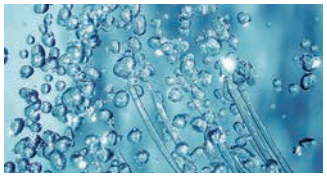
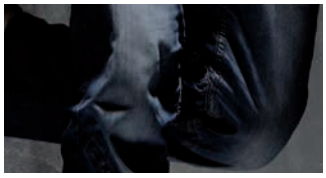
ARCHROMA
LIFE ENHANCED

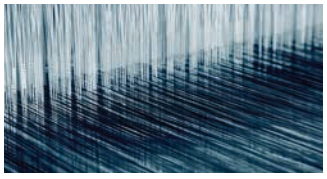
DENIM BOOK

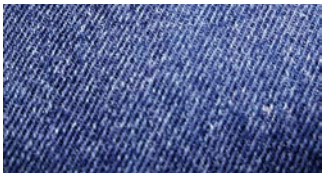
From cotton to fashion

Index









Introduction

01

"The Archroma denim book has been designed and written by the Archroma's denim specialist team in Barcelona.

It offers an overview of the many processes and products currently involved in the manufacturing of jeans.

Denim is in constant evolution and new innovations will surely influence the future of the industry. That is why Archroma's experts supports brands' and stylists' creativity with state-of-the-art chemistry for exciting colors and effects that bring together technology and sustainability.

The Pad/Sizing-Ox process, introduced under Archroma's ADVANCED DENIM concept, is an awe-inspiring illustration of our commitment: manufacturers can now dye denim whilst saving up to 92% water, 30% energy and 87% cotton waste compared to traditional dyeing process.

Read on; we hope that the Archroma's denim book will be an enjoyable source of information and inspiration for your future denim projects."

/ DENIM BOOK BY ARCHROMA

Introduction

The story of jeans begins in the mid-19th century simultaneously in two European cities:

Nîmes in France, where the fabric itself was created, the so-called “Serge de Nîmes” which led to the name “denim”.

Genoa in Italy, where the color comes from, called in French “Bleu de Gênes” which led to the expression “blue jeans”.

The fabric and color come together to become the jeans, denim.

1860 • Beginning of denim • Strong and durable material for the workwear market

In these two cities the strong and resistant fabric started being used for the production of workwear, especially for sailors and dockworkers.

This blue fabric, which was going to replace the classical brown and beige workwear, established itself many kilometers away from Europe, in the United States of America.

A young immigrant from Germany, called Levi Strauss, started marketing the new garment with riveted copper buttons which considerably reinforced pockets.

Jeans became more and more popular in the 1920s and 1930s and consolidated their reputation as a common work garment.

Little by little an industry was established and it returned to Europe in the form of some newly-founded brands (such as Morris Cooper Overall, later called Lee Cooper). Like in the USA, the first European jeans were intended for the labor market.

In the 1950s, jeans entered a new phase in the USA as an article of fashion. They gained ground due to their appearance in Hollywood films where popular actors and actresses such as James Dean, Marlon Brando or Marilyn Monroe wore them.

This way jeans very quickly became an object of many young people's desire.

This new fashion trend came after World War II to Europe, not without difficulties, which were due to the economic and trade problems of the time.

In the 1960s brands such as the American Levi's or Wrangler, established their first outlets in Europe in response to the steady increase in demand. Later, others such as Lee started flocking in.

Until then dyeing and production of jeans was an exceedingly laborious and not very productive task. However, in the 1960s new dyeing systems were introduced and the production of the denim fabric increased and was optimized.

Slowly, the first European jeans brands appeared: Carrera in Italy, Lois in Spain or Chipie in France.

Although quite popular, jeans were not able to gain adequate recognition in the fashion industry. Nevertheless, at the beginning of the 1970s new brands appeared. They put emphasis on sales strategies that were completely different from those established so far and provided the denim fashion with a definite impulse. It was consolidated in the 1980s with the creation of brands such as Goldie, Diesel, Replay and others.

At present denim is not just a garment, but an entire lifestyle.

Nowadays brands make clear their commitment on the protection of the environment. The use of organic cotton and chemical products with low environmental impact is becoming usual as well as industrial processes which minimizes consumption both of water and residues generated during the entire process: from thread manufacturing to the final creation of the garment.

This is a path which has to be followed for the benefit of future generations.

1930-70s • The demand of jeans as a fashion item increased in this period

1980-2000s • Denim revolution

Denim will continue 'reinventing' itself every day in each brand, each new collection, creating new fashion trends. No doubt remain on the topic of commitment to the environment, as far as natural resources are concerned as well as the employment of dyestuffs and chemical products used in the production of the final jeans garment.

Comfortable, risky, adventurous, relaxing, glamorous, attractive, aggressive, smart, casual, funny, dynamic, energetic, fashionable, practical, creative… universal.

All these adjectives define denim not only as a style in fashion but as something more: **a lifestyle**.

Spinning

02

Cotton and its intimate blends with other cellulose-base fibers is a material used for most denim-type fabrics. Such fabrics are used to create comfortable, loose garments.

Two types of spinning can be distinguished:

- **Continuous fiber threads**, for example artificial fiber thread such as PA or PES.
- **Discontinuous or staple fiber threads**, as in the case of cotton, a type of spinning which will be discussed in depth.

"THE PROCESS OF MAKING FIBROUS MATERIAL INTO YARN OR THREAD"

/ OUR FIBER YARNS

Spinning

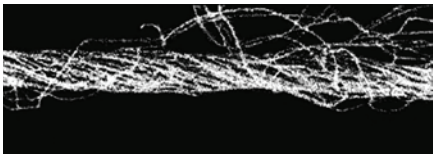
2.1 Systems of Manufacturing Staple Fiber

Currently, it is possible to obtain different types of thread in the denim yarn market, according to the manufacturing system used:

- Rotor or Open-End (OE) System
- Ring System
- Compact System

Rotor or Open-End (OE) System

This type of spinning was historically the most frequently used for the manufacturing of denim items. In the OE system differences in length of fibers when they are grouped together are accepted, thus making it possible to work with medium or low quality cotton. Furthermore, fibers in the final yarn can be arranged irregularly.



Cotton yarn manufactured by open-end system. Macro view

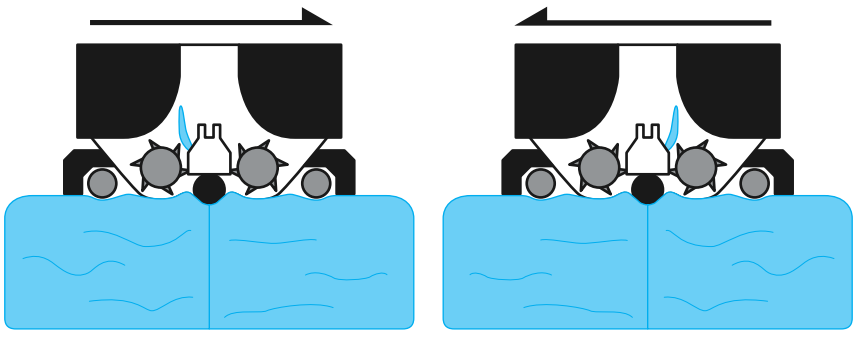
The manufacturing process includes the following operations:

Cleaning: a process during which impurities and cotton seeds are eliminated.

Mixing: cotton from different origins is mixed and finally emerges in the form of fleece. This process is also called the opening of cotton, as it arrives in the form of bales. The machine used for this initial operation is known as the opener. With this operation it is possible to achieve a high degree of regularity in the final yarn.

Opener range

Inner workings



Cotton fibers are mixed in the first phase of yarn formation

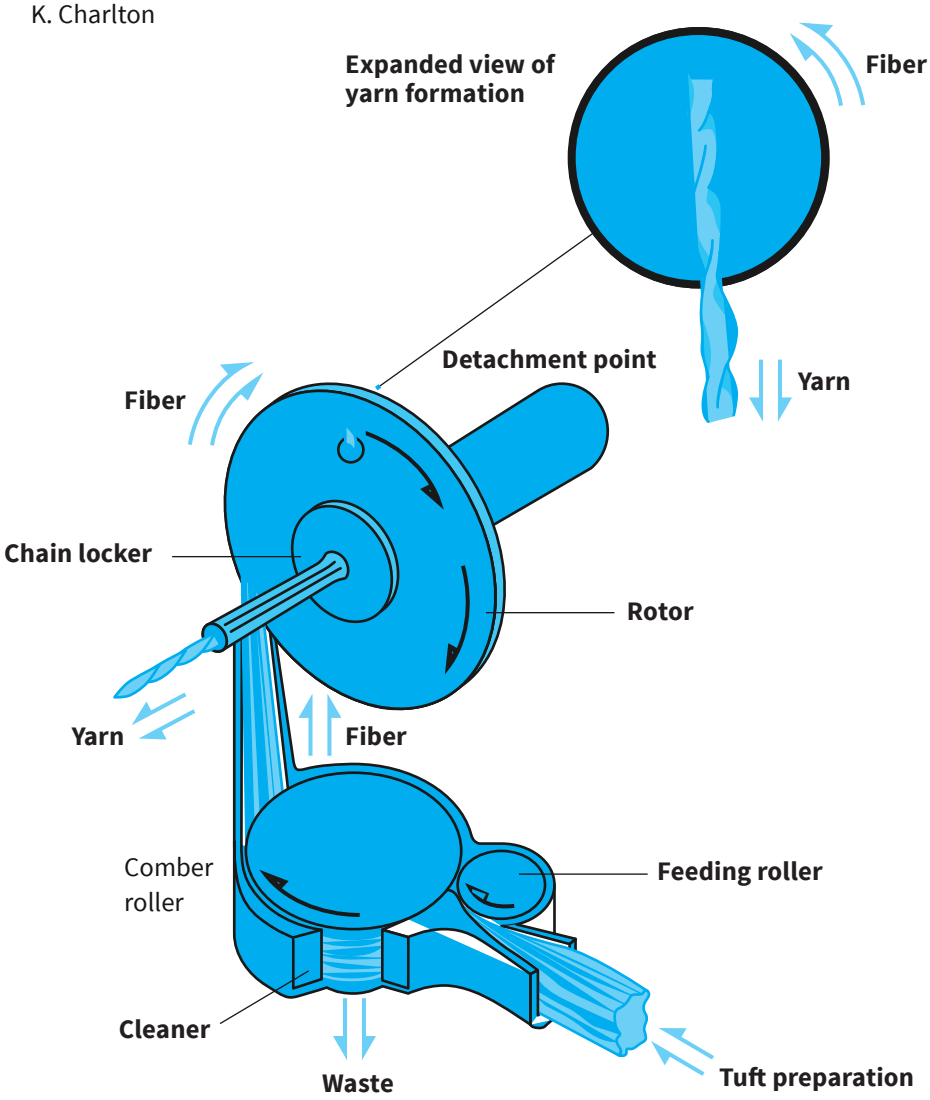
Carding: an operation that involves the elimination of fibers which are too short, their orientation and the formation of tufts (ropes) using fibers of adequate length. In addition to carding, the threads might be also combed. In this case, the fibers laid parallel, superior in smoothness to carded yarn.

Passage through the spinning machine: an operation during which the final degree of thread twist is determined, as well as thickness, regularity and weight. The thread is formed by passing the tuft through a spinneret where a combination of tension and air finishes the process of production. The resulting thread is then placed on the bobbins.

Accumulation of tufts or ropes after coming out of speed frames

Operating diagram of a open-end (rotor) spinning

Functional diagram
K. Charlton



Ring System

At present the majority of yarn destined for denim is manufactured using this system. Rotor or OE system is gradually losing ground to the ring system.

The main characteristics of ring yarn include: greater volume, softness, elasticity and resistance than that of yarn produced through the OE system.

The ring thread has fibers of greater length and regularity than those of the open-end yarn.

The production of the ring thread includes more operations within the global process of spinning than those needed for the manufacturing of open-end yarn.

Apart from the operations of cleaning, mixing, carding and the passage through a continuous spinning machine, the production of ring yarn also includes the following steps:

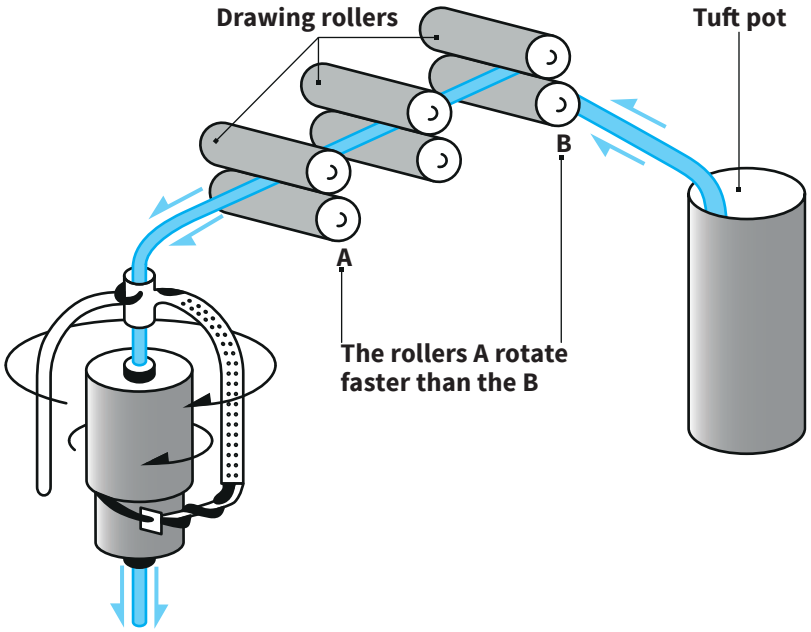
Drawing frame step, during which a more intimate blend is produced from cotton of different origins, the fibers stay more parallel and the tuft is thinner.

Speed frames or drawing frames step, during which the tuft is drawn apart. A certain number of fibers are eliminated in order to obtain the final desired thickness. These fibers come out completely parallel to each other.

Spinning machine step, during which the final yarn is not formed by passing through a spinneret, but by passing the tuft through a drawing and rotation system by means of a ring, at very high velocities. Then the yarn passes on to spindles and finally to the bobbins.

Operating diagram of a speedframe

Functional diagram

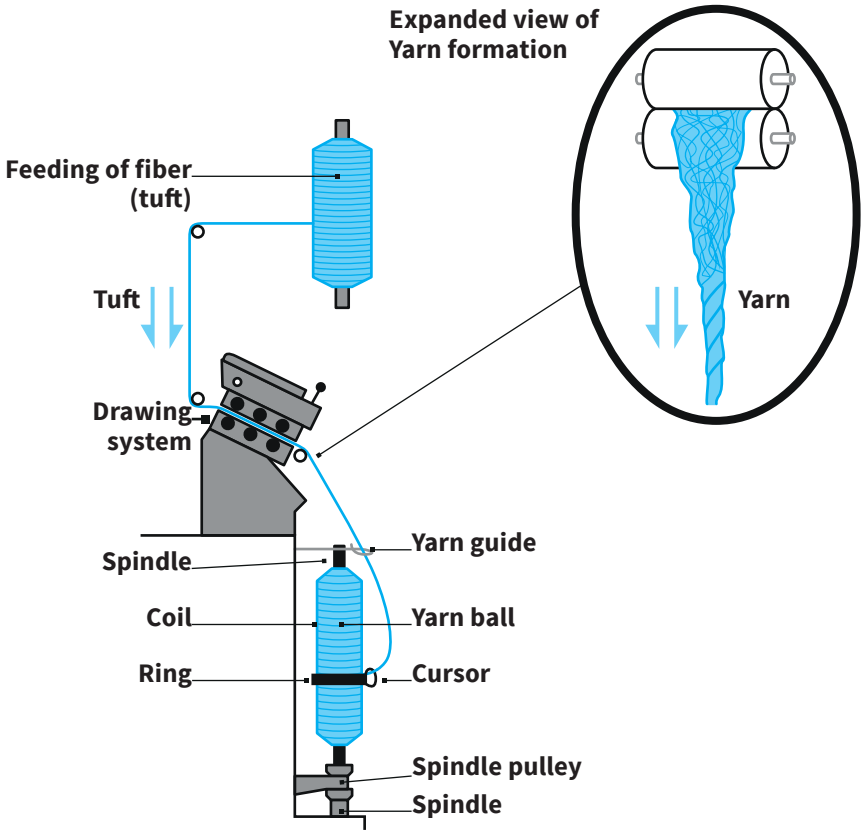


“Ring spun yarn has greater length and regularity of fibers”

Spinning machine and spindles with ring yarn

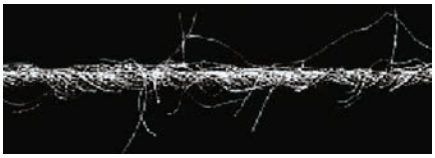
Operating diagram of a ring spinning

Functional diagram



Speedframe machine working

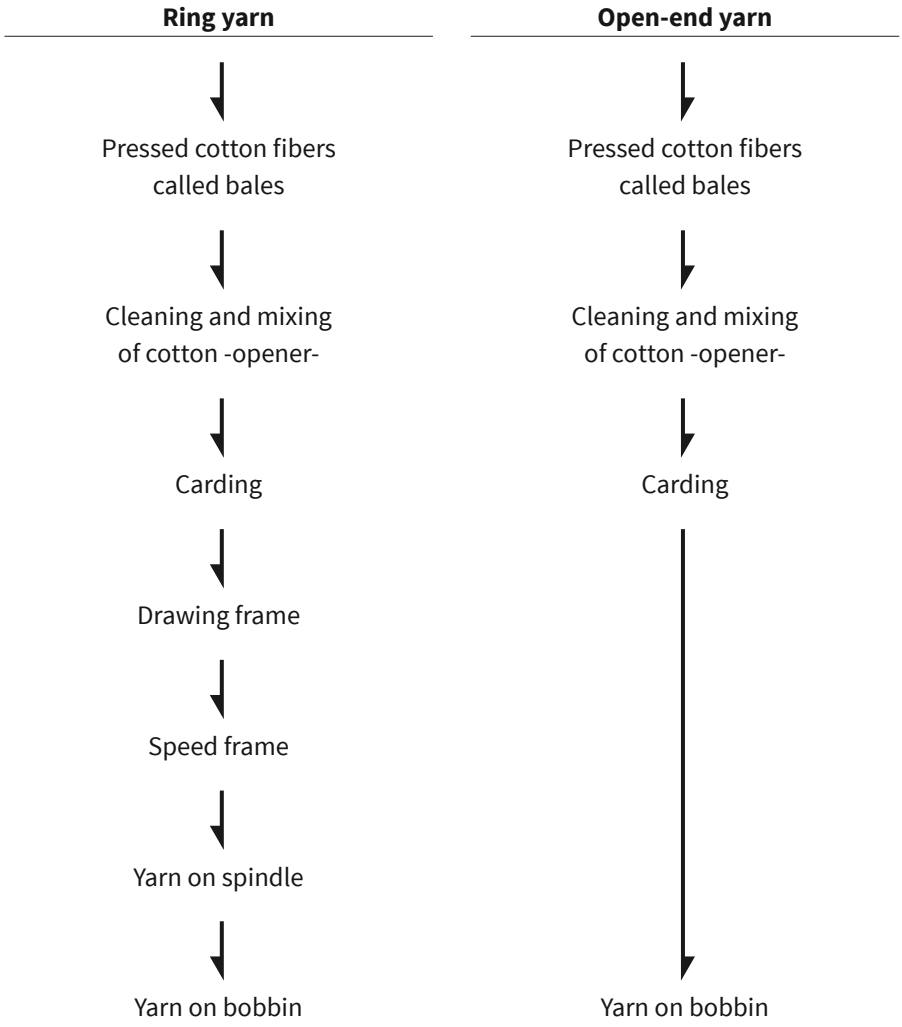
This way the ring system ensures that cotton fiber length is more regular, which implies better cotton quality and therefore higher costs (*Diagram 1*), because of additional operations as mentioned earlier.



Cotton yarn manufactured by ring system. Macro view

Production phases of the two most important types of thread

Diagram 1



Compact System

Currently a new type of spinning system is gaining importance. It is called the compact system and does not differ much from the ring system as regards the quality of the obtained thread.

In this case, a special system of fiber orientation exists which gets the thread at considerably higher velocities than through the ring system, but with a similar efficiency as that attained by using the open-end system. Other notable characteristics of compact spinning are considerable less fluffiness of threads manufactured by this system, compared with those produced through the ring or OE systems.

Thanks to this property, denim fabrics produced through a manufacturing system using compact-type thread, usually have a cleaner surface than fabrics with ring threads.

Handle, volume, absorption capacity, capillarity and softness are other characteristics that differentiate one type of spinning from the other.

Sketch of the final appearance of thread

Cotton yarn manufactured by ring system

Cotton yarn manufactured by open-end system

Cotton yarn manufactured by compact system. Macro view

2.2 Characteristics of Different Types of Yarn

Yarn destined for warp dyeing should present certain physical properties which make them suitable for their application in the phases of preparation, dyeing and subsequent operations.

Yarn is characterized according to the following criteria:

- Type of fibers
- Thickness or diameter
- Degree and direction of thread twist
- Strength
- Elasticity
- Regularity
- Absorption capacity

The type of fibers forming the thread (in respect of length, thickness and form) is determined by the origin of cotton (*Table 1*).

Thickness or diameter, called the count or number of the thread, are the numbers which describe characteristics of a thread and are preceded by the system symbol which was used to name them. In general, two types of systems can be distinguished:

- Direct systems: they determine how much a certain length of thread weighs, for example the Tex system, which refers to the weight in grams of 1000 meters of thread.

It is used mostly for continuous type nylon filaments, PES or Rayon.

- Inverse systems: the most common systems for cotton warp yarn destined for denim fabrics. They are based on calculations of the length of a certain weight of thread and are called inverse, because the higher the number, the thinner the thread.

Various inverse systems are known:

- Metric number: indicates the length in meters of 1 gram of thread, indicating also how many ends the thread has.

