DYNAMIC CLOTH FELL MOVEMENT
Part I: Critical review

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Abstract

Extensive coverage of previous work in the area of cloth fell movement, the circumstances of its beginning, and its influences are reviewed. The review also includes previous work describing factors that affect cloth fell movement.
The advantages and disadvantages of the methods used hitherto are underlined and the need of a satisfactory measuring method is emphasised.

Key words:

weaving technology, cloth fell movement, warp tension

Introduction

When surveying the available literature related to the present investigation, we focused on publications concerning cloth fell movement.

The relationship between the weft density and the position of the cloth fell presents a practical problem of great importance to the weaver. When the warp is gated up and weaving is started, the cloth fell gradually finds its position spontaneously, which is due to the action of the take-up motion. This position is maintained as long as the loom runs satisfactorily.

There are many reasons for the cloth fell position to change during weaving, temporarily and permanently. Temporary changes could be due to weft yarn break and loom turnover for one or two revolutions without inserting weft yarn, or the loom may be stopped for the night or for a break and the cloth fell could creep away from its correct position as an action of warp-fabric relaxation. Permanent changes in the cloth fell position could be due to too many weft yarns having been inserted (height weft density) or changing the fabric pattern to a short float weave. Permanent changes in the cloth fell position are the major concern in this investigation.

In all these cases, the weaver has to restore the cloth fell to its correct position (in the case of a temporary change) or reduce the cloth fell movement as much as possible (in the case of a permanent change). With many fabrics, this operation has to be carried out with such accuracy that only a highly skilled weaver can adjust the loom setting without trials.

The importance of the cloth fell position is, of course, fully appreciated by the weavers and has been commented on by many research workers, mainly from the point of view of its effect on the warp tension. During weaving, the warp tension undergoes a cyclic change due to shedding, which in turns causes a cyclic variation in the position of the cloth fell. Superimposed on this is the effect of beat-up, which causes a sharp raise in the warp tension combined with the sudden displacement of the cloth fell.

Cloth fell movement

After beat-up (as the reed recedes)

Plate [1,2] described the cloth fell movement after beat-up as it depends on the weft density. If a fabric is woven at a sufficiently large pick-spacing, there will be no movement of picks at the cloth fell after beat-up, and during beat-up only the new pick being beaten in will move in relation to the warp. In this case, the new pick is in its final position relative to the warp as soon as it has been pushed fully forward by the reed. As the reed recedes, the pick remains fixed in relation to the ,warp and it is then moved forward towards the take-up roller together with the warp.

As the pick spacing in the fabric is reduced, a point will be reached at which the force exerted on the last pick, which tends to push this pick back in the warp, is just balanced by the frictional restraint on the pick. If the pick is now driven any further into the warp, it will have a net force acting on it when the reed recedes, and this force will cause it to slide back in the warp. There is thus a minimum attainable pick-spacing between the last two picks in the fabric, and no matter how much further the pick is beaten into the fabric, when the reed recedes it will move back in the warp until it is at the minimum pick-spacing.

During beat-Up

Zhonghuai [3] indicates that during beat-up, the reed positions the weft's yarn in the fabric, and the pick-spacing is generally controlled by the action of the take-up mechanism. As the weft yarn is being pushed into the cloth fell, the warp tension increases and the fabric tension decreases. In addition, the frictional force between the weft and warp ends causes weaving resistance.

Factors affecting the cloth fell movement

Many researchers have established that the cloth fell position depends on several parameters such as warp and fabric tensions, warp-weft coefficient of friction, warp and fabric elastic modules, loom speed, shed timing and geometry, warp and fabric free lengths, fabric structure, and take-up and let-off motions. The effect of all these parameters will be discussed in details as follow:

Warp tension

Warp tension has been the subject of many investigations and discussions; Greenwood [4] has pointed out the contradictory roles played by warp tension during weaving. On the one hand, warp tension provides the only means of holding or supporting the cloth fell in position during beat-up; this is referred to as the supporting function. On the other hand, higher warp tension tends to increase the weaving resistance, and can be said to oppose the entry of the new weft into the fabric; this is referred to as the opposing function.

