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Seam Pucker

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1. INTRODUCTION

Sewing, as a means of joining two or more fabrics to make a garment or other article is likely to remain the most common and versatile method in the foreseeable future. In spite of the long history and development of sewing techniques and technology the problem of puckered seams frequently arises, and it is one of the most recurring and troublesome problems facing the apparel industry. The problem of puckered seams occurs in most branches of the sewing industry and it is accentuated by an increase in the amount of synthetic fabrics being used[1].

For the purpose of this publication the seam pucker is defined as a distortion of the fabric along the seam line (Fig. 1) causing a wrinkled appearance. Seam pucker may occur immediately after sewing, dry relaxation, steaming or laundering.

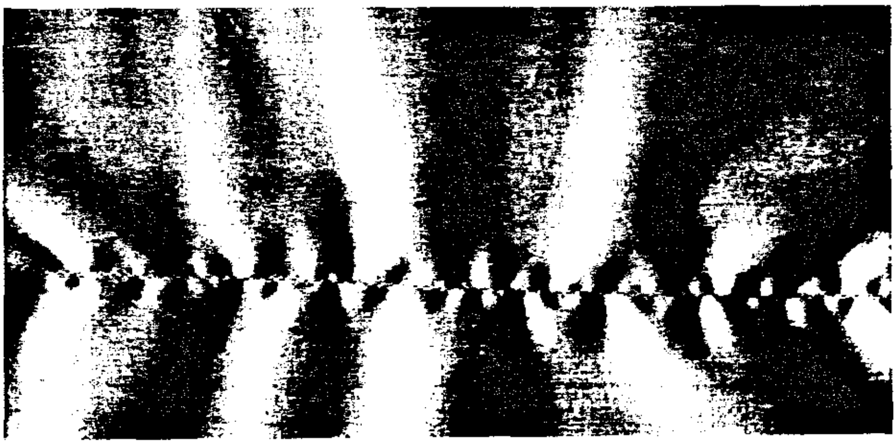


Fig. 1 – An example of a puckered seam.

A survey[1] of the problem showed that the main types of seam pucker are:

— feeding pucker (pucker created by differential feed between top and bottom fabric layers);

— tension pucker (pucker resulting from tension of sewing thread);
— inherent pucker (pucker resulting from fabric structural jamming);
— shrinkage pucker (pucker created by differential shrinkage of joined fabrics).

In this publication the mechanism of seam pucker, its causes, prevention, identification and evaluation are discussed in terms of available literature, and have been compiled into a reference guide for industrial use.

2. THE MECHANISM OF SEAM PUCKER

A seam consists of a number of components such as: an upper and a low fabric, the needle thread and the bobbin thread. When a seam is made, these components are acted upon by the feed and needle mechanisms of the sewing machine (Fig. 2) which exert on each seam component a fairly complex system of forces. However, the forces acting on the different components may differ, as may the amount of deformation produced in each component. Consequently, on release after seam formation as the components start to recover, seam pucker may occur.

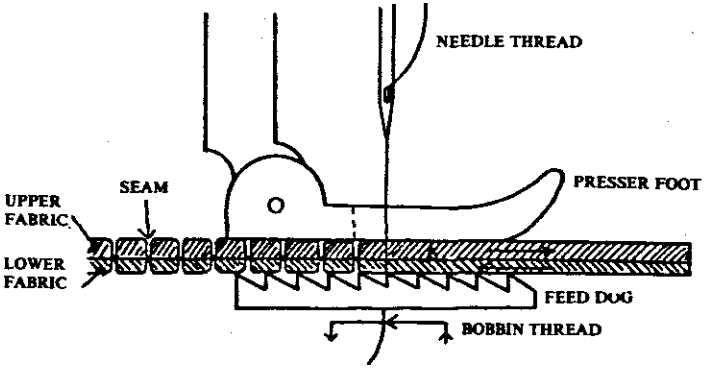


Fig. 2 – Factors involved in seam formation[2].

There have been a number of attempts to explain the mechanism of seam pucker. Dorkin and Chamberlain[2] looked into the problem in terms of elongation and contraction of seam components. Taylor and Clarke[3] made an attempt to relate classical wave theory (as used in engineering mechanics), to the fabric buckling and deformation which occurs during sewing. Zorowski and Patel[4] introduced a model where seam pucker was treated as a mechanical instability phenomena between the fabrics and sewing thread. However, they noted that this was only one of the many causes of seam pucker. They considered the threads and the fabrics as deformable bodies where individual behaviours could be related in terms of the inherent mechanical properties, the geometry and shape of the component, and the load to which it is subjected.

Another cause of seam pucker (in woven fabrics) which was given some theoretical consideration was inherent pucker, also defined as fabric structural jamming in the fabric due to the insertion of the sewing needle, the sewing thread or both.

The first explanation of the creation of seam pucker due to fabric structural jamming was given by Dorkin and Chamberlain[2]. They claimed that when a fabric already has maximum number of yarns per unit length (or very nearly so) there is no room for insertion of a sewing thread. In consequence, to make room for the sewing thread, the fabric must be extended along the line of the seam. However, there is no extension on either side of the seam. The extension along the seam line must then be accommodated by the fabric along the seam line producing a puckered seam.

There have been some attempts to predict by means of equations when inherent pucker would appear when sewing parallel to one of the yarn systems in the fabric. Townsend and Chamberlain[5] introduced the term "percentage distortion" (defined as two sewing thread diameters over the stitch length, 2d/s). However, they did not incorporate the fabric geometry in their "percentage distortion" formula.

Fabric geometry and sewing thread diameter were incorporated in the analysis made by Taylor and Clarke[3]. They stated that fabric structural jamming occurs whenever the number of stitches sewn per inch exceeds the amount of space available to accommodate them. They derived a formula for determining the number of stitches which can be safely accommodated when sewing a given fabric.

Fabric structural jamming in terms of yarn, thread diameter, stitch and yarn density was discussed by Schwartz[6]. According to his equations, jamming, as to cause seam puckering, would occur when

$$d_s > \frac{1}{2S}\left(1 - \frac{2d}{p}\right) \qquad (1)$$

where: d_s = sewing thread diameter

S = number of stitches per length unit

d = yarn diameter

p = yarn spacing

For compressible yarns this equation reads:

$$d_s > \frac{1}{2S}(1 - \frac{2dk}{p}) \quad \text{.........(2)}$$

where: k - thread compressibility factor, $0 < k < 1$

Neither of the above models[5–6] deals with sewing in a bias direction which gives a reduction of the effective fabric sett.