Example: Nm16.79/1. It means that 1 gram of this thread is 16.79 meters long and that in this case a single end thread was used.

- English number: indicates the number of hanks of 840 yards – equivalent of 768,08 meters – which weigh 1 lb (451,59g). The way of expressing the value is the same as in the case of Nm.

- Catalan number: similar to the English number, indicates the number of hanks of 777,5 m, which weigh 440 grams.

Conversions form

Table 2

Nm = **Ne** x **1.7**

Nm = **Ncat** x **1.767**

In this way (*Table2*) a thread of Nm 16,79 / 1 can also be called Ncat 9.5/1 or Ne 9.9/1.

The degree and the direction of thread twist is the number of turns given to the thread per unit of length. The purpose of the twist is to increase the cohesion of fibers in order to better preserve their position in the yarn.

Type of fibers

Table 1

Description	Length	Width	Thick	Avg. Wt.
American	60-71	32-35	19-22	500
Indian	48	22	17	410
Egyptian	50	30	20	740
Turkish	38	34	34	400

Length, width and thickness are in inches, average height and weight charts in libras

The direction of the thread twist can be either Z (left twist) or S (right twist) (*Figure 1*).

The twist influences thread resistance: the greater the twist, the higher the resistance, but less elasticity – which is the degree of thread recuperation, after it is stretched.

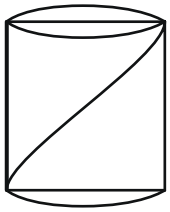
In warp threads the twist is usually greater because it has to endure more tension in the dyeing machine as well as later, in the loom.

Strength, which should be greater than the tensions that the thread has to endure during different phases of the textile process.

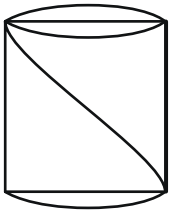
Elasticity is the degree of extension of the thread after it recovers its initial length. Depending on the type of thread, elasticity will be greater, such as in the case of the ring or compact yarn, and less in the case of open-end.

Z & S twist directions

Figure 1



Spindle rotating clockwise produces Z twist



Spindle rotating counter-clockwise produces S twist

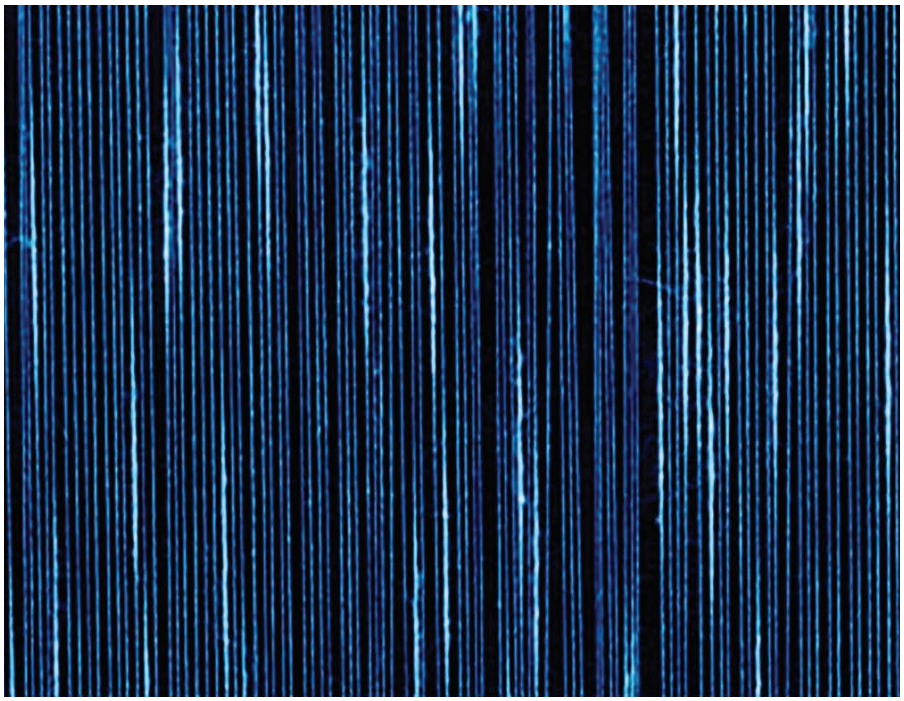
Regularity of the thread is determined by the presence or lack of:

- Knots: loops formed by fibers.
- Flames or slubs: thick parts of the yarn. The flame effect is an accumulation of fibers in alternate areas of the thread. These accumulations appear due to consecutive stretching and overfeeding of material. Each of these accumulations is called slub. When the number of slubs in yarn is very high, it is called multiflamé. The final appearance of a fabric with this type of thread is very uneven, with thicker and thinner areas, therefore washing the garment will eventually shows special uneven effects. This is the case of 'controlled unevenness'.
- Multicount: this type of thread irregularity is produced by alternating threads with different numbers, in such a way that areas of thinner thread (26/1c) pass on to areas of thicker thread (22/1c). Changes in periodicity, length and thread number can be controlled 'on-line', which results in 'controlled irregularities.' Depending on the available type of spinning, the same effects could be obtained in open-end type spinning as well as in ring or compact, by following pre-established spinning computer programs.
- Neps: entangling of fibers.

Depending on what effect is supposed to appear in the final garment, more or less irregularities are created.

Absorption capacity of a thread in a dye bath is determined by the quality of cotton and by the orientation of fibers in the thread. The greater the orientation in the same direction, the lower the absorption capacity.

Presence of flames or slubs in the yarn



Expanded view of slubs in the yarn

2.3 Influence of a Type of Yarn on Dyeing

During warp dyeing the quality of the yarn, as well as its type, is an important factor when it comes to enduring tensions with which the ranges work. Generally, open-end type yarn have a good absorption capacity in short periods of bath-material contact in dye vats. Ring type yarn also has a good absorption capacity, although lower than that of open-end yarn. If the ring yarn is additionally combed (with greater orientation of fibers in the same direction), absorption capacity is even lower, although yarn quality is the best.

2.4 Influence of the Type of Yarn on the Finish: Effects

The type of yarn used in the construction of a fabric and later in garment production decidedly influences the latter's final appearance.

Among the different existing possibilities, already commented, when it comes to type of yarn, ring or open-end, we can find differences as regards the regularity/irregularity, which influence decidedly the final appearance of the garment.

The use of yarn that display certain irregularities is related to the current tendency to produce final garments with worn-out or 'old' appearance. Attempts are also made to manufacture jeans using methods that were used in the past, when the operation of weaving was craftwork and the irregularities were produced accidently or by chance.

Technology and systems

03

At present there are three different types of preparation and dyeing systems for warp yarn denim which are carried out by the following ranges:

3.1. Rope dyeing range

3.2. Slasher dyeing range

3.3. Loop dyeing range

The first system used for denim was rope, while slasher and loop were incorporated later. Historically, you could observe a clear differentiation between geographical areas, which gradually disappeared. In the past, rope was a system widely used in North America and Japan, slasher in Europe and loop in South America.

"THE THREADS ARE SET PARALLEL OR FORMING ROPES IN A DENIM RANGE"

/ DENIM APPLICATION

Technology and systems

These types of continuous process systems differ in two aspects:

- The way of preparation and transportation of the yarn in the range
- Mechanical construction of the range

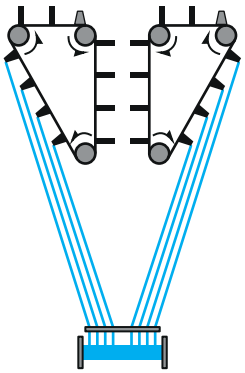
Before entering the dyeing range the yarn has to be prepared in the form of big cylindrical structures called beams where the threads are wound in optimal conditions of pressure and regularity. This process, which is begun by spinning cones is called warping.

Depending on the type of dyeing range, beams are constituted from yarn set parallel, flat and open in the case of slasher and loop, or arranged in small groups forming ropes, as in the case of rope range.

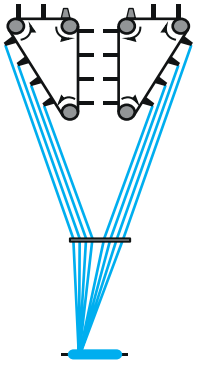
To conclude, the different types of existing machinery are made up of a certain amount of vats or boxes destined primarily for the preparation of the material and dyeing and also vats or boxes for cleaning or final rinsing.

Types of warp yarn preparation

Functional diagrams



Beam Warping (slasher and loop)



Ball Warping (rope)

Ball warp in rope form ready to dye

3.1. Rope Dyeing Range

In this type of denim range warp threads are extended along the range in the form of a rope. Yarn groups are composed of 300 and 400 ends forming ropes or cables.

The total width of rope ranges is taken up by a number of ropes ranging between 12 and 48, depending on the width of the machine. The total number of ends, depending on the number of ropes, can range between 3600 and 19200.

3.2. Slasher Dyeing Range

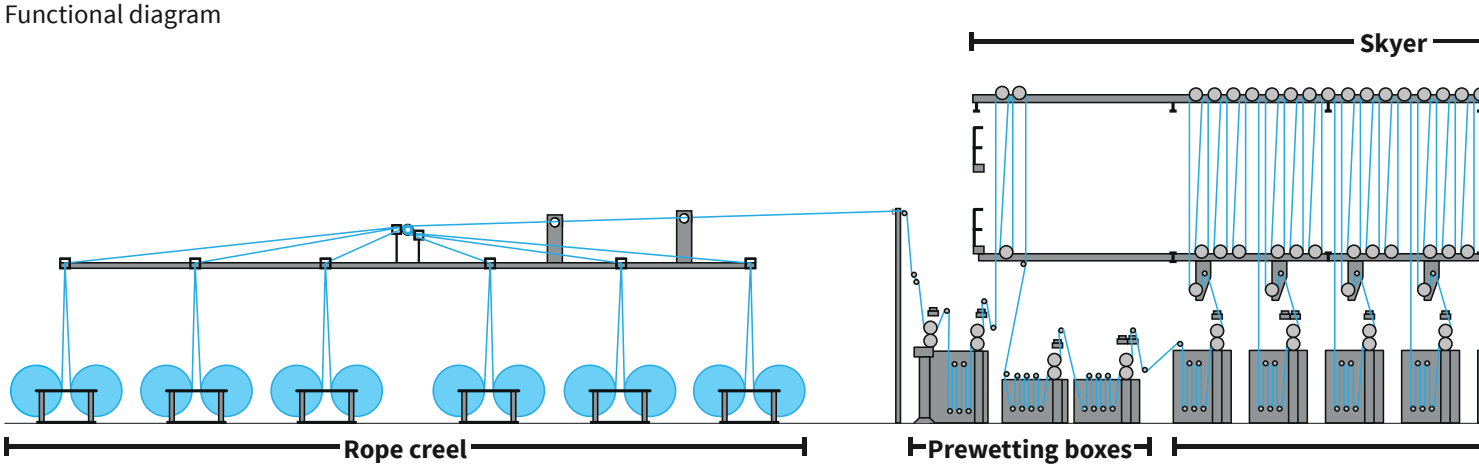
In this type of dyeing range, warp yarns are extended flatly and separately and are arranged parallel to each other, with a millimetric gap between them in individual layers. The range's width corresponds to the sum of all warp yarn.

The number of yarns per beam ranges between 300 and 750, while the total number of threads which make up the warp yarn vary between 3500 and 9500, according to the thickness and diameter of the used yarn, the type of warping range and the denim fabric design in the weaving process.

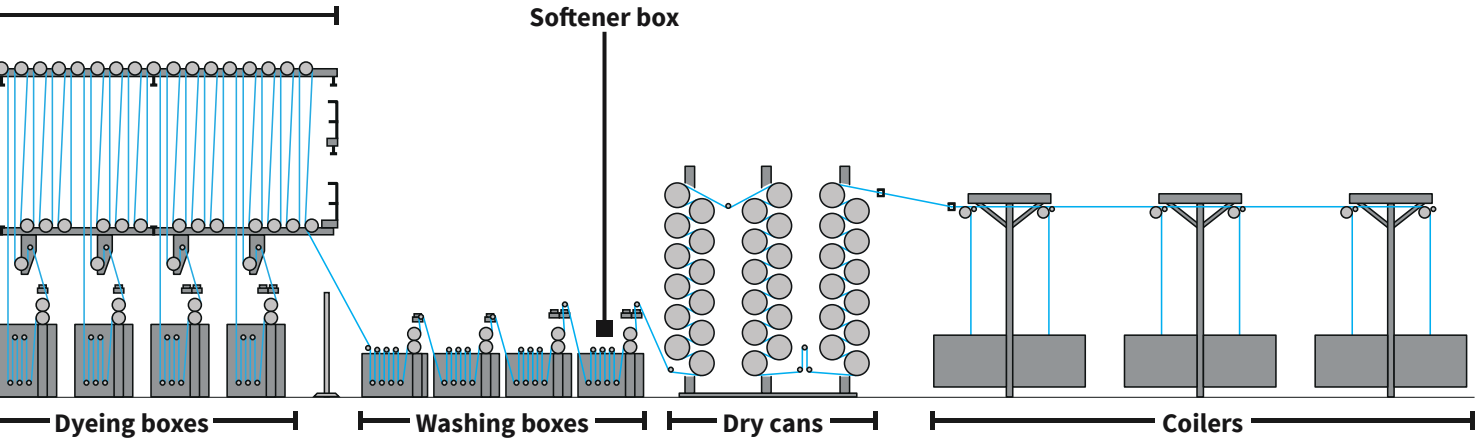
"Slasher and rope systems represent at least 95% of worldwide denim production"

Rope range

Functional diagram



View of ropes in the rope range



3.4. Loop Dye Range

The system of preparation of beams as well as the way of circulating yarn in the loop range is the same as in slasher range, which means that parallel threads enter and circulate in one layer.

In loop range, as opposed to slasher, yarn does not circulate along a machine composed of various boxes. After the impregnation with a solution of dyestuff and squeeze, the yarn pass through a closed circuit to enter again into the single vat.

This lap of yarn passes as many times as required through the single dyestuff impregnation vat. The number of times the lap passes through the same indigo vat is determined by various factors: the type of yarn used, the number of this yarn, the number of yarn forming the warp, as well as the desired color intensity.

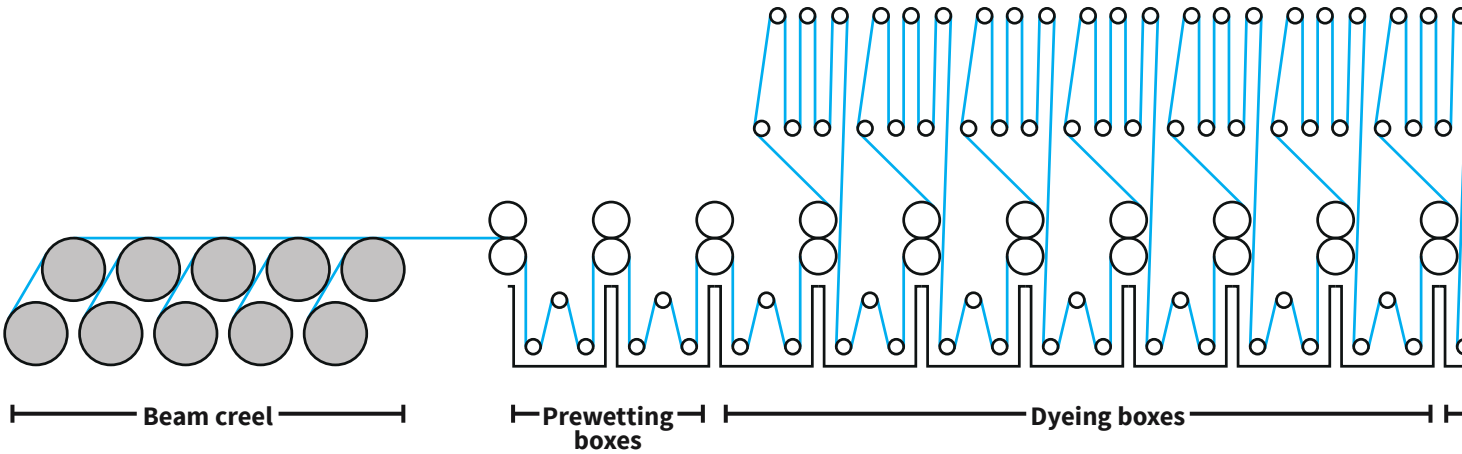
Beaming head

It is necessary to maintain precise control during squeezing, since during each pass, threads from different layers are being accumulated and all of them have to be squeezed out in an absolutely regular and homogeneous way in the squeezing mangle.

Once the warp sheet has passed through the dye vat, the latter turns to the final skying time to oxidize the indigo dyestuff, then washing, drying and sizing , in the form of a single layer (like in the slasher).

Sheetdyeing, slasher-dyeing

Functional diagram

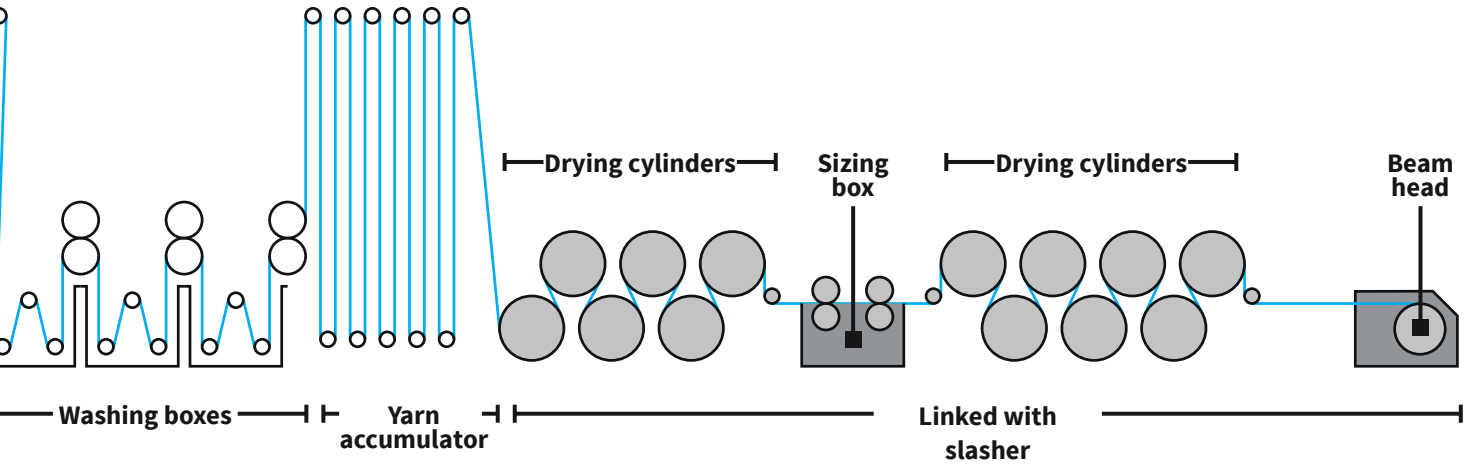


3.5. Analysis of the Ranges at Work

In each of the three ranges it is possible to apply sulfur dyestuffs without restrictions of intensity or fastness. However, with the new Diresul® RDT Indicolors (under the “Advanced denim” umbrella) alternative to indigo, small ranges begin to appear on the market. They consist of only one dye padder and 4 boxes, sufficient for sulfur dyeing application and having the advantage of reducing water consumption. They also have more flexibility with smaller and varied batches, which are a rising tendency on the fashion market.

In case of both open, one-layer slasher type ranges as well as multilayer ones such as loop there is a possibility of working with dye vats under nitrogen atmosphere. This is done in the effort to maintain homogenous chemical conditions in the bath for a longer time after the impregnation of the dye. It improves the quality of dyeing and fastness properties of the dyed yarn. It also requires less consumption of chemical products.

“Small and compact denim ranges begin to appear on the market”



Oxidation time (air passage or skying time) which the indigo needs for its complete oxidation (air oxidation), at the speed at which ropes are usually transported, is approximately 4-6 times longer than the duration of the rope-bath contact. This period depends also on other factors such as the degree of squeezing of each rope in the exit from the dye vat in the squeezing mangle and the speed of the range.

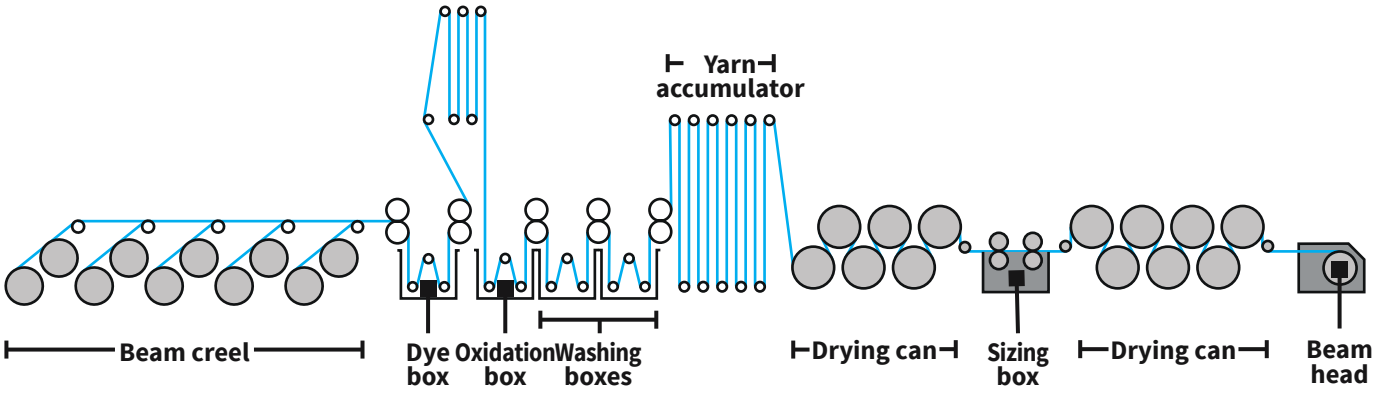
In case of sulfur dyes Diresul® RDT liq dyes, oxidation time is not of great importance because as a general norm our dyes need a chemical (type) oxidation in order to completely develop the color.