Greenwood [5] indicates that there is a definite upward trend in the weaving resistance as static warp tension is increased. However, it is important to note that the change in weaving resistance is very much less than the corresponding change in warp tensions. Therefore, the warp tension has a small but significant effect on the weaving resistance force. Moreover, he concludes that the warp tension at beat-up increases with the cloth fell's movement.

Plate [2] concludes that a high warp tension before beat-up and a low fabric tension during beat-up minimise the increase in beat-up force that is due to pick movement. Also, the picks slipping back in the warp after beat-up are responsible for a very large increase in beat-up force. In addition, he indicates that a low fabric tension is ideal during beat-up, because it allows the weft yarns at the cloth fell to move freely as possible, but as the reed recedes, the situation reverses, and it then becomes desirable to restrict the cloth fell's movement. The possibility of achieving this is realised to some extent by using a higher static warp tension.

Attention is drawn to the work of Zhonghuai [3], El-Deeb [6], and Shaheen [7]; they indicate that the increase in static warp tension leads to an increase in all the dynamic warp tensions.

Beat-up force and weaving resistance

The beat-up force and its relation to the cloth fell's movement have been the subject of much research [1,2,3,4,5]. Three distinct theories have been put forward to account for the variation of the intensity of bet-up with the cloth fell's position. The first one (which appears to be most commonly accepted in industry and by many research workers, termed as velocity theory) relates to the fact that the reed velocity decreases as the reed approaches its front position. This means that the kinetic energy of the slay at the impact of the reed with the cloth fell, and hence the intensity of the beat-up, depends on the cloth fell distance. The second theory (termed as the contact theory) is put forward by Stein [4], and suggests that the intensity of beat-up depends on the length of the period of contact between the reed and the cloth fell. This period in turn depends on the cloth fell distance, and hence the intensity of beat-up also depends on the cloth fell distance. The third theory (termed as the excess tension theory) is put forward by Greenwood [4]. This theory is based on the fact that the force of beat-up has to be balanced by an excess of warp tension over fabric tension. This excess can be created only by a displacement of the cloth fell during beat-up, and this displacement in turn will depend on the cloth fell distance. Therefore, the intensity of beat-up depends on the cloth fell distance.

Greenwood [4] developed the relation between the cloth fell distance and the force of the beat-up based on the excess tension theory as:

$$R_s = (S-L)\cdot\left(\frac{E_1}{L_1}+\frac{E_2}{L_2}\right) \qquad \textit{(In case of non-bumping condition)}$$

$$R_s = (S-L)\cdot\left(\frac{E_1}{L_1}+T_o\right) \qquad \textit{(In case of bumping condition)}$$

where: R_s is the beat-up force, S is pick-spacing, L is the cloth fell distance, E_1 and E_2 are the warp and fabric elastic modulus respectively, L_1 and L_2 are the warp and fabric free lengths respectively, and T_o is the basic warp tension.

When the cloth fell position rises through the shed, the beat-up slackens the fabric. In practice, the fact that the fabric is slack at beat-up is easily recognised by the noise made when it becomes taut again as the reed recedes. This noise is known to weavers as ‘bumping’”, although in industry the term ‘bumping’ is not well defined, and is often used merely to describe unsatisfactory weaving conditions. In this research, ‘bumping’ describes a condition which may be quite normal, particularly when heavier fabrics are being woven.

In addition, Greenwood explains the relation between beat-up force and weft density as follows; the beat-up force at any instant is equal to the weaving resistance. The later arises from many factors: the friction between warp and weft, the rigidity and tension of warp and weft. The total weaving resistance can be regarded as the sum of a frictional resistance and elastic resistance. The difference between the two could be explained as the energy used in overcoming the frictional resistance is dissipated in heat and to some extent, in the form of static electricity. So, when the new pick has been forced to a point near the cloth fell, the friction force will tend to keep it there. The energy used in overcoming the elastic resistance is stored in the form of potential energy; and so, when the new pick has been forced to a point near the cloth fell, the elastic resistance will tend to eject it from the fabric. In spite of these differences, the elastic and frictional resistances have many common features. As the new pick approaches the fell, both resistances tend to infinity for a finite value of the distance of the new pick from the fell. Both increase with an increase in warp tension.

