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Seam Pucker in Apparels: A Critical Review of Evaluation Methods

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ABSTRACT

Seam pucker is a wrinkled appearance along the seam, which influences the appearance to a considerable degree. The various causes of seam pucker are discussed here. This critical review article basically presents the various methods of evaluation of seam pucker. There are several methods emerged with time to evaluate the seam pucker, however the research is still continuing to find our more accurate and easy methods. The initial methods of seam pucker evaluation was based on subjective assessment, but it suffered from the limitations of higher evaluation time, inconsistency among judges and need for training and the results are not reliable. The objective assessment of seam pucker is carried out by the various methods; photometric instruments, cognitive theory, parallel light, fractal dimension, artificial neural network, neuro-fuzzy logic, sensory measurement and structured light projection. The advantages and disadvantages of various methods of objective assessment are brought out.

Key words: Artificial neural network, neuro-fuzzy logic, objective evaluation, seam appearance, seam pucker, subjective evaluation

INTRODUCTION

The visual appeal of the garment is a principal factor deciding its value. Seam pucker, which is a wrinkled appearance along the seam, influences the appearance to a considerable degree. Seam pucker, identified as a sewability problem about seventy years ago, has been regarded as one of the most important parameter of quality control in garment manufacturing industries. As defined in Oxford Dictionary, seam pucker is a ridge, wrinkle, or corrugation of the material or a number of small wrinkles running across and into one another, which appear in sewing together two pieces of cloth. It is usually caused by improper selection of sewing parameters and material properties, which results in unevenness on fabrics being stitched together, thus impairing their aesthetic values. In severe cases, seam pucker could appear like a wave front, originating from the seam and extending to the entire piece of garment, e.g., when the seam is the cent ridge linking the two pieces of fabrics in the back of a man's suit. In less severe cases, the wave formation is less pronounced, but nevertheless discernible. Indeed, garments exhibiting pronounced seam puckers are certainly unwelcome by customers (Mark and Li, 2008).

It has been well recognized that elimination of seam pucker entirely is almost impossible and the common practice is to accept a small amount of pucker is as normal. Hence, in such a scenario the exact and accurate evaluation of seam pucker carries much importance for manufacturers and as well as to the customers. Here, the authors have undertaken the exercise of consolidating the various evaluation methods of seam pucker to work as a spring board for manufacturers and customers to evaluate it in many ways to assure the apparel quality.

CAUSES OF SEAM PUCKER

Structural jamming: During seam formation, stitches are made by interloping of bobbin and needle thread. These sewing threads displace the fabric yarns from its original position. Fabric yarns attempt to return to original position and they are prevented from doing so by the sewing threads. This causes the fabric layers to displace in a plane perpendicular to fabric plane and results in seam puckering. This kind of pucker is visible mostly in tightly constructed fabrics which do not have enough space to accommodate sewing threads. Use of fine sewing threads may help to reduce the problem, but the elimination can only be accomplished with proper selection of fabric. High stitch density which calls for more space also causes structural jamming in tightly constructed fabrics. This kind of pucker is visible in both sides of the fabric.

Differential feed: Differential feed of feed dog produces feeding pucker. During sewing operation, bottom layer fabric is moved forward by feed dog positively. But the movement of top layer fabric is effected through frictional contact between top and bottom fabric. Thus movement to top fabric is not a positive one. The velocity of top layer fabric is generally lower than that of bottom layer fabric. This causes accumulation of bottom layer fabrics and produces feeding pucker, which is visible at one side only.

Sewing thread tension: Tension pucker occurs when sewing thread is under very high tension. Sewing thread extends due to very high tension, afterwards attempts to relax. If elastic recovery of thread and shrinkage of fabric coincides, pucker does not occur. But in most situations recovery of thread is more than fabric shrinkage causing fabric to pucker. This is inevitable from the point of view of sewing operation, which requires higher needle thread tension than bobbin thread tension to snatch the later for stitch formation.

Sewing thread shrinkage: High shrinkage potential of fabric is another source of seam pucker. Threads made of cotton and other natural fibres often shrink, when wet. This may cause seam pucker when fabric shrinkage and thread shrinkage differs. This problem can largely be overcome with the use of synthetic sewing threads. These threads are normally dry heat stabilized to withstand up to temperature of 150°C. They may also cause seam pucker during pressing, if the pressing temperature is above heat-set temperature.

Fabric shrinkage: Different shrinkage of plies of fabric causes seam pucker that is visible only after few washing cycles. They will never occur during the sewing operation. They are concerned with dimensional stability of plies of fabric.

