Mansoura Engineering Journal

Volume 15 | Issue 2 Article 25

5-23-2021

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Recommended Citation
Abou- Taleb, Hemdan (2021) "Objective Evaluation of Quality of Cotton Denim Jean.," *Mansoura Engineering Journal*: Vol. 15 : Iss. 2 , Article 25.
Available at: https://doi.org/10.21608/bfemu.2021.171471

OBJECTIVE EVALUATION OF QUALITY OF COTTON DENIM JEANS

تقييم جودة أقمشة الجينز القطنية

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خلاصة ـ في هذا البحث استخدمت عدة طرق مختلفة لتقييم جودة أقمشة الدينم القطنية بدون خبراء وذلك لاختيار الأفضل منها في صناعة الملابس الجاهزة والتصدير للخارج · خواص الأداء الضرورية لتقييم جودة أقمشة الدينم أمكن اختيارها وترتيبها بعناية حسب درجة أهميتها · طرق التقييم المختلفة مثل المتوسط الحسابي ، المتوسط الهندسي ، المتوسط التوافقي ، المتوسط الأسي بمساحة الشكل المتعدد الأضلاع ، رقم الجودة وأيضا دالة الرغبة العامة أمكن استخدامها لتقييم جودة أقمشة الدينم بدقة ·

In this work several methods are used to assess the quality ranking of some denim fabrics objectively and to choose the best fabric for ready garments mills. Also the necessary performance characteristics of denim could be selected and arranged carefully in decreasing order of importance. Quality assessment methods such as arithmetic mean, geometric mean, harmonic mean, expontional mean, polygon area, quality number and generalized desirability function can be used for assessing the quality ranking of denim fabrics accurately.

1. INTRODUCTION

Jeans became a favoured item of apparel for youth towards the end of the 1950, the popularity of the jeans reaching a peak in the late 1970. Since then, the competition with respect to the convenient-wear market has grawn. The classic jeans retain a 8% share of the women's outerwear market and a 21% share of the men's outerwear market. The greatest demand comes from the 15-19 age.[1]

The future sale pattern for jeans may well depend upon the price at which they are sold in the light of world economies and on the quality of the fabric and clothing designer to retain and attract new markets.

Jeans, by their nature, are tight fitting, at least between waist and thigh, and since body demand is not satisfied by garment volume when the body assumes a bent position.

Kirk [2] found that skin stretches between areas of local stress as between knee and seat. Also the human form is always in motion. Limbs are rarely straight. Even in a sitting position, knees and hips are at right angles to the body and frequently bent at an acute angle. Therefore, fabric must stretch to meet body demand and to provide dynamic comfort while it retains a longer service life.

It is known that fabric properties depend upon fabric construction, of which fabric tightness is an important aspect, but tightness factor is not cleaely defined.

Denim is characterized by a blue cotton warp and undyed yarns in the grey state in the weft. Because the ratio of warp threads/cm to weft threads/cm is approximately 3:2, the blue warp shows predominantly on the face and the grey weft on the back.

No work has yet been carried out to assess objectively the quality of denim fabrics varying in construction, which are used in ready garments industry.

The object of this paper is therefore to assess objectively the quality ranking of some local denim fabrics and to find the relationship between the construction factor and quality index. The main difficulty of this work was to choose the best denim fabric required for ready garments mills.

2. PERFORMANCE SPECIFICATIONS OF JEANS

All textile materials are designed and manufactured to achieve certain functions. If the jeans functions well and satisfies the consumer, then its performance may be said to be acceptable. However, it must be remembered that the price paid by the customer will influence his or her judgement[3].

Jeans fabrics must offer a careful balance of performance and cost. Performance factors or criteria may be defined and quantified in terms of measurable properties. For example, fabric strength criteria may be quantified as tensile, tearing or bursting strength or any combination of these properties; wear-life and durability as performance criteria of jeans may be measured in terms of abrasion and bending resistance. Easy-care criteria of jeans may be determined in terms of wrinkle-resistance, stiffness and dimensional stability. Comfort criteria may be expressed in terms of air-permeability and moisture vapour permeability which they are being the main sources of body temperature control. Also criteria of cost may be measured in terms of weight per unit area. These five criteriae form the basis of jeans specifications, which may be determined by standard test procedures.