3. KNITTED FABRICS — CAUSES AND PREVENTION OF SEAM PUCKER

According to Blackwood and Chamberlain[7] seam pucker is rarely encountered in knitted fabric seams because of the relatively high extensibility and compressibility of such structures, which allows a certain amount of differential stretch to take place along the seam line without producing a puckered seam.

Other workers[8–13] found that seam pucker does occur when sewing knitted fabrics and is caused by:

— displacement between fabric layers[8,10];

— sewing thread tension[8];

— sewing thread contraction[8,9,11];

— differential shrinkage[8,9,13];

— diameter of sewing thread and needle[8,11,12];

— type of stitch[8,11,12];

— pressure of presser foot[8,12].

The following explanations of how and why the seam pucker occurs were given.

3.1 DISPLACEMENT BETWEEN FABRIC LAYERS

The displacement between the fabric layers is caused by the pressure of the presser foot[8,10] which tends to hold back the top layer with which it is in direct contact (Fig. 3). This is mainly confined to the case where a drop-feed mechanism is used.

It was stated[8] that seam pucker is more noticeable when seams are made in the bias direction since the presser foot, which has a breaking action, tends to

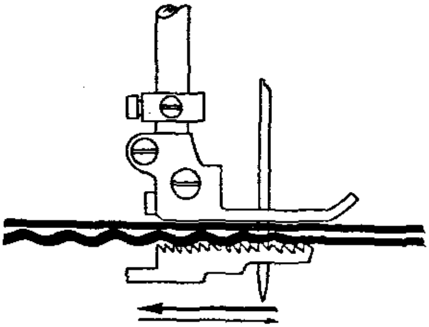


Fig. 3 – Pucker caused by fabric displacement[8].

cause the upper layer to stretch diagonally. To avoid or reduce the degree of pucker caused by the fabric displacement, the pressure of the presser foot should be at the lowest possible level and a non-drop feed mechanism used.

3.2 SEWING THREAD TENSION

According to Marturio[8] seam pucker due to sewing thread tension (Fig. 4) occurs mainly in sewing lightweight fabrics. It is caused by the tension to which the needle and bobbin threads are subjected during seam producing deformation of the fabric within the stitch. To avoid this type of seam pucker the sewing thread tension should be kept at the minimum practical level.

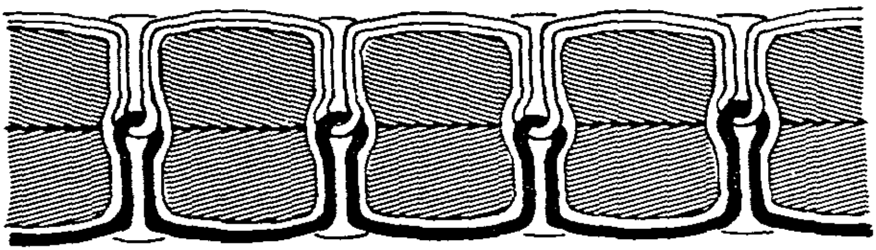


Fig. 4 – Pucker caused by sewing thread tension[8], lock stitch.

3.3 SEWING THREAD CONTRACTION

During sewing the sewing threads are under some tension. When the thread tension is relieved, the threads start to contract, resulting in a decrease in stitch length. If the decrease in stitch length is greater than the contraction of fabric within the stitch, the seam will pucker[3,9,11]. The amount of thread elongation and contraction depends on sewing thread composition and tension[2–4,8,9,11,14]. Threads of low elastic modulus (generally synthetic threads) are easier to elongate. The amount of elongation, and also the contraction, due to the applied tension to these threads is greater than that for threads of high elastic modulus (cotton). To reduce this type of seam pucker the sewing thread tension should be kept very low.

3.4 DIFFERENTIAL SHRINKAGE

Differential shrinkage may take place between fabric layers, fabric and thread, or the seam and another component joined to it, e.g. a tape. It may occur immediately after sewing, after some relaxation, during wear, or after laundering.

A difference in shrinkage between two components causes the component of lower shrinkage to buckle producing a puckered seam[8,9,13]. The only way to reduce or avoid this is the use of compatible components in terms of dimensional stability.

3.5 DIAMETER OF SEWING THREAD AND NEEDLE

Sewing threads and needle can also cause seam pucker when the geometry of the fabric is such that there is insufficient space to accommodate the needle or sewing thread or both[8,11,12] (known as swelling). This problem occurs particularly when dealing with dense fabrics (short yarn loop length) and is more noticeable when the stitch is small[8,12]. It can be avoided using a fine needle, a longer stitch or both.

3.6 TYPE OF STITCH

It was found that the type of stitch used can contribute towards seam pucker[8,11,12]. A stitch which has a low ability to stretch, or of a geometry (stitch length) easily affected by thread shrinkage, has a tendency to cause seam pucker. The best example of such a stitch is the lock-stitch (Fig. 4). A stitch with ability to stretch and react to thread contraction without producing significant changes in stitch length, is unlikely to produce seam pucker. The double locked chain-stitch is one of the best examples (Fig. 5). In such a case the latter seam uses its third dimension to recover the amount of required thread length to maintain the same stitch length. Furthermore, the double locked chain-stitch also has an advantage over the lock-stitch in that the locking of the needle and bobbin threads occur on the outside of the fabric.

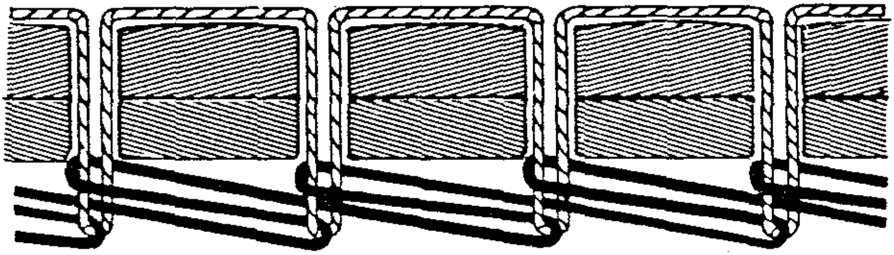


Fig. 5 – Double locked chain stitch[8]

3.7 PRESSURE OF PRESSER FOOT

One of the causes of seam pucker due to the pressure of the presser foot[8,12] has already been described in section 3.1. However, the pressure of the presser foot can produce another type of seam pucker which is called "waviness"[8] (Fig. 6).

