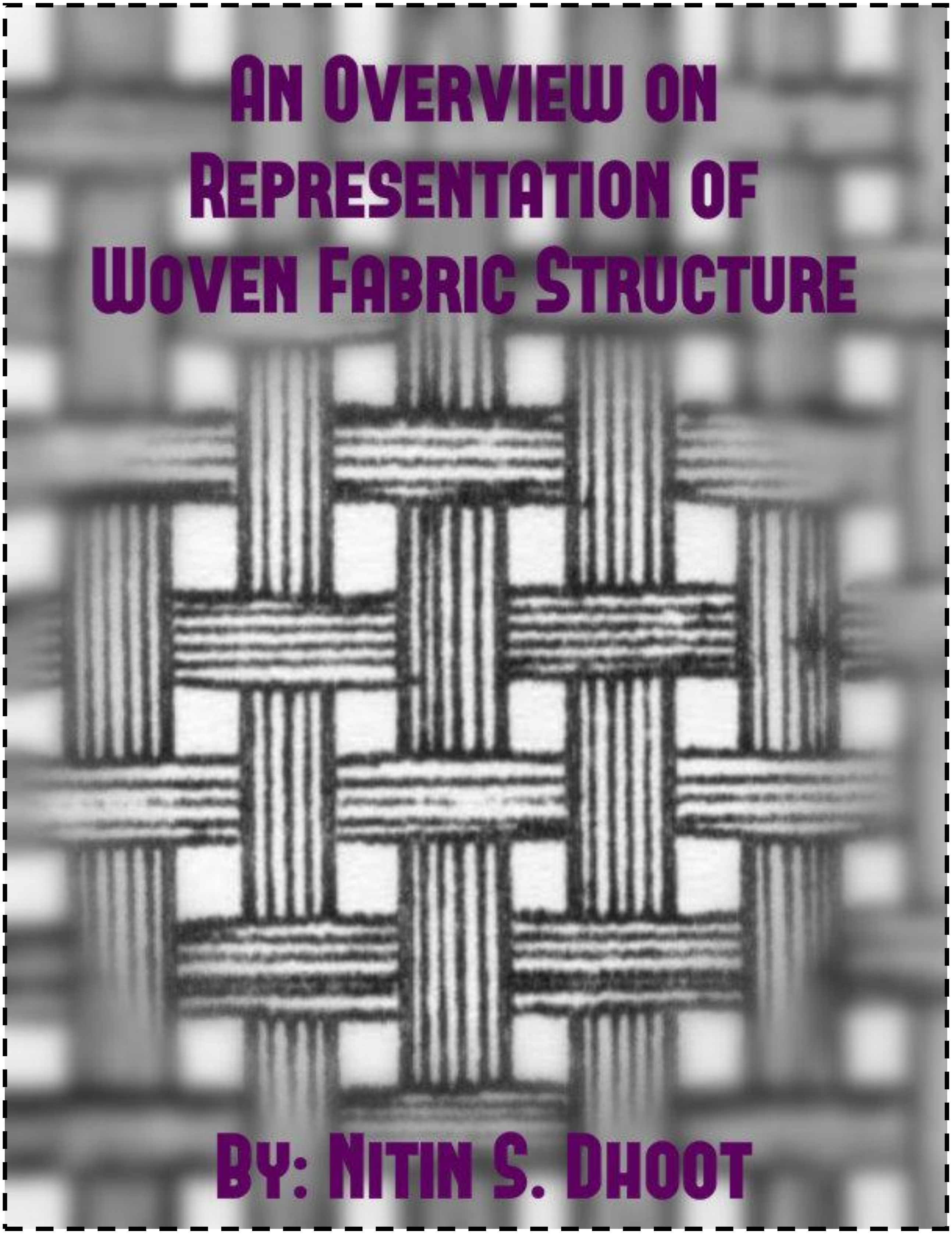
An Overview on Representation of Woven Fabric Structure

