# Design engineering of woven fabrics

# Contents

# From fibre to woven fabric

In this session you will be introduced to the processes used to create a woven fabric. In particular we will look different process from converting raw materials into yarn or thread and joining the individual threads together to create fabric.

**The manufacturing process of fabric**

1. Fibre production:
   - Natural fibre
   - Man-made fibre

2. Yarn spinning:
   - Drafting
   - Insertion of twist in fibres

3. Yarn storage:
   - Preparing and storing yarn using processes: twisting, steaming, winding, yarn dying and weft winding
4. Warping
   - Preparing warp beam with a large number of yarn
5. Drawing-in:
   - Drawing the yarn through a drop wire, a heddle and reed dent

6. Weaving:
   - Interlacing of warp and weft in loom or weaving machine

7. Finishing:
   - Giving final quality to fabric through washing, dying etc

8. Woven fabric:
   - Woven fabric with its final quality and dimension

Warping is a process in which a great number of the yarn ends from the cones are wound onto the warp beam.

# Types of warping

**Direct warping (direct beaming)**

This system is a single operation that involves winding the total number of warp ends in full width from a creel, either onto a weaver's beam or onto a sectional beam.

This system is suitable for long series and basic patterning (one colour in warp direction).

**Section warping**

This system is a two-stage-machine method of preparing a warp on a beam, consisting of firstly winding a warp in sections on a drum, and then beaming-off the complete warp from the drum onto a warp beam.

This system is appropriate for warping shorter series and several colours in the warp direction.

# Weaving process

Weaving is the interlacing of warp and weft strands to create fabric. The weaving machine (loom) provides the mechanisms needed to deliver and control warp threads for interlacing weft yarns.

1. Warp beam: Leading the warp for weaving process
2. Warp tension mechanism: The warp yarns are led from a warp beam over a beam that controls the warp tension
3. Drop wire: The warp threads pass through drop wires which stop the machines in the case of any warp breakage. Then a reed moving forward and backward beats the weft (filling) yarn into position and the process is repeated.
4. Heddles: The heddles raise or lower warp in order to make a shed.
5. Reed: The reed moved forward and backward to beat the weft (filling) yarn into position and the process is repeated.
6. Weft insertion system: Weft yarns are inserted using a weft insertion device to transport the weft yarn from one side to the other.
7. Temples: Temples are placed on both sides in order to control the fabric width and make sure the warp strands do not break in the selvage.
8. Feed beam: This beam transports the fabric through the loom.
9. Cloth beam: The fabric is taken-up by the cloth beam.

Watch a short clip on the weaving process in the online version of this resource.

## Weaving process/Loom timing

In order to interlace warp and filling yarn to make woven fabric, it is necessary that four basic operations are implemented in sequence and continuously. These include:

**1. Shedding**

The separation of the warp threads into two (or more) sheets according to a pattern to allow for weft insertion (the most important weaving operation)

**2. Weft insertion (picking)**

To place weft yarn in the shed (the complementing weaving operation)

**3. Beating-up**

Forcing the inserted pick into the shed up to the fell of the cloth

**4. Letting off and taking up**

**Warp let-off**: supplying more warp yarn by unwinding of the warp beam as the cloth is woven.

**Fabric take-up**: draw forward the woven fabric as a new pick is inserted.

## Weft insertion

**Weaving machines are classified according to their filling insertion mechanism.**

1. Shuttle
2. Shuttle-less
    - Rapier
    - Projectile
    - Air-Jet
    - Water-Jet
    - Others

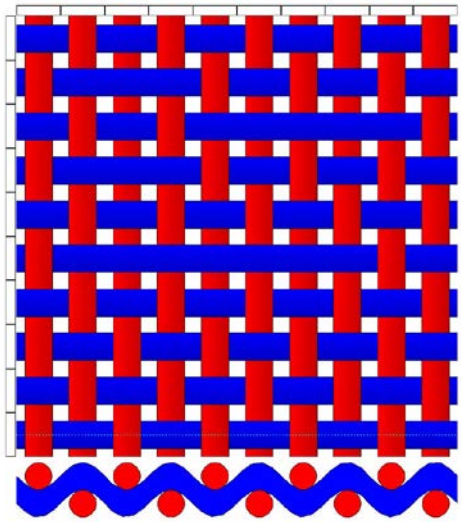
## Woven fabric applications

Woven fabrics are used in two main product groups: clothing and technical textiles.