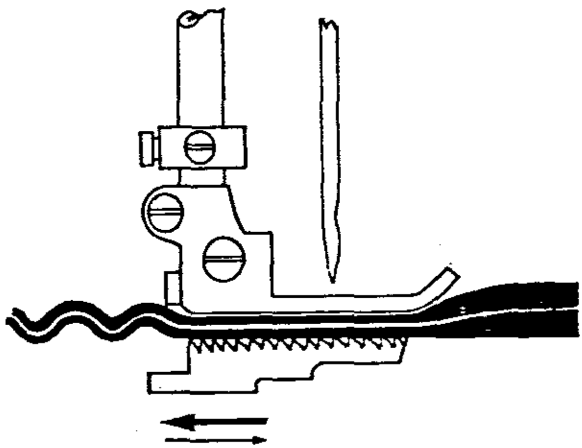


Fig. 6 – Waviness[8].

The pressure exerted by the presser foot against the needle plate causes the fabric to spread. Thus the seam is made on a fabric of which dimension has been momentarily altered. When the fabric returns to its normal dimension the waviness occurs. To prevent this phenomenon the pressure of presser foot should be kept very low.

Apart from the above factors there are others such as the operator's skill, mismatched garment pieces, etc. which may also lead to seam pucker.

4. WOVEN FABRICS — CAUSES AND PREVENTION OF SEAM PUCKER

Seam pucker in woven fabrics, its causes and prevention, has been the subject of many investigations and a number of papers have been published. The following types of seam pucker have been distinguished.

- — inherent pucker;
- — feeding pucker;
- — tension pucker, and
- — shrinkage pucker.

It was found that seam pucker is caused by a number of various factors. These factors can be listed under the following headings:

- — fabric; its structure[1—3,5,6,15—35]; mechanical properties[1—4,16—19,28,30,35—42] and dimension instability[1—3,17,19,23,25,28,35,42,43];
- — sewing thread; its tension, extensibility and relaxation[1—6,9,11,16—19,21,23—26,28—33,35,39,41,44,45] diameter[1,2,5,6,15—19,21,23—26,28,29,31—33,35] and shrinkage[1,2,15—17,19,21,23—25,28,29,33,35];
- — stitch type, length[1—6,11,17,18,22—26,29,31,33,34,44,45,48—50], and seam type[1,17,18,26,29—32,35];
- — incompatibility of fabric and threads[1—3,15,16,19,21,23—25,28,29,31,33,35,42,43] (discussed in sections 4.1.3 and 4.2.3)
- — sewing machine, its feed[1,2,15—21,23—35,38,39,41,42,44,45,49—54], needle[1,17—19,25—32,34,35], needle/throat-plate assembly[1,18,19,31,35,49] and sewing speed[28,31,35,44,45,50,51].

In addition to the above there are some other factors such as setting of the sewing machine, skill of operator, mismatched patterns, etc. which may influence the degree of seam pucker.

4.1 FABRIC

4.1.1 Fabric structure

Seam pucker due to fabric structure has already been discussed in section

2. This type of pucker is called fabric-structural jamming or inherent pucker.

It is generally believed that a high fabric sett leaves little or no room in the fabric to accommodate the needle or sewing thread[1–3,5,6,15–35]. Therefore, in order to accommodate the needle or sewing thread, some of the fabric yarns have to be moved aside along the seam line. This leads to some fabric elongation and compression along the seam line resulting in a puckered seam (Fig. 7).

Fig. 7 – Structural jamming (inherent) pucker[16].

During yarn side-way movement it has to overcome some frictional forces and yarn flexural rigidity, the magnitudes of which depend upon the type of yarn and fabric structure. If the opposing forces to yarn movement within the fabric are small, the yarn would move (slip) reducing the amount of elongation, and there would be less chance of producing seam pucker.

There is a limit as to how close any two adjacent yarns can be positioned in a fabric and this is defined as jamming (no straight yarn section at the yarn intersetion). Usually, when jamming conditions are reached (for the yarns within the stitch length), there is no further movement of individual yarn, only yarn elongation or the sliding of a group of yarns, thus causing fabric gathering to occur. After removal of the needle or sewing thread or both from the fabric the pucker may or may not disappear depending on the degree of deformation imposed on the fabric and yarn.

The seam pucker caused by fabric structural jamming can be identified[2,17] by the cutting of a few stitches. If the pucker disappears it means that it was caused by the thread tension. If, however, it does not disappear the cut threads must then be removed. As the threads are removed the pucker should dissappear indicating that it was caused by fabric structural jamming due to presence of sewing threads (Fig. 8). However, there may be cases where after removal of the sewing threads the pucker would still exist. In such cases it is possible that the penetration of the needle led to the fabric structural jamming (see section 4.4.2).

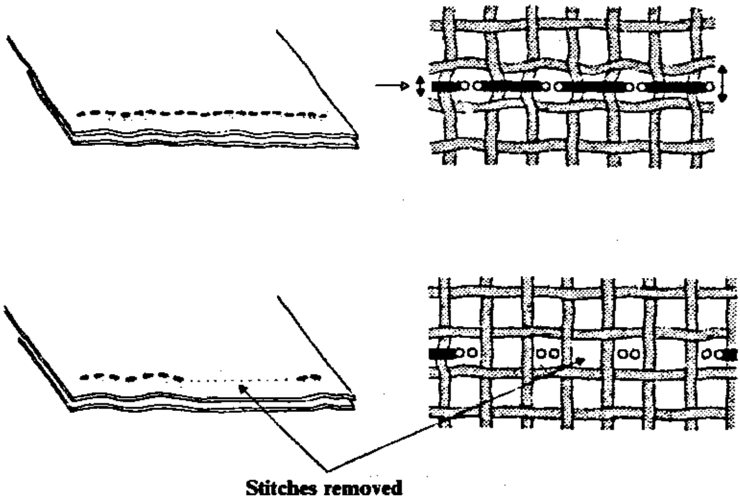


Fig. 8 – Identification of inherent pucker[17].

Generally, in order to avoid or reduce this type of seam pucker the following suggestions are made:

— sew in the weft or bias direction;

— use of a fine needle, and

— use of a fine thread.

4.1.2 Fabric mechanical properties

According to the literature, the following fabric mechanical properties can affect the degree of seam pucker:

— fabric elastic modulus[1–2,19,28,30,32,37,39–41];

— fabric resistance to compression[3,8,22,28,35,42];

— frictional properties of the fabric surface[16–19,29–32,35–42]

and

— fabric flexural rigidity[4,35–37,42].