Mismatched patterns: If the patterns of fabric that are to be matched are of unequal length, experienced tailor will feed more length of pattern which is longer. This compensates for extra length, but fabric accumulates in the form of wrinkles and seam pucker appears.

EVALUATION OF SEAM PUCKER

Subjective evaluation: In subjective evaluation method, experts or experienced judges grade the fabric seam appearance according to certain standards. Variety of standards has been proposed and

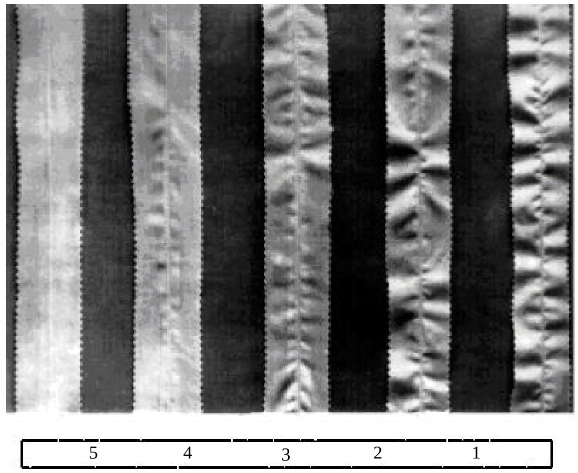

Fig. 1: Reference seams for the seam inspection

AATCC standard 88B is the most commonly practiced today. According to AATCC method, seam appearance is classified into five grades: grade1 refers to worst fabric which is heavily puckered and grade 5 refers to smooth fabric with little pucker or no pucker at all. Figure 1 illustrates the photographs of reference seam specimens from AATCC. The sample fabrics are sewn as per standard procedures and the appearance of seam is compared with standard reference specimens. The grade of fabric is the grade of the reference specimen which matches most nearly to sample fabric specimen.

The subjective evaluation method outlined above though simple and easy to perform, has shortcoming such as subjectivity, human bias towards a particular colour or pattern, higher evaluation time, inconsistency among judges and need for training. Thus evaluation based on subjective technique is not reliable.

Method based on thickness and length measurement: There are two other methods, which are practiced for seam pucker evaluation. First method is based on measurement of fabric thickness. The fabric thickness increases due to distortion of fabric layers from fabric plane. The thickness of unpuckered fabric seam equals the addition of thicknesses of individual fabric plies. The increase in thickness can be used as an indicator of the extent of puckering:

$$SP\% = \frac{(T_2 - T_1)}{T_1} \times 100 \quad (1)$$

where, SP is Seam pucker %, T_2 is thickness of puckered seam, T_1 is thickness of fabric seam (thickness of individual fabric plies added together).

This method though considered better than subjective evaluation, but suffers from the limitation like more time consumption and inconsistency.

Second method employs the difference in length of fabric due to pucker as an indicator. The sewing thread is unraveled from sewn fabric and length of fabric is measured after the fabric is pressed. The difference between original length and puckered length gives an indicator of pucker:

$$SP\% = \frac{(L_2 - L_1)}{L_1} \times 100 \quad (2)$$

where, SP % is seam pucker percentage, L_1 is length of sewn fabric, L_2 is length of unraveled fabric.

This method also suffers from limitations such as inconsistency and more time consumption. This calls for alternative evaluation techniques based on objective measurement, which can eliminate these shortcomings.

Objective evaluation techniques: The pioneer proposal for the development of objective evaluation technique was reported in the middle of last century. Over the decades, many different techniques have been proposed by researchers around the world. But they did not receive much attention and acceptance from apparel industries due to certain limitations. These techniques attempt to infer the geometric shape of seam and characterize it by a quantitative value.

Evaluation using photometric instruments: Belser *et al.* (1968) proposed an instrument for grading seam pucker based on photometric principle. A properly masked fabric is illuminated by a collimated lighting source and the reflection of light is sensed by a photometer whose output is connected with an *x-y* recorder. The profile of the trace from the chart is analyzed and seam pucker is characterized by a descriptor, which is used to grade from a look-up table. The specimen is kept horizontal and collimated light is placed at the vertical position. The variations in intensity are registered by photometer as the illuminated zone traverses the seam parallel to seam line. A photometer angle of 30° to horizontal was reported to be optimum for instrumentation. A trace of intensity is shown in Fig. 2, in which straight line represents the unpuckered intensity and values above and below this line represents increases and decreases in intensity. Two descriptors were used for objective evaluation; area between the curve and centre line in intensity trace (higher the area the trace covers, lower will be the seam pucker grade) and ratio of trace length and straight line (higher the ratio, lower will be the seam grade). The regression equations relating these two descriptors and subjective grades by AATCC were obtained. The tracing length ratio varied from 1. 077 to 1.522. The tracing length ratio values are divided into 5 bands. The seam is graded the value of band which has that tracing length ratio of the specimen. This method is based on only one trace, not the entire specimen. The predictions based on this instrument are highly unrealistic and reliability of the instrument is poor. The report is based on white fabric and sewing thread, so the method cannot be used for fabrics of different colours and patterns.