A theoretical investigation was carried out by Plate [1,2] illustrating that the enormous increase in beat-up force was caused by picks sliding in the warp after beat-up.

Fabric structure

The term fabric structure includes all the parameters related to the fabric setting, such as yarn counts, yarn density, and weave fabric pattern. Therefore, to investigate the effect of the fabric structure on the cloth fell movement, all these parameters should be taken into consideration.

Weft density

Greenwood [4,8,9] has commented on the relation between weft density and cloth fell movement. He explains the fact that the pick-spacing depends on the cloth fell movement as it is due to both a simple geometrical cause and a more complex physical cause. The geometrical aspect exists because the new pick is always carried to the front position of the reed, while the previous pick is at the position of the cloth fell. Therefore pick-spacing will depend on the position of the later, i.e., on the cloth fell distance. The geometrical aspect would be the only relevant factor if no force were required to beat-up the new pick and is, in fact, important where the applied beat-up force is small, i.e., in the weaving of low-pick fabrics.

At weaving with high weft density, the physical aspect becomes important; it exists because while beating up the new pick a resistance is encountered, which increases as the new pick approaches the cloth fell. A higher beat-up intensity will therefore cause closer pick-spacing and vice versa.

Greenwood [4] derives a relation representing the cloth fell equation, which determines the pick-spacing in terms of the cloth fell distance as follows:

$$L = -\frac{K}{S-D} + S \qquad \textit{(In case of non-bumping condition)}$$

$$L = -\frac{\left[k/(S-D)\right] - T_o}{E_1 / L_1} + S \qquad \textit{(In case of bumping condition)}$$

where: *D* is the theoretical minimum pick-spacing, *k* is the weaving resistance coefficient, and *K* termed as the cloth fell coefficient.

$$K = \frac{k}{(E_1/L_1) + (E_2/L_2)}$$

The theoretical investigation into the relation between the cloth fell distance and weft density under bumping conditions indicates that the elastic modulus of the fabric and its free length are unimportant, whereas the warp tension acquires additional importance. Thus, under bumping conditions the weft density increases with the cloth fell distance at different basic warp tensions. Therefore, the increase in basic warp tension at a constant weft density led to a decrease in the cloth fell distance.

The experiments were carried out by Greenwood [9], and Kohlhass [10] showed that the weft density increases with the cloth fell movement.

Weft count

A range of fabrics with varied weft counts and weft densities were woven by Greenwood [5]. He concludes that, for any given warp and weft material, the weaving resistance was virtually unaffected by changes in weft count and pick-spacing as long as the weft cover factor remained constant. In addition, the cloth fell position is mainly related to the weft cover factor. Moreover, Plate [2] indicates that the beat-up force is a function of the weft cover factor, although relatively independent of the weft count at constant cover factor.

Fabric pattern

El-Deeb [6] analysed the interchange forces between warp and weft threads in the fabric woven with different patterns. He found that the tension in the warp ends decreases with the increase in the float of the weft yarn. The crimp value is affected by the interchanging force between warp and weft, and the value of crimp increases with the increase in the interchanging force. Therefore, the crimp value increased with decreasing the fabric float.

Shed timing and shed angle

The effect of shed timing was investigated by Greenwood [5] using shed crossing with the crankshaft at an angle of 79° before, and 22° after beating. The results indicate that there is a slight increase in the beat-up. During his theoretical investigation, Plate [2] found that the use of early shed timing is recommended for weaving tight fabrics. It is thought that the reason for this is to allow beat-up to occur with an already crossed shed, which is considered to assist beat-up because of the scissors action of the crossed warp. In addition, he concludes that a large shed angle at beat-up greatly reduces the movement of the cloth fell after beat-up. Zhonghuai [3] set the shed to be crossed at 300°, 310°, 330°, and 360° respectively. He found that this caused the beat-up force to decrease and the pick motion period to be reduced. Basu [11] found during his experimental investigation that the amount of increase in the warp tension during beat-up depends on the actual shed angle, which could be controlled by loom timing.