Fabric elastic modulus affects the amount of fabric elongation during sewing. Fabrics with a low value of elastic modulus are easy to elongate. The elongation is caused by the pressure of the presser foot which holds back and stretches the top fabric during sewing producing differential feed between the top and bottom fabric. Therefore, after sewing the top fabric contracts more than the bottom fabric causing seam pucker on the side of the lower fabric. Generally, the lower the fabric elastic modulus the higher degree of pucker.

Fabric resistance to compression may result (depending on sewing conditions) in another type of seam pucker — waviness (see Fig. 6). It is usually associated with soft and extensible fabrics, where the pressure of the presser foot spreads the fabrics, so the length of the seam is different than the length of the fabrics. Another cause is the temporary reduction in fabric thickness during stitch formation, which may lead to distortion of seam appearance.

Frictional properties of the fabric surface affect the amount of displacement between the top and bottom fabric during feeding. Feeding of the bottom fabric, and advance of the seam during sewing is obtained by a frictional force produced between the feed dog and the bottom fabric. Feeding of the upper fabric is obtained by the frictional force produced between the fabrics and through an advance of the seam. During this movement the feeding and seam advancing forces have to overcome some frictional force (braking force) produced between the presser foot and the top fabric. Therefore there is a need for a high value of frictional force between feed dog and bottom fabric as well as between the fabrics. At the same time the frictional force created by the presser foot should be very small.

The *topography of the fabric surface* also has an important role as its frictional properties (coefficient of friction) can vary with direction of movement. A movement in the warp direction would create lower frictional force than that in the weft direction. In the latter case some interlocking between fabrics would take place.

Generally, the risk of fabric displacement, and thus seam pucker, is greater when a relatively low coefficient of friction between the fabrics exists.

Fabric flexural rigidity is another factor which may affect the amount of seam pucker. Its effect comes through fabric resistance to buckling. Fabric with high resistance to buckling can withstand relatively higher pucker making forces produced by sewing thread tension or shrinkage. A good agreement (Fig. 9) was found between flexural rigidity and the amount of seam pucker[36], showing that the degree of seam pucker increases with a decrease in fabric flexural rigidity. The stiffer the fabric, the less propensity to seam pucker.

4.1.3 Fabric dimensional stability

One of the causes of seam pucker is the difference in dimensional changes

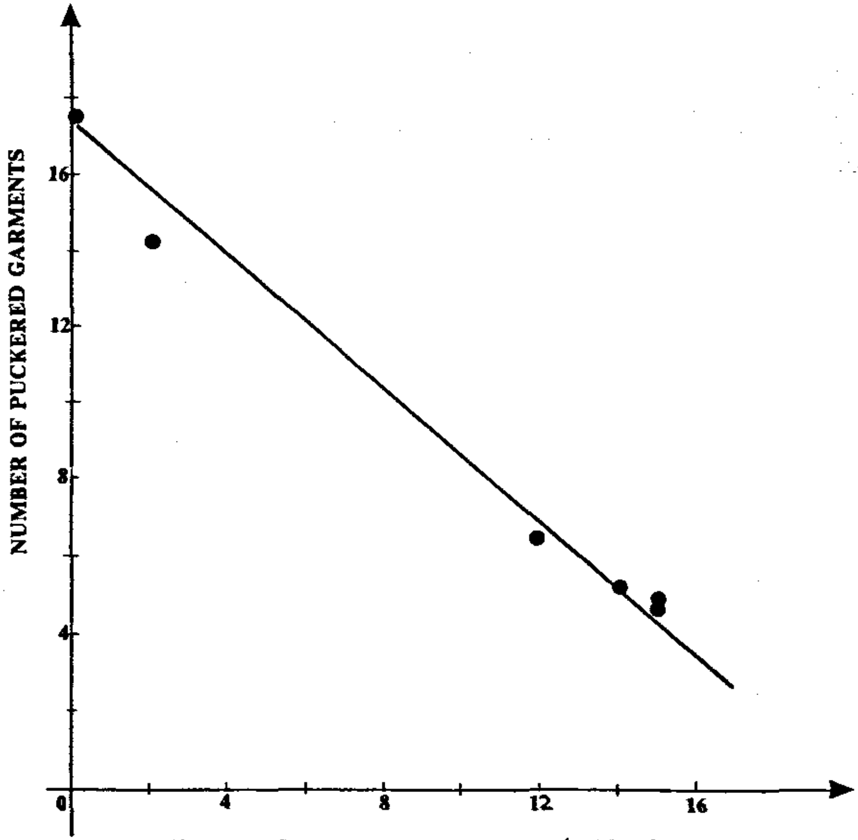


Fig. 9 – Relation between fabric flexural rigidity and seam pucker[36].

of the seam forming fabrics, which takes place when the fabrics are not compatible in terms of their dimensional stability. In such cases the seam may appear perfectly flat and unpuckered as it leaves the machine. However on subsequent laundering or steaming, pucker may occur due to the dimensional instability of the seam components.[1–3,17,19,23,25,28,35,42,43]

The following causes of fabric dimensional changes were distinguished[43]:

— elongation or compression of the fabric, which recovers when conditions are changed, i.e. relaxation shrinkage;

— reversible dimensional change with moisture content, i.e. hygral expansion.

Relaxation shrinkage appears in steaming and pressing processes during garment manufacturing, but may also occur in subsequent cleaning or wear of the garment.

Hygral expansion is the reversible dimensional change caused by change in moisture content of the fabric. The type of fibre, yarn, fabric construction and finish all influence the hygral expansion. Steaming and pressing during garment make-up may produce temporary setting effects, but influence the hygral expansion only to a small extent.

According to Dorkin and Chamberlain[2] fabric dimensional instability may be suspected when:

— the two fabrics constituting the seam are of different fibre composition and/or structure;

— one of the fabrics is noticeably more puckered than the other.

