of determining the priority, suitability and optimization procedures which are importance functions of TMDS. The role of each functions are dealt in detail to show the methodology and their important. Three case studies were illustrated to show the priority, suitability and optimization methodology. Further, a simple methodology to assist in deducing the conceptual design is dealt with some case studies.

(Received Dec. 18, 1997)

(Accepted for Publication April 7, 1998)

1. Introduction

In part I and II of this series the need, scope and importance of settling priority, checking suitability and optimization are outlined, however, this part explores more in detail about their related methods^{1,2)}. Especially, checking the suitability of the designed elements plays a vital role in achieving a quality design for producing the target product (refer Fig. 8 in part I and Fig. 7 in part II). Fig. 1 shows the role of priority and suitability functions within the flow of TMDS.

PRI_L (priority level)¹⁻⁸⁾ : to settle the priorities of the design elements. The priorities to be developed for the design elements are further

classified as two sections : one is for unfeatured¹⁾ design elements u_i of the target product and the

Fig. 1 The role of priority and suitability functions

* **Department of Textile Science, Kyoto Institute of Technology, Matsugasaki, Kyoto, ***Toyobo Co., Ltd., Mie Factory, Nakagawara, Yokkaichi-shi, ****Toyobo Co., Ltd., Dyeing & Finishing Development Center, Shogawa Factory, Daimon-cho, Toyama Prefecture, *****Toyobo Co., Ltd., Katata Research Center, Otsu-shi

other is featured design items f_i in comparison with ref_sam . The priority settlement has to be conducted during the activities of CPD and FED phases (refer Fig. 6 in part II)

SUT_FAB (suitability of the designed elements)¹⁻⁸⁾ : Suitability is a measure of checking the assumptive design elements and expressed as a criteria function J. SUT_FAB is to determine the suitability judgement function 'J' in order to check the suitability of the A_BSD and A_BMD from the view point of CPD and FED. Here, determining the J-function is most important. The preliminary investigation has already been established¹⁻⁸⁾. If the suitable design settlement by the same function has large number of alternatives then the optimization (OPT_STR) has to be done (refer Fig. 7 in part II).

2. Method of Determining Priority

In textile product design, selection of suitable FED elements plays a vital role in deciding the quality of the target design²⁾. If there are important design parameters which play a significant role in overall design, each design parameter should be prioritized based on its contribution in realizing the target design. The priorities can be fixed by creating a suitable hierarchy by breaking down the design elements into their constituent elements, structuring the elements hierarchically, and then composing, or synthesizing on the relative importance of the elements.

The priorities can be generally fixed by the judgement given by the designer/subject experts. Priorities has to be settled for featured and unfeatured design elements. This will help to analyze the importance of each FED elements given by a good translation of each conceptual design elements. The featured design elements can be prioritized among the selected design elements in comparison with the ref_sam to realize the concept of the product more precisely. Unfeatured design elements are the elements which are related with CPD in general other than feature elements. Especially in FED stage, the priorities can be set more precisely based on the

above said categories and these can be set by the designer/subject expert. Following are the advantages of settling priorities²⁾ ;

- the deduced concept can be realized more effectively by prioritizing suitable FED elements
- relationship between the elemental parameters can be analyzed thoroughly
- helps in identifying the very important element leading to simplify the design procedure

Application Example : priority settlement for FED of designing formal black wear fabric (refer section 3 in part I)

the concept : -Deep black formal wear fabric (deeply darken than usual black wear fabric) keeping soft hand

-a little higher cost is tolerable

general elements : - <appearance, hand, mechanical, dimensional,cost>

priority settlement :

- <appearance (color) I (first priority)
- hand I (first priority)
- cost I (first priority)
- mechanical II (second priority)
- dimensional III (third priority)
- etc.>

featured elements : - [appearance (color), Hand (B, HB, 2HB), cost]

priority settlement :

- <color [L-value] I (first priority)
- hand : [B] I (second priority)
- [HB] II (second priority)
- cost : [overall] I (first priority)>

3. Method of Determining Suitability Judgement and Optimization

The background and methodology of generalized suitability judgement criteria function J has been dealt in part I, section 5. Although suitably judgement can be expressed in several forms, J function found to be most reasonable form. Basically, the incorporation of J function in TMDS is a measure to analyze whether the assumptive design elements related to BSD and BMD is suitable for realizing FED so far settled.