By: Nitin S. Dhoot



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Woven Fabric Formation

There are many ways of making fabrics from textile fibers. The most common and most complex category comprises fabrics made from interlaced yarns. These are the traditional methods of manufacturing textiles. The great scope lies in choosing fibers with particular properties, arranging them in the yarn in several ways and organizing in multiple ways interlaced yarn within the fabric. This gives the textile designer great freedom and variation for controlling and modifying the fabric. The most common form of interlacing is weaving, where two sets of threads cross and interweave with one another. The yarns are held in place by the inter-yarn friction. Another form of interlacing where the thread in one set interlocks with the loops of neighboring thread, by looping is called knitting. The interloping of yarns results in positive binding. Knitted fabrics are widely used in apparel, home furnishing and technical textiles. Lace, crochet and different types of net are other forms of interlaced yarn structures. Braiding is another way of thread interlacing for fabric formation. Braided fabric is formed by diagonal interlacing of yarns. Braided structures are mainly used for industrial composite materials.

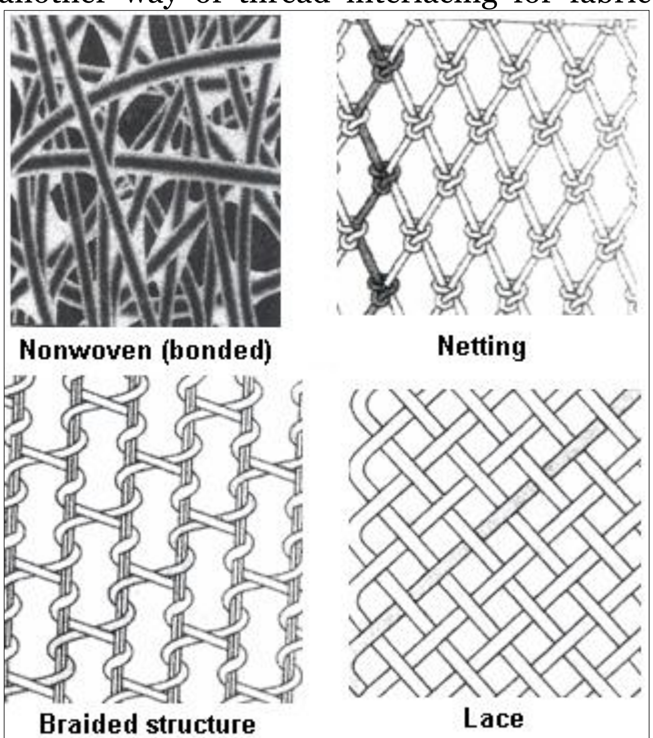

Figure 1: Fabric structures produced by different methods of fabric formation

Other forms of fabric manufacture use fibers or filaments lay down, without interlacing, in a web and bonded together mechanically or by using adhesive. The former are needle punched nonwovens and the latter spun bonded. The resulting fabric after bonding normally produces a flexible and porous structure. These find use mostly in industrial and disposable applications. Figure 1 shows the schematics of fabrics produced by the methods discussed above. All these fabrics are broadly used in three major applications such as apparel, home furnishing and industrial.

The traditional methods of weaving and hand weaving will remain supreme for expensive fabrics with rich design content. The woven structures provide a combination of strength with flexibility. Flexibility under low strains is achieved by yarn crimp due to freedom of yarn movement, whereas at high strains the threads take the load together, giving high strength.

Modeling different weaves

The firmness of a woven fabric depends on the density of threads and frequency of interlacements in a repeat. Fabrics made from different weaves cannot be compared easily with regard to their physical and mechanical properties unless the weave effect is normalized. The concept of average float has long been in use, particularly for calculating maximum threads per cm. It is defined as the average ends per intersection in a unit repeat. Recently this ratio, known as weave factor, has been used to estimate the tightness factor in fabric.

Weave Factor

The weave factor is a number that accounts for the number of interlacements of warp and weft in a given repeat. It is also equal to average float and is expressed as

$$M = E/I$$

where E is number of threads per repeat and I is number of intersections per repeat of the cross-thread.

The weave interlacing patterns of warp and weft yarns may be different. In such cases, weave factors are calculated separately with suffixes 1 and 2 for warp and weft respectively. Therefore, $M1 = E1/I2$; E1 and I2 can be found by observing individual pick in a repeat and $M2 = E2/I1$; E2 and I1 can be found by observing individual warp end in a repeat.