In rope type range, and especially in case of mercerized yarn, it is common to use a lubricant/softener in the last vat before drying in order to diminish friction between the yarn and to facilitate the opening of the rope (rebeaming).

This action facilitates the separation of one thread from another inside the rope. It also supports subsequent operations such as the formation of the beam (the rope is opened and later the ends are rolled out flatly on a cylindrical surface the warp beam) and the chemical finish (sizing).

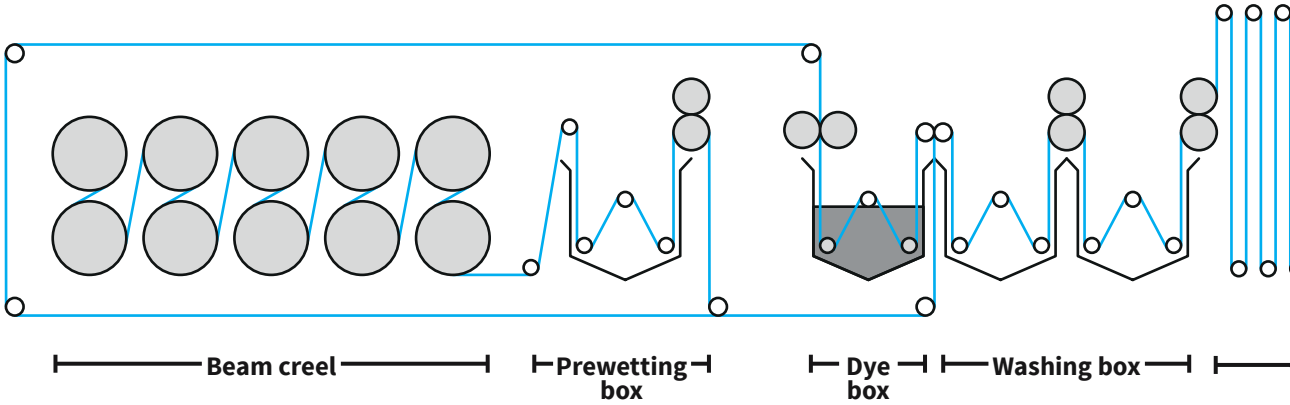
Advanced denim

Functional diagram

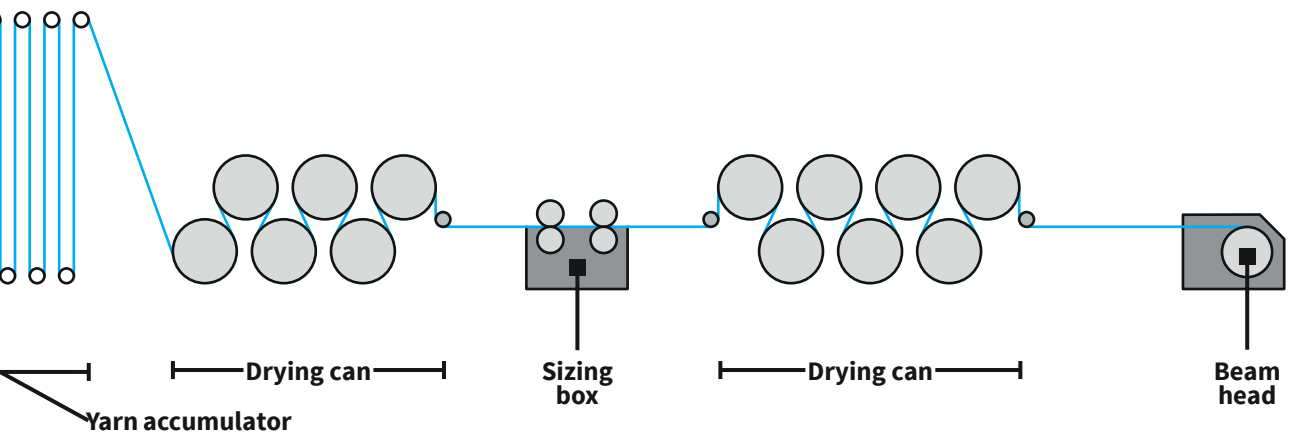


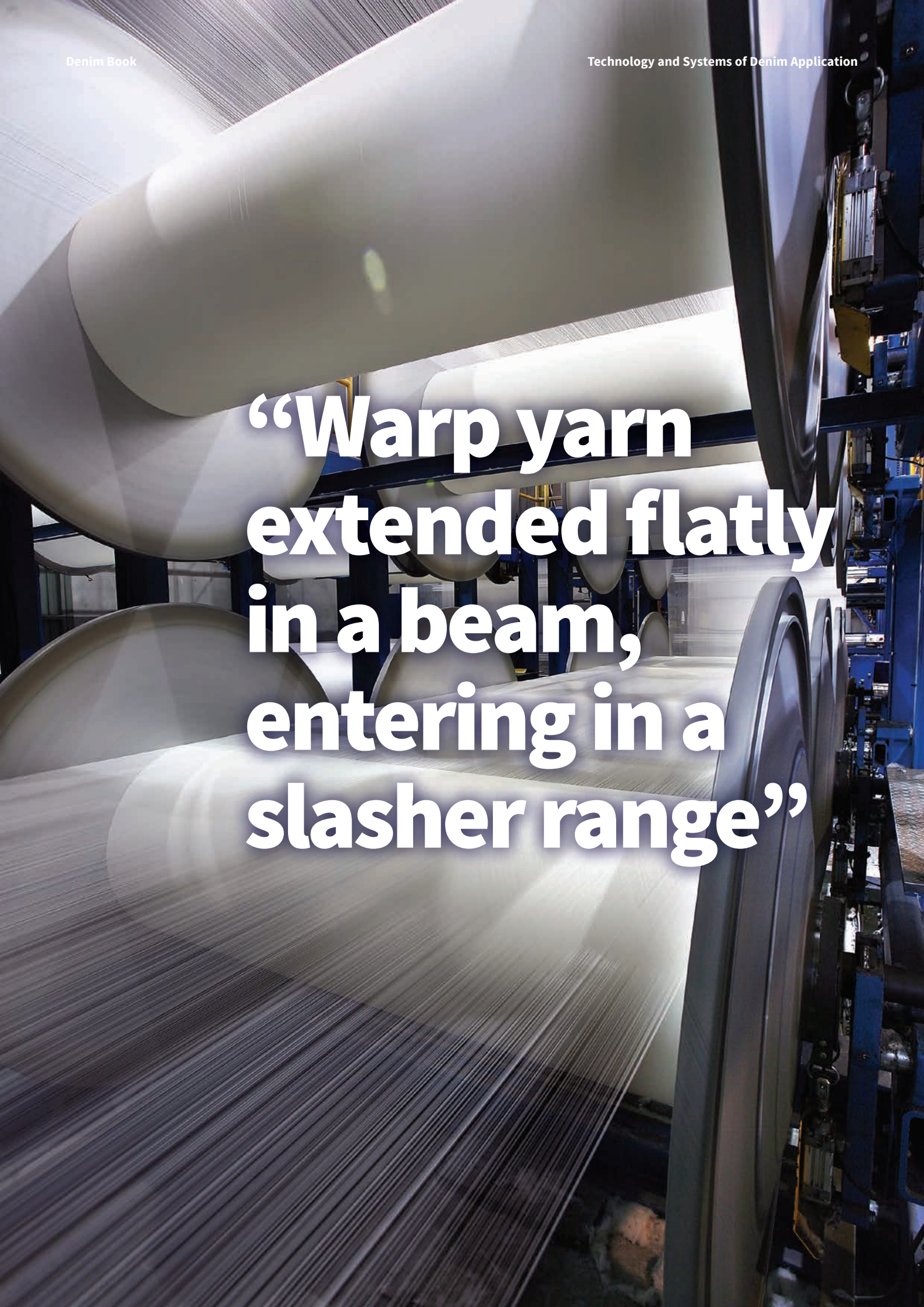
Loop range

Functional diagram



Ropes entering the range from ball warp





“Warp yarn extended flatly in a beam, entering in a slasher range”

Comparison between ranges

Table 3

Range	Advantages	Disadvantages
Rope	• High productivity • No side-center variations • Low waste of thread • No time lost during lot change • Higher intensities of Indigo	• Low flexibility • Taking up a lot of space • Necessity of employing an additional step of opening ropes after dyeing
Slasher	• More compact design • Flexibility in dyeing processes • Continuous process • Possibility of adaptation of the machine in order to obtain more superficial or ring sulfur dyeing	• Risk of selvedge-center variation • Greater risk of thread rupture • Thread loss during change of article • Limitation in high intensities of indigo
Loop	• Very compact system • Minimal consumption of chemical products, dyestuffs and water	• Risk of selvedge-center variation • Greater risk of yarn breakages • Thread loss during change of article • Limitation in high intensities of indigo • Limitations in flexibility as regards different processes and dyeing methods.

Beam warp for slashering

Pretreatment

04

Preparation of yarn before dyeing can be realized in rope ranges as well as in loop and slasher type ranges. They just need to have all the necessary characteristics in terms of the number of pre-dyeing boxes and the possibility of maintaining constant conditions.

Among the main preparation operations, which can be carried out on the warp yarn, we include:

4.1 Prewetting

4.2 Scouring

4.3 Mercerizing

4.4 Special Operations

In all of them the main aim is to obtain a regular absorption in yarn, which is a fundamental requisite for successful dyeing.

“THE WAY TO OBTAIN A REGULAR ABSORPTION IN THREADS, A REQUISITE FOR SUCCESSFUL DYEING”

/ OF THE WARP YARN

Pretreatment

4.1 Prewetting

The quickness of prewetting is the most important parameter of the warp yarn wetting agent and is due to time limitation in the contact between the fiber and the bath in normal application conditions.

The prewetting of the yarn should be uniform and constant. If this condition is not fulfilled, subsequent differences in the degree of penetration of the dyestuff could appear, and as a consequence, different intensities.

The wetting agent of anionic nature is usually applied at room temperature with at least one post-rinsing, in order to prevent possible problems with stability when the yarn enters successive dye vats.

It is also recommended to use a dispersing agent, capable of maintaining dispersed those oils and impurities which are being removed during prewetting.

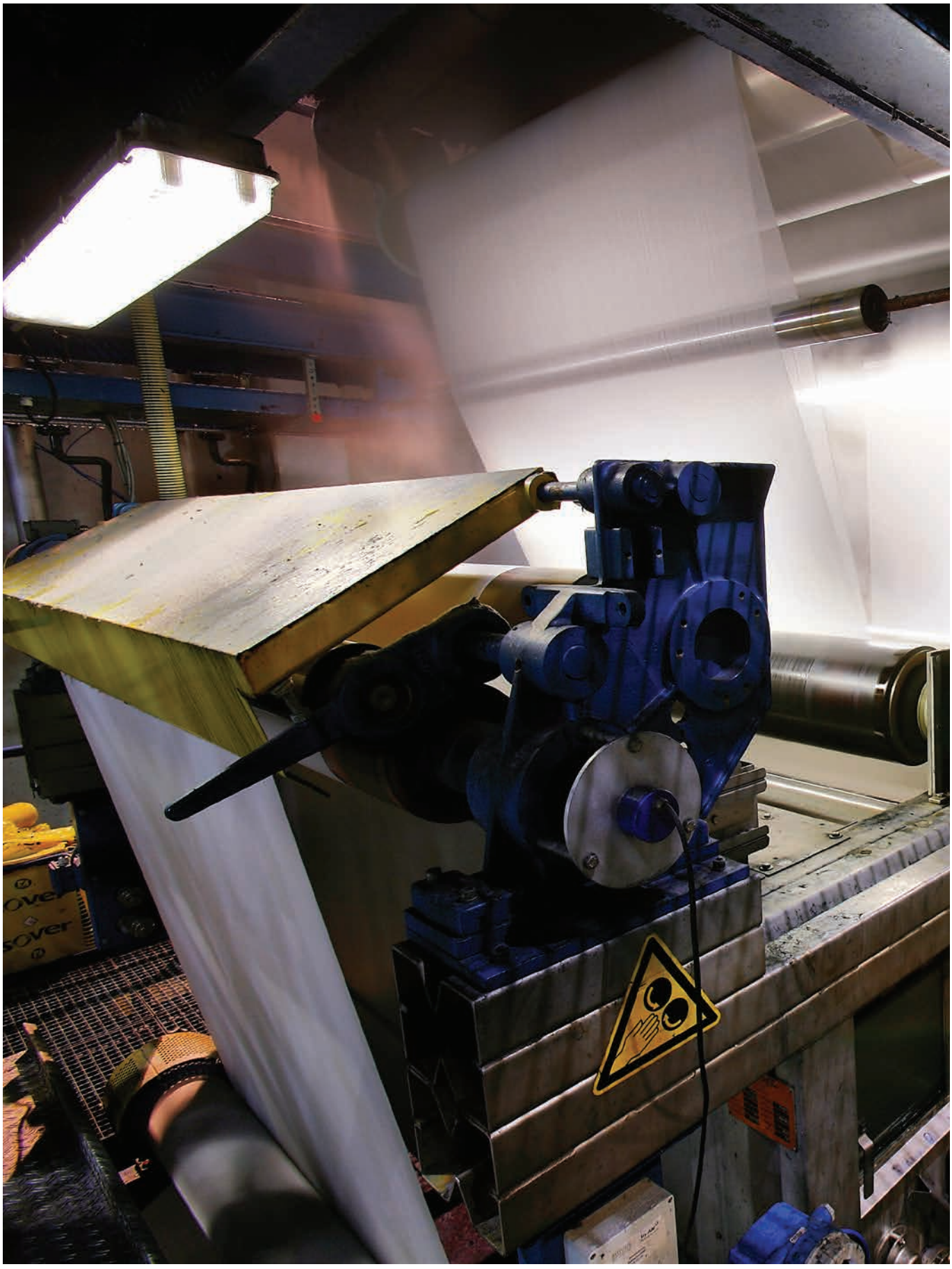
4.2 Scouring

The aim of this operation is to eliminate natural impurities of cotton such as fat, organic matter, wax, pectin and even heavy metals and/or alkaline earth metals, in order to prevent possible interferences in subsequent operations.

As a result, regular dyeings are obtained with optimal performance of the chemicals and dyestuffs used.

In order to scour the cotton some detergents-emulsifiers, alkali, sequestering and wetting agent, which resist medium -low alkalinities should be used.

It is important to obtain a regular cleaning of the cotton and this is the reason why the turn over of the bath should be quick enough to avoid it being filled up with too much dirt from the yarn. This could produce certain irregularities in subsequent dyeing operations.



Denim range. Prewetting vat

4.3 Mercerizing

This process consists of subjecting yarn to high alkalinity during a short period of time, which will vary depending on the velocity and the type of the denim range used.

The effect produced on cotton involves a change in its crystalline structure, a swelling or rounding-off of the cellulose fiber and its shrinkage. This change in structure should be controlled because high tensions to which threads are exposed, breakage could easily occur.

The quality and the origin of cotton influences the degree of mercerizing.

This way, mercerizing treatment helps to obtain:

- More intense colors
- Brighter shades
- More ring dyeing, superficial dyeing

This operation can be carried out always when the quality of the thread allows it. Generally, the typology of the open-end yarn accepts mercerizing. In the ring type yarn it is necessary to ensure that the piecing-up has been very well done.

The mercerizing process is basically carried out by using caustic soda as an alkali. Its concentration should be the necessary one to obtain a density of the bath with values between 6-22º Bè, although this value should be adjusted to the requirements of each type of yarn.

Other auxiliary products include:

1. Wetting agent: stable to high alkalinity and with a quick prewetting capacity. Preferably of anionic nature.

2. Sequestering agent: especially for heavy metals such as iron and alkaline earth metals, such as calcium and magnesium. Stable to high alkalinity.

3. Dispersing agent: optional. On the market there are products which combine various functions.

“The mercerizing process produces a change in the crystalline structure of the cotton fibers”

The best mercerizing effect is obtained in cold temperatures, but it is usual to find applications of up to 30ºC. This is because an exothermic reaction occurs between the alkali and water, which increases the temperature of the mercerizing solution.

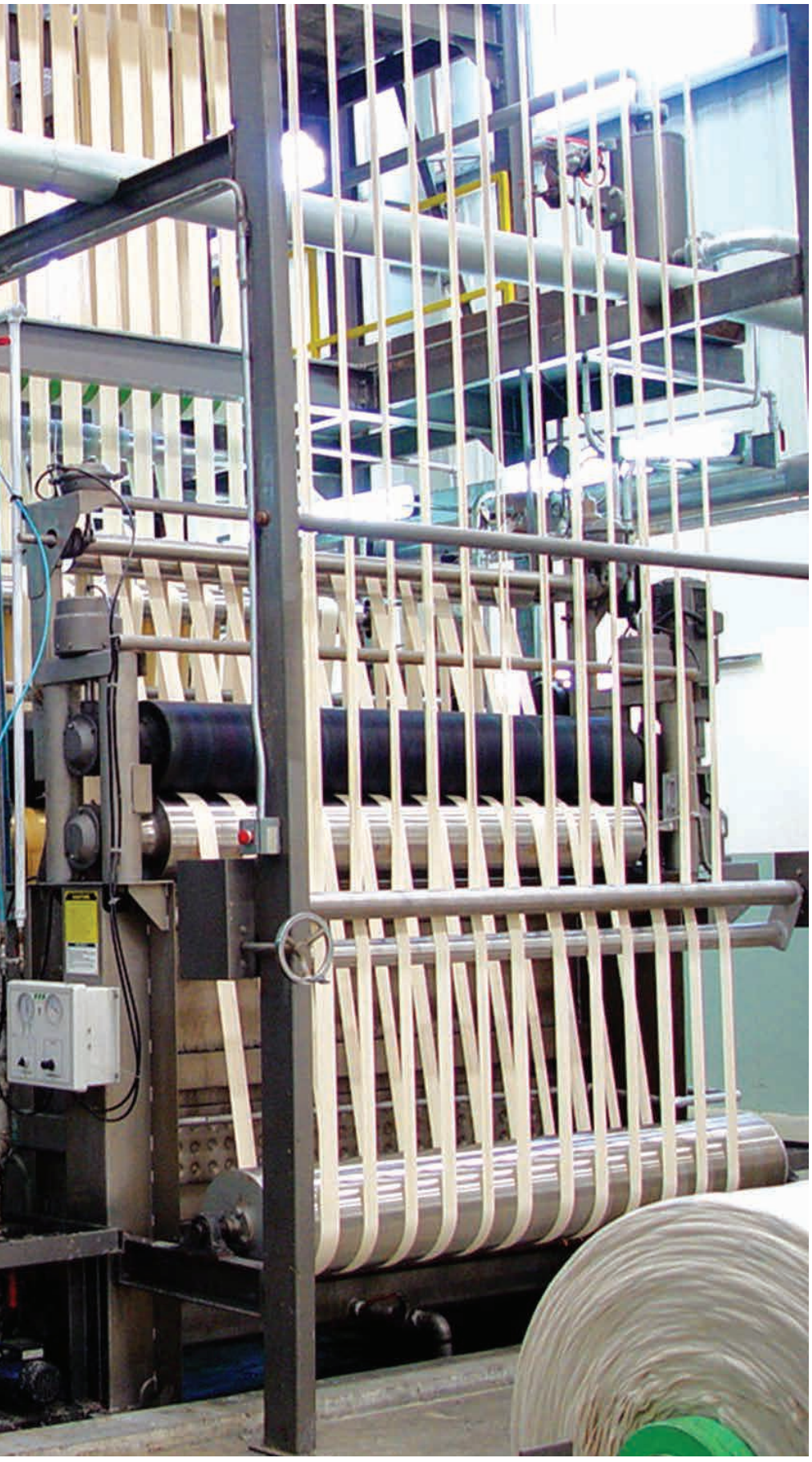
After the application, the yarn has to pass through a relaxation area where shrinkage/swelling of the cellulose fiber occurs. It is important at this moment to control the tension of the thread to avoid breakage.

The contact between the alkali and the yarn should last 30-60 seconds to obtain a complete reaction and swelling of cotton.

Finally, it is important to eliminate the excess alkali from the fiber. For that purpose an energetic washing of the yarn is realized, in order to eliminate the rest of alkalis or at least minimize their presence.

This is especially important when a subsequent dyeing with indigo is going to be carried out. In the case of sulfurous dyestuffs Diresul® RDT,

Details of a preparation vat in a slasher type range



Rope denim range. Preparation vats in front of dye vats

a slight presence of alkali in the bath does not have a negative influence.

To sum up, the factors which affect the degree of mercerizing are the following:

- The origin and the quality of cotton
- The temperature of application
- Degree of alkalinity
- Fiber-solution reaction time
- Auxiliary chemicals

4.4 Special Operations

In many cases, open-warp dyeing slasher or even rope ranges, are currently fitted with vaporizers which allow a more complete preparation of the material.

The steamer is usually located immediately after the first squeezing of the yarn, following the prewetting vat.

This type of installation allows to carry out for example extra energetic scouring and even processes of semi-bleaching, in this case it is necessary to add a preset quantity of hydrogen peroxide and a stabilizer chemical.

The stabilizer product should be capable of controlling the release of oxygen from hydrogen peroxide so that it correctly conducts the bleaching, without spoiling cellulose fiber resistance (oxycellulose formation due to a catalyctic attack which can cause yarn breakage).

This process considerably improves the regularity of subsequent applications, as well as the obtaining of a higher degree of hidrophility.

In any case, the type of preparations carried out on the yarn depend on the type of existing installation, as well as on the final effect which the manufacturer wants to obtain in the planned article.

Dyeing

05

For more than a century, indigo has been used as the main dyestuff in the production of standard blue denim cotton fabrics. However, indigo has a limited range of effects and during the 1980s, traditional sulfur dyestuffs were combined with indigo in topping and bottoming to create new looks and effects.