The suitability will be checked after A_BSD and A_BMD parameters are estimated^{2,5,6,8)}. The suitability judgement criteria function J for the design of apparel woven fabric to check the suitability of A_BMD and A_BSC can be given as follows ;

$$J = F_c(C) \Pi [F_u(X_i)]^{\alpha_{ui}} [F_f(X_j)]^{\alpha_{fj}}$$

Here, J function can be broadly defined in simple terms as product of partial suitability of unfeatured $F_u(X_i)$, featured $F_f(X_j)$ and cost $F_c(C)$ elements. Further, α_{ui} and α_{fj} are defined as the powers of unfeatured and featured/specified design elements respectively. The character of J function is that if any parameter values of $F_u(X_i)$, $F_f(X_j)$, and $F_c(C)$ is not designed properly, there will be an immediate effect on J value. Therefore, it is one of the possible and effective form to check the overall effect of all design parameters used in the function for checking the suitability. In other words, multiple of each suitability values of $F_u(X_i)$, $F_f(X_j)$ and $F_c(C)$ make a good sense to evaluate the importance of each parameter for overall design. The $F_u(X_i)$, $F_f(X_j)$ and $F_c(C)$ takes different forms case by case as given in Fig. 2. These are explicated in the following sections. α_{ui} and α_{fj} are incorporated to clearly distinguish their priority levels by assigning judgement values for $F_u(X_i)$, $F_f(X_j)$ and $F_c(C)$, where $F_c(C)$ is one of the very important factors. For example, the priority values (for 100%) for α_{ui} and α_{fj} can be given as 0.20 (20%) and 0.80 (80%) respectively against the relative importance of $F_c(C)$, where the power of $F_c(C)$ is 1. The suitability judgement values for $F_u(X_i)$, $F_f(X_j)$ and $F_c(C)$ are settled based on the scientific analysis of each designed parameter by the de-

signer/subject expert. The suitability is good if the J value is higher. The related application examples are given in the following sections. The major advantages of the developed J function are ;

- the suitability of each and overall design parameters can be checked and analyzed objectively.
- J function can be an effective measure to achieve an almost accurate design through TMDS logic.
- the design parameters can be optimized by maximizing the value of J function. From the preliminary investigation¹⁾ it was observed that there is no work available in describing specific methodology for optimizing the design parameters. Toward this end, J function can be effectively used also for optimization (OPT_STR).

3.1 Case study I : Suitability Judgement of BSD and BMD for Designing Formal Black Wear Fabric

The related case study has been dealt in part II, section 3. In this study, the deduced concept is attaining deep black keeping soft hand and a little higher cost is tolerable. The important elements related to BSD and BMD are cost, L-value and B-value. The scientific analysis of estimated J functions are given in Fig.2. These are evaluated by the subject experts.

a). Suitability of cost element : An estimated increase of cost 8% up against the target cost of 10% up (during FED stage) compared with ref_sam was tolerable. If the partial suitability of cost (F_c) is 1 then the relative target cost can be expressed as 10% as shown in the figure. In other words, the estimated cost function for relative cost 8% should lie nearer to 1.2 or lesser. Then the suitability function value of cost F_c (8%) can be given as $F_c = 1.2$. Here, greater value of J is preferable.

b). Suitability judgement of L-value :

In the similar way, the suitability of L-value can be fixed as follows ;

Fig. 2 The suitability judgement criteria for some design elements for designing formal black wear fabric

*estimated L-value : 11 and target (FED)
value : 12

*estimated suitability judgement value : F_L
(11)=1.09

c). Suitability judgement of B-value :

*B-value : 0.07 (gf.cm²/cm)