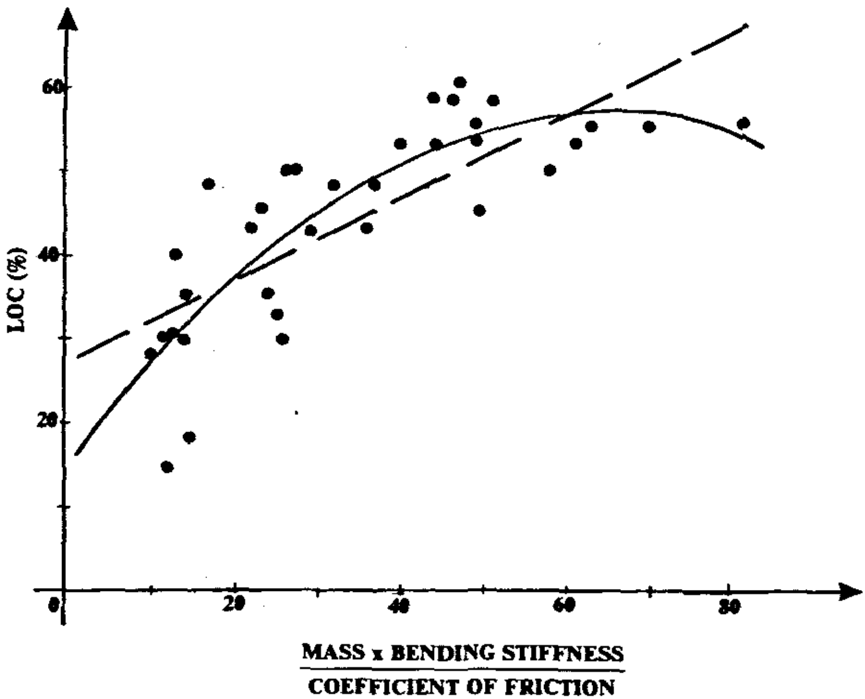


Fig. 10 – Effect of fabric stiffness and friction on limit of contraction (LOC)[2].

In doubtful cases it is necessary to test the fabrics for their stability characteristics[2]. If the fabrics show a difference in contraction of 2% or more, by test[2], then seam pucker due to the dimensional change may be expected to occur in finished garments after laundry treatments.

Rosenblad-Wallin and Cednäs[42] introduced the term "Limit of Contraction" (LOC) to define the decrease in fabric length which can occur before visible puckering of the fabric is observed. They[42] found that the coefficient of friction, bending stiffness and mass had an important effect on the magnitude of LOC (Fig. 10).

4.2 SEWING THREAD

4.2.1 Sewing thread tension, extensibility and relaxation

Sewing thread tension, extensibility and relaxation properties are some of the most common causes of seam pucker, and they have been subject of many publications[1–6,9,11,16–19,21,23–35,39,41,44–45]. Seam pucker due to sewing thread tension and relaxation is a result of the tension applied to the thread during sewing.

No known sewing thread is completely inextensible under the action of a tensile force. Therefore it is extended as a result of the sewing tensions, and passes into the seam in this extended form. When the tension is removed it tends to contract. If the fabric components of the seam contract by about the same amount, there would be no visible effect, but if the sewing threads contract more than the fabric then seam pucker results.

Seam pucker may not become visible immediately after the sewing operation because the relaxation process of the sewing thread and fabric may take some time. Therefore the aim in stitch making should be to "lay on" the thread as opposed to *"bedding in"*[15,16] *(Fig. 11), which would reduce the* probability of seam pucker to occur. The test described in section 4.1.1 can be used to identify the seam pucker caused by sewing thread tension.

Generally, the effect of sewing thread tension, extensibility and relaxation on seam pucker can be summarised as follows:

— an increase in thread tension leads to an increase in the probability that seam pucker would occur, the greater the tension, the greater the pucker;

— sewing threads with low elastic modulus and high recovery (synthetic threads) produce greater pucker than threads with a high elastic modulus.

To avoid or reduce this type of seam pucker the lowest practical thread tension should be used.

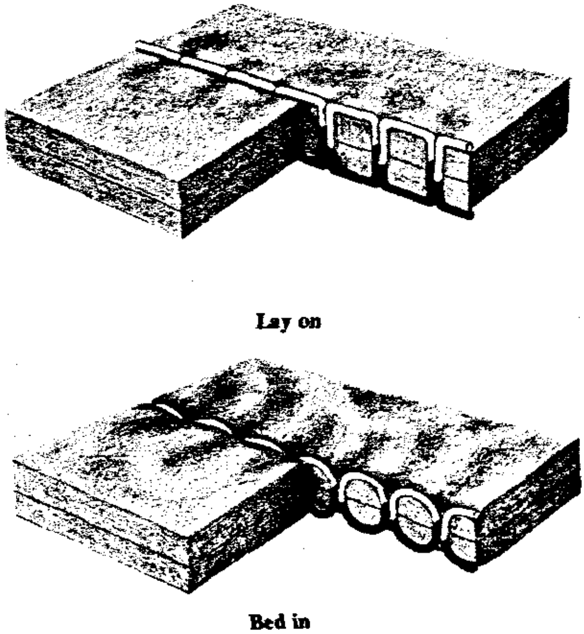


Fig. 11 – Effect of sewing thread tension on stitch geometry[16].

4.2.2 Diameter of sewing thread

The importance of sewing thread diameter as a cause of seam pucker has been recognised by several workers [1–2,5,6,15–19,21,23–26,28,29,31–33,35]. Generally, it was reported that the introduction of the sewing thread between the fabric threads may cause a fabric structural jamming type of seam pucker (as has already been shown in sections 2 and 4.1.1), depending on fabric structure.

An increase in sewing thread diameter increases the probability of occurrence of seam pucker.

Identification and prevention of this type of seam pucker are the same as those for fabric structural jamming given in section 4.1.1.

4.2.3 Sewing thread shrinkage

Shrinkage of the sewing thread is another major cause of seam pucker. However, a distinction should be drawn between the decrease of the thread length due to relaxation and that due to moisture (wet treatment). The former was discussed in section 4.2.1, therefore, only the latter is given attention here.

When the shrinkage of a sewing thread, due to steaming, laundering, wetting, drycleaning, etc. is greater than that of the fabric, the new seam length is smaller than the fabric length which has to be accommodated in the seam length. This leads to fabric gathering resulting in seam pucker[2,15–17,19,21,23–25,28,29,33,35]. This kind of seam pucker can be identified through comparison of the seams before and after wetting, laundering, etc.

A procedure for testing sewing threads in terms of their extensibility, contraction and shrinkage was put forward by Dorkin and Chamberlain[2]. They suggested to take the sum value of percentages (calculated in terms of elongation and contraction) of 3% or less as satisfactory whilst sum-values greater than this may be potentially troublesome as regards pucker depending on fabric. They stressed that the test is concerned only with finding those threads which may give rise to pucker in certain types of fabric.

Compatibility in dimensional stability of seam making components or use of unshrinkable threads would help to reduce the occurrence of the seam pucker caused by sewing thread shrinkage.

4.3 STITCH TYPE, STITCH LENGTH AND SEAM TYPE

When dealing with inherent pucker (see sections 2 and 4.1.1) it was shown that this type of pucker may be caused by the sewing needle, the sewing thread or both. Therefore, stitch type[11,22,26,29,48,49], stitch length[1–6,34,45–50] or both[11–18,25,31–33,44] may have a significant effect in the formation of the degree of seam pucker.