In the 1990s, in order to widen the jeans color range, sulfur dyestuffs started being used individually, not combined with indigo. Black has always been the second most commonly used dyestuff after indigo blue. Other colors, such as brown, olive, burgundy etc. were incorporated as well.

Today the scope of possibilities in effects and colors is wide and the new Archroma specialties: indicolor, make possible the option of Indigo free blue denim.

"THE SCOPE OF POSSIBILITIES IN COLORS AND EFFECTS IS WIDE NOW IN WARP YARN DYEING"

/ WARP YARN DYEING

Dyeing

5.1 The Origin of Denim: Indigo

The indigo dyestuff has not undergone big modifications, neither in its chemical form nor in the way of application.

Commercial forms in which indigo is offered are diversed. However, powder or granulate is still the most common, in relation to liquid or dispersed forms which are being established on the market.

From a chemical point of view indigo is based on an oxidation-reduction principle, like in the case of sulfur dyestuffs.

Indigo is an insoluble pigment, without affinity for cellulose in oxidized state. For application the dyestuff should be in reduced leuco-alkaline, soluble state.

In order to maintain the reduced conditions of indigo, a particular concentration of alkali is used (usually caustic soda) as well as strong reducing agent, the sodium hydrosulfite, as well as auxiliaries like dispersing or wetting agents, etc.

Indigo dyebath should be controlled by means of chemical parameters such as pH and reduction. Significant changes in these values could make way for variations in the reaction's oxidation-reduction kinetics, which in turn might lead to differences in the diffusion of color, shade and intensity (*Diagram 2*).

The passage of yarn through a denim range consists of impregnation in preparation, dyeing and washing vats.

Pre-reduced indigo is applied in numerous big capacity dye vats, containing a low concentration of the dye. The indigo is applied to the yarn by means of repeated impregnations, and then passed through the skyer to become gradually oxidized.

Contrary to sulfur dyes, indigo is characterized by a low affinity and a quick oxidation tendency. Due to these two factors the dye needs several impregnations in order to reach medium-high intensities (from 4-6 to 10-12 impregnations).

After impregnation and squeezing in the squeezing mangle, the yarn should spend some time in the air duct, where the indigo dye becomes gradually oxidized. It becomes insoluble and fixed on the yarn by means of weak bonds (Eg Van der Waals bonds). This way the indigo is deposited in as many layers on the yarn, as impregnations take place. In any case the final effect of indigo on the yarn is superficial, due to the low diffusion of the dye.

This characteristic implies certain limitations as far as fastness is concerned, especially when high intensity colors are required.

During the dyeing process it is necessary to control certain chemical parameters, such as:

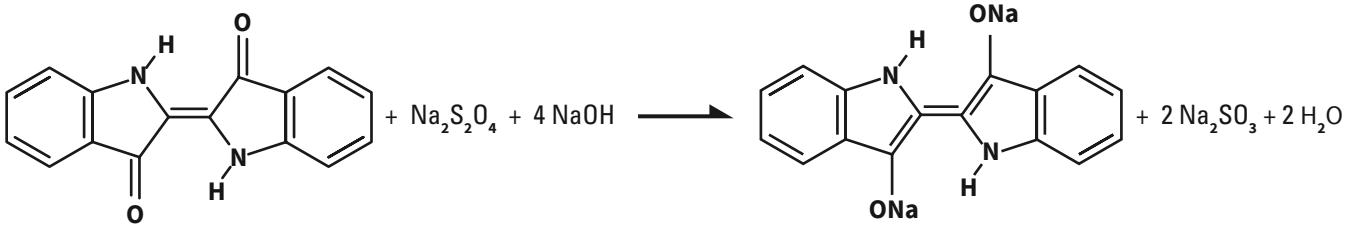
- Alkalinity (pH)
- Reduction (mV)
- Temperature
- Concentration of indigo in the bath
- Impregnation time; impregnation time of the yarn in the dyebox

The usual **pH** values move between 11.5-13. Values lower than this range could trigger inconsistency in shade during dyeing. This is due to the fact that indigo presents a chemical form called acid vat, insoluble and without affinity. Generally at higher pH values the shade is more reddish, dye diffusion is greater and the intensity is lower.

Reduction is measured as a function of the concentration of free sodium hydrosulfite for an optimum state of indigo reduction. Generally a certain concentration of this reducing agent is used which assures the presence

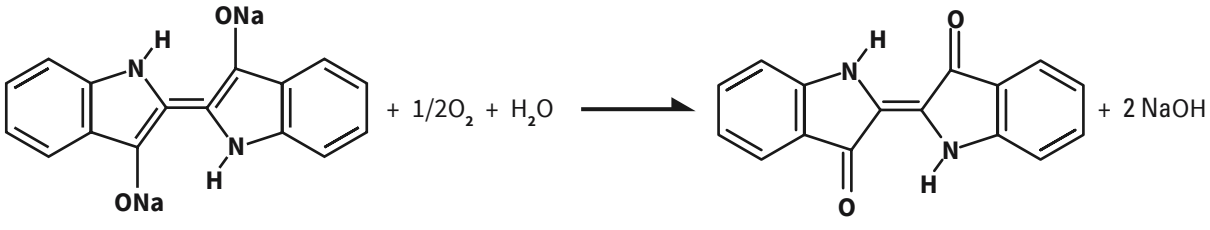
Reduction

Diagram 2. Indigo molecule in its reduced form and after oxidation



Indigo + Dithionite + Alkali → **Leuco-Indigo** + Na- Sulfite + Water

Oxidation



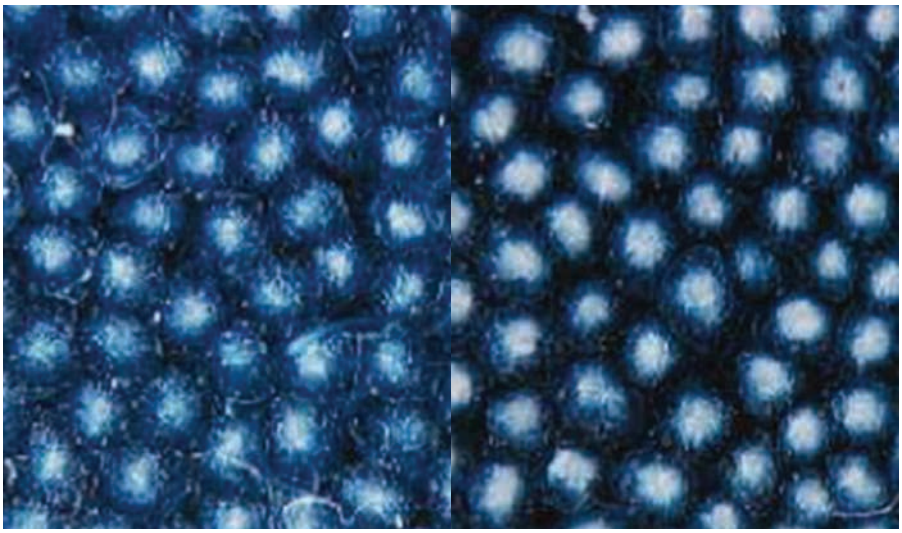
Leuco-Indigo + Oxygen + Water → **Indigo** + Alkali

of sodium hydrosulfite without reacting, that means free in the indigo bath to prevent excessively quick oxidation which causes low fastness of the washing. The usual values of free sodium hydrosulfite vary, also depending on the type of range used (rope or slasher). The general rule is that the values run from a minimum of 0.2 g/liter to more extreme values of 7-8 g/liter.

The **temperature** of application is room temperature. Considerable differences in temperature in the same workplace produce variations in the degree of indigo oxidation and a greater consumption of hydrosulfite. The higher the temperature the greater the degree of oxidation and consumption of sodium hydrosulfite.

The **concentration of indigo** in the bath can be measured by conducting a titration reaction at a laboratory or by using a spectrofotometer and taking a sample from the indigo bath.

The **impregnation time** of the dye in the dye vat is directly related to the speed at which the yarn passes through the denim range.



A section of a cotton yarn dyed with indigo where the superficial effect can be observed

An example of an indigo recipe with 6 consecutive impregnations and 6 skying cycles:

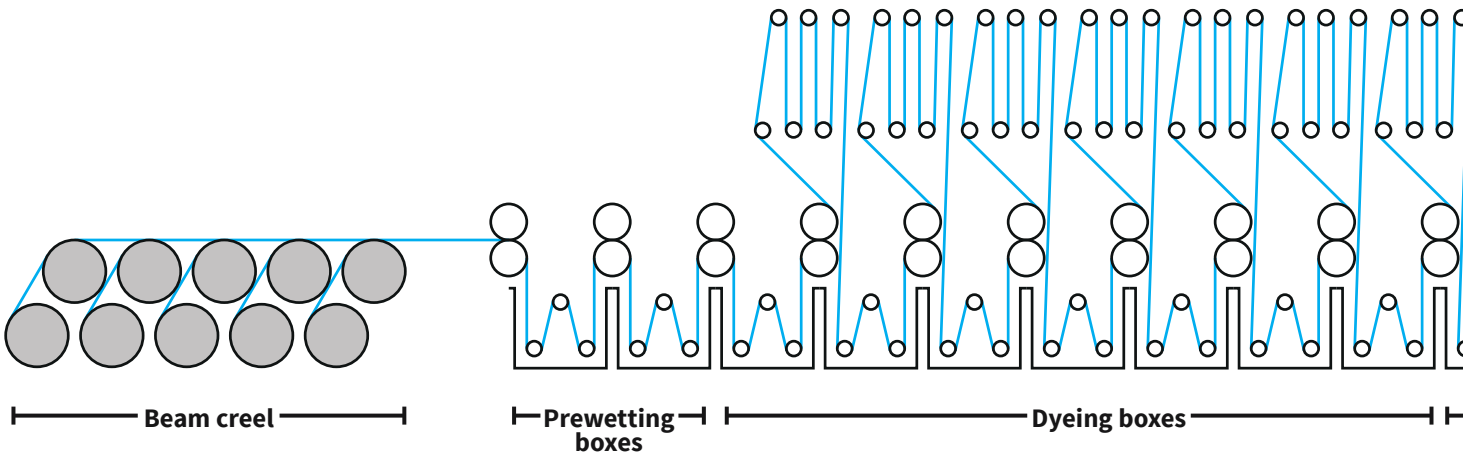
Concentration of indigo in the bath: 4.00 grams/liter (considering powder indigo) 6 impregnations of indigo normally take on cotton fiber approximately 2.4% of indigo (This percentage indicates that 2.4 grams of indigo is fixed on 100 grams of cotton yarn).

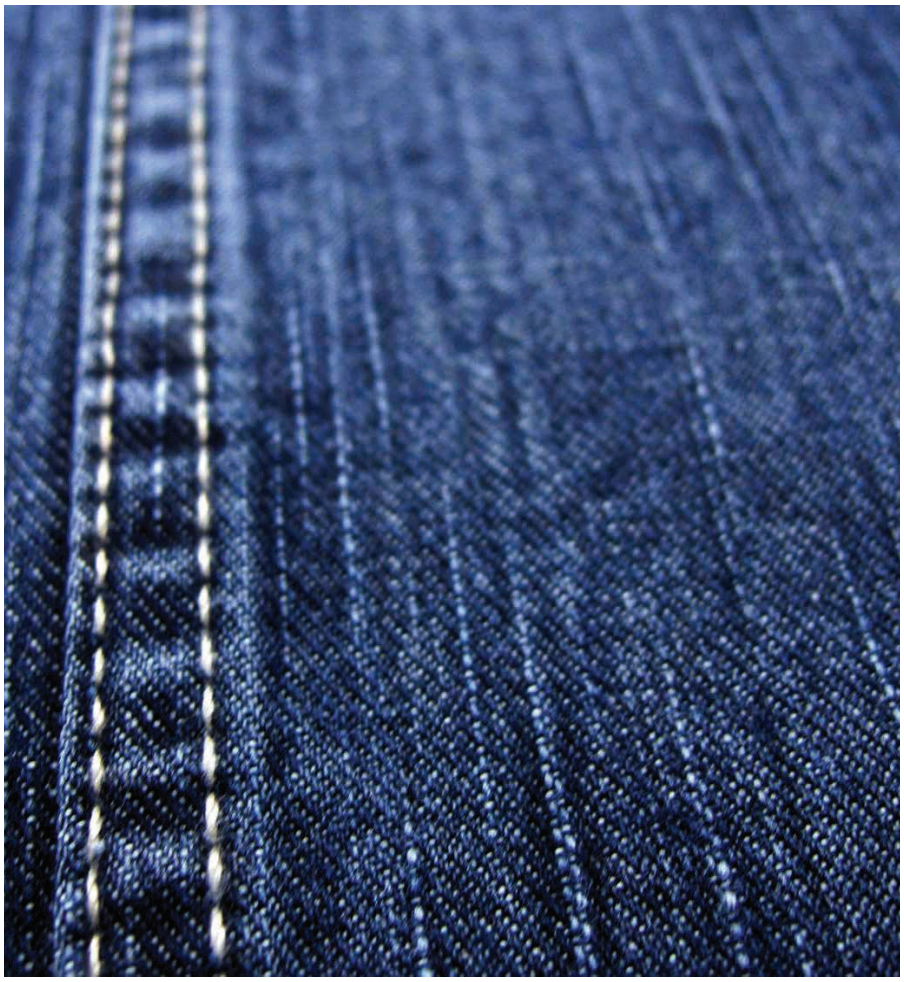
Just as it can be observed in the previous Redox reaction, the indigo needs a relation of specific quantities of caustic soda and the sodium hydrosulfite in order to reach the soluble leuco-alkaline state.

Concentration of caustic soda in the bath: 3.6 - 4.8 ml (considering NaOH 48º Bè). Normally the ratio cautic soda

Sheetdyeing, slasher range

Functional diagram



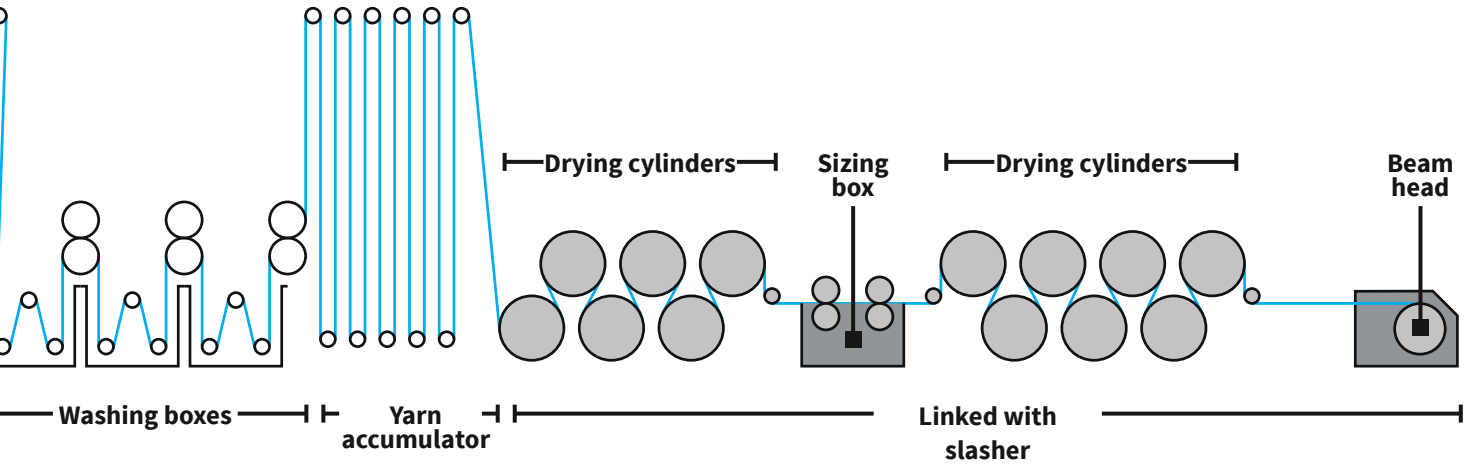


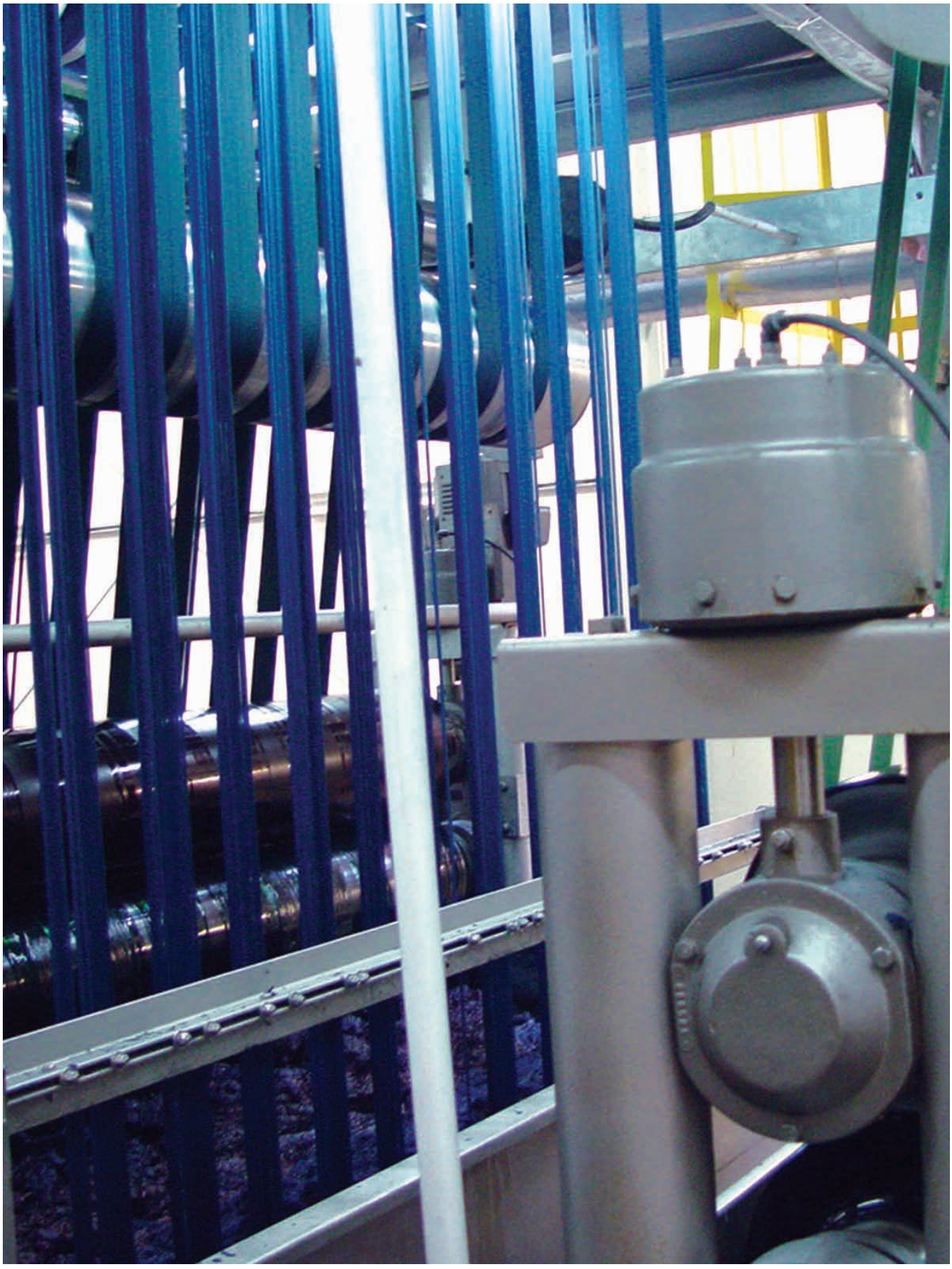
Detail of denim fabric with indigo

48 Bè /indigo is: 0.9 - 1.2 grams caustic soda 48 Bè per 1 gram of indigo (this relation is an average proportion of what is usually used, since it might be slightly higher or lower).

Concentration of sodium hydrosulfite in the bath: 4 - 6 grams (1.0 - 1.5 g of sodium hydrosulfite/gram of indigo, as an approximate or average value).

Additionally, other auxiliary dyeing agents can be incorporated such as sequestring, dispersing and wetting agent.





Detail of the colored ropes coming out of an indigo dye vat

5.2 Sulfur Dyestuffs

Sulfur dyestuffs evolved from commercial powder forms with a high content of sodium sulphide into the present day liquid forms with a minimal content of sodium sulphide. The latter are more practical and ecologic, such as in the case of Archroma sulfur dyes, Diresul® RDT liq.

The sulfur dye molecule can be depicted in the following way (*Diagram 3*).

These molecules are often long and contain few solubilizing groups. In fact, just as in the case of indigo, sulfur dyestuffs are insoluble in their "pigmentary" form which is their oxidated state.

Sulfur dyestuffs transform into their soluble pre-reduction form when reducing agents are added in an alkaline medium. The application of these dyestuffs to cellulose fibers is based on the oxidation-reduction balance of their molecules.

Although the chemical rule of application of both sulfur and indigo dyes is very similar, the physical behavior of the sulfur dye presents greater affinity and diffusion capacity in the yarn.

This implies more changeable and compact conditions of application, since, in order to obtain medium high intensities sulfur dyes need only one or two dye vats.