*estimated suitability judgement value : F_B
(0.07)=0.99

d). Overall suitability judgement J function
value

$$J = F_C(C) \Pi [F_u(X_i)]^{\alpha_{ui}} [F_L(L) \cdot F_B(B)]^{\alpha_{fi}}$$

C=cost, L=L-value, and B=bending rigidity

if $X_i = X_{i, ref, sam}$ then $F_u(X_i) = 1.00$

and if $\alpha_{fi} = 1$

then, $J = 1.20 \times 1.00 \times 1.09 \times 0.99$

$$J = 1.29$$

Since the J value is more than 1, the designed parameters can be considered as suitable for BSD and BMD phase. The suitability and the design elements have to be reevaluated if the J function takes lower value below 1 in this case. If the J function takes the value below 1 then the assumptive design parameters for BSD and BMD are not suitable.

3.2 Case study II : Suitability and Optimization of BMD for Designing Comfortable Fabric for Pants

a). Design problem : the customer wants the manufacturer to produce 100% cotton twill woven comfortable fabric for pants.

b). Design Description

< product features

product name : new/none
customer name : new/none
usage : internal (domestic use)
material : cotton 100%
product type : pants

• conceptual design phase (CPD)

ref_sam : Conventional fabric made of 100% cotton for pants

-comparing to ref_sam

**more comfortable to wear with good quality stretchability

**a little higher cost is tolerable

• function/effect design phase (FED)

**EMT% : above 6

**RT% : above 50

*B (gf/cm²/cm) : around 0.38

*2HB (gf/cm) : below 0.4

*cost : <18% up

• assumptive basic structural design phase (A_BSD)

**fiber configuration : relaxed coily structure of fiber within yarn

**yarn configuration : relaxed crimped structure of yarn within fabric

**yarn twist : 671 T/m

-structure : single twill

-areal density (g/m²) : 230 (fabric)

• assumptive basic manufacturing design phase (A_BMD)

Although several methods to achieve A_BSD are available, three suitable methods (A, B, and C) are considered from the factual database as given in Table 1.

Method A :

**yarn processing : twisting to attain coily structure (to increase EMT)

**bleaching/mercerization : relaxed and NaOH treatment under low tension to attain relaxed coily structure of fiber configuration and freedom in stretch recovery movements (to increase EMT and RT)

**chemical treatment : anion softening treatment to attain low fiber friction (to increase RT)

**physical treatment : sanforizing to attain well relaxed crimped yarn configuration (to increase EMT)

**cost : 15% up

Method B and C : refer Table 1

c). Suitability and Optimization Procedure for BMD

Once the A_BMD is arrived, the next step is to check the suitability of the manufacturing method design elements including the cost function. Table 1 and 2 gives the related scientific database of BMD and with methods and cost database respectively. In Table 1, A, B and C are

Table 1 Factual database related to BMD

BMD Method	Yarn (twist)	Bleaching/ mercerization	Finishing		Additional cost (%)
			chemical treatment (softening agent)	physical treatment (tumbling)	
ref_sam	671 T/m	NaOH (25° Be)	anion softener	-	-
A	671 T/m	-relaxer -NaOH under low tension(25° Be)	silicon softener	sanforizing	15
B	671 T/m	-NaOH under low tension(25° Be)	anion softener	tumbling under 50° C for 20minutes	21
C	1080 T/m	-relaxer -NaOH under low tension(25° Be)	anion softener	sanforizing	23

the three different manufacturing methods to achieve the A_BSD. The method included yarn processing, bleaching treatment and followed by finishing process. The corresponding increase in cost function by additional process compare to the cost of ref_sam is also given in the Table 2. Table 3 gives the factual database of the parameter properties after the related treatments for EMT, RT, B and HB. The optimized suitability has to be calculated among three methods. The general J form for A_BMD to realize A_BSD is as under :

$$J = F_C(C) \prod [F_u(X_i)]^{\alpha_{ui}} [F_{ENT}(ENT).F_{RT}(RT)]^{\alpha_{F1}} [F_B(B).F_{2HB}(2HB)]^{\alpha_{F2}}$$

if $X_i = X_{i\text{ ref_sam}}$ then $F_u(X_i) = 1.00$
 $\alpha_{f1} = 1.0$ and $\alpha_{f2} = 0.25$

$F_u(X_i)$ has taken 1 which is s same as ref_sam.