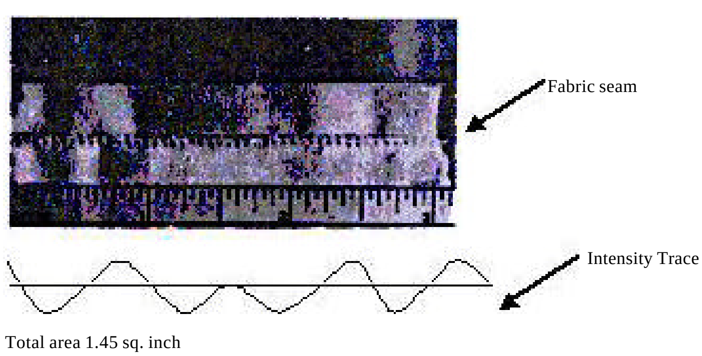

Fig. 2: A sample photometer trace

Shiloh (1971) constructed a similar instrument called Sivim Wrinkle Meter for measuring the wrinkle parameters of the fabric. Two lines each at 2 mm from the seam line were selected for trace. On each line three tracings were made to calculate height (h), slope (t) and density along the seam line. The means of the two traces were used for final assessment. An index called puckering-severity index, which is the product of height and slope was suggested for objective evaluation. The possibility of distinguishing slightly puckered seam by analyzing height and slope of seam profile was also mentioned.

Methods based on computer vision

Evaluation using cognitive theory and computer vision: Stylios and Sotomi (1993a, b) developed a cognitive theory of human perception for evaluating of seam pucker. The human eye is replaced by CCD camera and cognitive processing by brain is replaced by computer algorithms. When human eyes see a garment, they gain a measure of the severity of seam pucker largely from the relative differences between the bright and dark spots of the deformed or wrinkled surface of the fabric along the seam line. The 256 gray levels in an intensity image of garment can be used for evaluation of seam pucker based on cognitive theory. The pucker profile was considered similar to a profile of wave. The pucker amplitude is defined as the distance between a peak and an adjacent trough measured along a direction perpendicular to the plane of the seam. The pucker wavelength is the distance between the two adjacent troughs of pucker profile. The puckering of increasing wave frequency results in decreasing seam quality. In the same manner, puckering with increasing amplitude results in decreasing quality. Based on this cognitive theory descriptors were developed for grading. The descriptors used were based on the wave profile of pucker. A profile is shown in Fig. 3. As can be seen, pucker b is inferior to pucker a due to higher pucker amplitude and pucker c is inferior to pucker d due to shorter wavelength.

Based on the cognitive theory, they developed an evaluation system called Pucker Vision System. It uses a CCD camera to capture the intensity image of fabric specimens mounted vertically. The intensity variations or gray level is assumed to be proportional to height variations of seam. Figure 4 shows the image obtained from CCD camera. Each fabric requires at least two specimens one sewn and another one unsewn. The pucker index was calculated for both the