# Woven fabric structure

### Weave design

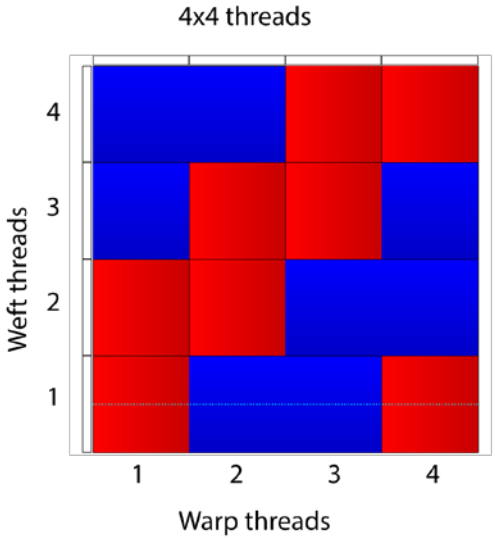
A weave design shows how the warp and filling threads are interlaced.





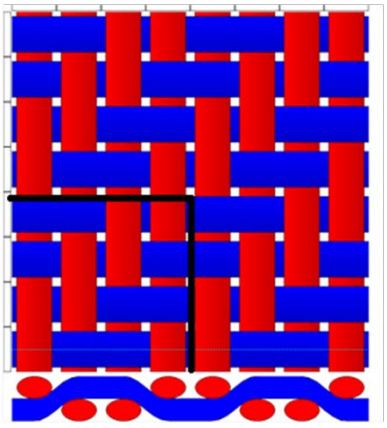
### Weave report

A weave report is the number of warp and filling yarns in the smallest part of pattern.



**Weave pattern**

A weave pattern is a number of weave reports.



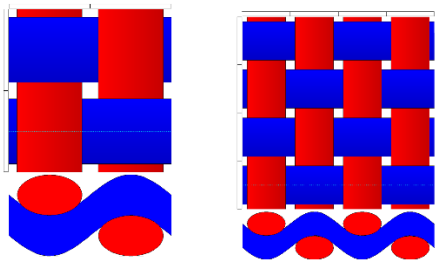


## Basic weaves

There is basically an unlimited number of weaves that can be developed, but weave patterns have three basic designs:

### Plain weave

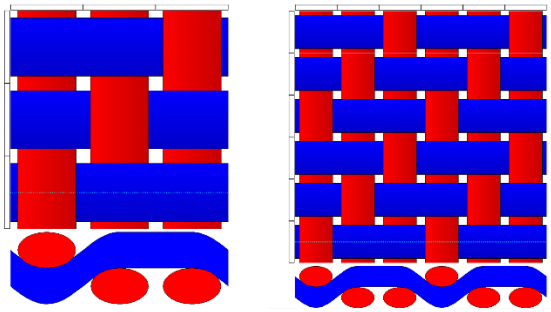
**Plain weave report** **Plain weave pattern**





### Twill weave

**Twill weave report** **Twill weave pattern**



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This pattern can be described in the formula:

$$T\frac{1}{2}Z$$

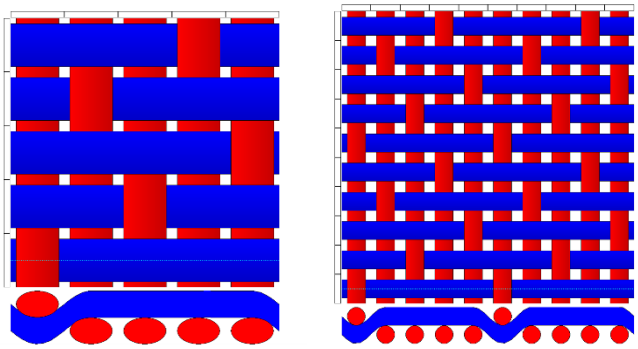
**Where:**

- **T** = Twill
- **Fractional line** = warp rise above and weft rise below
- **Z** = twill direction

## Satin weave

Satin weave has just one weave point for each warp in the weave report. The points of interlacing should be scattered over the weave and cannot be placed side by side.

**Satin weave report** **Satin weave pattern**



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This pattern can be described in the formula:

$$S\frac{1}{4}(3)$$

**Where:**

- **S** = satin
- **Fractional line** = warp rise above and weft rise below
- **(x)** = step number

  **The step number cannot be 1 or a number equally divisible by the report number.**

## Examples

- The possible step numbers for a report 5*5: 2 and 3
- The possible step numbers for a report 7*7: 2, 3, 4 and 5
- The possible step numbers for a report 8*8: 3 and 5

**Three steps are required to draw a satin pattern:**

1. Adding the numbers in the formula to get the report. In the figure: 1 + 4 = 5 which means the report is 5 * 5 squares or threads.
2. Beginning from the left corner with a filled square for a weft-faced satin or an empty square for a warp-faced satin. In this figure it is a weft-faced satin.
3. Count the number of squares equaling the step number and step to the right. Fill it for a weft-faced satin or keep it empty for a warp-faced satin.