Shed geometry

Zhonghuai [3] during his theoretical investigation of beat-up indicates that the beat-up force increases the harness lift. Moreover, since the back rail is raised above the central warp line, the unbalanced shed yields better fabric appearance, closer pick-spacing, and shorter fell movement. Efremov [12] founds that the shed dimensions and the number and disposition of the heald shaft affects the position of the cloth fell during shedding.

Backrest movement

Huang [13] conducted an analytical examination to ascertain the effect of the backrest movement in the warp tension fluctuation and beat-up strip width (cloth fell movement) in weaving. His study reveals that the improved backrest movements enable the warp cycle tension to be more even. In addition, the increase in the hardness of beat-up as a result of the modified backrest motion reduces the cloth fell movement by 23%.

Take-up motion

In a conventional power loom, the way to obtain a desired pick-spacing is to make the rate of the cloth take-up per pick equal to the pick-spacing by suitable adjustment of the take-up motion. During normal weaving, the amount of fabric woven is increased by a length equal to the desired pick-spacing at beat-up, and the function of the take-up motion is to take-up this length so as to ensure that the cloth fell stays in the same position. Attention is drawn to the work of Greenwood [4], who was probably the first to develop a mathematical expression relating the rate of take-up to the position of the cloth fell. He founds that the equilibrium between the amounts of fabric woven and the amount taken-up will be disturbed if, for some reason, the instantaneous pick-spacing has a value S which differs from the take-up rate P. In this case there will be a net increase in the free length of fabric, $S-P = (a)$, when the take-up has operated and the cloth fell distance L will have changed by an amount a. He deduced the relation $dL/dn = P-S = -a$, where n referred to the number of picks woven, and referred to this relation as the take-up equation. Thus the function of the take-up motion is to maintain a constant cloth fell distance when pick-spacing is correct, and to cause a change in the cloth fell when the pick-spacing is incorrect. The direct effect of the take-up motion is therefore confined to the cloth fell distance, and it can affect pick-spacing only to the extent that the later affects pick-spacing. The relation between the rate of take-up and cloth fell distance is given by the take-up equation. The cloth fell distance in terns is related to the pick-spacing. This shows that the cloth fell distance is a vital link between the rate of take-up and weft density, and also explains the importance of the relation between the cloth fell distance and weft density.

Let-off motion

Investigations by Greenwood [2] and Basu [11] indicate that the choice of let-off motion depends on the type of fabric woven. With heavier fabrics, warp tension is more critical and, therefore the dead-weight type of let-off appears preferable because it keeps warp tension constant at the expense of the cloth fell position. With lighter fabrics, the cloth fell position is more critical and the break type let-off appears preferable, since it keeps the cloth fell position more constant in return for a fall in a warp tension.

Loom speed

As commented by some research workers [3,5,9], the effect of loom speed provides an indication of the fundamental cause of the variation of the intensity of beat-up with the cloth fell position. Previously, three theories that may explain this variation were discussed. In most aspects, theses theories lead to similar conclusions, but they differ radically in their predication of the effect of loom speed on the cloth fell position. According to the contact theory, a reduction in loom speed would cause a movement of the cloth feel towards the weaver. In contrast, the excess tension theory expects that this would not cause any change in the cloth fell position. Investigation carried out by Greenwood [9] with loom speeds of 128 and 158 picks per minute showed that the cloth fell moves away from the weaver when the loom is running more slowly, as would be expected from the velocity theory. In addition, Greenwood [5] investigates the same parameter with loom speeds of 128 and 190 picks per minute. The results indicate that at the lower speed, the beat-up force is slightly higher. However, the main differences between the tow traces are in the width of the peak, which is inversely proportional to the loom speed, suggesting that no significant change in the cloth fell position has taken place. Zhonghuai [3] has investigated the effect of the loom speed theoretically at rates 500, 600, and 700 RPM; he showed that the beat-up force will increase and the pick motion period will be reduced with the increase in loom speed.