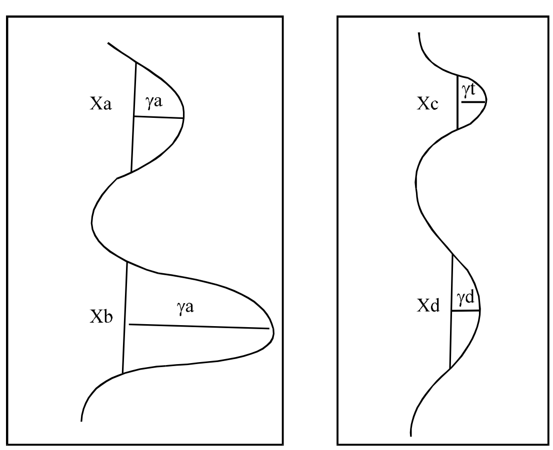

Fig. 3: Seam pucker: effect of amplitude and wavelength

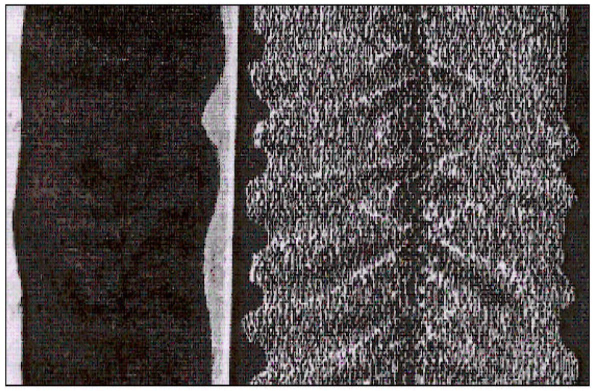

Fig. 4: Schematic demonstration of principle of shadowing

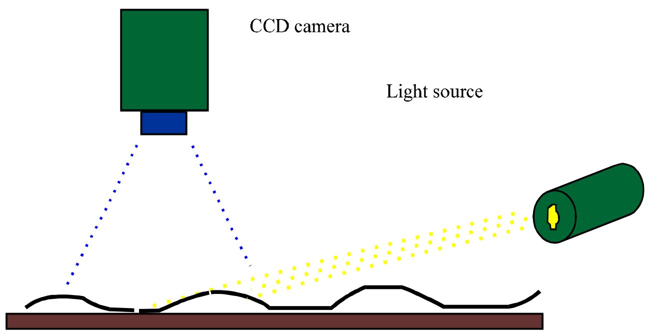

Fig. 5: Schematic demonstration of principle of shadowing

specimens. The difference in pucker index of sewn and unsewn specimens is quite predictive of quality of seam. The problem of evaluation of different coloured fabrics was compensated by using a factor called seam brightness factor. According to this study, shift in the order of magnitude of parameters from dark fabrics to brightly coloured fabrics is given by the ratio of the maximum reflectance possible to the reflectance of the specimen. To evaluate fabrics of different patterns, another factor called seam texture and pattern factor was used in evaluation. The seams are graded using empirical equations developed for this purpose. Pucker Vision System depends on intensity variations of image for measurement. The intensity variations are influenced by lighting conditions and maintenance of uniform and consistent illumination condition is somewhat difficult.

Evaluation using shadows by parallel light: This method relies on shadows created by seam when illuminated by a parallel light source at an angle to horizontal. The area of shadows depends upon the severity of seam pucker. Heavily puckered fabric produces higher shade area and vice versa. Kus (1999) reported an evaluation system based on this principle. A parallel light beam is illuminates the fabric specimen at 25° to horizontal. The image was captured using a CCD camera and analyzed using digital image analysis techniques. The schematic diagram of setup is shown in Fig. 5. The digital image processing procedure involves conversion of colour image to grey image, threshold to get binary image and area measurement by pixel counting of black pixels. Figure 6a and b show the colour image and binary image converted by digital image analysis. The correlation between area fraction and puckering degree was reported to be 0.998 (Kus, 1999).

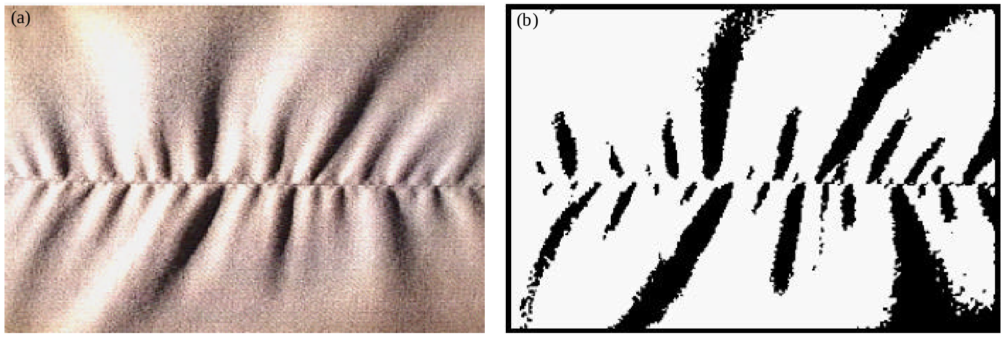

Fig. 6: Colour and binary image of puckered sample (a and b)

$$\text{Area fraction} = \frac{\text{Total sample area} - \text{shaded area}}{\text{Total sample area}} \quad (3)$$

Smooth fabric without puckering has theoretical area fraction 1:

This method holds good for white and brightly coloured plain fabrics. Fabrics with dark colours cannot be evaluated because the shadows created by puckers may not be distinguishable from smooth area. The patterned fabrics also cannot be evaluated reliably because shadows created by puckers are undistinguishable from pattern effects. But this system is very simple in principle and can be used for certain range of fabrics if fine-tuned.