Table 2 The cost database for the related treatments

No.	Treatment/processes	cost (%)
1	higher twist process	+8
2	relaxer treatment	+5
3	NaOH treatment	+4
4	anion silconic treatment	+2
5	sanforizing treatment	+4
6	tumbling 50° C Be, 20 minutes	+15

The vale α_{f1} and α_{f2} are given based on the significance as 1.0 and 0.25 respectively. Fig. 3 gives the scientific analysis for five design elements for three manufacturing methods respectively. Table 4 gives the suitability judgement of the corresponding design elements and the calculated J value. Among three methods, the J function of method A is much higher compared to the method B and C. On the other hand, the method

Fig. 3 The suitability judgement method of some design elements for designing comfortable fabric

Table 3 The factual database of BMD methods and related values of the design parameters

method	after bleaching/mercerization				after chemical treatment				after physical treatment			
	EMT	RT	B	2HB	EMT	RT	B	2HB	EMT	RT%	B	2HB
conven-tional	1.80	23.3	-	-	2.54	28.6	0.38	0.406	-	-	-	-
A	4.83	42.0	-	-	4.80	53.2	-	-	6.11	50.9	0.36	0.388
B	4.01	39.3	-	-	3.91	43.7	-	-	6.31	49.5	0.28	0.320
C	5.91	48.2	-	-	6.30	52.1	-	-	6.80	52.2	0.42	0.342

Table 4 Settlement of suitability judgement and corresponding J function values

Items	Design Elements	Suitability Judgement	calculated J function
A			
EMT	$F_{EMT}(6.11)$	1.05	1.31
RT%	$F_{RT}(50.9)$	1.01	
B	$F_B(0.36)$	0.95	
2HB	$F_{2HB}(0.39)$	1.20	
COST%	$F_C(15)$	1.20	
B			
EMT	$F_{EMT}(6.31)$	1.20	0.99
RT%	$F_{RT}(49.5)$	0.99	
B	$F_B(0.28)$	0.90	
2HB	$F_{2HB}(0.32)$	1.30	
COST%	$F_C(21)$	0.80	
C			
EMT	$F_{EMT}(6.80)$	1.35	0.73
RT%	$F_{RT}(52.2)$	1.20	
B	$F_B(0.42)$	0.50	
2HB	$F_{2HB}(0.34)$	1.35	
COST%	$F_C(23)$	0.50	

B and C are not suitable because the J function value is below 1. Method A is the optimized result and can be proposed as BMD method. Although the present application has only few alternatives, the complex design problems will have more number of alternatives for more design elements. Therefore, J function can be effectively applied for checking the suitability as well as optimizing.

4. A systematic Method to Assist Conceptual Design (CPD) Phase

In TMDS, the CPD plays a vital role in deciding the quality product. The settlement of CPD can be done in many ways. Some of them are as under :

- marketing information and requirement by the customer
- designer's intuition and notion
- based on judgement of the general CPD elements by some systematic approaches

Toward this end, hierarchical approach is one of the best systematic ways to analyze the general conceptual elements and its related factors for developing accurate concept.

Therefore, Analytical Hierarchy Process technique (AHP) ⁹⁾ which works based on the hierar-

chy has been applied, as an ever first application in textile design related area. This technique is very effective to analyze and select the general CPD elements. Also, this will provide a solid foundation in arriving a clear concept. As a next step, the selected general elements through this technique can be evaluated more precisely to settle the concept clearly in comparison with ref_sam.

AHP is a very simple and efficient tool which is effectively used and applied in the selection and ranking of different achievement goals in resource allocations, managerial decisions and so on. This process involves breaking down a complex unstructured situation into elements for constructing hierarchy, establishing ranking among the elements by synthesizing the subjective judgements and checking the consistency of these judgements. Systems thinking help to analyze the complex relationships by taking pairs of elements and relating them through their attributes. The subjective judgements in the pair-wise comparisons are numerical values which are synthesized to get ranking of elements. The pair-wise comparisons in the form of matrix offers a framework for testing consistency and analyzing the sensitivity of overall

ranking for a change in judgement.