3. MATERIALS AND METHODS

Eight fabrics of 100% cotton denim jeans were selected. Constructional details of all the fabrics are given in Table I.

Tensile strength for each fabric was carried out in warp direction on ravelled specimens 20 cm gauge length and 5 cm wide on PT-250M Tensile Tester. Fabric specific work of rupture and tenacity were calculated. Tear strength was measured on an Elmendorf Tester. Bursting strength was determined on Ball Burst Tester. The fabrics were tested by means of Flexing and Abrasion Tester following ASTM standard methods[4]. Resistance of fabrics to repeated flexing is determined on M.I.T. Flex Endurance Tester. The used static load was 25% of breaking load of specimens with 5 mm wide. Wrinkle resistance was measured on the instrument established by the author[5]. The fabrics were given ten cycles of wash in Evreka Washing Machine at 80 C° for 110 min and then dried in flat state overnight and the area shrinkage was calculated. Fabric stiffness was determined on Shirley Stiffness Tester. The air permeability was determined on a Shirley Air-permeability Tester at 1-cm pressure. Water vapour permeability was measured by calculating the loss of water weight after putting it into a glass covered with the fabric in an oven at 32 C° for 30 min. The typical values of test results are given in Table II.

4. COMPLEX ASSESSMENT OF QUALITY RANKING

From such study performance properties of jeans can be divided into two groups : positive properties such as specific work of rupture, tenacity, tear, bursting, flex abrasion, bending resistance, wrinkle resistance, air permeability and water vapour permeability; and negative properties such as stiffness, shrinkage and weight per unit area.

Table I
Details of Fabric Construction

Fabric	Threads per 10 cm		Linear Density, tex		Crimp, %		Weave Design	Surface Density,	Fabric Thickness,	Construction Factor,
	Warp	Weft	Warp	Weft	Warp	Weft		g/m²	mm	T
1	192	160	56.8	35.1	5.65	9.05	plain 1/1	239	0.6439	3.332
2	198	130	82.1	84.6	8.40	5.85	2/1 S twill	294	0.7912	1.746
3	200	171	83.3	72.7	11.90	6.40	2/1 S twill	382	0.9855	2.951
4	200	202	87.0	77.3	12.90	7.55	2/1 S twill	410	1.0211	3.674
5	200	184	85.1	87.9	15.10	8.85	2/1 S twill	495	1.0070	3.536
6	208	202	76.0	104.7	15.10	9.60	2/1 S twill	492	1.0224	4.111
7	200	220	84.0	76.6	13.80	7.30	2/1 S twill	468	1.0883	3.919
8	210	180	83.9	88.3	14.85	9.30	2/1 S twill	416	0.9385	3.614

Table II
Typical Performance Characteristics of Fabrics

Fabric criteria	Fabric							
	1	2	3	4	5	6	7	8
1. Criteria of strength:								
- Specific work of rupture, g/tex	1.738	1.828	1.769	1.675	1.727	1.409	1.280	1.594
- Tenacity, g/tex	10.126	11.114	8.557	6.530	6.269	4.702	4.852	5.984
- Tear strength, grams	4270	6130	12807	8395	9390	7548	8438	8835
- Bursting strength, kg	44.82	53.59	89.82	73.00	97.50	100.23	88.41	91.64
2. Criteria of wear-life:								
- Flex abrasion resistance, cycles	830	1610	1757	1430	1595	1213	1457	1413
- Bending resistance, cycles	1074	5240	3352	1136	4088	6341	2996	3645
3. Criteria of easy-care:								
- Wrinkle-resistance, %	77.1	79.9	76.2	70.8	75.7	83.2	81.0	81.6
- Area shrinkage, %	16.61	15.48	14.98	11.84	9.57	7.36	8.32	9.00
- Bending modulus $\times 10^{10}$, kg/cm^2	4400	4228	3964	8628	4173	5841	2497	3994
4. Criteria of comfort:								
- Air permeability, $cm^3/cm^2.sec$	19.7	11.9	2.8	1.17	1.18	1.0	0.73	1.78
- Water vapour permeability $\times 10^3$, $mg/cm^2.sec$	1.758	2.730	1.747	1.897	1.319	2.464	2.545	2.267
5. Criteria of cost:								
- Weight per unit area, g/m^2	239	294	382	410	495	492	468	416

Relative characteristics of each property can be calculated by the following equations[6]:

$$\text{positive relative characteristics} = \frac{X_i}{X_{max}} \qquad \ldots (1)$$

and

$$\text{negative relative characteristics} = \frac{X_{min}}{X_i} \qquad \ldots (2)$$

where X_i - typical value of each property ;
X_{min}, X_{max} - minimum and maximum values of each property.