Principle of laser triangulation: Human-beings perceive the severity of seam pucker principally from the 3D geometric shape of the seam. Consequently, researches were attempted which captured 3D geometric shape of seam and seam pucker was characterized by a 3D digital image analysis. The sensors or scanners used for this purpose principally relied on laser light source. The laser sensors or scanners are already in use in various engineering fields such as laser range finding, 3D model making, electronic circuit board inspection etc. Laser is an abbreviation for light amplification by stimulated emission of radiation. The laser is monochromatic, unidirectional, intense, coherent light and the wavelength and power of the beam can be determined by the laser design. These properties make them suitable for 3D shape scanning. Most laser scanners operate on the principle of laser triangulation. These sensors fall into category of non-contact height or range measurement devices. A triangulation sensor may provide the same information as a linear variable differential transformer or contact probe, but without touching the object to be measured. The sensors work by projecting a beam of light onto the object of interest like fabric and calculating the distance from a reference point by determining, where the reflected light falls on a detector (Fig. 7).

As the point of falling on the object moves closer to or farther away from the reference point, the spot position on the detector changes. By analyzing the position of spot on the detector, the heights of various point of object are determined. These data can be transferred into a cartesian coordinate system in which x and y axis represents the length and width of fabric and z axis represents the height. With the use of these, 3D shape can be reconstructed and analysis can be made from this shape. Inui and Shibuya (1992) proposed the idea of seam pucker evaluation using laser displacement meter.

The laser displacement meter can measure the height of a single point at a time. Consequently, system has been designed with help of moving stages to measure the height at various points of the

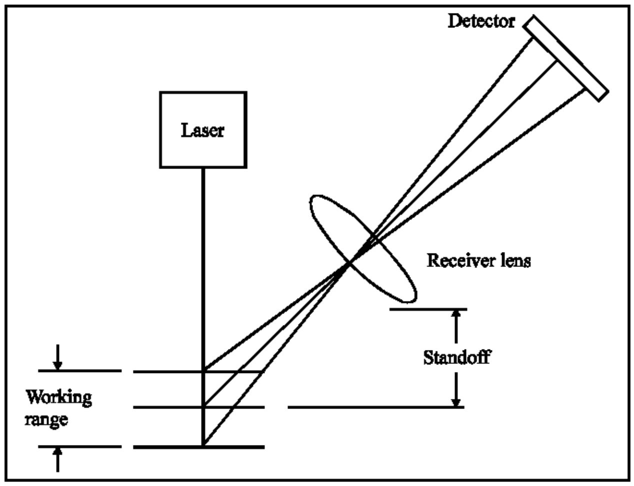

Fig. 7: A diffuse triangulation sensor

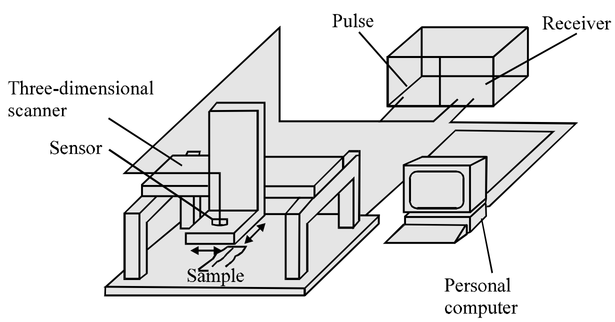

Fig. 8: Laser displacement meter

seam (Inui and Shibuya, 1992). The schematic diagram of the instrument is shown in Fig. 8. A sample of 18×102.2 mm was selected for measurement. The measurement starts at the end of a seam and progressed parallel to seam line towards another end. The distance between measuring points in a line is 0.2 mm. After the completion of single line, fabric is moved 2 mm perpendicular to seam line for the measurement of another line. Thus 10 lines were scanned resulting in 5120 data points. A scanned profile is shown in Fig. 9.

The data on one line of the seam profile is used for calculation of power spectra of that line using FFT. It is observed from samples that the span of seam pucker is short and its height is low near the seam line, on the other hand the height and span of pucker is high near the seam edge. Consequently the position and frequency of the power spectra are used for evaluation of seam. The logarithmic power spectra are dived into 9 areas representing various frequency and position. The logarithmic power spectra in each area is summed up and used for evaluation using discriminant analysis. The subjective evaluation of slightly puckered seam was observed and hence the grading system was converted into three grade system from AATCC five grade system. Similar to subjective evaluation, difficulty of distinguishing slightly puckered seams using objective measurement is also observed.