4.1 Case study 1 : Selection of General Conceptual Design Elements for Designing Formal Black Wear Fabric.

Toward this end, a computer program was developed using 'C' language and tested for application purposes. Fig.4 gives the simple computer flow of the developed program.

Overall, hierarcal structure of CPD parameters to be ranked is given in Fig. 5. Depending on this application of the structure, the related CPD parameters are subdivided into three levels in general. They are as below :

- Focus : formal black wear fabric
- Criteria : CPD elements related to focus
- To be selected : general CPD parameters leading to the concept

Initially, the selection of general CPD elements will be structured depending on the design target. Then settlement of clear concept has to be done with the help of ref_sam.

Selection and Ranking of General Conceptual Elements

The focus of the concept itself is to design

Fig. 4 Computer flow of analytical hierarchy process

Fig. 5 A hierarchy for designing formal black wear fabric

formal black wear fabric. Comfort, appearance, durability, formability and price are some major criteria of ranking. D1 to D9 are the general CPD elements which are to be ranked. The main idea is to select the important elements to realize the concept scientifically to make the design process much simpler and accurate.

According to the methodology of AHP, at first, pair-wise judgement comparison of criteria functions were carried with the help of subject experts (industrial and academic). Table 5 gives the computed result of the ranking of criteria elements. In the result, appearance, comfort, and cost elements are lies in higher level of ranking and, durability and formability lie in the lower level of ranking. Nevertheless, these will get change when the focus of the hierarchy changes.

In the next level of hierarchy, the general CPD elements from D1 to D9 are ranked for each criteria elements. Table 6 gives the ranking of general of the CPD elements from D1 to D9 which are relatively ranked for the criteria of appearance based on their significance and relations with the criteria elements. Table 7 gives the final result of ranking of the CPD elements in relation with criteria elements. The overall judgement is obtained by calculating the average of each row values of each column, which are ranked earlier based on criteria elements. In this way, overall ranking can be obtained for any level of hierarchy.

Table 5 Computed results of ranking of criteria elements

	comfort	appearance	durability	formability	price	Ranking%
Initial table						
comfort	1.00	0.50	7.00	6.00	3.00	
appearance	2.00	1.00	8.00	5.00	2.00	
durability	0.14	0.12	1.00	0.20	0.12	
formability	0.17	0.20	5.00	1.00	0.33	
price	0.33	0.50	8.33	3.03	1.00	
average	3.64	2.33	29.33	15.23	6.45	
Ranking table						
comfort	0.55	0.43	0.27	0.33	0.31	0.38
appearance	0.27	0.22	0.24	0.39	0.47	0.32
durability	0.04	0.05	0.03	0.01	0.02	0.03
formability	0.05	0.09	0.17	0.07	0.05	0.08
price	0.09	0.22	0.28	0.20	0.16	0.19
Consistency table						
comfort	0.63	0.38	0.25	0.42	0.38	5.46
appearance	0.32	0.19	0.22	0.50	0.57	5.67
durability	0.05	0.05	0.03	0.02	0.02	5.16
formability	0.05	0.08	0.16	0.08	0.06	5.17
price	0.11	0.19	0.26	0.25	0.19	5.31
CONSISTENCY INDEX : 0.088000						
NORM FOR YOUR NUMBER OF VARIABLES IS : 1.120000						
CONSISTENCY RATIO : 0.078571						
YOUR JUDGEMENT IS VERY CONSISTENT						
WOULD YOU LIKE TO CONTINUE [Y/N]?:						

