Development of a comprehensive fabric quality grading system for selected end uses

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Abstract

This study focuses on the development of a comprehensive fabric quality grading system for selected end uses. This system goes beyond currently existing methods by reflecting the suitability of a candidate fabric for a specific end use, by evaluating its key properties and grading the fabric with respect to its overall quality level and has been developed by studying the retailer fabric specification standards. A set of fabric parameters was selected for each of four retailer customers who were identified by an industrial survey. The selected fabric parameters were transformed into a sub-index value calculated by an equation for each parameter using test values obtained from the considered fabric. Weights were assigned to the parameters considering the level of importance identified by the survey for each fabric parameter. A weighted arithmetic mean function was used as the aggregation function in which the aggregate of the products of sub index value and the weighting for each parameter were taken as the overall fabric quality value on a scale of zero to hundred. This system is designed to assist decision makers in selecting a suitable fabric material for a specific end use by comparing the overall quality of several fabrics. A computer application was developed as the user interface to evaluate fabrics using the developed system. The results obtained from this system compared favourably with those obtained through manual evaluation of the fabric.

1. Introduction[1]

Fabric quality is of prime importance in determining the suitability of a fabric for a specific end use. The fabric should possess a set of fabric properties or parameters to fulfil the requirements expected by the textile product. Textile fabrics are manufactured for many different end uses, each of which has different performance requirements. The overall fabric quality comprises of three major components, namely physical properties, chemical properties and the visual appearance of the fabric. The chemical and physical structures of a fabric determine how it will perform and ultimately whether it is acceptable for a particular use. At the same time considering the performance requirements for the end use there are fabric parameters that should fulfil the laws and regulations of the countries in which they will be used in. Therefore, in the case of garments, customer brands need the fabrics to fulfil their requirements of performance and regulations.

Fabric testing provides information about the physical and structural properties and the performance properties of the fabric. An understanding of testing procedures and the knowledge to interpret results are important in correlating a fabric with desired performance. Merchandisers, designers, fabric technologists and quality controlling personnel who have an understanding of fabric properties and testing are responsible for making decisions that will benefit their customers.

Analysis helps to study the individual characteristics of a fabric in order to determine what each contributes to the overall performance properties of the garment. It also helps to understand why a particular garment fails to meet consumer expectations. Therefore knowledge of fabric properties and performance characteristics can contribute to efficiency in solving consumer problems with garments, and to the development of products that perform acceptably for consumers. Consumers have become more aware and more demanding of products, and thus the needs of methods to evaluate the fabric quality has grown rapidly.

Fabric test methods have been designed to measure physical and chemical fabric properties. National and international organizations such as ISO, ASTM, and AATCC develop and publish standard test methods as well as standard performance specifications that are used to ensure product quality in the market place and to facilitate global trade as shown by Collier and Epps [1]. Apparel customer brands also issue their own standard performance specifications and test methods for a fabric that will be used for a specific garment.

In current fabric evaluation systems being used it can be found that subjective measurement techniques & objective measurement techniques are mainly used to evaluate fabric handle. In subjective measurement fabric is evaluated by hand feel & tactile sensation as demonstrated by Luible et al. [2]. Because hand feel is subjective there may not be a consistent assessment and there are methods which are introduced to measure the fabric handle by fabric mechanical properties according to Kawabata and Niwa [3]. And also prevailing systems include measuring garment appearance quality as demonstrated by Geršak [4] and fabric comfort to determine the wearability according to Raj and Sreenivasan [5].

Evaluating fabrics by testing & measuring the individual properties separately will not give an overall quantifiable measure of the quality of a particular fabric. Because the influence fabric properties have on the fabric

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quality may vary with the property analysed. A certain fabric may obtain a higher or an acceptable value for a certain property but may show a lower or an unacceptable value for another property. There may be properties which have a higher weight in terms of their influence on the quality, while other properties may have a lower weight. This may cause confusion in deciding the suitability of the fabric for a specific end use. It was found that current fabric evaluation systems are focused on evaluating fabric handle, wearability and appearance. They do not take into account overall fabric quality targeting and end use.

The study seeks to develop a comprehensive fabric quality grading system by a study on overall quality of the fabric related to several end uses to evaluate fabric quality and decide suitability of the fabric for a specific end use. The proposed fabric quality grading system for the selected end uses is developed by considering many factors that affect the particular end use such as performance requirements and customer.

This paper describes the methodology used in developing the new system and contains a discussion on the results obtained and on how the system can be further improved.

2. Methodology

Development of the fabric quality grading system is based on four main steps.