The methods described so far were based on samples laid on a plane surface, but garment has very few flat seams. Fan (1999) attempted to evaluate the seams that are laid on both curved and tilted surfaces to simulate the three dimensional garment seams. Five kinds of surfaces have been used for simulating garment seams. Of these, one surface is plane, two were tilted with respect to x and y axis and another two were curved to have concave and convex shapes. The seam profiles were obtained from the commercial laser scanner. These scanners measure the height of the seam at various points of the seam and a seam profile is obtained. The minimum wavelength of pucker near the seam was found to be 2 mm. Filter was used which exclude any detail with a wavelength less than 1.5 mm to remove noise due to individual threads and surface texture from profiles. The maximum wave length near the seam edge is less than 50 mm. The tilt and curvature of the seam was excluded by the filter which removed wavelength higher than 60 mm. The cut-off frequency of band pass filter is 16.7 and 667. All the profiles were filtered using a filter that was realized by FIR implementation of a chebyshev filter (Fan, 1999). The resulting profiles were analyzed and characterized by four descriptors; mean deviation (Re), variance (σ^2), skews (S) and kutosis (K):

$$R_a = 1/n\sum\left|z(i) - \overline{z(i)}\right| \tag{4}$$

$$\sigma^2 = 1/n\sum\left(z(i) - \overline{z(i)}\right)^2 \tag{5}$$

$$S = 1/n\sum\left(\frac{z(i) - \overline{z(i)}^3}{\sigma^3}\right) \tag{6}$$

$$K = 1/n\sum\left(\frac{z(i) - \overline{z(i)}^4}{\sigma^4}\right) \tag{7}$$

where, z (i) is the height of ith point; $\overline{z_i}$, average height; n, total number of points; σ, standard deviation of height distribution.

Fan and Liu (2000) extended this theory to evaluate the seams cut from manufactured garment. The seam profiles were obtained from laser scanner and virtually reconstructed using spline interpolation. The reconstructed surface was cross-sectioned by planes parallel to x-z and y-z planes to create a mesh. These cut profiles were filtered using a 2D FIR filter designed from 1D FIR filter described in earlier work. The seam is graded by regression equation relating subjective AATCC grade and descriptors as used in their earlier work. It was noted that fabric colour and pattern do not affect the evaluation based on laser. The correlation between subjective grade and objective grade showed more-spread out point for checked fabric. This was attributed to the fact that subjective evaluation of fabrics is biased towards colour and pattern (Fan and Liu, 2000).

Characterization of seam puckers by fractal dimension: Kang and Lee (2000) and Kang *et al.* (2001) reported the use of fractal geometry for characterizing the seam pucker and fabric wrinkles. The fractal dimension is a quantitative value to describe a crinkled, random structure. The surface contour of the fabric specimen for calculation was obtained from the laser scanner. Two methods box-counting and cell counting were proposed for the calculation of fractal dimension (Kang and Lee, 2000; Kang *et al.*, 2001). According to theory of fractal geometry, the following relationship holds good for a self similar structure (Eq. 8, 9):