Calculation of weave factor

Regular weave

For e.g.: Plain weave is represented as 1/1; for this weave, E1 the number of ends per repeat is equal to 1 + 1 = 2 and 12 the number of intersections per repeat of weft yarn = 1 + the number of changes from up to down (vice versa) = 1 + 1 = 2. Table I gives the value of warp and weft weave factors for some typical weaves.

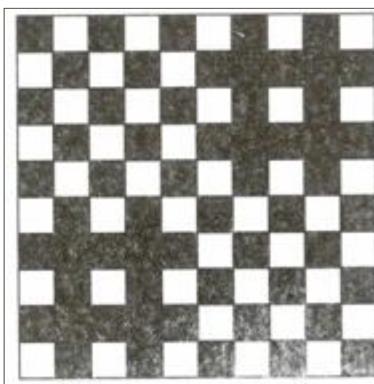

Figure 2: 10 end irregular Huckaback

Irregular weave

In some weaves the number of intersections of each thread in the weave repeat is not equal. In such cases the weave factor is obtained as under:

$$M = \sum E / \sum I$$

For e.g.

So, Therefore

$$\text{Weave factor} = \frac{10+10+10+10+10+10+10+10+10+10}{10+6+10+6+10+10+6+10+6+10}$$

$$= 100/84$$

$$= 1.19$$

Table 1: Weave factor for standard weave

Weaves	E_1	I_2	E_2	I_1	M_1	M_2
1/1 Plain	2	2	2	2	1	1
2/2 Twill	3	2	3	2	1.5	1.5
2/2 Warp rib	2	2	4	2	1	2
2/2 Weft rib	4	2	2	2	2	1

Index of interlacement

Index of interlacement (I)

$$= \frac{\text{No. of actual interlacement/repeat}}{\text{No. of possible interlacement/repeat}}$$

A fabric designs is considered based on two factors, interlacement and float. For any fabric structures as the interlacements per repeat increases the float decreases. The plain weave fabric have highest index of interlacement (1=1) with zero float. In a repeat size of 8x8 the plain weave has 64 possible interlacement and 64 actual interlacement. Table II gives the value of Index of interlacement for some typical weaves.

Table 2: Index of interlacement for standard weave of repeat size 8x8

Weaves	Actual interlacement /repeat	Possible interlacement /repeat	Index of interlacement (I)
1/1 Plain	64	64	1
2/2 Twill	32	64	0.5
2/2 Warp rib	32	64	0.5
4/4 Twill	16	64	0.25

Prabir Kumar Banerjee, Ph.D, Swapna Mishra, Thiyagarajan Ramkumar studied effect of Sett and Construction on Uniaxial Tensile Properties of Woven Fabrics. Four weaves were chosen for the study namely plain, 2/2 twill, 3/1 twill and 3/1 satinette. Of the four weaves the plain weave has the highest index of interlacements, defined here as the ratio of the actual number of interlacements to the maximum possible ones. The other three weaves repeat on 4 ends and picks, have same index of interlacement, which is half of that of the plain, but differ in many other respects. Both the 3/1 twill and the 4-end satinette are unbalanced regular weaves based on the same floating pattern of individual yarns, that is, a float over three

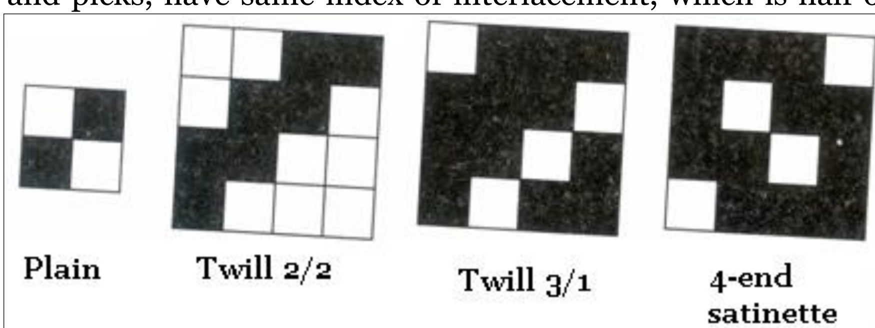

Figure 3: Weave repeat units of different weaves studied

yarns followed by a float under one.

However, the former exhibits a constant positive shift of one step whereas the latter exhibits positive cyclic steps of 2, 3, 2 and 1. The 2/2 twill is a balanced regular weave. The repeat units of all the four weaves are shown in Fig.3 while their characteristics are listed in Table 3.