Selection of the best fabric is difficult enough without using special methods for assessing the quality such as complex characteristics or generalized desirability function.

4.1. Complex Characteristics

Complex characteristics of quality assessment may be determined by calculating the arithmetic mean, geometric mean, harmonic mean, expontional mean, polygon area and quality number of the average relative characteristics (y_i) of each criteria given in Table III as follows:

$$\text{Arithmetic mean (A)} = \sum_{i=1}^{n} y_i / n \qquad \ldots (3)$$

$$\text{Geometric mean (G)} = (y_1 \cdot y_2 \cdot y_3 \cdot \ \ldots \ y_n)^{1/n} \qquad \ldots (4)$$

$$\text{Harmonic mean (H)} = n \Big/ \sum_{i=1}^{n} 1/y_i \qquad \ldots (5)$$

$$\text{Expontional mean (E)} = \ln \left(\frac{1}{n} \sum_{i=1}^{n} e^{y_i} \right) \qquad \ldots (6)$$

$$\text{Polygon area (P)} = 1/2 \sin \frac{2\pi}{n} (y_1y_2 + y_2y_3 + y_3y_4 + y_4y_5 + y_5y_1) \qquad \ldots (7)$$

$$\text{Quality number (Q)} = y_1 + y_2^2 + y_3^3 + y_4^4 + y_5^5 \qquad \ldots (8)$$

where $y_1 - y_5$ = the average relative characteristics of the criteria of strength, wear-life, easy-care, comfort and cost respectively ; which these five criteriae are arranged in a decrease order according to its importance ; and
n - number of the criteriae.

Values of relative and complex characteristics of fabrics are given in Tables III & IV respectively.

4.2 Generalized Desirability Function

Generalized desirability function D can be calculated[7-9] by the geometric mean of the individual characteristics of the desirability (d_i) as follows:

$$D = (d_1 \cdot d_2 \cdot d_3 \cdot \ \ldots \ d_m)^{1/m} \qquad \ldots (9)$$

Table III
Relative Performance Characteristics of Fabrics

Fabric Criteria	Fabric 1	2	3	4	5	6	7	8
1. Criteria of strength:								
- Specific work of rupture	0.951	1.00	0.968	0.916	0.945	0.771	0.700	0.872
- Tenacity	0.911	1.00	0.770	0.588	0.564	0.423	0.437	0.538
- Tear strength	0.333	0.479	1.00	0.656	0.733	0.589	0.659	0.690
- Bursting strength	0.447	0.535	0.896	0.728	0.973	1.00	0.882	0.914
* Average relative characteristics (y_1)	0.661	0.753	0.908	0.722	0.804	0.654	0.635	0.718
2. Criteria of wear-life:								
- Flex abrasion resistance	0.473	0.917	1.00	0.814	0.908	0.691	0.829	0.805
- Bending resistance	0.169	0.826	0.529	0.179	0.945	1.00	0.473	0.575
* Average relative characteristics (y_2)	0.321	0.872	0.764	0.497	0.927	0.845	0.651	0.690
3. Criteria of easy-care:								
- Wrinkle resistance	0.926	0.960	0.915	0.851	0.910	1.00	0.973	0.981
- Area shrinkage	0.443	0.476	0.492	0.622	0.769	1.00	0.885	0.818
- Bending modulus	0.568	0.591	0.630	0.290	0.599	0.428	1.00	0.625
* Average relative characteristics (y_3)	0.646	0.675	0.679	0.587	0.759	0.809	0.953	0.808
4. Criteria of comfort:								
- Air permeability	1.00	0.604	0.142	0.059	0.060	0.051	0.037	0.090
- Water vapour permeability	0.644	1.00	0.640	0.695	0.483	0.903	0.932	0.830
* Average relative characteristics (y_4)	0.822	0.802	0.391	0.377	0.272	0.477	0.485	0.460
5. Criteria of cost:								
- Weight per unit area	1.00	0.811	0.624	0.581	0.482	0.484	0.510	0.574
* Average relative characteristics (y_5)	1.00	0.811	0.624	0.581	0.482	0.484	0.510	0.574