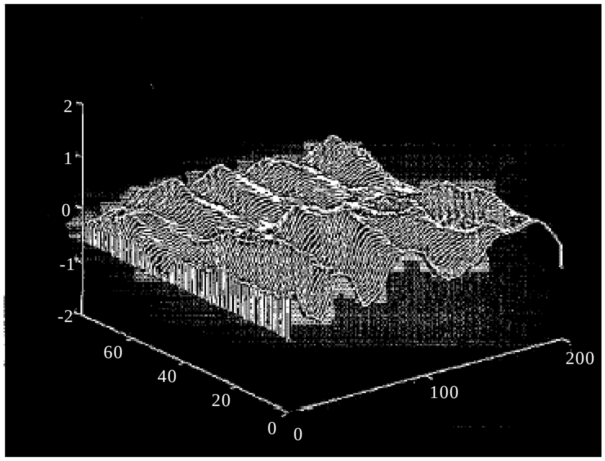

Fig. 9: Seam profile from laser scanner

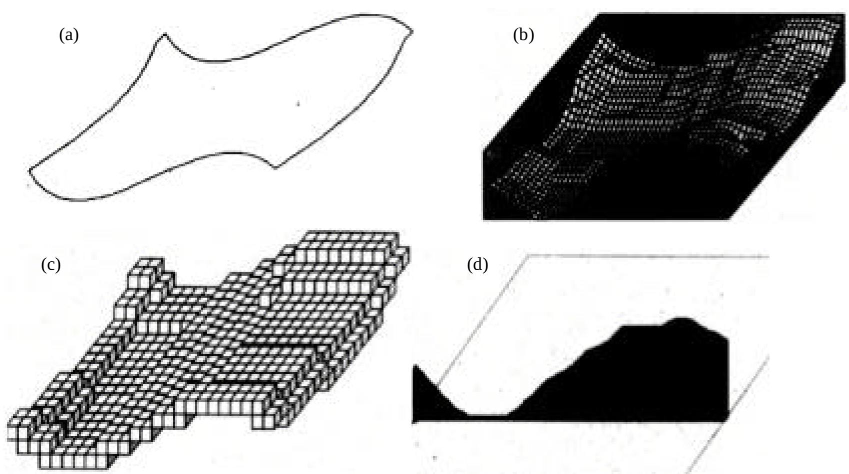

Fig. 10: (a) Surface of object (b) reconstructed surface after scanning (c) cube counting method (d) reduced cross-sectional method

$$N = e^{-D} \quad (8)$$

$$\text{In } N = -D\text{In}l+K \quad (9)$$

where, N is number of occupied unit cells; E is magnification factor (l/L); D is fractal dimension; l is unit cell length; L is side length of the object and K is constant.

The procedure for calculation of fractal dimension is shown in Fig. 10a-d. The surface contour of the fabric revealed from the laser scanner is put into a 3D structure composed of cubes. The number of cubes that intersect the fabric surface is calculated. This procedure is repeated for various cube dimensions and a double logarithmic plot between cube dimension and number of cubes is obtained. The slope of this plot will give the fractal dimension of the object. A smooth fabric is expected to have fractal dimension of 2 and an extremely puckered fabric will have a fractal dimension of above 2, but less than 3.

Grading using artificial neural networks: Park and Kang (1997) proposed neural networks for grading of seam pucker. An artificial neural network, or neuro computing, is based on mathematical modeling that simplifies biological neurons and their connections. A neural network is characterized by its pattern of connection between neurons and its method of determining the weights on the connections, as well as its activation function. The neural network information is represented by lots of structural components called neurons which means distributed knowledge representation possible. The profiles of the seams were revealed using laser sensor. About 2176 equally spaced points are measured in the fabric specimen of 80 mm wide and 254 mm long. The measured data are transferred to frequency domain using FFT (Fast Fourier Transform). From the frequency domain, power spectra is calculated, which characterizes the seam pucker shape in frequency domain (Park and Kang, 1997).

Prediction using neuro-fuzzy logic: Park and Kang (1999a, b) developed an objective measurement based on neural networks and fuzzy logic. For evaluation, they developed a seam pucker simulator based on a geometric model. In this model, the pucker profile was assumed to be sinusoidal wave. They defined five shape parameters for objective measurement including number of random wave generating points, wave amplitude at seam line and edge line, wave length at seam line and edge. Once these five parameters are specified, simulator simulates the pucker profiles based on some assumptions and conditions such as amplitude and wave length changes from seam line to edge line and conditions for collision of wave (Park and Kang, 1999a, b). Figure 11 shows the five shape parameters and simulated profile from simulator.

The laser scanner gives the data in a three dimensional co-ordinate system. These data are converted into power spectra using the Fast Fourier Transform. The power spectra values are converted into specified fuzzy patterns using fuzzification process and fed into fuzzy neural networks. The neural networks are trained with simulated pucker profiles from simulator with known shape parameters and power spectra information. These networks acquire are trained by learning process and transform fuzzy input into fuzzy output. The output from the fuzzy neural

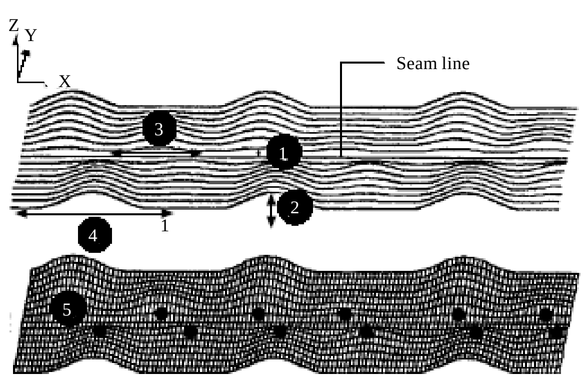

Fig. 11: Shape parameters on the simulated profile of seam. 1: Start amplitude, 2: End amplitude, 3: Start wave length, 4: End wave length, 5: No of random point

network is the fuzzy values of shape parameters of seam. These are defuzzified to have five shape parameters and AATCC pucker grade.