1. Parameter Selection
2. Transformation of the parameters of different units and dimensions to a common scale
3. Assignment of weightings
4. Aggregation of sub indices

2.1 Parameter Selection

The designed fabric quality grading system would become unwieldy if each and every property required is included in the system. Instead, it is required to choose a set of parameters which, together, reflect the overall fabric quality for the particular end use. Parameter selection is as fraught with uncertainty and subjectivity as it is crucial to the usefulness of any index. Enormous care, attention, experience and consensus-gathering skills are required to ensure that the most representative parameters are included in the fabric quality grading system. The major sources for parameter selection are information gathered from the experts in the apparel industry and the customer specifications for a given end use.

In this study, fabric quality grading system is developed considering a basic active wear T shirt which is used for running and jogging purposes.

Quality is characterized by several properties expressing the ability of a product to fulfil functions it was designed for. There are plenty of physical and chemical properties which affect the quality of fabric manufactured for an active T shirt. The number of properties required varies with the targeted consumer. Different retailer brands address different market segments, and thus the required number of properties varies with the intended market segment.

Regardless of the market segment to which the T shirt is designed for, there are a set of properties that the fabric should have in order to make it suitable for a basic T shirt. The fabric should be flexible which would support the body movements, so the stretch and flexibility are two most important properties for any type of T shirt. Since a T shirt is used mainly for running and jogging purposes, the fabric should have high moisture management properties in order to provide comfort to the wearer. The strength of the fabric is a key parameter related to the durability properties of the fabric. Since the fabric of the T shirt is subjected to multi directional forces, bursting strength is used to measure the strength of the fabric. Colour fastness properties and dimension stability for washing are also key quality parameters which decide the durability of the T shirt.

Four main retailer brands were identified by an industrial survey and a set of properties were selected specifically for each brand. Therefore the set of fabric quality parameters vary from brand to brand.

2.2 Transformation of the Parameters of Different Units and Dimensions to a Common Scale

Different fabric quality parameters are expressed in different units. Further, the ranges of levels to which different parameters can occur vary greatly from parameter to parameter. Before the designed fabric quality grading system can be formulated, all these have to be transformed into a common scale which is a sub index. Sub indices are value functions to transform the different units and dimensions of fabric quality variables to a common scale. Mathematical equations which transform the parameter values to individual sub indices are formulated for all the parameters.

A sub index will be in a scale from zero to ten. If a fabric quality parameter fulfils the given retailer fabric specification values, a value of ten is allocated. If a given fabric quality parameter is not within the specification values, the respective sub index equation for the parameter is used to calculate the variation of each fabric quality parameter from the value given in the specification. In developing equations, linear functions are formulated as correlation between fabric quality and fabric parameters is identified as fairly linear from this study. Variation within the fabric specification is not taken into consideration. In order to convert the fabric quality parameters which do not fulfil the given fabric specification values into a common scale, possible upper limit or lower limit of each parameter is identified due to the chosen scale having an upper limit and a lower limit. Possible upper limit or lower limit for the fabric quality parameters are decided with the use of opinions of the experts who participated in the survey as well as the theoretical knowledge.

In this method fabric quality parameters are divided into two groups in developing sub indices.

1. One side bounded properties

Fabric quality parameters, in which the required value is given as a minimum or maximum value, belong to this category.

- One side bounded properties with an Upper limit

Ex: Spirality

$$\text{Sub index} = \begin{cases} 0 & \text{if } U_i \le Y_i \\ \left(\frac{Yi-Ti}{Ti-Ui}\right) & \text{if } T_i \le Y_i \le U_i \\ 10 & \text{if } Y_i \le T_i \end{cases}$$

Where,

Y_i= Actual value of the i^{th} property

U_i = Upper limit of the i^{th} property

T_i = Specification value of the i^{th} property

- One side bounded properties with an Lower limit

Ex: Bursting Strength

$$\text{Sub index} = \begin{cases} 0 & \text{if } Y_i \le L_i \\ \left(\frac{Yi-Ti}{Ti-Li}\right) & \text{if } L_i \le Y_i \le T_i \\ 10 & \text{if } T_i \le Y_i \end{cases}$$

Where,

Y_i = actual value of the i^{th} property

L_i = lower limit of the i^{th} property

T_i = target value of the i^{th} property

- Two side bounded properties

Fabric quality parameters, which have limitations on both sides, belong to this category. Fabric quality parameters of this category have an acceptable range.

Ex: Areal density (GSM)

$$\text{Sub index} = \begin{cases} 0 & \text{if } Y_i \le L_i \\ \left(\frac{Ti-Yi}{Ti-Li}\right) & \text{if } L_i \le Y_i \le T_i \\ 10 & \text{if } T_i \le Y_i \end{cases}$$

Where,

Y_i = actual value of the i^{th} property

L_i = Absolute limit of the i^{th} property

T_i = target value of the i^{th} property

2.3 Assignment of Weightings

After short-listing parameters, weightings are allocated for each property considering the relative importance for the active T shirt. Because even though all short-listed parameters are deemed to be important as fabric quality parameters, they would still not be equally important. Within the selected parameters, some would have greater importance than some others. The assignment of weightings is based on a survey done using ten experts in fabric quality from the apparel industry and it is similar to the selection of parameters. For this too, well formulated techniques of experts' opinion gathering such as Delphi are utilised to minimise subjectivity and enhance credibility. Value range for weightings is from zero to ten as total of the weightings is ten.