Table IV
Complex Characteristics of Fabrics

Complex Characteristics	Fabric 1	2	3	4	5	6	7	8
Arithmetic mean (A)	0.690	0.783	0.673	0.553	0.649	0.654	0.647	0.650
Geometric mean (G)	0.646	0.780	0.649	0.541	0.594	0.635	0.627	0.638
Harmonic mean (H)	0.596	0.777	0.622	0.528	0.532	0.616	0.611	0.625
Expontional mean (E)	0.714	0.785	0.688	0.559	0.676	0.666	0.661	0.657
Polygon area (P)	1.157	1.449	1.088	0.718	1.033	1.032	0.982	0.999
Quality number (Q)	2.489	2.585	1.923	1.258	2.131	1.976	2.013	1.828

Table V
Values of the characteristics of the Desirability (di) and (zi)

Gradation of Property	Value of d by formula (11)	Value of z by formula (11)
Excellent	$\geqslant$ 0.80	$\geqslant$ 1.5
Good	$\geqslant$ 0.63	$\geqslant$ 0.77
Pass	$>$ 0.37	$>$ 0.00
Bad	$\leqslant$ 0.37	$\leqslant$ 0

where m - number of typical performance properties.

The performance properties X_i of jeans are related to the dimensionless characteristics Z_i as follows:

$$Z = a_0 + a_1 X \qquad \text{. . . (10)}$$

where a_0, a_1 - constants.

Then the characteristics of desirability d_i can be calculated by the following equation:

$$d = \exp[- \exp - Z] \qquad \text{. . . (11)}$$

where $\infty \angle z < \infty$

The constants a_0 and a_1, given in Table VI, are calculated from knowledge the limited values of d_i and the corresponded values of Z_i given in Table V. For example, for specific work of rupture X_1

$$Z = a_0 + a_1 X_1$$

From Table V, for excellent sample Z=1.5 and for bad sample Z=0 ; also from Table II, maximum value of specific work of rupture is equal to 1.828 g/tex (Fabric No.2) and minimum value of specific work of rupture is equal to 1.28 g/tex (Fabric No.7).

Then $1.5 = a_0 + 1.828\ a_1$

$0 = a_0 + 1.28\ a_1$

By solving the above two equations, the constants a_0 and a_1 can be calculated as given in Table VI. By means of knowing the typical values of specific work of rupture for each fabric, the corresponded values of Z can be determined. Consequently, the value of d_1 for each fabric can be calculated. With the same manner the values of d_2 to d_{12} can be calculated as listed in Table VII where d_1-sp. work of rupture; d_2-tenacity; d_3-tear; d_4-bursting; d_5-flex-abrasion; d_6-bending resistance; d_7-wrinkle resistance; d_8-area shrinkage; d_a-bending modulus; d_{10}-air permeability; d_{11}-water vapour permeability and d_{12}-weight per unit area. Therefore, the values of D can be easily calculated from Equation 9 and the fabrics can be ranked according to its quality.

4.3 Rank Agreement

The eight fabric samples are to be ranked in order of general quality using the seven methods of quality assessment (A, G, H, E, P, Q and D). These fabrics have been ranked from 1 to 8, No.1 representing the best fabric and No.8 representing the worse one. The rankings of all the methods are set out in Table V111. If all the methods were in complete agreement, the rank totals would be in the series 7,14,21,28,35,42,49 and 56. The sum of the rank totals is 252. If the methods of assessment had no ability in ranking the fabrics, the ranking numbers would be random and therefore the rank totals[10] would be one-eighth of the total 252, equal to 31.5. The actual rank totals are now compared with 31.5 as given

Table VI
Values of Constants a_0 and a_1

Symble	Performance Property	a_0	a_1
X_1	Specific work of rupture	- 3.504	2.737
X_2	Tenacity	- 1.1	0.234
X_3	Tear strength	- 0.750	1.757×10^{-4}
X_4	Bursting strength	- 1.213	0.027
X_5	Flex abrasion	- 1.343	1.618×10^{-3}
X_6	Bending resistance	- 0.306	2.848×10^{-4}
X_7	Wrinkle resistance	- 8.565	0.121
X_8	Area shrinkage	2.694	- 0.162
X_9	Bending modulus	2.111	$- 2.447 \times 10^{6}$
X_{10}	Air permeability	- 0.058	0.079
X_{11}	Water vapour permeability	- 1.861	1411.1
X_{12}	Weight per unit area	2.896	$- 5.853 \times 10^{-3}$