Warp and fabric elastic modulus

Greenwood [5] indicates that the increase in weft cover factor permits the elastic modulus of fabric in the warp direction to be reduced. In addition, Basu [11] founds that the warp tension at the moment of beat-up and weaving resistance depends on the warp elastic constant; both increase with the warp elastic constant. Also, the increase in the warp elastic constant leads not only to an increase in tension, but also makes the tension in the front part of the shed much greater than that in the back part, thus causing excessive yarn breakage. Moreover, Huang [13] concludes that the increase in warp and fabric stiffness results in a decrease in the beat-up strip width (cloth fell movement). Beljaew [14] also indicates that the increase in warp and fabric stiffness decreases the cloth fell movement; he recommended that using a single temple across the fabric width would increase the fabric stiffness, and in turn decrease the cloth fell movement. Nosek [15] developed a mathematical equation relating the cloth fell movement *(x)* to the warp and fabric elastic constant *(C_w and C_f)* with the beat-up force *(F_B)* as:

$$x = \frac{F_B}{C_w + C_f}$$

Warp and fabric free lengths

Experiments were carried out by Basu [11] using two different let-off mechanisms with different warp free lengths, 169 and 190.5 cm. The results showed that these values have an important effect on the yarn tension during the loom cycle. In addition, he related the free length to the elastic constant; the higher warp elastic constant value was due to the lower value of the warp free length. Greenwood [9] shows that the increase in the warp free length makes the cloth fell position less critical. In addition, he indicates that increase the warp free length will reduce strain in shedding, which is also helpful concerning pick spacing. Greenwood [8] concludes that a short length of warp and fabric tends to be more advantageous, since it reduces the cloth fell displacement caused by relaxation.

Frictional properties

Plate [1] indicates that the average stable position of the pick at higher friction between warp and weft is much greater than that found at the lower friction. Zhonghuai [3] illustrated that the beat-up forces increase with the frictional coefficients (yarn to yarn and yarn to metal).

Methods of measuring the cloth fell movement

Microscopic method

Early measurements of the cloth fell position were carried out by Greenwood [9], by means of a microscope mounted on a rigid frame on the loom. However, it was found that measurements could be made more conveniently and quickly by the use of an optical arrangement.

Optical method

Many researchers [5,9,16] have measured the cloth fell position by the use of an optical arrangement whereby an image of the cloth fell was projected with a magnification of twenty times upon a screen, as shown in Figure (1).

The technique is based on a source of light being placed under the loom and focused on the cloth fell with a 5-inch focal length lens, the illumination area being approximately 0.5 inch in diameter. A 4-inch focal length projector lens was mounted about 5 inches above the cloth in line with the source and the first lens. The image of the fell formed by this lens was thrown horizontally onto the wall by a mirror inclined at 45° and mounted 20 inches above the cloth surface.