Each stitch type gives a different geometrical configuration to the sewing thread which in turn can affect the degree of seam pucker. As an example, the two most common stitches, i.e. lock stitch and chain are taken. Generally, it is claimed that the lock stitch produces more pucker than the chain stitch. This is due to the fact that if the top and bottom threads are balanced in the lock stitch, the interlooping of the threads will occur within the fabric layers forcing a bulk of thread between the fabric yarns. In the case of the chain-stitch formation there is no crossing or looping of the sewing threads in the fabric layers, and consequently there is less thread bulk for each stitch formation.

The introduction of a sewing thread between the fabric yarns may cause a distortion of the seam appearance leading to inherent seam pucker. This distortion is more visible as the stitch length becomes smaller.

A general recommendation was made that in order to prevent or reduce the degree of pucker due to stitch type, the chain stitch should be used instead of lock stitch, wherever it is possible, and stitch length should be kept to a maximum provided that the required seam quality is obtained.

Seam pucker due to stitch type and length, can be identified in the same way as discussed earlier (see section 4.1.1).

Seam type may also play an important part in the occurence of seam pucker since various types of stitches and number of fabric layers can be employed in seam formation.

As a recommendation for reducing seam pucker due to seam type the following hints were given:

— use of chain stitch instead of lock stitch seams;

— use of blind seams;

— use of single seams instead of double ones, and

— application of an interlining wherever possible.

4.4 SEWING MACHINE

A sewing machine, through its mechanisms can also contribute to seam pucker. According to various investigations, the major causes are:

— feed mechanism (including presser foot)[2,15–21,23–35,38,39,41,42,44,45,49–54];

— needle[17–19,25–32,34,35] ;

— needle/throat-plate assembly[18,19,31,35,49] , and

— sewing speed[28,31,35,44,45,50,51]

4.4.1 Feed mechanism

A number of feed mechanisms[35,49,52–54] are available but the most common (and pucker creating) is the drop feed. However, different feed systems were developed to replace the drop feed system[52–54].

The role of the feed mechanism is to feed the fabrics to the zone of stitch formation and then take up the sewn fabrics. As shown earlier the advance of the fabrics is achieved through frictional forces produced between the feed dog and the bottom fabric and between the fabrics. There is also some force opposing fabric movement created by the pressure of the presser foot. This opposing force causes some elongation of the top fabric and thus some displacement between the top and bottom fabrics may occur. This means that two different lengths of fabric try to conform to the same length along the seam thus producing a puckered seam (Figs 12).

Generally, the following factors have a major effect on the degree of seam pucker caused by the feed mechanism:

— pressure of presser foot; the greater the pressure the greater the pucker;

— frictional force between the fabric layers; the smaller the force the greater the pucker;

— sewing speed; the lower the speed the smaller the pucker.

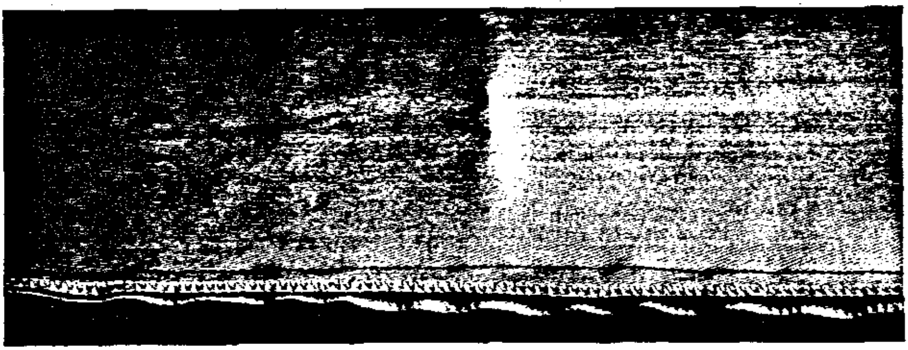


Fig. 12 – Puckered seam created by feed mechanism[41].

Other factors such as type and depth of feed dog teeth, geometry and type of presser foot contribute to the magnitude of seam pucker, but the amount of contribution depends on the fabric and the setting of the sewing machine.

As a test to identify seam pucker due to the feed mechanism certain procedures have been recommended[2,29].

WIRA[55] designed a "Pukka Tester" to facilitate prediction of the amount of differential feed before seam pucker would occur. The instrument holds two fabric strips with a determined difference in extension, so that they can be sewn together to produce a seam with a controlled amount of overfeed. The appearance of the seam after opening and pressing indicates whether the overfeed limit has been exceeded.

A number of proposals have been made[2,15—21,23—25,38,39,41,42,44,45,49—56] to reduce seam pucker as caused by the feed mechanism, which can be summarised as follows:

— application of rollers to take-up the material during sewing;

— application of such feed mechanisms as differential feed, reciprocal feed compund feed, feeding foot, alternating feed, walking foot, upper and under wheel feed, puller feed (Fig. 13);

— feed dog teeth, finer teeth would be more beneficial in reducing pucker;

— pressure of presser foot should be kept as low as possible;

— the presser foot should just cover the feed area, and be level with it;