Table VII
Values of Generalized Desirability Characteristics (d and D)

Fabric	Characteristics of Desirability												
	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	d_{11}	d_{12}	D
1	0.752	0.755	0.368	0.368	0.368	0.368	0.627	0.368	0.7	0.8	0.584	0.8	0.541
2	0.8	0.8	0.486	0.455	0.754	0.737	0.717	0.435	0.711	0.661	0.872	0.734	0.664
3	0.769	0.666	0.8	0.745	0.8	0.593	0.594	0.465	0.727	0.428	0.579	0.596	0.635
4	0.712	0.521	0.616	0.628	0.685	0.374	0.368	0.631	0.368	0.381	0.643	0.544	0.523
5	0.745	0.5	0.666	0.787	0.748	0.655	0.575	0.727	0.715	0.381	0.368	0.368	0.581
6	0.495	0.368	0.570	0.8	0.584	0.8	0.8	0.8	0.603	0.376	0.820	0.373	0.588
7	0.368	0.381	0.618	0.736	0.696	0.561	0.747	0.771	0.8	0.368	0.838	0.426	0.582
8	0.655	0.477	0.639	0.755	0.677	0.618	0.763	0.748	0.725	0.398	0.769	0.533	0.634

Table VIII
Quality Ranking of Fabrics

Assessment Method	Fabric							
	1	2	3	4	5	6	7	8
A	2	1	3	8	6	4	7	5
G	3	1	2	8	7	5	6	4
H	6	1	3	8	7	4	5	2
E	2	1	3	8	4	5	6	7
P	2	1	3	8	4	5	7	6
Q	2	1	6	8	3	5	4	7
D	7	1	2	8	6	4	5	3
Rank totals	24	7	22	56	37	32	40	34
Final rank	3	1	2	8	6	4	7	5

Table VIIII
Ranking Difference of Fabrics

Fabric	Rank Total	Difference d $\lvert 31.5 - R.T \rvert$	$(\text{Difference})^2$ d^2
1	24	7.5	56.25
2	7	24.5	600.25
3	22	9.5	90.25
4	56	24.5	600.25
5	37	5.5	30.25
6	32	0.5	0.25
7	40	8.5	72.25
8	34	2.5	6.25
			1456 (Sum of d^2 = S)

in Table VIIII. Let S-the sum of the squares of the differences; V-the number of methods, and C-the number of fabrics. The measure of the degree of agreement among the different methods is given by the cooefficient of concordance, W,

$$W = \frac{S}{[V^2(C^3 - C)]/12} \quad \ldots (12)$$

In this example, W = 0.71 approximately. Thus, the different methods of assessment exhibit a high degree of agreement on the ranking of fabrics for quality. The significance of the coefficient of concordance may be tested by reference to the F Tables. The value of F is then calculated:

$$F = \frac{(V-1)\,W}{1 - W} = \frac{6 \times 0.71}{1 - 0.71} = 14.5 \quad \text{approx.} \quad \ldots (13)$$

It could be concluded that the different methods are really in close agreement because the calculated value of F, 14.5, is above the 1 per cent level of F, 3.12 for the degrees of freedom of $f_1 = (c-1)- \frac{2}{v}$ and $f_2 = (v-1)\,[(c-1)- \frac{2}{v}]$.

The results of final ranking are given in Table VIII. The fabrics are arranged in order of increasing final ranking. It could be noticed that the fabric No.2 and fabric No.4 has the best and worse quality respectively.

5. CONCLUSIONS

From the work described in this parper the following conclusions have been deduced:

1. Performance properties of jeans could be selected and arranged carefully in decreasing order of importance.
2. Quality assessment methods such as arithmetic mean, geometric mean, harmonic mean, expontional mean, polygon area, quality number and generalized desirability function can be used for assessing the quality ranking of jeans farics.

ACKNOWLEDGEMENS

The author wishes to thank Dr.Abdel Menem Hafez, the manger of Samannod Ready Garments Company and Mr.Ahmed Sarhan, the manger of Mansoura - Espania Ready Garments Company for their assistance in supplying denim fabrics.

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