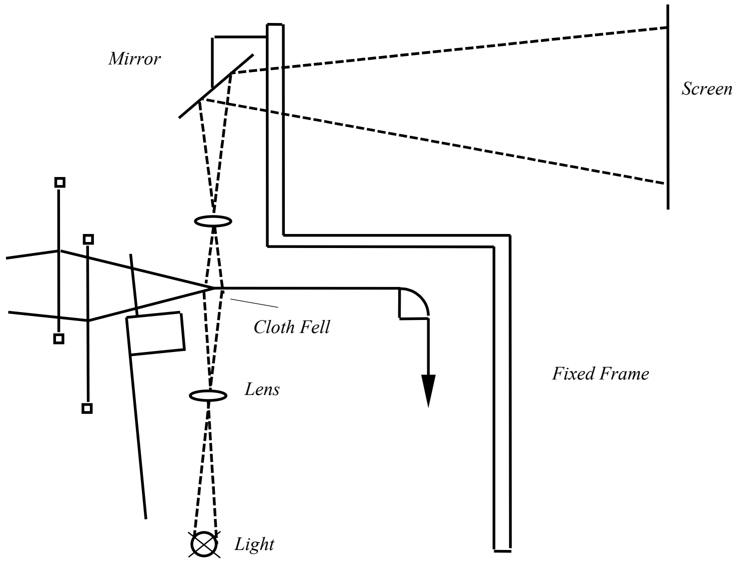

Figure 1. Optical method for measuring cloth fell movement

A white screen fixed to the wall enables the image to be clearly seen and its position measured. It is essential to avoid movement and vibration in the lens and mirror, and so both were mounted on a frame of 2-inch steel tubing bolted firmly to the floor.

The disadvantages of this method are as follows; there is no way to measure the cloth fell's position dynamically during the loom running, so the loom has to be stopped to take the measurements. Moreover, it is impossible to measure the cloth fell position immediately before beat-up, since at this stage the race board of slay obstructs the path of the light from the source of the fell. In addition, the system is excessively complex, especially regarding the arrangement made to fix a reference point and adjustable pointer at the front position of the reed.

Greenwood [5] improved upon the method for locating the front position of the reed. The fabric was pulled up by about 4 inches and one weft thread was inserted in the shed. The take-up motion was temporarily disabled, and the crank shaft was rotated forward past its front centre position, so that the reed deposited the weft thread at its front position. The position of this thread was then read on the screen.

Electronic needle wheel method

Kohlhass [10] described a continuous measuring system for determining the cloth fell movement. The movement is measured in the immediate vicinity of the fell by a small needle wheel, as shown in Figure (2), and is evaluated electronically.

The disadvantages of this method are the difficulty in fixation on the loom, the difference between the measuring point and the cloth fell is greater than 10 mm, and a great deal of electronics were used.

With respect to all the previous methods for measuring the cloth fell position, many researchers have made statements of the following kind; "Today, no method is available to measure cloth fell position with the required accuracy on the loom" [17], "Until now, it has not been possible to measure the cloth fell position, which is a major disadvantage" [18], "The big problem is that at present, no satisfactory method exists to measure cloth fell position on the loom" [19].

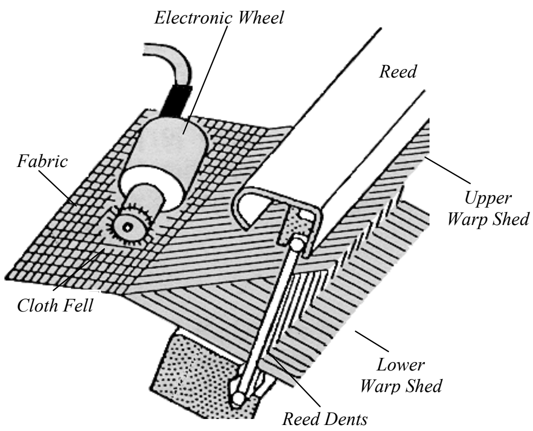

Figure 2. Electronic needle wheel method for measuring cloth fell movement

Conclusion

In this paper, previous work in the area of cloth fell movement has been extensively reviewed. Many theoretical and experimental trials have been covered, and a scientific background and understanding of cloth fell movement has been provided.

For this review, we have been able to conclude that cloth fell movement depends on loom, fabric, and yarn parameters. The shed timing, shed angle, shed geometry, backrest movement, take-up and let-off motions, static warp tension, warp and fabric free lengths, and loom speed represent the loom parameter, while the weft density, weft count, and fabric pattern represent the fabric parameter. In addition, the frictional properties and elastic modulus for warp and weft represent the yarn parameter.

Thus, the weave designers must know their loom's capabilities as well as their yarn characteristics, in order to benefit fully from the theoretical and empirical studies that have been reviewed.