Table 3: Fabric Characteristics

Characteristics of weave	**Plain**	**Twill 2/2**	**3/1 Twill**	**4-end satinette**
Nature	Balanced, regular	Balanced, regular	Unbalanced, regular	Unbalanced, regular
Index of interlacement	1	0.5	0.5	0.5
Steps of interlacement	+1	+1	+1	+2/+3/ +2/+ 1
Floating pattern	1/1	2/2	3/1	3/1

Edita MALCIAUSKIENE, Algirdas MILASIUS, Ginta LAURECKIENE, Rimvydas MILASIUS studied Influence of Weave into Slippage of Yarns in Woven Fabric. Woven fabric is a sophisticated structure material and its characteristics are influenced by its structure. There are seven parameters influencing woven fabric structure: the raw material of the warp and the weft, the linear density of warp and weft, the warp and weft setting and the weave of the fabric.

All seven parameters of the fabric's structure can be evaluated by integrated fabric structure factors. Various scientists proposed different evaluations of all these fabric parameters. According to the methods of evaluation of these parameters, two groups of integrated factors are distinguished: the first is based on the Peirce theory and the second on the Brierley's theory. Peirce's group factors express the covering of a fabric surface with threads, and Brierley's group factors are defined as a ratio of analyzing fabric density with standard fabric density. This group also includes average float length F, which was offered by Ashenhurst and weave factor P offered by V. Milasius.

It is well known factor - the average float length F, wh ich was offered by Ashenhurst. It was very simple and widely used factor. Later it was observed that th is factor didn't describe all the properties of a weave, which are important from a technological and end-use point of view. This factor could not evaluate the difference between types of weaves (it is well known that the weaves twill 7/1, satin 8/3 and panama 4/4 have a different tightness, but are still counted with the same value, F = 4) and unbalanced weaves, whose average warp float is different from the average weft float (warp rib 4/4 and weft rib 4/4 behave very differently during weaving but sti II evaluated using the same value, F = 2.5).

Weave factor P offered by V. Milasius is calculated directly from the weave matrix. Factor P evaluates not only a single thread float, but an interlacing of adjacent threads too 'and can be calculated for all the types of the weaves. Weave factor P describes beating-up process very well and it measures fabric structure describing some of its properties, such as elasticity, air permeability and other. However, factor P is very good for balanced weaves but it cannot evaluate the difference between unbalanced weaves - warp rib 4/4 and weft rib 4/4 have the same value, P = 1.205. Later V. Milasius proposed factor P1, calculated in the warp direction. It covers most of the weaves used.

Weave factor P proposed by V. Milasius was calculated by the following equation:

$$P1 = \sqrt{\frac{3R_1R_2}{3R_1R_2 - (2n_f + \Sigma^6_{i=1} K_i n_{fi})}}$$

where: R_1 and R_2 are the warp and weft repeat of the weave, respectively, n_f - the number of free fields, n_{fi} - the number of free fields belongs to group i, K_i - elimination factor of group i.

The Ashenhurst's weave factor F, alternatively called the average float length was calculated by the following equation:

$$F1\ (2) = R_{2(1)}/t_{1(2)}$$

where $R_{2(1)}$ are repeats of warp and weft, respectively, $t_{1(2)}$ are the numbers of intersections of warp and weft, respectively.

There have also been several attempts at characterizing weaves through factors like the Firmness of a cloth (Brierley, 1952), Fabric Tightness (Hamilton, 1964), Cloth Tightness (Love, 1954), Weave Firmness Factor (Milasius V and Reklaitis V, 1988 & Milasius, 2000a), Integrated Structure Factor (Milasius, 2000b), Tightness Factor (Newton, 1995) and Construction factors (Russell, 1965) Kumari S (2005) developed a C++ program following the approach outlined by Ping and Greenwood (1986) and calculated the number of possible weaves for given repeat size and worked out their structural characteristics. Singh N. (2007) generated different programs to map regular as well as irregular woven constructions and calculated their values of tightness factor (Newton, 1995). It was observed that for many weaves only a few distinct values of tightness factor exist, indicating that weave tightness factor cannot define each weave or interlacement pattern uniquely.

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