## Exercise

Please complete the activity in the online version of this resource.

# Weave factor

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

$$M = \frac{E}{I}$$

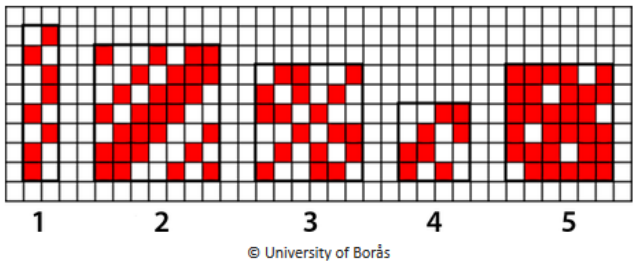
**Where:**

- **E** is number of yarns per repeat
- **I** is number of intersections per repeat of the cross yarn.

**For example:**

Cover factor for weave pattern (1) = 8/6 = 1.3

- M (2) = 7/5 = 1.4
- M (3) = 6/4 = 1.5
- M (4) = 4/2 = 2
- M (5) = 6/2 = 3





**Question:**

If you produce woven fabrics with these weaves with the same drawing in the warp and weft and using the same yarns, which weave pattern can be assumed to be loosest and which to be tightest respectively?

1. Pattern 1 because of lowest cover factor and pattern 5 because of highest cover factor?
2. Pattern 3 because of low cover factor, pattern 5 because of highest cover factor?
3. Pattern 5 because of highest cover factor, pattern 1 because of lowest cover factor?
4. Pattern 2 because of low cover factor, pattern 4 because of high cover factor?

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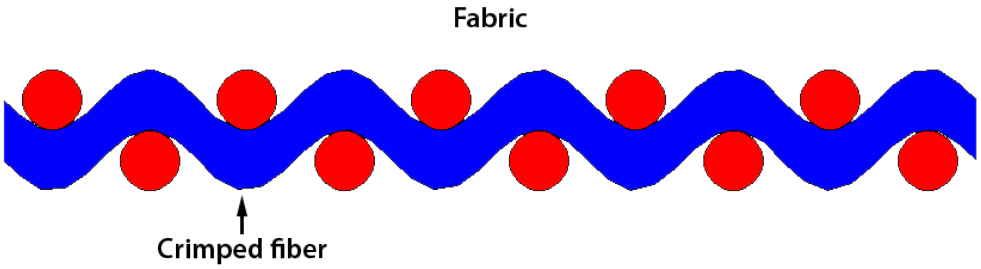
Pattern number ☐ is assumed to be loosest.

Pattern number ☐ is assumed to be tightest.

## Design engineering of woven fabrics

Several parameters could characterize the fabric geometry. Yarn diameter, thickness, cover factor, crimp, etc. are all structural parameters of woven fabrics.



## Yarn count

Yarn count is generally classified into:

**Indirect system:**

This system is applied for the measurement of length per unit weight of yarn, where weight is considered to be constant. When count increases, fineness increases. In this system the normally used units of measurement are:

- English System (1 Ne = 1 Hank/ lb)
- Metric System (1 Nm = 1 Km/ kg)

**Direct system:**

This system is applied for the measurement of weight per unit length of yarn where length is considered as constant. In this system the usually used units of measurement are:

- Tex = 1g/ 1000m
- Grain = 1g/ 10,000m
- Denier = 1 Denier = 1g/ 9000m

**Example:**

If we have a cotton yarn with 20Ne then what will be the Tex count?

- Ne = 590.5/Tex
- Tex = 590.5/20
- Answer = **29.5**

## Summary

**You should now be able to:**

- Describe the process of weaving in a shaft loom, including the main operations.
- Do a complete analyse of a fabric sample and define for example warp density, weft density, name of construction/composition, interlacing patterns, drafting with threading (one repeat unit), etc.
- Draw one weave report based on a formula for example $T\frac{2}{2}\frac{1}{2}\frac{2}{1}S$
- Calculate the yarn number and convert to a different system.

## Further reading


- Giovanni Castelli, Salvatore Maietta, Giuseppe Sigrisi, Ivo Matteo Slaviero. (2000) *Reference Books of Textile Technologies – Weaving*.
- *Woven Textile Structure: Theory and Applications*