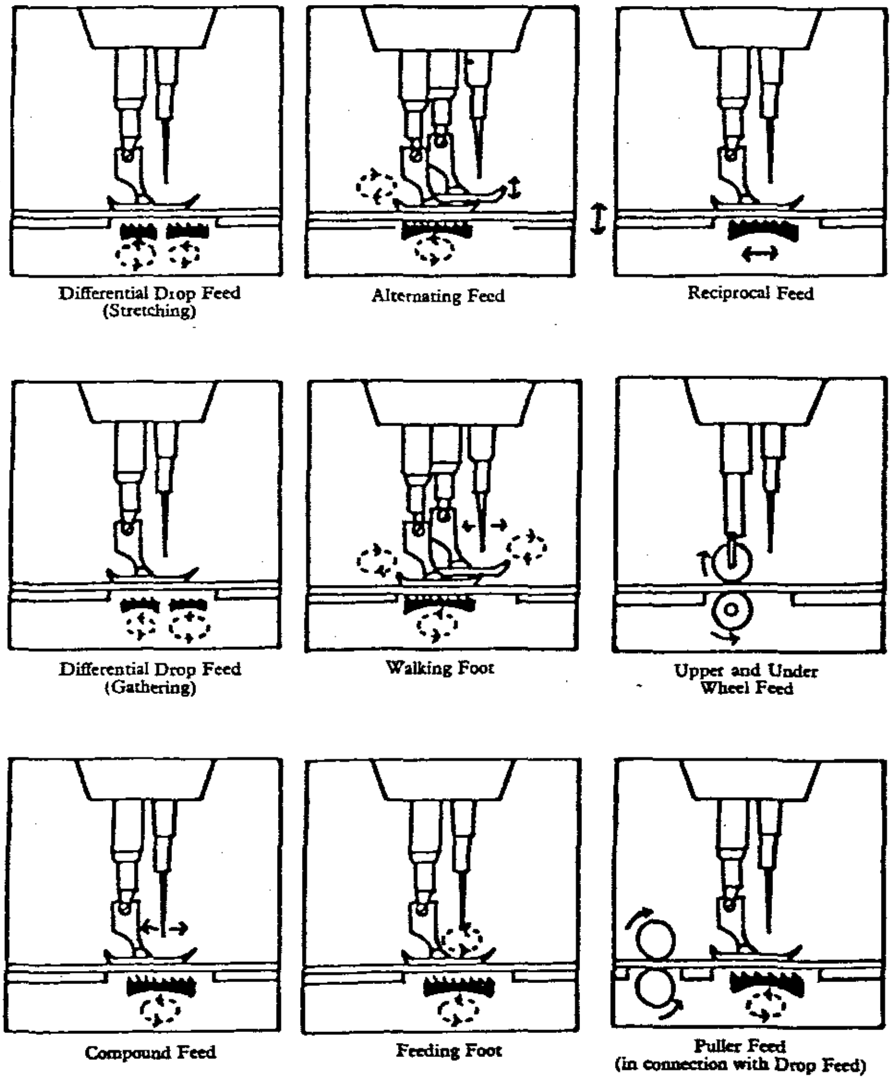


Fig. 13 – Feed mechanisms[64].

— direction of sewing should be chosen so as to provide the highest friction between the fabric layers. Generally, sewing in weft direction is recommended;

— when sewing different fabrics the fabric with the lower elastic modulus should preferably be the bottom fabric;

— application of a sewing aid "Kräusel Stop"[41], a special self adhesive tape attached to sewing machine which has a braking effect on the lower fabric so that it is delayed to such an extent that a displacement between top and bottom fabrics caused by the feed mechanism is prevented;

— use of "nip and run" technique of sewing. This technique involves the operator nipping the fabrics in front and behind the presser foot and then allowing the firmly gripped seam to move forward in synchronisation with the feeding action of the machine. The seam must not be pulled through the machine or retarded in any way.

4.4.2 Needle

The sewing needle as a cause of seam pucker has a similar effect to that of sewing thread diameter. Penetration of the needle through the fabric may cause inherent pucker (see sections, 2, 4.1.1. and 4.2.2) which can be visible even after sewing without a sewing thread. The thicker the needle the greater the possibility of seam pucker to occur. The needle point may have an important effect [30–32], and it was suggested that the ball point needles cause pucker[31].

— use of fine needles;

— sewing in bias or weft direction;

— use of long stitch length.

The simple test of sewing a single layer of fabric without a thread and careful examination should provide the answer as to whether the needle causes seam pucker or not.

4.4.3 Needle/throat-plate assembly

The needle/throat-plate assembly can cause seam pucker if the difference between the diameter of the needle hole in the throat-plate and the needle diameter is too large [18,19,31,35,49]. In such a case the fabric is forced down into the needle hole (Fig. 14) causing some fabric elongation and additional fabric feed, producing a puckered seam.

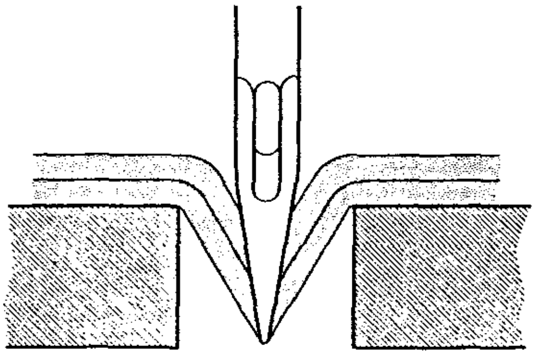


Fig. 14 – Fabric funnel due to wrong relation between needle diameter and throat-plate hole diameter[23].

Generally, the diameter of the needle hole in the throat-plate should be greater than the needle diameter by 0,3-0,6 mm, to give an adequate clearance.

4.4.4 Sewing speed

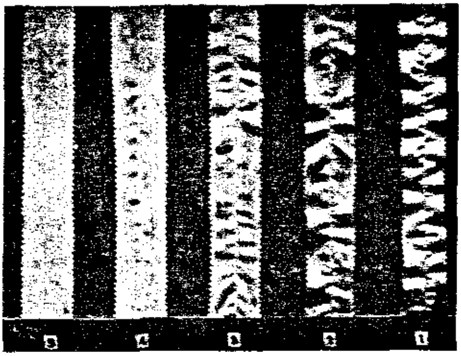
Experimental findings[44,45] showed that an increase in sewing speed increased the differential feed between fabrics resulting in a higher degree of seam pucker.

It is claimed[28,31,35,50,51] that an increase in sewing speed requires an increase in the pressure of the presser foot in order to control the feed and prevent the presser foot from bouncing under the impact of the feed dog movement. The bouncing of the presser foot disturbs the fabric feed leading to puckered seam and uncontrolled sewing conditions. To obtain controlled conditions some additional pressure has to be applied to the presser foot. This in turn results in a greater retarding force between the presser foot and the top fabric producing further displacement between the fabrics, leading to greater seam pucker.

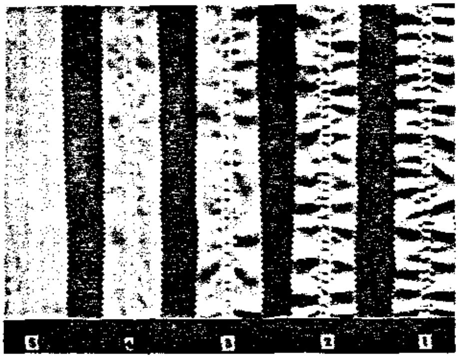
To overcome these problems a new presser foot bar was developed[50,51] which allows higher sewing speeds with reduced seam pucker.