Mean response for each property is calculated to verify the information theoretically. When the mean response is calculated, it is easy to compare the relative importance of each property. Calculated mean response values are modified on some properties by using the theoretical knowledge where the relative importance is not properly emphasised by the calculated mean value.

$$\text{Mean response} = \frac{\sum Importance\ marked\ by\ eac\square\ expert}{Number\ of\ responses}$$

The weighting of each fabric quality parameter is calculated by considering the modified mean weightings. Before calculating the weightings it is required to verify the modified relative importance level with the assistance of experts.

$$\text{Weighting} = \frac{Relevant\ mean\ reponse}{\sum mean\ reponses} \times 10$$

Weightings will differ from brand to brand because the required number of fabric quality parameters varies with the buyer.

2.4 Aggregation of Sub indices

Aggregation of sub-indices is performed using the weighted sum method. Weighted sum method is selected considering the following general criteria:

- It should consider weighting factors, as all variables included in the index are not equal contributors to garment quality
- It should be relatively easy to use
- Sensitivity
- Free of ambiguity, eclipsing and rigidity

$$Final\ Quality\ value\ = \sum_{1}^{n} W_i P_i$$

P_i is the sub index for i^{th} variable and W_i is the weight for i^{th} variable.

Total value of the weightings assigned for parameters is ten and maximum value for sub- index value is also ten. Hence the maximum value for final quality that the evaluated fabric can obtain is hundred. The value in the scale zero hundred reflects the level of quality of evaluated fabric.

2.4 Developed Computer Application

A simple computer application is developed to provide a user interface to evaluate a given fabric using the developed fabric quality grading system. Four customer specifications are stored in the system and an option is given to the user to select the buyer prior to the evaluation

of fabric quality. After selecting the buyer from the application, the properties required for the selected buyer is automatically displayed in the interface.

Test values for the given fabric quality parameters will be entered by the user. For the properties which vary with the structure of the fabric and the fibre content, an option will be given to select the fabric structure, fabric colour and the fibre content for the selected fabric. After entering the test values, system will calculate the appropriate grading for the given fabric with the use of the developed equation.

3. Results and Discussion

3.1 Important Fabric Parameters required for a Basic Active T shirt

According to the methodology described, a set of fabric quality parameters are selected for each buyer considering the information gathered from questionnaires and customer specifications of each buyer.

Since the system is focusing on a basic T shirt which is washable, properties related to dry cleaning and bleaching are eliminated because the T shirt is not subjected to dry cleaning or bleaching. Phenolic yellowing, which indicates the yellowing of white fabric during the storage was also eliminated as it has the least impact on performance of the fabric. Brand C sometimes uses fabric with special finishes such as anti microbial finishes and it has some T shirts designed especially for various sports activities. Since the basic active wear T shirt is intended to be used in running and jogging activities, high performance properties such as air permeability and thermal transmittance are not required. Yarn count, yarn diameter and fabric count are also eliminated because the impact of those fibres can be measured from other properties such as GSM. The effects of those properties are hidden in the selected parameters. Concentrated basic T shirts manufactured for Brand A and Brand D address the high end customers with a high price range. Since those two brands focused on high quality fabric, the number of properties concerned is comparatively higher than other two brands.

So as one of the main outcomes of the study most important fabric parameters that are required for a basic active T shirt are identified.

3.2 Calculated Weightings for Fabric Properties

Relative importance of each fabric quality parameter is calculated by the information gathered from the questionnaires. All the calculated mean responses are verified with the theoretical knowledge and the experience of experts before calculating weightings. The calculated weightings are used in calculating the final formula. Hence another outcome of the study is the calculated weightings for the parameters brand wise as showed in Table 1.

Brand A

Bursting Strength and Moisture absorbency are the two most important properties of active T shirt. Bursting strength is a major factor which determines the durability of the T shirt while moisture absorbency determines the comfort. So the calculated values should be changed into the value representing the highest importance. Colour fastness to perspiration is another important factor for the active T shirt. It should have an equal importance level when compared with colour fastness to crocking. Since the product is washable, the importance level of colourfastness to water should be more than the calculated mean response value.

Brand B

Composition of the fabric is a factor mentioned in the care label. Therefore it is mandatory to meet the given value of fabric specification and so the level of importance is very high. Colourfastness to water and colourfastness to light are two most important colourfastness properties for the active T shirt. So the calculated mean response values of those two properties need to be changed.