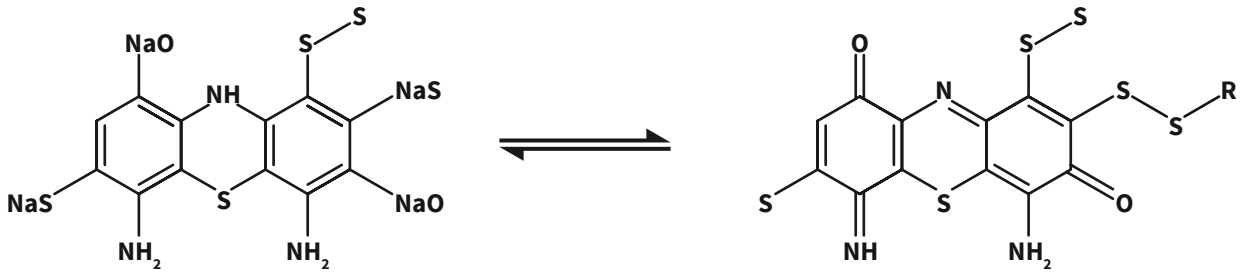
Sulfur dyestuffs require a much more energetic oxidation in order to completely develop the final color. Contrary to indigo, which becomes completely oxidized while passing several times through air passage skying, the sulfur dye needs a chemical oxidation through the impregnation of the yarn in a solution with some kind of oxidizing agent.

Most commonly used oxidizing agents for sulfur dyeing are: sodium bromate at acid pH, hydrogen peroxide at both alkaline and acid pH and sodium chlorite.

In the oxidizing bath the dye returns to its initial state - insoluble but already post-reaction and fixed inside the fiber.

Reduction and oxidation

Diagram 3. Sulfur dye molecule in its reduced and oxidation form



Soluble reduced form (with affinity)

Insoluble oxidized form

NaO-R-SNa ⇌ (Oxidant / Reducing) **O=R-S-S-R=O**

Quinonic reacting group
Responsible for color development

Thiol reacting group
Responsible for color fixation

Quinonic reacting group
Oxidized form
Color totally developed

Thiol oxidized group
Sulfur molecules linked to each other and also to the cellulose.

The chromophore is always united by disulfuric bridges (S---S)

5.3 Bottoming/Topping Processes

Bottoming/topping are the dyeing processes in which the indigo is combined with an additional dye in different dyebaths.

These processes were created for two major reasons:

- The need to obtain high intensity colors with acceptable fastness values in yarn dyeing.
- Market demand for diverse shades of blue color.

There are various dye ranges which can be used in these processes, such as reactive dyes or vat dyes. However, due to the changeability of the application conditions, the main range of dyes used together with the indigo is the sulfur dye range.

The names of the processes refer to the order in which the sulfur dye is applied with respect to indigo.

In the case of bottoming the sulfur dye is applied before the indigo.

In the case of topping the sulfur dye is applied after the indigo.

Dyeing range with different vats where both bottoming as well as topping processes are carried out

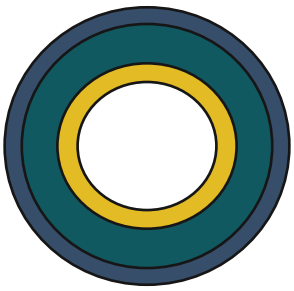
On the picture below you can see a cross section of a thread showing the effects obtained with a bottoming process, depending on the conditions of application.

The illustrated cases show two examples of extreme effects which can be obtained through the bottoming process. The presence or absence of the steamer is the deciding factor.

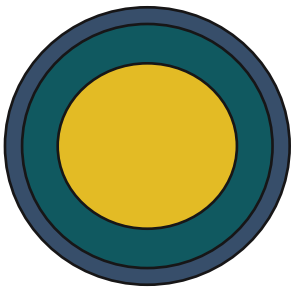
Bottoming Effect (Sulfur Dye + Indigo)

The most popular bottoming processes are used to obtain a ‘dirty’ look (with brown or orange sulfur dyes), a ‘greenish cast’ look (with yellow or olive dyes), a ‘reddish cast’ look (with burgundy or red dyes) as well as more shiny shades (with blue or green sulfur dyes combined with indigo).

The effects and contrasts on the fabric or garment are different depending on the color, the concentration and the diffusion of the dye.



Cotton yarn: non mercerized yarn
Temperature: medium
Immersion time: short
Wetting agent quantity: low
Steaming: no
Dye concentration: medium/low



Cotton yarn: non mercerized yarn
Temperature: high
Immersion time: long
Wetting agent quantity: high
Steaming: recommended
Dye concentration: medium/high

Keys on cross section on a thread pictures

Yellow sulfur dye Diresul® RDT liq — Interface indigo - sulfur dye Diresul® RDT liq — Indigo

“The main range of dyes used together with the indigo is the sulfur dye range”

However, there are also other factors which influence the intermediate effects, such as: the preparation of cotton, concentration of the dye, concentration of the wetting agent, impregnation time and the temperature of the dye bath.

The steamer is an additional element in the denim machine. It is becoming more and more popular due to the fact that with this mechanism the sulfur dye has a greater capacity of diffusion while maintaining the reduction conditions and solubility during a longer period of time.

If a high concentration of the sulfur dye (over 100g/l in the dye vat) is combined with the steamer effect, the contrast between the sulfur dye and the indigo is more distinct in the thread section. This way it is possible to obtain more diverse fashion effects.

Without steamer conditions and with the sulfur dye concentration lower than 100g/l the contrast effect with the indigo is less pronounced due to the fact that the diffusion of the sulfur dye in the fiber is lower. That is why the obtained dye is a bit more superficial and presents a certain blending between the sulfur dye and the indigo.

A clear example of a blending or combination of a sulfur dye with indigo is the case of bottoming with sulfur yellow. The interface between indigo blue and yellow can be observed after local scratching which reveals a greenish shade – the result of the combination of the two colors.

On the other hand, there are application processes which minimize blending. That is why two different phases of color can be observed.

Topping Effect (Indigo + Sulfur Dye)

The sulfur dye topping process is performed after the indigo so that the characteristic indigo effect of superficial dyeing prevails in the yarn. It produces a change of shade of the indigo blue due to the sulfur dye effect applied later. Even in the specific case of using sulfur yellow, the final effect is a greenish shade, due to mixing sulfur yellow and the indigo.

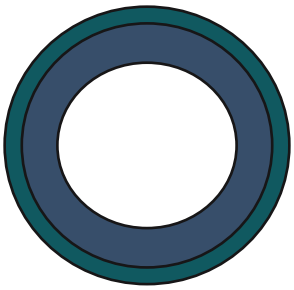
In this case the center of the thread remains uncolored because neither the sulfur dye nor the indigo are capable of entering there.

Only in case of long immersion time and high concentration of wetting agent in the dyeing recipe, the diffusion of the sulfur dye may increase.

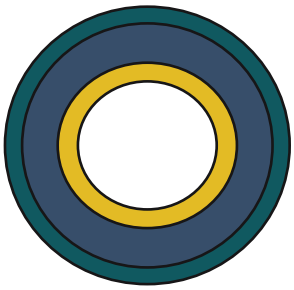
Identically as in the case of bottoming, there are other parameters which influence the change of the dyeing conditions as well as the final effect on the fabric. These are: the preparation of cotton, concentration of the dye, concentration of the wetting agent, impregnation time and the temperature of the bath.

The presence or the absence of the steamer in the case of topping also influences the diffusion of the sulfur dye (although a bit less than in the case of bottoming) due to the fact that the indigo already creates a physical 'barrier' on the thread. That is why the sulfur dye does not have a great capacity of diffusion in the fiber.

Denim fabric after a bottoming-type application. The initial dyeing performed with a sulfur dye and later with indigo



Cotton yarn: indigo dyed yarn
Temperature: medium
Immersion time: standard
Wetting agent quantity: standard
Steaming: no required/optional
Dye concentration: medium/low



Cotton yarn: indigo dyed yarn
Temperature: high
Immersion time: long
Wetting agent quantity: high
Steaming: no required/optional
Dye concentration: high

Keys on cross section on a yarn pictures

Yellow sulfur dye Diresul® RDT liq Interface indigo yellow - sulfur dye Diresul® RDT liq Indigo

Yarn dyed by using bottoming process

5.4 Black Denim Processes

Warp dyeing with black sulfur dyestuffs and without indigo has begun almost at the same time as the introduction of combinations of indigo with sulfur dyestuffs.

Black sulfur colorant's shades and effects (jet black, gray shades, wash down effecs, etc) allowed it to carve out a niche in the overcrowded blue denim market.

We can distinguish two standard processes of sulfur black:

- **Mercerized black denim.**
- **Non mercerized black denim.**

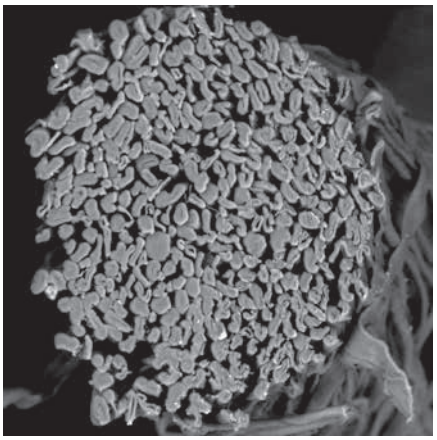
Mercerized Black Denim

Cotton changes its physical structure through mercerizing. Fibers become more rounded and develop a crystalline structure which boosts colors intensity and allows for superficiality.

The processes of mercerizing and subsequent dyeing are used to achieve high colors intensity and low degree of dyestuff diffusion (ring effect). The fact that the yarn enters the dye while damp also causes the dye to set superficially. Water creates a physical barrier against colors diffusion.

After the application and posterior washing, the dye has to set in the fiber. Generally a chemical oxidation with some kind of oxidizing agent in acid conditions is recommended. This way we obtain a complete insolubility of the dye in the yarn and a high regularity of the final shade. At a practical level and only in the case of sulfur black an acidic bath is frequently used in order to obtain insolubility.

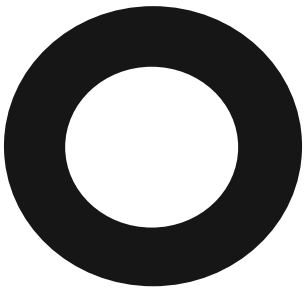
The diagram below shows a section of mercerized yarn with an undyed centre.



Mercerized thread in cross-section

Non Mercerized Black Denim

Non mercerized black denim is a process through which generally a solid effect is obtained, with high diffusion of the dye in the fiber (especially when the yarn is steamed after dyestuff impregnation).



Cotton yarn: mercerized yarn
Temperature: medium/high
Immersion time: low
Wetting agent quantity: low
Steaming: no
Dye concentration: very high
Process: wet on wet

This is not the most common process for black denim application, since the yarn enters unrefined, with all the cotton's impurities and low hydrofility, which limits the intensity and regularity of the dye to a certain point.

This dyeing process is most common in the case of bottoming due to the limitation of dye vats in such a long and complex process.

This type of process can be carried out in two different ways:

• By dyeing crude/raw yarn with sulfur black directly in the first preparation or pre-wetting vat. The process in question is at technical level called dry/wet process due to the fact that the yarn enters the dye bath without undergoing any previous weting treatment.

• By applying sulfur black to a yarn which was pre-soaked or partially scoured in the first vat. This process is called wet/wet as the yarn is already treated in the first vat. This method is not very common and it is similar to the standard Indigo process. Sometimes the yarn is prewetted or scoured when its quality does not allow for more strong treatments such as mercerizing.

In order to obtain complete diffusion of the dye in the fiber, the latter has to be steamed in order to achieve complete diffusion.

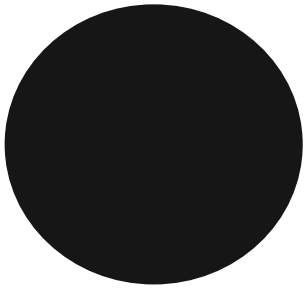
It is also possible to boost diffusion of the black sulfur dye by substantially increasing the quantity of caustic soda

Keys on cross section on a thread pictures

● Sulfur dyestuff Diresul® Black RDT liq

to amounts similar to those used in mercerizing. Dyeing and mercerizing take place simultaneously. With this type of recipe a black dye with increased solubility is obtained due to which it has higher diffusion capacity in the fiber as well as greater intensity.

The diagram below shows a section of yarn with its centre dyed through the non mercerizing process.



Cotton yarn: non mercerized yarn
Temperature: high
Immersion time: high
Wetting agent quantity: high
Steaming: yes
Dye concentration: high
Process: dry on wet

5.5 Color Denim Processes

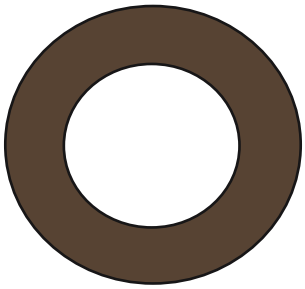
We use the name color denim for all the colors which are dissociated with the traditional blue and black denim.

Dyes used for these types of shades (brown, gray, olive green, etc.) are usually sulfur dyes. However, it is also possible to use other dye ranges such as reactive or vat dyes, but in this case more complex dyeing installations are required and there are limitations on final effects in garments.

In the area of color denim, such as in the case of black denim, mainly processes of mercerizing and non mercerizing are used.

Mercerized Color Denim

Such as in the case of black sulfur dyes, the processes of mercerizing and subsequent dyeing can be carried out. The objective is to obtain high color intensity at low degree of dye penetration (ring effect).

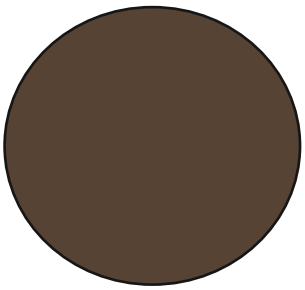


Cotton yarn: mercerized yarn
Temperature: medium/high
Immersion time: low
Wetting agent quantity: low
Steaming: no
Dye concentration: very high
Process: wet on wet

Non Mercerized Color Denim

This type of process can be carried out in two different ways:

- By dyeing raw yarn with a sulfur color directly in the first preparation or pre-soaked vat. On a technical level this type of dyeing process is called dry/wet due to the fact that the yarn enters the dyeing without any previous wetting treatment.
- By applying sulfur color dye to a yarn which was pre-soaked or partially scoured in the first vat. This process is called wet/wet due to the fact that the yarn is already treated in the first vat. It is a very uncommon process.



Cotton yarn: non mercerized yarn
Temperature: high
Immersion time: high
Wetting agent quantity: high
Steaming: yes
Dye concentration: high
Process: dry on wet

Keys on cross section on a thread pictures

Sulfur dyestuff Diresul® Brown RDT liq

Color denim jeans with sulfur green

“Regularity and consistency throughout the process are the main goals during dyeing”

In order to obtain total diffusion of the dye in the fiber, the latter can be steamed.

In this case it is also possible to boost diffusion of the colors in the yarn by increasing the concentration of caustic soda in the dye bath. However, as opposed to black, not all of the sulfur colors are stable at higher concentrations of caustic soda in the dye bath. That is why only in some cases it is possible to apply dyeing and mercerizing processes together in the same bath.

In the case of color denim, a chemical oxidation of the dye with a specific oxidizing agent is recommended. Generally sulfur colors need a more energetic and controlled oxidation in order to obtain more regular dyeing which are easier to reproduce.

5.6 Important Dyeing Paramethers

Regularity and consistency throughout the process are the main goals during dyeing. This implies controlling the parameters which considerably influence this regularity.

These are the most important points to consider when establishing control over the process and our suggestions for its correct development.

Temperature: Diresul® RDT liq dyes are used together with reducers such as Reducing agent D pw.

It means that the minimum application temperature has to be 60ºC and the maximum temperature 90º-95ºC and it should be maintained constant.

Diresul® RDT liq dyes have greater cotton affinity and exhaustion at elevated temperatures. That is why variations of ±10 ºC during the dyeing produce shade intensity differences.

Dye concentration: due to the affinity of Diresul® RDT liq dyes (pre-reduced liquid dyes) the dye concentration in the bath requires control, which is carried out visually in various ways:

• By taking a sample of the thread (once the yarn is dyed) from any part of the denim range.

• By using an online spectrophotometer (colorimetric control of the yarn while it circulates in the denim range). This is a visual color control.

• By taking a dyebath sample every now and then and applying it on yarn or fabric in the laboratory.

During denim dyeing the initial concentration of the sulfur dye should be reinforced both in the case of dry on wet as well as wet on wet dyeing. To adjust the concentration of the feed it is possible to use the Archroma feed-up program.

Speed: this parameter influences the time of contact of the fiber with the bath. The longer the contact, the greater the bath-material exchange and, consequently, a greater intensity of the dyeing and diffusion of the dye in the fiber.

pH and the Redox potential in the dye bath: Diresul® RDT liq dyes are in a soluble and pre-reduced state. This implies that they already themselves present an alkalinity and a sufficient and stable state of reduction in their liquid form.

It is very important to keep this reduced state in alkaline conditions in the dye bath. That is why Archroma recommends recipes which assure optimal conditions of the dye bath during the entire process.

Closed dye vat which can be used for both indigo as well as for sulfur dyes

The pH and Redox potential values should fit between the following margins:

pH: 11.5- 12.5

Redox Potential: -600 to -750 mV.

Depending on the recipe and the conditions of application, the pH can be little higher.

“The Diresul® RDT dyes are endorsed by the most important eco-labels”

5.7 Diresul® Recipes. Preparation of the Dye Baths

A thorough dyeing procedure always starts with the preparation of adequate dye baths. In the case of dyeing with Diresul® RDT liq sulfur dyes the order of the introduction of constituents should be the following:

1. Water (1/3 of the total volume)
2. Ladiquest® 2005 liq c (sequestring agent)
3. Reducing agent D pw.
4. Caustic soda 50%
5. Diresul® RDT liq
6. Leonil® EHC liq c (wetting agent)
7. Complete the final volume

All the products should be diluted in water before their introduction.

5.8 Reusing Dye Baths

After denim warp dyeing dye baths with Diresul® RDT dyes can be stored and reused in the next dyeing.

There are two main advantages of reusing dye baths:

• Conservation of chemical products and the dye.

• The bath remains stable and balanced after the previous dosage time in bulk production.

Before beginning the dyeing it is required to check the conditions of the bath. Normally it is necessary to add 20% of the initial quantity of both the Reducer D pw as well as of 48º Bè caustic soda.

5.9 Chemical Characteristics of Diresul® RDT liq Sulfur Dyes

As mentioned before, the dyes in question are pre-reduced and with a minimal content of sodium sulphide. These characteristics make them adequate products for special dyeing application such as Archroma´s Denim-Ox type processes.

This characteristic also implies the absence of sodium sulphide both in the work environment, as well as in the effluent generated after dyeing. Sodium sulphide is a product which is difficult to eliminate using the usual systems of waste water treatment, such as the physical-chemical system.

Effluent purification in waste water treatment plants is carried out through a physical chemical process of color coagulation and flocculation.

As far as the composition of Diresul® RDT liq dyes is concerned, we can distinguish:

• The lack of heavy metals in the composition of the dyes, due to their absence in raw materials used for the production of the dyes.

• Absence of halogen elements in the composition which might derive from AOX (organohalogen derivatives) in the waste water.

• Absence of dangerous chemical compounds such as formaldehyde, trichlorophenol or pentachlorophenol.

• They do not generate amino derivatives, as they are not azo products.

Apart from that, fabrics dyed with Diresul® RDT liq dyes are endorsed by the most important eco-labels. They also fulfill the RSL (restricted substance list) requirements of various well known fashion and sportswear brands.

Advanced Denim

06

After analyzing the origins and evolution of denim from the beginning to the present moment, Archroma proposes a new approach to the textile industry and especially to the denim sector.

Forget about classical and standard products, complicated applications of dyestuffs and auxiliary chemicals which require excessive consumption of energy and resources.

By introducing Archroma Advanced Denim we are entering a new concept where sustainability, effectiveness and optimization of resources are the key, but at the same time market needs stay in focus.

"BY INTRODUCING ADVANCED DENIM WE ARE ENTERING A NEW CONCEPT WHERE SUSTAINABILITY, EFFECTIVENESS AND RESOURCES OPTIMIZATION ARE THE KEY."

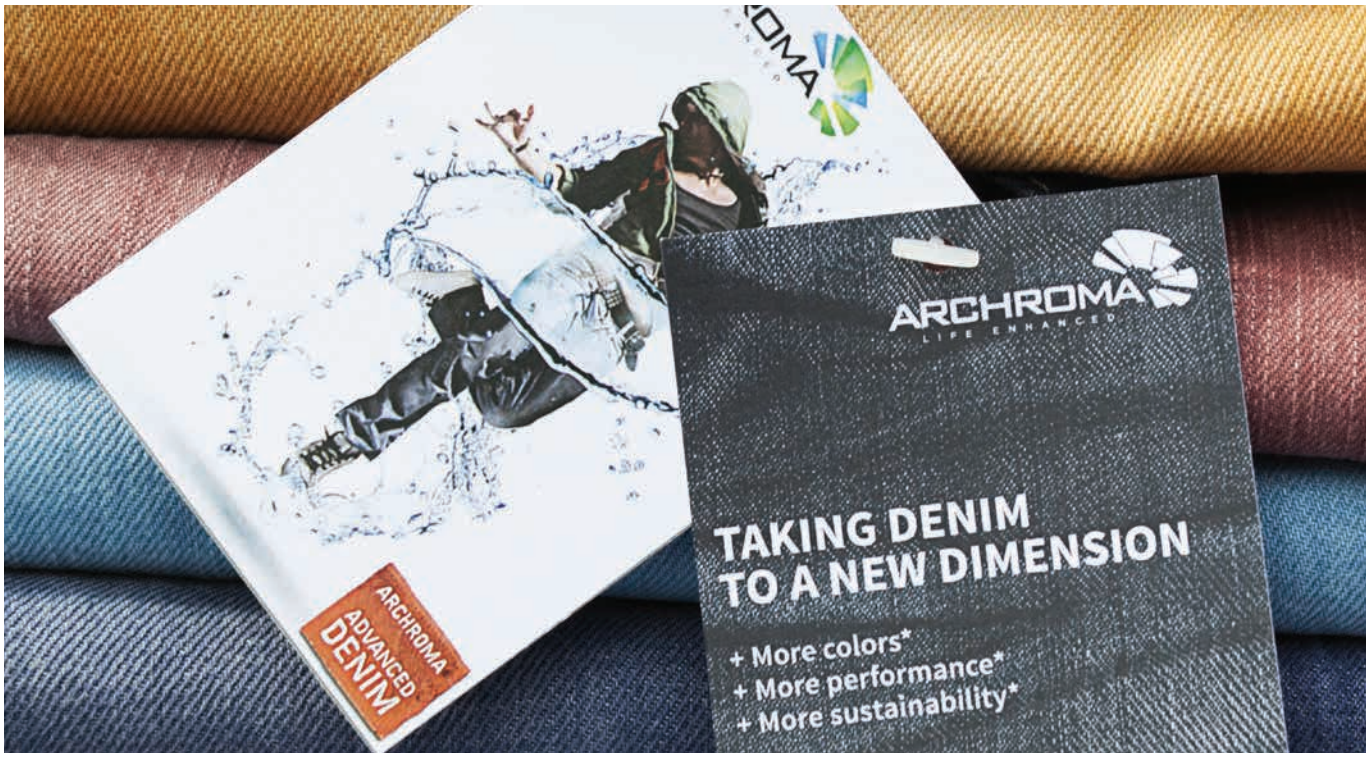
/ BY ARCHROMA

Advanced Denim

Advanced Denim came to life thanks to Archroma's experience and efforts in the field of denim in collaboration with major denim fabric producers. It was created to satisfy the necessity of more efficient denim processing.