Table 6 Ranking of CPD elements for appearance

APPEARANCE	D1	D2	D3	D4	D5	D6	D7	D8	D9	RANKING(%)
hand (D1)	0.08	0.33	0.05	0.05	0.07	0.05	0.04	0.05	0.03	8
color (D2)	0.08	0.33	0.42	0.36	0.33	0.42	0.40	0.47	0.60	38
hygral-expansion (D3)	0.08	0.04	0.05	0.10	0.03	0.02	0.02	0.03	0.06	5
washability (D4)	0.05	0.02	0.05	0.20	0.02	0.02	0.03	0.06	0.06	6
drape (D5)	0.08	0.07	0.09	0.02	0.07	0.05	0.09	0.05	0.06	6
texture (D6)	0.08	0.04	0.09	0.10	0.07	0.05	0.04	0.05	0.02	6
luster (D7)	0.08	0.04	0.09	0.10	0.03	0.05	0.04	0.05	0.02	6
sewability (D8)	0.08	0.04	0.09	0.10	0.07	0.05	0.04	0.05	0.03	6
cost (D9)	0.33	0.07	0.09	0.10	0.13	0.29	0.28	0.21	0.12	18

Table 7 Overall judgement of all CPD elements and their ranking

Focus: design of formal wear fabric	comfort (0.38)	appearance (0.32)	durability (0.03)	formability (0.08)	price (0.19)	overall judgement (%)	Ranking
hand	0.25 (0.38)	0.08 (0.32)	0.10 (0.03)	0.34 (0.08)	0.12 (0.19)	17	II
color	0.10 (0.38)	0.38 (0.32)	0.13 (0.03)	0.09 (0.08)	0.10 (0.19)	19	I
hygral-expansion	0.06 (0.38)	0.05 (0.32)	0.11 (0.03)	0.08 (0.08)	0.09 (0.19)	6	VII
washability	0.07 (0.38)	0.06 (0.32)	0.13 (0.03)	0.08 (0.08)	0.10 (0.19)	7	VI
drape	0.07 (0.38)	0.06 (0.32)	0.14 (0.03)	0.08 (0.08)	0.07 (0.19)	7	VI
texture	0.11 (0.38)	0.06 (0.32)	0.08 (0.03)	0.07 (0.08)	0.10 (0.19)	9	V
luster	0.15 (0.38)	0.06 (0.32)	0.08 (0.03)	0.06 (0.08)	0.12 (0.19)	11	IV
sewability	0.11 (0.38)	0.06 (0.32)	0.12 (0.03)	0.10 (0.08)	0.09 (0.19)	9	V
cost	0.10 (0.38)	0.18 (0.32)	0.10 (0.03)	0.10 (0.08)	0.21 (0.19)	15	III

From the overall judgement as shown in Fig. 6, it can be observed that, among all CPD parameters, color, hand, and cost takes highest level of ranking. Hence, these can be ranked as I, II, and III respectively based on the judgement per-

centage. However, these indicate the importance of role of each parameter for designing. The lower level ranked parameters need not to be considered, nevertheless, should be noted while performing the design task.

Fig. 6 A graph showing the ranking levels

Overall, the above discussed method and selected elements give an approximate idea on the elements which are need to be concentrate more. From the above systematic selection procedure, hand, appearance and cost elements were considered as the main conceptual elements which are to be designed to produce formal black wear fabric.

5. Conclusions (including the overall summary and remarks of the series of study)

In fact, from the series of our study (part I, II and III) it has been observed that the research and developments in color pattern design have led to the development of commercial design systems and are widely being used world wide. Now a day's, one can see many software industries producing powerful high-tech design systems particularly in Europe, USA and Japan. In contrast, the research development in material design technology is still in progressing stages, however, the design processes and product range are very complex. Therefore, a comprehensive study and material design system development was very much necessary and needed. Toward this end, the 'material design' has been redefined as 'total material design' and a study was undertaken to provide a prominent base for the future developments and applica-

tions. Based on the investigation results, and developed system framework, executorial procedure, suitability structures with optimization and a methodology for determining CPD (part I, II and III), the following conclusions can be drawn.