5. METHODS FOR EVALUATION OF SEAM PUCKER

The method in use is that recommended by the American Association of Textile Chemists and Colourists[56]. The test procedure relies on a visual assessment of the appearance of the seam viewed under standard lighting conditions where the test specimen (Fig. 15) is compared with photographic standards grouped into five classes. Class 5 represents a pucker-free seam, and



(a)



(b)

Fig. 15 – AATCC photographic comparative ratings[56] of seam pucker
(a) single row stitches
(b) double row of stitches

Class 1 a badly puckered seam. This method is purely subjective and therefore, it is recommended that three or more observers should be employed and their results averaged.

Some instruments have been developed[1,44,57] and a wrinklemeter has been used[58] to measure the magnitude of seam pucker on a quantitative basis.

Belser *et al*[57] designed an apparatus where the magnitude of seam pucker was evaluated quantitatively by examination of the surface profile of the seam using a photoelectric device (Fig. 16). In this way the profile of the test sample was represented by a curve. As the measurement of seam pucker they used the ratio of the total length of the curve to that of a reference line (seam length) (Fig. 17). The length of the curve was evaluated using a stadimeter.

Using the above method, 553 samples were examined and the ratios calculated[57]. The specimens were also visually evaluated according to AATCC method[56]. The results obtained (Fig 18) showed good agreement between visual rating and tracing. (The index of correlation was 0,89). These workers put forward the following ratio values for each visual rating.

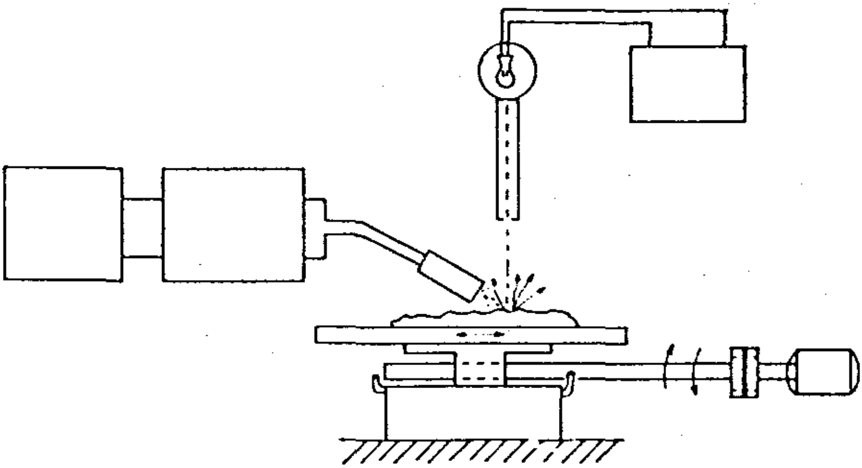


Fig. 16 – Belser's instrument for grading seam pucker[57].

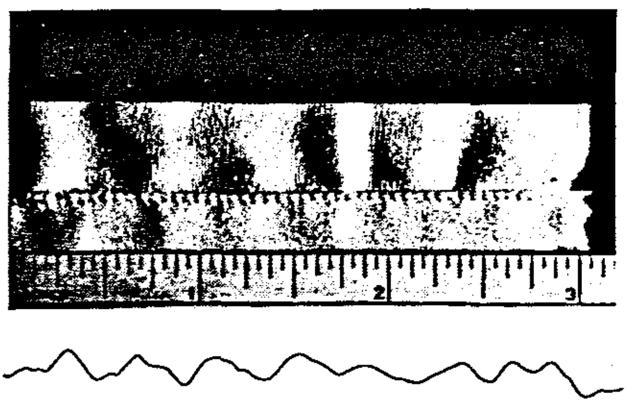


Fig. 17 – Photometer trace and photograph of a portion of a seam judged poor[57].

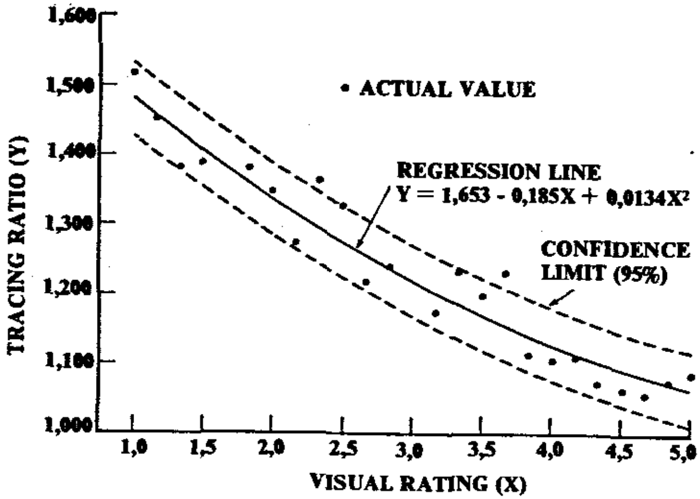


Fig. 18 – Relation between visual rating and photometer data[57].

Rating class	Estimated tracing ratio
5	less than 1,077
4-5	1,078 - 1,109
4	1,110 - 1,148
3-4	1,149 - 1,193
3	1,194 - 1,246
2-3	1,247 - 1,305
2	1,306 - 1,370
1-2	1,371 - 1,443
1	1,444 - 1,522
less than 1	greater than 1,522

This method requires correction when fabrics of different basic structure or colour pattern are used, since the output signal of the photocell is directly proportional to the amount of light reflected by the fabric[44].

A similar apparatus was developed by Bertoldi and Munden[44]. Instead of measuring light reflectance, the apparatus assessed the shadow pattern created by the light falling on the puckered surface. The ratio of length of the recorded curve to the seam length was used as an index of seam pucker. However, they did not make a comparison with the AATCC method.

Shiloh[58] used the Sivim Wrinklemeter to evaluate seam pucker, and introduced the term "puckering severity index" as the product of height and slope.

6. SUMMARY AND CONCLUSIONS

In view of the available literature on the causes, prevention and evaluation of seam pucker it clearly emerges that the subject is very complex and dependent on many parameters. The literature provides a great deal of information on the subject and many suggestions have been put forward on how seam pucker can be reduced or even eliminated. However, the theoretical analysis of the mechanism of seam pucker appears to require some further considerations.

Although methods for quantifying the degree of seam pucker have been given, seam pucker is still being evaluated subjectively, probably due to the complexity of the proposed instrumentation. There is, therefore, a need for the development of a simple objective method which can be applicable both in the clothing industry and commerce.

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THE USE OF PROPRIETARY NAMES

The names of proprietary products, where they appear in this publication are mentioned for information only. This does not imply that SAWTRI recommends them to the exclusion of other similar products.

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