From a technical point of view, Advanced Denim is based on the substitution of the indigo dye by Archroma´s state of the art sulfur dyes, which are very versatile and allow obtaining a great variety of effects.

In the last few years Archroma has developed a new line of sulfur dyestuffs called Indicolors. From the point of view of application and handling they are identical with Diresul® RDT dyes, but they give a final look of similar characteristics to that of blue denim.



The ‘Indicolors’ line of liquid pre-reduced sulfur dyes includes at present:

Diresul® Indiblue RDT-R liq: medium-intensity blue with a reddish shade

Diresul® Indiblue RDT-G liq: medium-intensity blue with a greenish shade

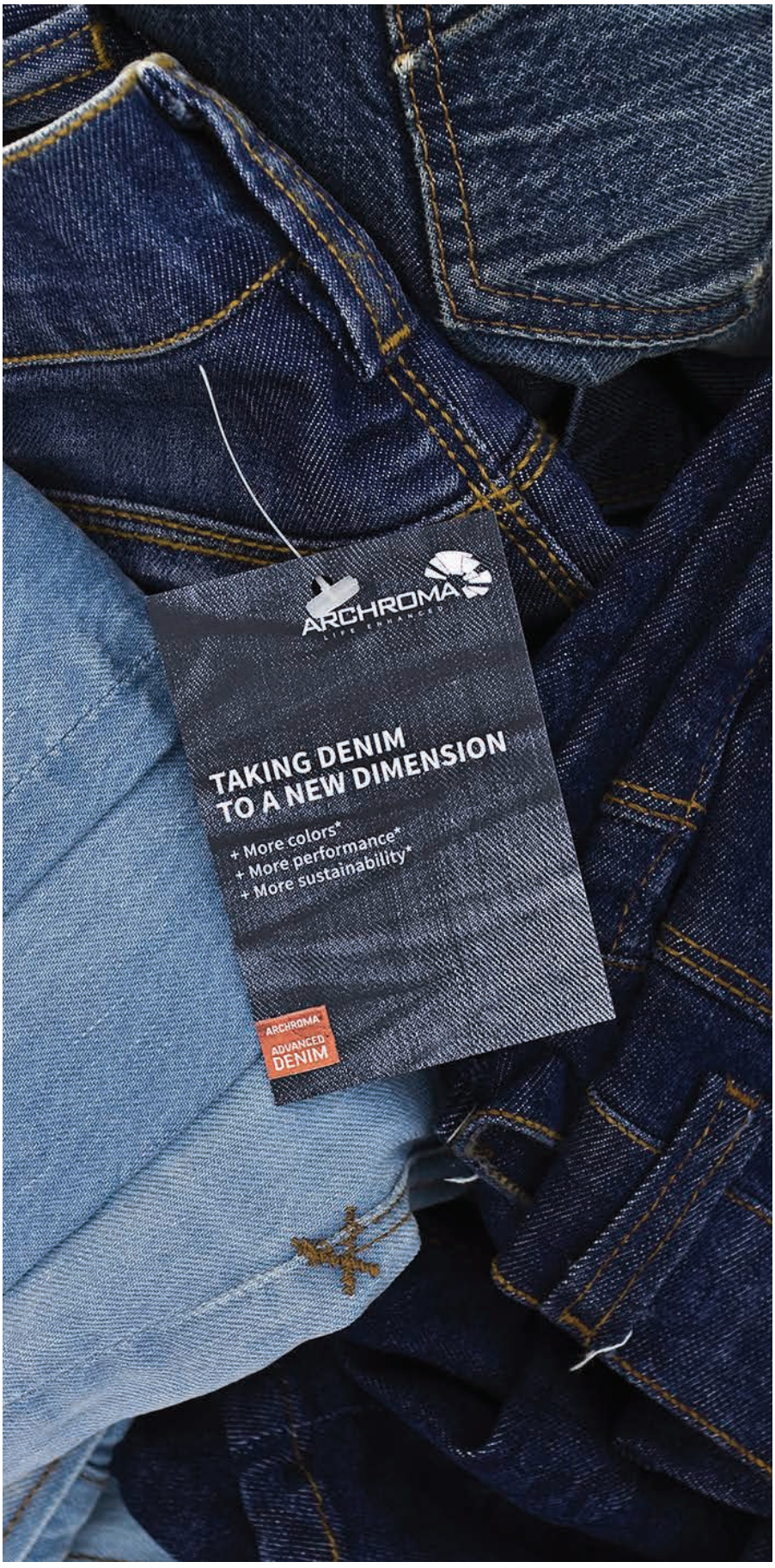
Diresul® Indinavy RDT-B liq: high-intensity navy blue with a neutral shade

Diresul® Indiblack RDT-2R liq: high-intensity shade of bluish black

As opposed to indigo, these dyes are especially designed to be used in a single dye bath. They can be also combined with each other or with the global range of Diresul® RDT liq in simpler and more compact processes, which guarantee a broad variety of blue shades.

On the other hand, there are no restrictions concerning the Diresul® RDT liq products (including ‘Indicolors’) when it comes to using them together with indigo in conventional bottoming or topping processes. This type of application is standard in present-day denim.

Together with Diresul® RDT liq dyes Archroma uses a series of chemical and auxiliary products which perfectly fit in with Advanced Denim technology. They are applied through specific processes, depending on the needs of each denim dyer.



Diresul® Indiblue RDT-R liq. Blue indigo-free denim

Wide range of colors and effects with Diresul® RDT liq dyes

6.1 Advanced Denim Technology

Efficient Denim

Thanks to chemical characteristics different to those of indigo, sulfur dyes can be employed in much simpler processes and in more versatile and compact dyeing ranges than the ones used at present.

The Advanced Denim technology is based on the optimization of application ranges. From mechanically complex ranges we turn to applications which radically minimize this complexity.
For example dyeing ranges consisting of 15 vats are substituted by systems which use no more than 4-5 vats.

The Advanced Denim technology can be considered the most efficient at present as far as the optimization of resources is concerned:

- Cotton waste is radically minimized.
- Water consumption is minimal. It also means considerable conservation of water which should be treated in the waste treatment plant.
- Energy consumption is also considerably reduced in comparison with conventional processes.

As far as conventional dyeing processes are concerned, Advanced Denim has the following advantages:

- Easy and quick shade adjustment during dyeing.
- Easy and quick color change in the dyeing range.
- Suitable for dyeing short batches.

These three points results in greater productivity.

Denim-Ox process:

Several years ago Archroma started developing a new technology called pad-OX, which is a system of sulfur dyes application through the continuous process.

The pad-OX technology is used for fabrics as well as warp yarn dyeing. In case of the latter, called denim-Ox, it is used for black/color/blue denim and in bottoming processes together with indigo.

Pad-OX can be applied thanks to the use of Diresul® RDT sulfur dyes with low sodium sulphide content. That is why there is no risk of direct contact with an acidic environment.

The diagram in the next page shows the arrangement of washing boxes used in pad-OX, which in comparison with conventional processes drastically reduces the water quantity and in consequence the consumption. Conversely, the type of fixation (oxidation) which is carried out on the dye results in improved control and reproducibility during the dyeing process, due to the degree of fixation of the dye on the yarn.

In the case of bottoming using the pad-Ox technology, there is also a minimization of sulfur dye discharge into the indigo bath, due to strong fixation of the Diresul® RDT dye.

Both sulfur dyes as well as indigo are applied under reductive and alkaline conditions. That is why they are soluble and have affinity for fiber. On the other hand, both need to be oxidized for their insolubilization – and fixation.
So, under reductive and alkaline conditions, the sulfur dye is partially resolubilized in the indigo bath.

Even though in all these cases the discharge is minimized thanks to the use of denim-Ox, there is also a range of Diresul® RDT lig dyes, which are especially adequate for the conventional bottoming application.

The following dyes minimize the stripping of the sulfur dye in indigo bath.

- Diresul® Yellow RDT-E liq
- Diresul® Brown RDT-GS liq 150
- Diresul® Navy RDT-GF liq 150
- Diresul® Blue RDT-2G liq 150
- Diresul® Olive RDT-B liq 150
- Diresul® Brown RDT-R liq
- Diresul® Olive Yellow RDT-Y liq

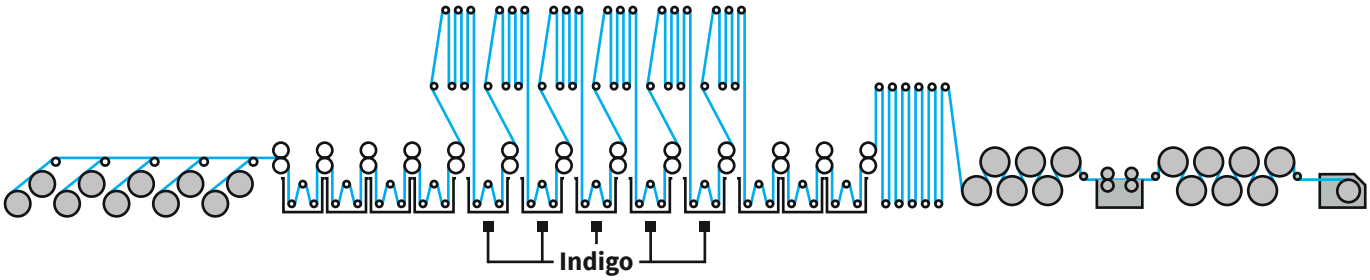
In the case of Diresul® Black RDT liq (or any dye from the black range) always when the denim-Ox system is used, indigo bath contamination is minimal in comparison with conventional application.

It is also important to note that the behavior of indigo when applying this technology is a bit different than in the conventional bottoming process.

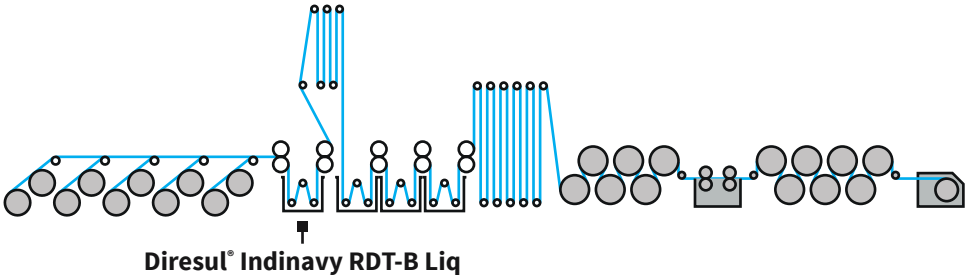
Indigo has greater affinity with an added ring effect, due to the fact that the yarn becomes cationized through the denim-Ox process. That is why indigo cannot diffuse entirely inside fiber.

Conventional denim

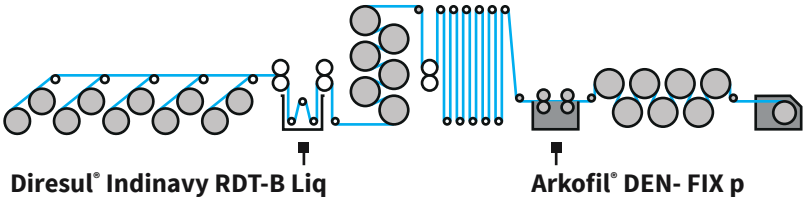
Functional diagrams



Advanced Denim: denim-OX process



Advanced Denim: Pad/Sizing-OX process



Advantages of Advanced Denim by Archroma:

Up to 92% less water
Up to 30% less energy
Up to 87% less cotton waste

Denim fabric dyed using Denim-Ox process

“21st century: new era of denim is coming”

Pad/Sizing-OX

Pad/Sizing-Ox is the latest development carried out using liquid sulfur dyes Diresul® RDT.

Pad/Sizing-Ox is carried out trough a continuous process in the warp thread and its most important characteristic is the total absence of washings during the process. This radically optimizes the sizing process, which is an essential stage preceding the weaving process.

This way the most efficient and simple process is obtained.

The machine consists of an impregnating mangle or a dye vat followed by dry cans. Later the sizing agent is applied in one or two sizing vats, depending on the available machinery.

In the Pad/Sizing-Ox process, like in the Pad Ox process (or Denim Ox in case of the warp yarn), it is possible to combine any of the Diresul® RDT dyes, including 'Indicolors.'

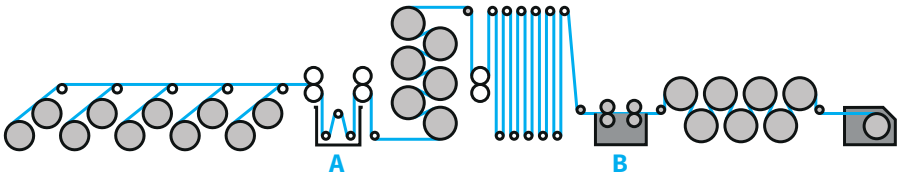
It is also possible to use Pad/Sizing-Ox to attain the 'topping' effect more easily from the technical point of view. It also gives more flexibility to yarn dyed with indigo in rope range.

In the case of the rope range the warp yarn is not sized during the dyeing process. It needs to be transferred to a beam (opening of the rope or rebeaming) and later sized.

This way the indigo yarn can be easily overdyed/shaded in small or medium batches.

Pad/sizing-Ox process

Functional diagram



A. Dyeing

x g/l Diresul® RDT liq*
7-10 g/l Reducing Dp
7-10 g/l NaOH 50%
2-5 g/l Leonil® EHC liq c
2-3 g/l Ladiquest® 2005 liq c

Padding at 70-90 ºC.

**Only suitable for Diresul® RDT liq (low sulphide range)*

B. Sizing / oxidation

6-8 % Arkofil® DEN-FIX p
0.2 % Trefix® MSW fla
2-3 % Diresul® Oxidant BRI liq*

Ajust pH at 4,5-5 with Opticid® PSD liq conc, temperature at 70-75 ºC, wet size pick up: 100-115%.

**if it is necessary, add Arkofil® G1p to maintain efficiency*

Industrial case: Blue Denim production

Batch 10.000m v=20m/min

Dyeing & Sizing	Standard Blue Denim	Pad / Sizing-Ox Advanced Denim	⟹	%
Water Consumption	58.000 L	4.590 L	**Less water**	**92**
Energy Consumption	14.740 KWH	10.744 KWH	**Less energy**	**27**
Cotton waste (Slasher)	215 Kg CO	27 Kg CO	**Less cotton waste**	**87,5**
Wastewater (dye bath recycled)	46.000 L with sulphites	0 L	**Less wastewater**	**100**

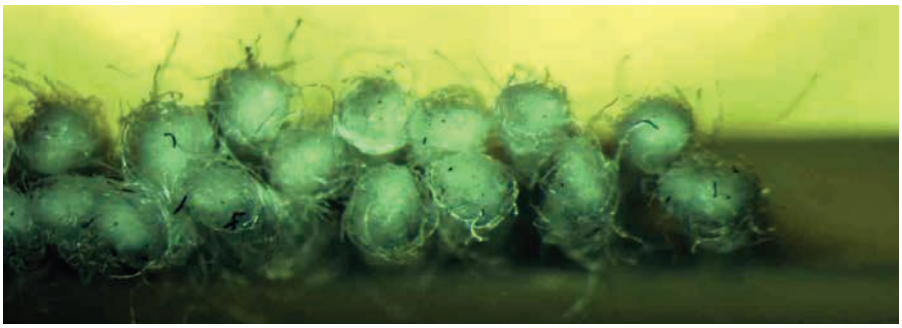
Solid/Ring Denim Effect

The versatility of the previous processes along with the more conventional propositions which are carried out with Diresul® RDT dyes increases the possibility of obtaining different effects on the fabric and the final garment.

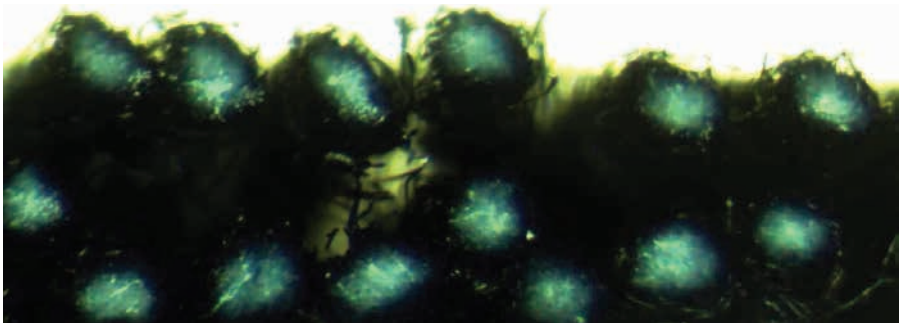
Efficient processes such as Denim-Ox or Pad/Sizing-Ox allow to obtain superficial dyeing, that is with low diffusion of the dye in the fiber. Apart from that processes which include mercerized yarn before dyeing also produce ring or superficial dyeing effects.

Both in the conventional as well as in the efficient processes it is possible to incorporate mechanical elements which are of benefit to the process when it comes to necessities. For example, the use of a steamer increases dye diffusion and consequently the obtained color is more solid.

A cross sections in optical microscope



Raw Cotton yarn



Cotton yarn dyed with indigo. Ring effect

Raw Denim

Raw denim or dark jeans has become a standard item in denim and sportswear brand collections thanks to its versatility and elegance which appeals to the users.

One of the most important characteristics of denim fabrics, which has an influence on the final quality of the garment, is their fastness.

In raw jeans the crocking fastness test of the fabric (especially the wet one) requires a certain level resulting from an increased concentration of the dye which is applied to the warp yarn. Even if the result of this test is acceptable, there is still a need for improvement.

The types of fastness most in-demand on the denim market are:

- **Repetitive domestic laundering:**

Fastness to domestic washing includes a series of standardized tests. Results depend on the test conditions (time, temperature etc.) as well as on the used detergent (more or less aggressive).

There is a possibility of applying specific processes for which we choose a range of Diresul® dyes to produce warp yarn with a special diffusion and fastness quality.

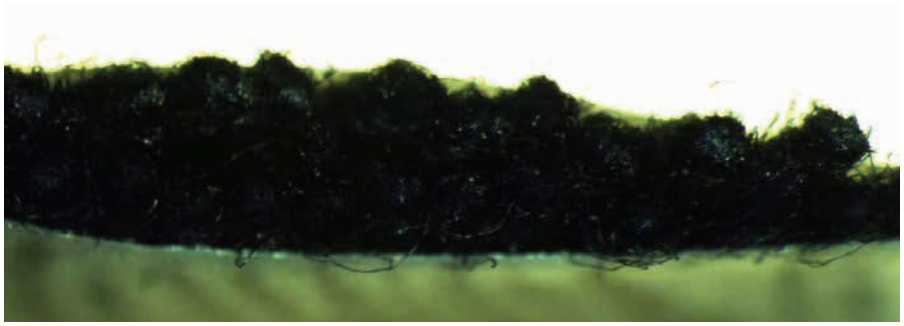
These processes are applied when an increased fastness to repetitive washings is required, greater than the conventional one (such as, for example, in 100% indigo dyeing processes or even the common sulfur dyeing processes).

- **Fastness to rubbing:**

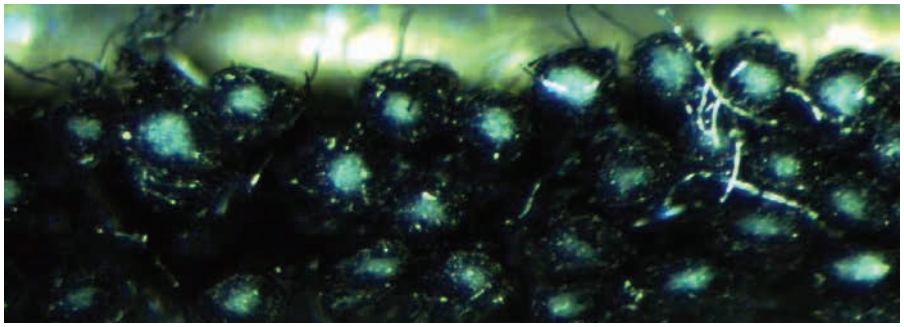
Fastness to rubbing is a test carried out on textile articles. It is a physical test in which the dyed fabric is exposed to controlled rubbing with a bleached cotton cloth. The degree of soiling of the cotton is evaluated according to an established scale such as the gray scale (in which the values range from 1 when the cotton is considerably soiled to 7 when the soiling is not noticeable).

Fastness to both dry and wet rubbing is one of the weak points of very intensive shade items generally dyed with indigo or using very intensive bottoming or topping processes.

Both in the industry as well as the market a determined minimal value



Diresul® Indinavy RDT-B liq. Solid effect



Diresul® Indinavy RDT-B liq. Ring effect

of fastness is adopted, especially in the case of dry fastness. However, this value is insufficient and often problems occur such as soiling of upholstery or complements like bags, shoes and generally fabrics and leather products in light shades.