Characterization based on sensory measurement: Kawabata *et al.* (1997) proposed objective descriptor for characterizing seam pucker based on Weber-Fechner law. This law states that the sensory value is proportional to logarithm of the quantity of physical stimulation. Based on this law, Seam Smoothness (SS) can be predicted from the logarithm of mean deviation of height:

$$SS = 5 - \frac{2.303}{n-1}(\log F - \log F_0) \qquad (10)$$

where, SS is seam smoothness by AATCC; F, mean deviation of height; F_0 = 0.0727; n = 2.3

The plot of subjective pucker grade and log F was found to be linear and it was proposed to use log F for objective measurement (Kawabata *et al.,* 1997).

Methods based on structured light projection: Xu *et al.* (1998) evaluated the fabric smoothness with a laser profilometer. The laser light source projects a single strip of light over a specimen at a slanting angle. When the specimen is smooth this line will be straight. As the wrinkling increases the profile of the line distorts from straight line, the degree of distortion being proportional to wrinkling. A camera captures the image of specimen. The fabric is rotated and the profile is captured at various angles. A customized software extracts the exact height from these profile based on triangulation principle. The various descriptors used for representing the seam pucker are; wrinkle roughness and wrinkle sharpness (Xu *et al.*, 1998). Wrinkle roughness describes the size of the wrinkles with no considerations of their shape. Two quantitative measures were proposed:

$$\text{Arithmetic average roughness} \quad R_a = 1/n\sum\left|z_i - \overline{z_i}\right| \qquad (11)$$

$$\text{Root mean square roughness} \quad R_q = \sqrt{1/n\sum\left(z_i - \overline{z_i}\right)^2} \qquad (12)$$

where, z_i is height of profile at that point; $\overline{z_i}$ is mean height; n, number of points. Wrinkle sharpness (k) is a shape measure of a wrinkle, which describes the top point of the wrinkle that forms a definite peak. The ratio of height to the width of wrinkle is used to quantify sharpness.

$$k = H/W \qquad (13)$$

Kang *et al.* (1999) developed a method of evaluation based on 3-D projecting grid. The fabric is illuminated by a grid of parallel light source at perpendicular to fabric plane. A camera captures the profile at a slanting angle. The distortion in the lines present in the image indicates the degree of wrinkling. This image is digitally processed to extract exact height measurements. The image is filtered with smoothing filters to remove noise signals followed by horizontal edge filters for edge enhancement. From the enhanced image, height measurements are obtained from the distortions of the profile from straight line using camera geometry. These data are used for characterizing wrinkledness of fabric. The various descriptors used for representing the seam pucker are; roughness ratio, surface area ratio, wrinkle density and power spectrum density:

$$\text{Roughness ratio} = \sqrt{1/n\sum\left(\left|z(i) - \overline{z(i)}\right|\right)} \qquad (14)$$

where, z (i) is the height at a point; $\overline{z(i)}$, mean height and n, number of observations.

Surface area ratio: A three height co-ordinates forms a triangle. The surface area is obtained by dividing the seam into triangles and summing up the area of each triangle. The calculated area is dived by area of orthogonal projection of seam to get normalized surface area ratio.

Wrinkle density: The number of wrinkles per unit area is inferred by counting the number of turning points in the profile. The range of height divided into five regions and the number of turning points in each region is counted. Each region is given a different weighting factor to indicate its weight in human perception.

Power spectrum density: The power spectrum density obtained from the FFT of the height data gives indication of wrinkles. The sum of frequency coefficients PSD values will give a representative index of that area. A smooth surface is expected to have low power value and vice-versa.

Han *et al.* (2003) constructed a similar instrument after considering the shortcomings in the projecting grid technique. He claimed that since the fabric is illuminated by about 30 lines by projecting grid technique, it is difficult to differentiate between the grid line and fabric area due to increase in illumination. Consequently they used a single strip of light at time and moved the fabric and repeated the procedure. The obtained images are processed digitally to get height information. These data are used for characterizing wrinkle by descriptors including standard deviation of height values of surface profiles, surface area ratio, increase in length in x- and y-directions and fractal dimension of surface profiles. These descriptors are correlated with subjective AATCC grade to obtain regression equations for grading (Han *et al.*, 2003).

CONCLUSIONS

The foregoing discussion gives an overview of the various subjective and objective methods developed so far for evaluation of seam pucker. The highlighted causes of seam pucker will motivate the manufacturers to search the solution for reducing it. The advantages and disadvantages of different methods brought out will be helpful for the manufacturers and customers to adapt to the sophisticated methods to exactly evaluate the seam pucker and accordingly control the quality of apparels. Finally, an inference may be drawn that the discussions made in this article is useful for the textile researchers as a tool for further research in the area of seam pucker evaluation. The objective assessment methods discussed herewith will work as spring board for the researchers for modeling the seam pucker in apparels.

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