Table 1: Weightings for brand wise selected properties

Property	**A**	**B**	**C**	**D**
Bursting Strength	0.65	0.77	0.71	0.74
Moisture Absorbency	0.65		0.71	
Wicking	0.65			
Dimensional change-laundering	0.63	0.75	0.69	0.71
Spirality	0.63	0.75		
GSM	0.63	0.75	0.69	0.71
Colourfastness to Crocking-Dry	0.59	0.71	0.65	0.67
Colourfastness to Crocking-Wet	0.59	0.71	0.65	0.67
Colourfastness to Perspiration	0.59	0.71	0.69	0.67
Pilling resistance	0.59	0.71	0.65	0.67
Colourfastness to Light	0.58	0.69	0.69	0.67
Colourfastness to water	0.58	0.69	0.63	
Colourfastness to Laundering	0.58	0.69		0.67
Snagging	0.56	0.66	0.65	0.67
pH	0.54	0.64		0.61
Dye migration	0.50			
Skewness	0.47		0.51	0.53
Fibre composition		0.77	0.71	0.74
Stretch and recovery			0.65	0.71
Dimensional change-commercial laundry			0.69	

Brand C

Relative importance of bursting strength, fabric composition, colour fastness to water and colour fastness to perspiration were modified.

Brand D

Relative importance of bursting strength, fabric composition, colour fastness to light and colour fastness to perspiration were modified.

3.3 Developed fabric quality grading system

$$Final\ Quality\ value \quad = \sum_{1}^{n} W_i P_i$$

W_i- Weighting of the i^{th} fabric property

P_i - Sub index value of the i^{th} fabric property

The methodology for the fabric quality grading system is designed considering the variation of each fabric quality parameter from the required value. The four main steps involved were parameter selection, developing sub-indices, assignment of weightings and aggregation of the developed sub indices. In developing equations, linear functions are formulated as correlation between fabric quality and fabric parameters is identified as fairly linear from this study. An extensive study has to be done to verify the actual relationship but once it is it can be used to refine the proposed system.

Weightings were calculated based on the opinion of ten experts who responded to the survey. The calculated weightings for each and every fabric quality parameter vary with the customer. In some cases, the relative importance of the fabric quality parameters does not show a significant variation with others. This is because for some customers such as Nike who address the high end market considers almost all the selected fabric quality parameters as important for the relevant product.

The pH value of fabrics is used as a fabric parameter in the developed system. Although it is assumed that all the parameters have a linear relationship with fabric quality ph has an exponential relationship with H^+ concentration.

The computer application was designed based on the developed fabric quality grading system so as to make the fabric evaluation process easy for the user. Flammability and formaldehyde release are the safety regulations which are mandatory for the selected customers. These two properties do not have an impact on performance of the selected end use. Therefore, the two properties are checked before entering the test values of other quality parameters to the application. The final grading value can only be calculated if the particular fabric meets the required values for the selected safety regulations.

The developed fabric quality grading system was verified using actual fabric samples. Final quality grading values for the fabric samples were obtained using the system. They were reviewed by the experts comparing with the test reports obtained by carrying out tests for individual fabric parameters.

The developed system can be modified accordingly following the same methodology applied in the project after completing the survey for different end uses.

The accuracy of the assigned weightings to the fabric parameters or the accuracy of the expert opinion will be higher if the number of participants or responses is higher.

In addition to that there are more variables that need to be considered when deciding the expected level of quality of a fabric. The expected level of quality which conforms to the performance requirements of the end use can be varied by the silhouette or the garment size. The system can be further improved by implementing methods to also consider these variables when evaluating the fabric.

In this developed fabric quality grading system only physical and chemical parameters of fabrics are considered. Hence in this method fabrics will be evaluated with respect to physical and chemical parameters only in the aspect of fabric performance requirements expected from a certain end use. However, visual inspection of fabrics also reflects another aspect of fabric quality as fabric defects impart serious repercussions on garment quality. Therefore, if the visual aspect of evaluating the fabric can also be incorporated to the fabric quality grading system, it will reflect the level of quality from both the aspects: physical and chemical testing and fabric defects.

In this system if a certain fabric parameter is within the customer specification value ten is assigned for the respective sub index value, and so variation within the specification isn't evaluated. Thus it is not possible to compare two or more fabrics with respect to the considered fabric parameter if it is within the specification. This feature can be incorporated to the fabric quality grading system in future developments.

A decision made considering performance requirements and test results could result in fewer customer complaints. An understanding of fabric tests and corresponding product performance characteristics can lead to the development of garments with a higher quality level. As a result the developed system can be used by both the fabric manufacturer and the garment manufacturer. At the fabric sourcing stage it can be used to evaluate and compare two or more fabrics from different suppliers with regard to an end use and it will be helpful in supplier evaluation as well.

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