- The proposed concept of a fundamental functional framework of total material design system can be applied for designing any textile products. In fact, the effective creation and usage of different kinds of databases to carry out the design process is one of the most prominent features in the framework. The network of TMDS was further developed in detail for designing of appeal fabrics. The designing of apparel fabrics basically belong to Modificational/adjustmental design type. Therefore, the idea of using ref_sam has been introduced effectively. This is one of the key factors in this work. On the other hand, the proposed suitability structure and the judgement criteria function J from which the suitability of the designed parameters can be checked is another very important key point of this work. Also, these are successfully proved and applied very systematically. (part I)
- The developed executorial procedure and logic suitable to the computer environment is a milestone toward the development of commercial material design system. These are carefully created and improved with the help of industrial experts for attaining practicability. Its effectiveness has been successfully shown by tracking them through various practical case studies in cooperation with industries. The related databases and its components have been successfully structures hierarchically and numerous examples were given, where not much attempts have been made so far. Nevertheless, there is a need to improve them for industrial applications and has to be done at the industrial level. (part II)
- The methodology of checking the suitability for confirming BSD and BMD has been successfully shown by various case studies. The

suitability forms for each design parameters are different and has to be done by subject expert, however, there is a possibility of tackling them more scientifically by defining standard forms for certain important design parameters. Also, the another benefit of J function is that the optimization of the design parameters can be done by optimizing the J function, which is illustrated with a case study. Although, the illustrated case study for optimization has been dealt with limited number of design parameters, it will be much more interesting if there are large number of parameters and complex criterions. Genetic algorithm may be the suitable technique for optimizing the J functions under complex criteria. (part III)

- The methodology shown for determining the CPD is one of the ways, however, the same can be applied for other related problems also. From this methodology, one can understand and analyze the relative important of each design parameter. (part III)

An important benefit of the type of research undertaken here is the improvement and understanding of deeper insights into the fundamentals of the system development as well as the relationships of every design parameter. Although, the fundamental and detailed TMDS which are most suitable to the computer environment has been presented, the actual computer-assisted TMDS is yet far from mature. However, an attempt in the development of a pilot version of TMDS for a case study is under progress to evaluate the developed logics and concepts.

Overall, a comprehensive practical computer-assisted TMDS needs to be developed for a prod-

uct range in order to progress the total material design technology in cooperation with academical and industrial experts. However, development of this kind of practical design system generally takes three stage process. First stage is to develop the detailed fundamentals of the system. Then a pilot version of design system has to be developed based on the clear fundamentals as a second stage process. Further, these stages have to be properly evaluated, tested and modified with the help of industrial experts for confirming practicability. Finally, development of practical TMDS can be realized. Toward this end, it is believed that the series of work belongs to the first stage and will definitely provide a solid basement in developing a pilot TMDS leading to the realization of practical design systems.

References

- 1) M. N. Surech, T. Matsuo and M. Nakajima ; J. Text. Mach. Soc. Japan, Vol. 50, No. 6, T146, part I (1997)
- 2) M. N. Surech, T. Matsuo and M. Nakajima ; J. Text. Mach. Soc. Japan, Vol. 50, No. 12, T323, part II (1997)
- 3) M. N. Surech, T. Matsuo and M. Nakajima ; Proce. 24th Text. Res. Symp., Mt. Fuji, Japan, Aug. 5-8, p. 127 (1995)
- 4) M. N. Surech, T. Matsuo and M. Nakajima ; Proce. 25th Text. Res. Symp., Mt. Fuji, Japan, Aug. 2-5, p. 141 (1996)
- 5) M. N. Surech, T. Matsuo and M. Nakajima ; Proce. 26th Text. Res. Symp., Mt. Fuji, Japan, Aug. 3-5, p. 9 (1997)
- 6) M. N. Surech, T. Matsuo and M. Nakajima ; Proce. IV Congress ATC Conf., Taipei, Taiwan, Vol. 1, p. 475 (1997)
- 7) T. Matsuo and M. N. Surech ; 'The design Logic of Textile Product', Text. Prog., The Textile Institute Publication, Manchester, UK. due summer (1997)
- 8) M. N. Surech, D. Eng. Thesis, Kyoto Institute of Technology, Kyoto, Japan (1997)
- 9) T. L. Saaty ; 'Analytical Hierarchy Process Series' Vol. I and II, RWS Publications, Pittsburgh (1995)