Generally, processes carried out with Diresul® RDT liq dyes improve the value of fastness, especially in the case of the dry rubbing fastness test.

Both dry and wet fastness could be improved by applying a finishing recipe with a range of recommended products which improve fastness without affecting the final handle of the cloth.

6.2 Advanced Denim´s Ecology

Ecology is an important factor in our everyday lives and of course the textile and denim industries are aware of that. It is our obligation to preserve and rationalize the existing resources, to use chemical products and dyes which are as harmless as possible to the environment and to commit ourselves to this end without reservation.

Archroma has been constantly focusing on the protection of the environment. One of the ways of doing this was the creation of the Diresul® RDT liq dye range. Archroma understands that the future of the textile industry must be very different to its present condition: excessive consumption of water which later has to be treated in waste water recycling plants and excessive production of subproducts which are difficult to deal with and eliminate from the environment.

Advanced Denim's ecology is based on:

- **Water conservation**: by means of using specific dyeing processes
- **Energy conservation**: minimizing CO_2
- **Minimizing cotton waste**.
- **Minimizing the production of wastewater**: less chemical treatment of water.
- **Using an environmentally friendly pack**: dye, chemicals and auxiliaries.
- **Possibility of sustainable wash-downs without the generation of AOX on the fabric**: ozone atmosphere, hydrogen peroxide.

6.3 Advanced Denim´s Fashion

At present fashion is affected by continuous changes in tendencies, not only in style or design, but also in color. Together with the design, shade and the applied mechanical finish it makes the denim fabric something unique and individual.

- **Indicolors: blue denim effects. New and vintage**

Generally and logically the reference color of denim is BLUE. However, blue is not based only on indigo anymore. Fashion demands various shades ranging from bottoming or topping dull blue to brilliant blue or greenish or reddish blue.

This variety of shades can be obtained with the Indicolors range, applied in different ways, such as it was explained before, and carrying out finish effects on the fabric using both dry as well as wet processing.

- **Global range. Variety of colors: color denim. Diresul® RDT liq range.**

We refer to color denim when the dyes used are not blue or black and for that reason the final look of the fabric is not the classic blue or black denim.

The majority of denim collections include color denim. This market niche is widening more and more.

The wide range of colors and effects can be obtained with relative easiness by using sulfur dyes both in sustainable processes as well as standard ones.

”Advanced Denim” Jeans dyed with Diresul® Indiblack RDT-2R liq and washed with hidrogen peroxide (eco-wash)

“Advanced Denim” jeans dyed with Diresul® Indinavy RDT-B liq

• Raw denim: intensity and variety of shades

'Raw' jeans are basically of intense blue color. They can be obtained with blue dyes from the Diresul® RDT liq range, especially with the 'indis' such as the Diresul® Indinavy RDT-B liq. Also, they can be combined with Diresul® Indiblack RDT-2R liq as well as Diresul® Blue Black RDT-2B liq in order to obtain different shades.

As already explained, in 'Raw' articles apart from increased intensity a higher level of fastness is required. It is obtained through adapted processes.

• Eco-wash down. Variety of shades

The range of shades which can be obtained with wash-downs of the fabric is continuously widening. Depending on the conditions of application of the diverse chemical products and auxiliaries a variety of shades can be produced.

The characteristics and properties described in this chapter are individual and in the majority of cases cannot be obtained in just one final fabric. That is why it is important to define and analyze the desired properties and set them as an objective.

Archroma works and collaborates to recommend and apply in each case the most adequate processes to attain the final objective.

More information at:

www.advanceddenim.archroma.com

Sizing

07

7.1 The Sizing Process

Neither classical weaving nor modern high speed weaving can be carried out without sizing agents. These adhere the individual fibers in the yarn to each other and form a protective film on the fiber surface which enables the yarn to survive the extreme mechanical stress during weaving without damage. Only the warp yarn has to be sized due to its function as skeleton of the fabric.

In the denim production this sizing process can be carried out continuously linked to the dyeing process on sheet or slasher dyeing machine or by using the rope dying machine after the warping of the ropes in a separate sizing machine.

The sizing process is necessary to achieve highest weaving efficiency on the looms.

“THE SIZING PROCESS IS NECESSARY TO ACHIEVE HIGHEST WEAVING EFFICIENCY”

/ OF THE WARP YARN

Sizing

The aim of this process is to provide the yarn with a protective coating in order to:

- Protect the yarn from friction;
- Increase resistance to traction;
- Prevent the warp threads from entangling or sticking to each other;
- Increase the tensile strength to avoid breakages in the loom;
- Reduce fiber dusting (formation of fiber clusters);
- Facilitate the use of a single yarn.

Sizing agents are applied to the warp threads from aqueous liquors. The threads pass from the warp beams through the sizing trough where they dip in the sizing liquor and impregnate with it. The surplus liquor is then squeezed off in the immersion rollers which allows a liquor pick-up of 50 - 150 %, depending on the physical warp characteristics, machine settings and sizing liquor parameters. The sized warp threads are dried in the cylinder drier, separated in the dry splitting field and wound onto the weaving beam.

After the weaving process the task of the sizing agent is complete and it must then be totally removed in the pretreatment process.

7.2 Types of Sizing Agents

Today a large number of classes of chemical substances are used as sizing agents; they can be classified in two main groups:

Natural or semisynthetic macromolecular products:

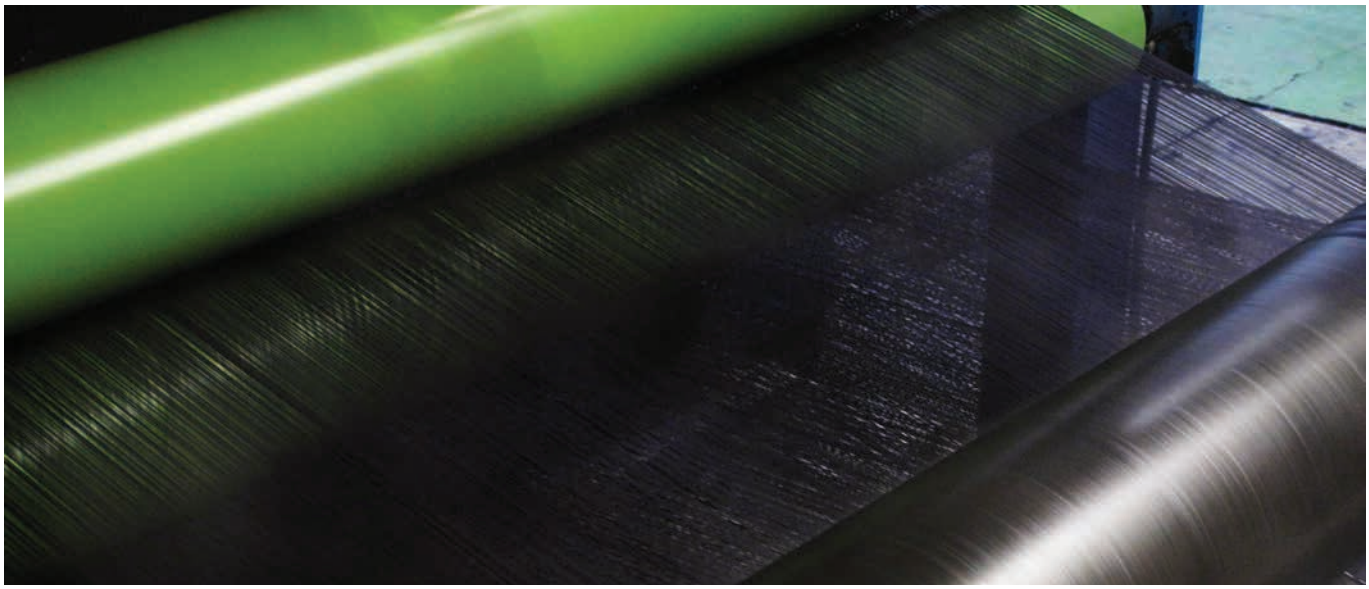
- Starches from potato, corn, wheat, rice, tapioca or manioc and their derivatives like CMS (carboxymethyl starch), starch ester and starch ether;
- CMC (carboxymethyl cellulose);
- CMG (galactomanan and tamarinde flour derivatives);
- Proteins (e.g. glue, saresh).

Most of the starch sizing agents are water insoluble and require enzymatic or oxidative desizing process. CMS, CMC and CMG are water soluble; they are easily removed in water, plus detergent and dispersing agent.

Synthetic polymers:

- PVA (polyvinyl alcohol);
- Polyacrylates;
- Polyester condensates;
- Vinyl acetate copolymers.

Synthetic polymers are water soluble and easily removable with water and washing agents under control of the corresponding pH.



Sizing trough

7.3 Sizing Recipes

These sizing agents can be applied as single product but mainly they are used in combination, due to their different properties. Only the blend of them achieves the necessary characteristics. Also the addition of waxes and lubricants is usual.

Characteristics of sizing agents:

- Adhesive power on the fibers;
- Liquor viscosity, from low to high;
- Film forming character; elasticity, humidity stable;
- No formation of skin in the bath or on the rollers;
- No foam building;
- Low stop mark tendency if range stops;
- Low dusting tendency;
- Easy splitting property;
- Stability to drying and singeing processes.

Choosing the right combination of sizing products depends on the textile features and the final purpose of the fabric. Also the impact of sizing- and weaving machine parameters and following process steps after weaving have an influence on finding the right sizing recipe.

Fabric factors:

- Yarn material; e.g. cotton, viscose, synthetic fibres or the blend of them;
- Yarn fineness; tex, Nm, Ne;
- Yarn properties; ring, open end, compact, tensile strength, hairiness;
- Fabric density; warp ends/cm, weft end/cm;
- Fabric construction; plain, twill, satin;
- Absorbing capacity.

Machine factors:

- Sizing machine; 1 or 2 troughs, squeeze pressure, warp process in box, speed, wet size pick up;
- Weaving machine; shuttle, rapier, projectile, air, speed of machine;
- Climate of weaving hall.

Subsequent process impacts:

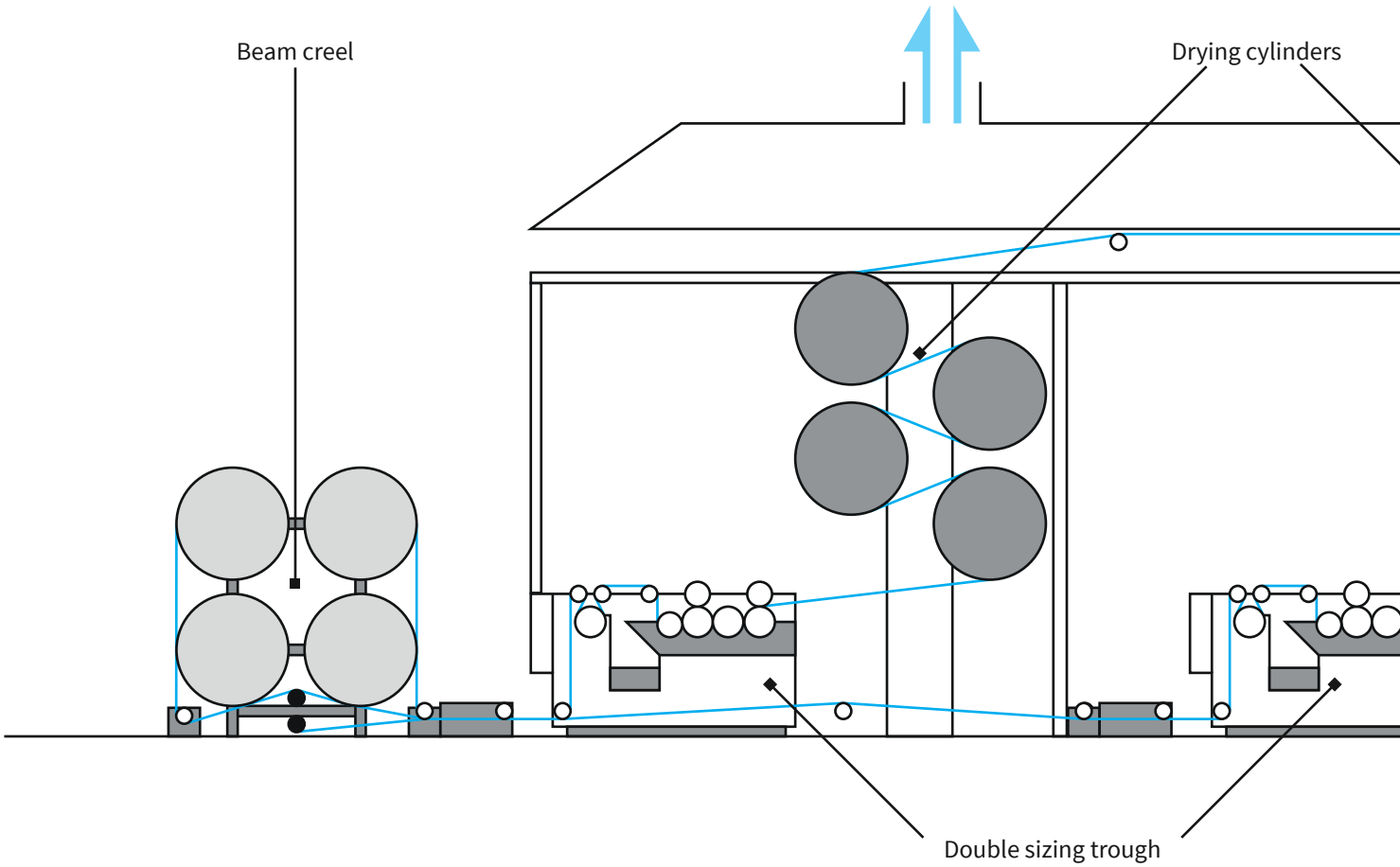
- Stability to electrolytes and alkaline solutions, post-mercerizing process.
- Compatibility to singeing, heat setting processes;
- Desizing process;
- Ecological compatibility.

Archroma supplies sizing products and processes that meet most requirements of the modern weaving technology. This includes economic and ecological products for all types of looms as well as the technique for size recovering. Our Vinarol® and Arkofil® range include all necessary sizing agents for the modern sizing process. Especially for the denim production a new generation of sizing agent, Arkofil®DEN-FIX p (patent in progress) was developed for a wide application field using the new Archroma´s Pad/Sizing-Ox process.

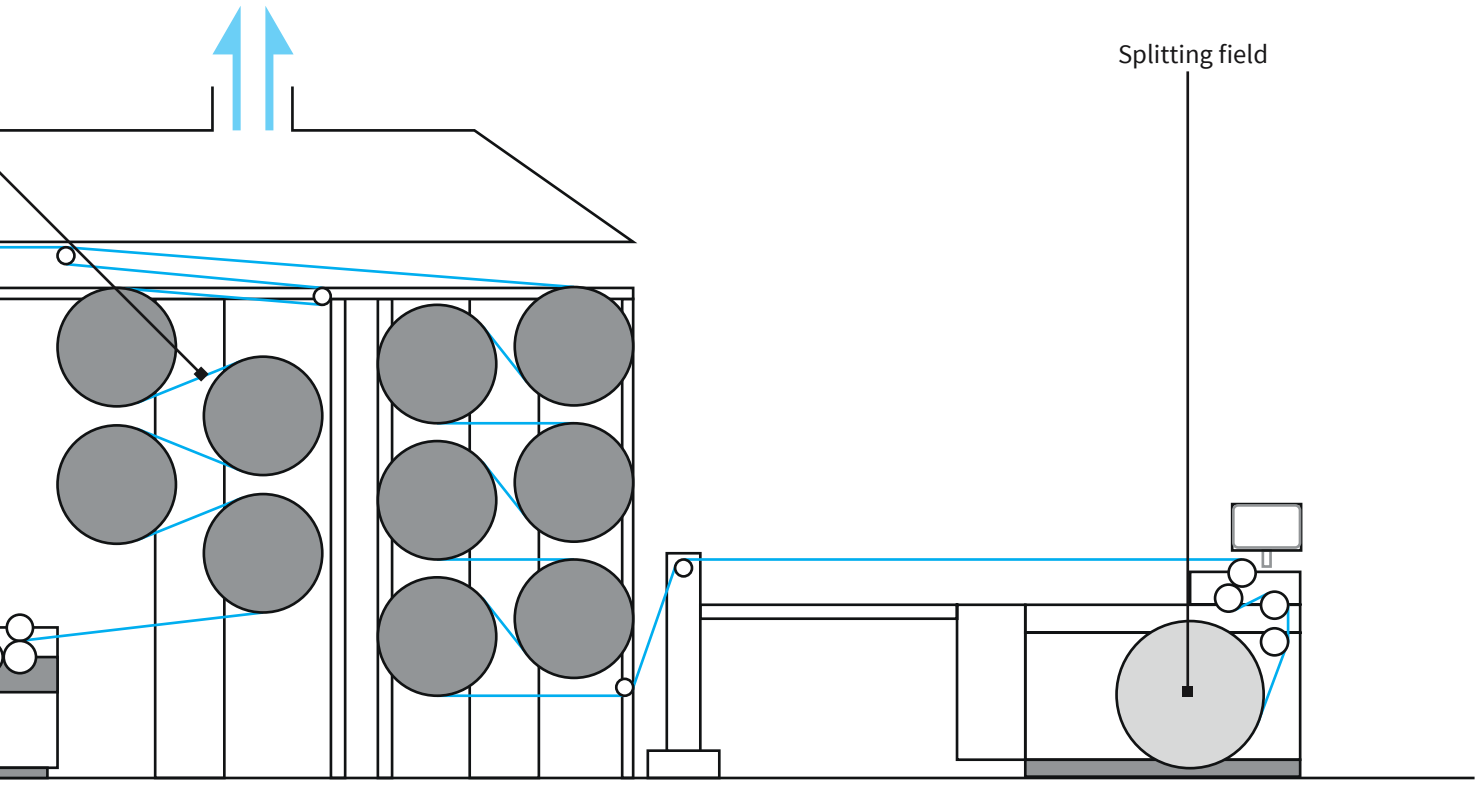
“New generation of sizing agents such as Arkofil® DEN-FIX pw is already in the market”

Sizing Machine

Functional diagram



Splitting field



Weaving

08

During the production of denim there is a variety of factors that can influence the final aspect of the garment, such as the type of machine, yarn and dyestuffs used, the dyeing process sequence and the stitching and garment finishing.

Furthermore, weaving section is also crucial.

Fabric is a material obtained in the form of a sheet by crossing and interlacing two series of threads, a longitudinal one called warp and a transverse one called weft. These two series of threads are most often cotton yarn.

Denim fabric is distinguished by a colored warp and a raw or uncolored weft.

The weaving process is achieved by using looms which are weaving devices that maintain the warp tension in order to facilitate the interweaving of the weft.

There are different shapes and mechanical looms according to the type of fabric produced. In the case of denim fabric the type of looms used are called plane looms.

“A FABRIC CALLED DENIM IS DISTINGUISHED BY A COLORED WARP YARN AND A RAW OR UNCOLORED WEFT...”

/ A FABRIC CALLED DENIM

Weaving

8.1 Weave structure

Weave structure is the way in which the warp and the weft ends cross and interlace each other.

The most common weave structures made by using plane looms are:

- Twill
- Taffeta
- Sateen

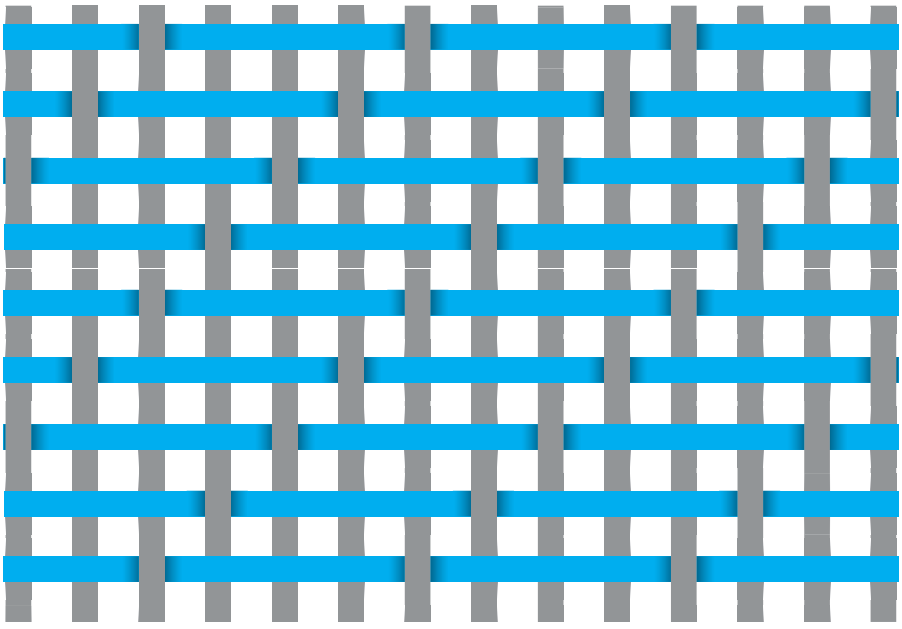
The most usual weaving structure used in denim fabric is **Twill**.

The twill is a loom-woven structure in which the points of interweaving are moved during each pass to attain a visual image of diagonal lines, also known as **wale**.

The portion of thread or yarn that crosses over two or more yarns from the opposite direction is called **float**.

Twill weave is normally designated as a fraction, such as 3/1. In this case the numerator indicates the number of harnesses which are raised when the filling thread is inserted (in this case it is 3). The denominator indicates the number of harnesses that are lowered when the filling thread is inserted (in this case is 1).

A common way to read a fraction like 3/1 twill it is “three up, one down”.



Eg. Structure of a 3/1 twill

Denim fabric with twill structure

8.2 Characteristics of Denim Twills

Twill fabric has technically two sides, front and back. Denim twill is a warp-faced twill with the front side more visible, the wale more pronounced, the aspect more attractive, so it is the side more often used to fashion the denim fabric.