However, as one can observe from the broad scope of literature dealing with the relations between warp tension, fabric structure, and cloth fell movement, we can still observe the voids and gabs that still remain, especially for cloth fell measuring; however, this in turn opens windows for further research to achieve the most reasonable level of knowledge. Developing such a method will be a subject for future research work.

References

1. *Plate, D. E. A., and Hepworth, K., "Beat-Up Force In Weaving (Part I)", Journal of Textile Institute, Vol. 62, No. 10, October 1970, 515-531.*
2. *Plate, D. E. A., and Hepworth, K., "Beat-Up Force in Weaving (Part II)", Journal of Textile Institute, Vol. 64, No. 5, May 1973, 233-249.*
3. *Zhonghuai, Z., and Mansour, H., "Theoretical Investigations of Beat-up", Textile Research Journal, July 1989, 395-404.*
4. *Greenwood, K., and Cowhig, W. T.," The Position of the Cloth Fell in Power Looms, Part I: Stable Weaving Conditions", Journal of Textile Institute, Vol. 47, No. 5, May 1956, T241-254.*
5. *Greenwood, K., and Vaughan, G. N." The Beat-up Force and Pick-spacing", Journal Of Textile Institute, Vol. 48, No. 2 , February, 1957, T39-53.*
6. *Shaheen, A., and El-Deeb, A., "Theoretical and Experimental Studies for Thread Floating in the Fabric", Egypt, Mansoura Engineering Journal (MEJ) Vol. 15, No. 2, December 1990, T27-T42.*
7. *Shaheen, A., and El-Deeb, A., "Warp Tension Distribution Across Warp Sheet on Air Jet Weaving Machine", Egypt, Mansoura Engineering Journal (MEJ) Vol. 15, No. 1, June 1990, T47-T60.*

8. *Greenwood, K., and Cowhig, W. T.," The Position of the Cloth Fell in Power Looms, Part II: Disturbed Weaving Conditions", Journal of Textile Institute, Vol. 47, No. 5, May 1956, T255-265.*
9. *Greenwood, K., and Vaughan, G. N. "The Position of the Cloth Fell in Power Looms, Part III: Experimental", Journal of Textile Institute, Vol. 47, No. 5, May 1956, T274-286.*
10. *Kohlhaas, O., "Gerät zur Ermittlung der Warenrandbewegung" Melliand Textilberichte, 6/1981, 457-460.*
11. *Basu, A. K., "Effect of Different Let-off Mechanisms on Fabric Formation and Dimension of Fabric in the Loom" Textile Research Journal, July 1987, 379-386.*
12. *Efremov, E. D., "The Movement of the Cloth Fell Due to Shedding", Tech. of Textile Industry USSR 1970, No. 3,. 59-63.*
13. *Huang, Gu, "Reduction of Warp Tension Fluctuation and Beat-up Strip Width in Weaving", Textile Research Journal, March 1984, 143-148.*
14. *Beljaew, W. N., "Über die Möglichkeit der Verminderung der Vortuchgröße", Technologija Tekstiljnoi Promyschlennosti, 1969, H. 7, 76-78.*
15. *Nosek, S., " The Dynamics of Fabric Forming on the Loom at High Weaving Rates", Indian Journal of Fiber and Textile Research, Vol. 19, September 1994, 125-138.*
16. *Lang, A., "Messung der Lage des Warenrandes" Textil Praxis, 1957, 1224.*
17. *Vangheluwe, L., and Kiekens, P., "Test Method for Cloth Fell Displacement Caused by Relaxation", Textile Research Journal, 65(9), September 1995, 540-544.*
18. *Vangheluwe, L., and Kiekens, P., "Modeling Mechanical Behavior of Fabric and Warp Yarn during Loom Stops", Textile Research Journal, 66(10), November1996, 722-726.*
19. *Vangheluwe, L., and Kiekens, P., "Simulation of Procedures to Avoid Set Marks in Weaving Caused by Relaxation", Textile Research Journal, 67(1), January 1997, 34-39.*

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