The effect in the front side is always reversed in the back one, eg. If there are floats in the front side (if the warp yarn crosses over two or more weft yarns), there will be weft floats in the back side (the weft yarn crosses two or more warp yarns).

Right hand twill: the diagonal ribbing or wale rises from the left selvedge to the top right selvedge. Single warp yarn is woven by using right hand twill.

Left hand twill: the diagonal ribbing rises from the bottom right to the top left selvedge. It is also called "Z twill". Double yarn warp is woven using left hand twill.

In denim fabrics, right hand twill is the most common.

Reverse twill: the weft is more visible and predominant than warp threads on the front side.

Broken twills: the direction of the diagonal produced by the weft threads is reversed after no more than two passages of the weft threads. The wale is "broken" by an interruption of the usual twill sequence.

The diagonal ribbon would be more or less predominant depending on the yarn used:

Yarn twist: tightly twisted yarn gives more diagonal effect than more weakly twisted ones. "Z" twist gives more diagonal effect in right hand twill.

Single or double yarn: Twisted double yarn gives more wale effect than just single yarn.

Yarn type: combed yarn (fibers lay parallel in a thread) gives more diagonal effect than just carded one(less uniform, regular and stronger yarn than combed ones).

Yarn density: twills of greater yarn density give prominent diagonal effect.

Yarn might reveal irregularities induced during the spinning phase like knots, slub , multi-count or multi-flamé yarn which produce irregularities in the denim twill. These yarn effects are created intentionally in order to obtain vintage effect.

Detail of a beam of colored thread placed in the loom, prepared for the weaving of a plane fabric

8.3 Stretch Denim

Stretch denim twills appeared in the 1990s, quickly becoming an indispensable type of fabric in women's and increasingly in men's denim collections.

Initially, elastomeric fibers were applied only in the weft, nowadays, bi-elastic fabrics are gaining ground with elastomeric fibers in both weft as well as warp (eg. Jeggins).

The main characteristics of these fabrics include high degree of adaptation to the body, comfort, softness as well as great durability.

The warp yarn containing elastomeric fibers can be dyed with sulfur dyes and also with sulfur dyes combined with indigo in bottoming or topping processes *(see chapter 6)*.

The general behavior of these fibers is similar to that of 100% cotton, it is only necessary to adjust some mechanical parameters in the denim range to use them.

At present, the strength of these artificial fibers allows to carry out chemical and physical effects such as bleach or stone wash, without losing strength and elasticity.

Taking the weight of the rigid denim fabric into account, the following classification can be done

Table 4 (Considering the denim fabric width 150 cm)

Denim fabric	**Very light**	**Light**	**Medium**	**Heavy**
Ounces (oz)	4 to 7	7 to 11	11 to 14	14 to 16
Weight g/m²	136 to 237	237 to 373	373 to 475	475 to 542
Weight g/lm	204 to 356	356 to 560	560 to 713	713 to 813

"Yarn containing elastomeric fibers are used in warp dyeing"

8.2 Example of Three Classic Fabrics From Denim Articles

Weight of fabric 12, 7 ounces 705 g/lm Width 164cm

2/1 twill

Composition of the warp

Metric number: 12.3 Nm irregular

Number of ends: 4072

Width of the loom: 170cm

Ends/cm: 24

Material: ring cotton yarn

Warp color: Diresul® Black RDT-D liq

Composition of the weft

Metric number:
24 Nm Irregular

Courses per cm: 20

Material: cotton/elastane

Weft color: raw

Elastane finish

Weight of fabric 6 ounces 285 g/lm Width 152 cm

2/1 twill

Composition of the warp

Metric number: 40 Nm regular

Number of ends: 6446

Width of the loom: 165 cm

Ends/cm: 39

Material: cotton. open-end yarn

Warp color: Diresul® Indinavy RDT-B liq

Composition of the weft

Metric number: 40 Nm regular

Courses per cm: 20

Material: cotton

Weft color: raw

Normal finish

Weight of fabric 6.5 ounces 355 g/lm Width 155 cm

3/1 twill

Composition of the warp

Metric number: 20 Nm regular

Number of ends: 5612

Width of the loom: 160 cm

Ends/cm: 35

Material: regenerated cellulose fiber 100%. Ring yarn

Warp color: Diresul® Blue Black RDT-2B liq

Composition of the weft

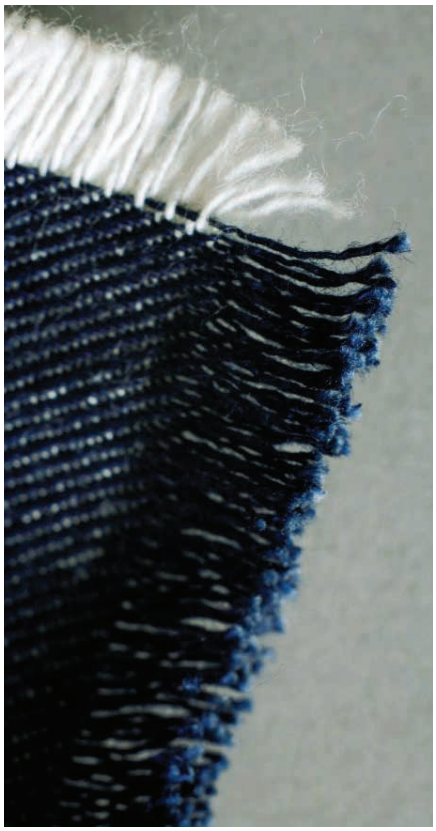
Metric number: 20 Nm

Courses per cm: 18.40

Material: regenerated cellulose fiber 100%

Weft color: raw

Regenerated cellulose fiber finish



Denim fabric with twill structure

The back of loom, where the fabric is visible

Cotton/regenerated cellulose fiber denim shirt

Finishing

09

Finishing for denim fabrics have been developed a lot over the past few years. Apart from conventional ones that assure standard quality, there are also special finishing treatments which improve the performance of the fabric and the final effect on the garment. Nowadays, finishing is an element of differentation in the denim market.

Fabrics need to be subjected to finishing before the manufacturing of the garment. It is necessary to obtain a correct physical behavior and stability of the garment during home laundering. On the other hand, the finishing treatments of the denim garments are based on fashion trends and effects. In this case physical and chemical treatments are used (dry and wet garment processing).

"THE FUSION OF THE DENIM FABRIC PERFORMANCE AND THE JEANS LOOK"

/ FOR DENIM FABRICS AND GARMENTS

Finishing

Generally, finishing processes can be divided into the following groups:

- Denim fabric finishing
- Special denim fabric finishing
- Denim garment finishing

9.1 Denim Fabric Finishing

Denim fabric finishing are those which are carried out after weaving and conclude with the quality control checking of the fabric or garment manufacturing. They consist of:

Basic Operations

Basic operations are always carried out on the denim fabric just after the weaving process. They are required for the correct physical behavior of the fabric when it is subject to posterior operations such as tailoring, final garment finishes as well as domestic laundering once the garment reaches the consumer.

- **Brushing and singeing**

Treatment of a still sized fabric recently out of the loom. It consists of the elimination of those superficial fibers which give the fabric a fluffy look. Brushing and singeing are consecutive operations.

During the operations the fabric is subject to a superficial combustion of the fibers with a gas flame at elevated speed (specially adjusted so that the fabric does not suffer any deterioration or damage).

After singeing a posterior washing is carried out in order to clean the fabric.

Fabric in the singeing phase. The flame is generated from high temperature gas. Superficial contact results in combustion of prominent fibrils

Sanforizing range. Exit Rubber belt section

- **Sanforizing**

Sanforizing is a physical treatment carried out on the denim fabric. It is technically called control of shrinkage due to compression.

Both weft as well as warp yarn undergo a series of movements which allow controlled shrinkage.

Shrinkage is required to prevent turning of seams in the direction of the twill structure once the garment has been tailored and washed.

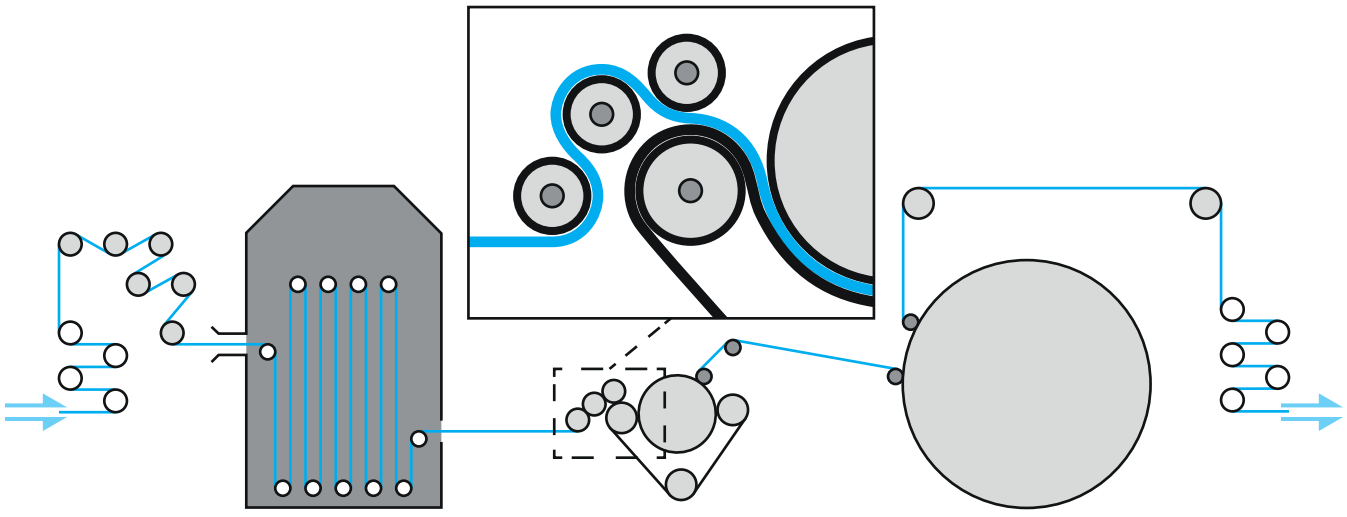
The *diagram 4* shows the passage of the fabric through the sanforizing range. First, the fabric needs to be pre-wetted in order to assist the movement of the yarn to facilitate the posterior shrinkage.

Then the denim fabric passes on to the most important sanforizing phase where shrinkage takes place. It is carried out in a cylinder with a rubber tape or mat stuck to it which exerts pressure on another cylinder as it can be observed on the picture. There is a pressure area between the cylinder and the rubber where the shrinkage of the fabric takes place, where the warp thread is joined and evenly shrunk.

“Control of shrinkage due to compression is a physical treatment on the denim fabric technically called sanforizing”

Sanforizing range

Diagram 4



After being 'compacted' in the rubber mat the fabric passes on to the drying phase where the fibers maintain their shrunk state until the residual moisture is removed.

During the sanforizing process both the length and the width of the fabric should be controlled. That is why occasionally samples of the fabric are taken, then washed and dried to check the shrinkage degree.

Optional Operations

Optional operations could also be regarded as 'usual'. However, as they are not always requested, they cannot be called 'basic'.

They are carried out always whenever operations such as tailoring or garment finishing is required (they are usually performed in vertical mills, which market finished garments).

- **Desizing**

Only in specific cases the removal of the sizing agent (which had to be applied to the warp threads to pass them through the loom during the weaving process) is carried out.

The type of proceeding depends on the type of sizing agent used. Hydrosoluble sizing agents they can be easily removed with energetic washings with the aid of a dispersing agent. On the other hand, to eliminate sizing agents based mainly on native or modified starch it is necessary to use amylase enzymes.

The desizing process is always necessary when a special final fabric finish is supposed to be carried out. It is also required when the fabric to be delivered to the final client should have a soft and smooth handfeel, without the stiffness of still sized fiber.

- **Stenter**

It is an operation which is performed on those denim-type fabrics, which contain a percentage of elastomeric fiber in their structure (generally in the weft). This way it is possible to control the fabric's free elasticity, which stays pre-set (thermo-set) adjusting and controlling the final shrinkage of the fabric.

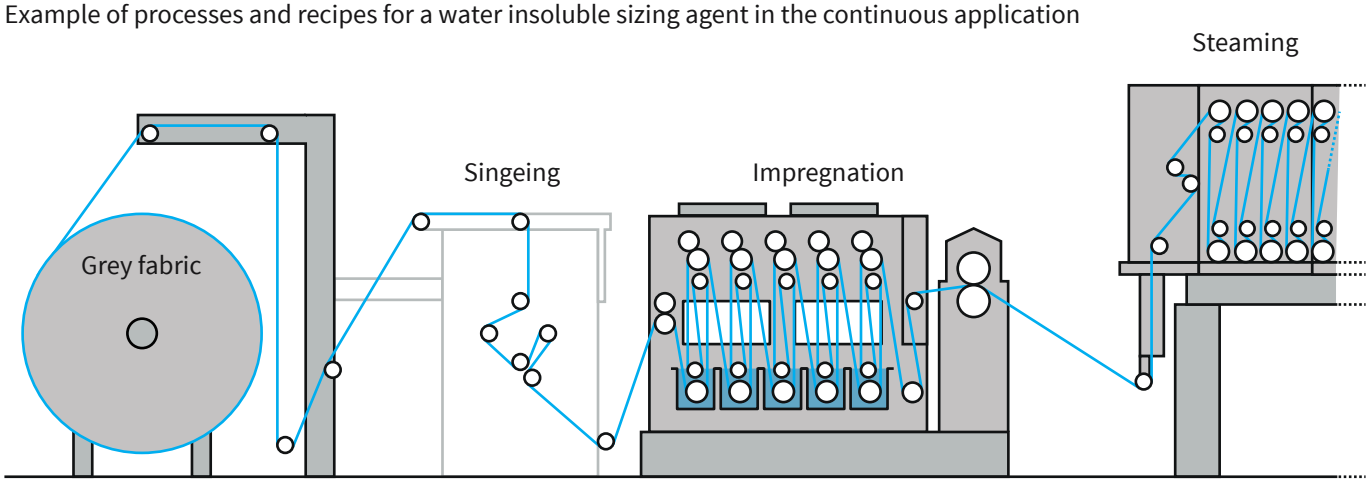
That is why the fabric, stretched and held by needles or pins, circulates through a series of chambers at elevated temperature.

The temperature, together with the time necessary for thermo-setting, is determined depending on the type of elastomeric fiber used, the structure of the fabric itself and the final conditions in which it is supposed to be left.

Before the fabric enters the chambers it can be impregnated in the squeezing mangle with a solution, like for example a softener (chemical finishing) to improve the handle and facilitate the posterior tailoring process.

Bactosol® PHC. Pad Steam desizing

Example of processes and recipes for a water insoluble sizing agent in the continuous application



Recipe

Hostapal® MRZ liq.	4 ml/l	Bath pH	5-6
Bactosol® PHC liquid	**1 ml/l**	Bath temperature	60-80 °C
hc	2 ml/l	Steaming time	1-3 min
Sirrix® ANTOX liq.		Steaming temperature	100 °C

- Fast swelling of sizes with the high temperature.
- Bioconversion of starch into water-soluble sugar.
- A strong final washing eliminates sugars from the fabric.

“Denim fabric containing elastomeric fibers needs to be thermo-set in the stenter range”

- **Denim fabric mercerizing**

Before mercerizing a denim fabric it is advisable (although not essential) to carry out a series of operations which have previously been explained such as singeing and desizing. This last process can be done simultaneously, desizing and mercerizing at the same time. However, this depends on the machine available.

The mercerizing effect generates a shinier look of the denim fabric, whether or not combined with sulfur dyes Diresul® RDT liq. At the same time a change in the physical structure of the cotton takes place (swelling of cotton) which produces a fuller appearance of the fabric and a more intense and regular shade.

Another effect is the improvement of the recuperation of dimensional stability after laundering (the effect is better if ironing is carried out after the washing).

- **Calendering**

This process changes the appearance of the fabric, leaving it more compact, smooth and shiny, which is similar to the effect created with strong ironing.

The process is performed by passing the fabric through heavy cylinders which rotate under pressure. These cylinders can be even heated in order to attain a polished and shiny effect.

This effect is not permanent and is used as a complement for postmercerizing, which was explained previously. Generally it is not a habitual process on denim.

“Mercerizing effect generates a shinier look of the denim fabric”

Washing vat after desizing. The fabric circulates thanks to a series of submerged cylinders

9.2 Special Denim Fabric Finishing

These operations give the final fabric certain physical properties contributing to the garment's appearance and comfort.

At present there are different possibilities in this field such as:

- **Chemical Finishing**: by using chemical products like binders, softeners, etc... to enhance special hand feel properties of the denim fabric.
- **Colored Finishing**: by using chemical products along with pigment dispersions (Printofix® range) in order to give the denim fabric certain fashionable properties developed in garment finishing. Other range of dyes such as sulfur dyes (Diresul® RDT liq) or direct dyes (Indosol® dyes) can also be used in these recipes.

The most often applied techniques for denim fabric finishing are the following:

1. Knife coating application;
2. Rotary screen coating application;
3. Dyeing trough padding application.

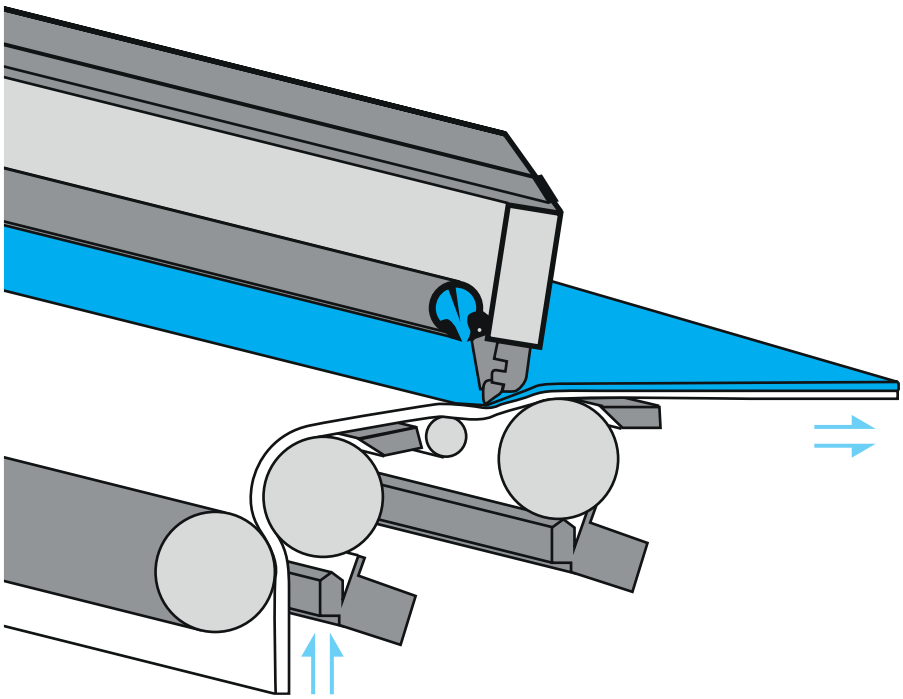
The finishing recipes in techniques 1 and 2 can be prepared both in the form of paste as well as foam.

These products are applied on the fabric in liquid form in case of padding application.

Nowadays, denim fabric finishing has become extremely important for denim quality differentiation as it gives an added value to the fabric.

Air knife

In orange the colored paste to be applied to the fabric



"Advanced Denim" jeans

9.3 Special Garment Finishing

These are physical, chemical or even combined finishing carried out on the garment. They are executed in machines called tumbler or rotary drums, similar to domestic washing machines, but with a greater capacity and resistance.

Garment finishes have become a cornerstone of fashion effects. During the last few years new mechanical (dry) as well as chemical (wet) effects for garments have been developed. By combining both a series of unique and individual looks in each pair of jeans, a vintage denim effect can be obtained.

Mechanical or Physical Effects on Garment (Dry Denim Processing)

Grinding: normally it is done on pocket edges and bottom hems by running them against an abrasive surface or a stone.

Tagging/clipping: this effect is achieved by using a swift tag machine with a plastic tag which is attached to the fabric. This way it is possible to obtain high contrast effects after washing at the waist, on the edges of the front and rear pockets as well as on the seam on the underside of the jeans.

Damages/breaks: controlled warp removal to achieve vintage worn-out effects and breaks. Pen grinding tools are used for the process. It is also possible to make damage holes both in the warp as well as the weft. These effects are obtained manually for a unique and individual look for the jeans.

Tie effects (such as tie net)**:** generally used when dyeing garments with irregular effects transferred to the denim garment by means of stone wash type processes. This way it is possible to obtain abrasion effects in certain areas of the garment.

Grinding effects in pockets

Damages/breaks effects

“Garment finishes have become a cornerstone of fashion effects”

3D effects with resin applications: permanent creases on specific areas of the denim garment (pocket, heel or the back of the knee area).

Patch and repair: manual processes used to obtain a vintage look and unique and individual effects. The effect consists of tearing the fabric in a certain area and then sewing it again manually or using a sewing machine. The obtained effect is new or used vintage.

Laser effects: laser marking, whiskers/moustaches. These are special effects generated with a laser beam to imitate creases which are formed naturally while wearing jeans.

This type of effects can be created in a predetermined way by using a big variety of designs and sketches.

Local tint staining effects / bleached spots: diluted solutions of oxidizing agents are sprayed on or applied with a sponge after the wet process neutralizing.

Pigments with resin can be used for local application on jeans in the same way, by being sprayed on or applied with a sponge

Chemical Effects on Garment (Wet Denim Processing)

Desizing: if the denim fabric has not been desized, this process is carried out on the garment with enzymes at the adequate pH according to the type of enzyme used. This procedure can be considered as a wash down technique for denim garments due to the abrasion they suffer in the washing drum.

Stone wash: it is still the most popular of all wash down treatments. Jeans are washed with oval or round pumice stones. The pumice stones are very light and with a rough surface.

Jeans sprayed with PP

“New technologies are becoming progressively popular for sustainable finishing treatments on jeans”

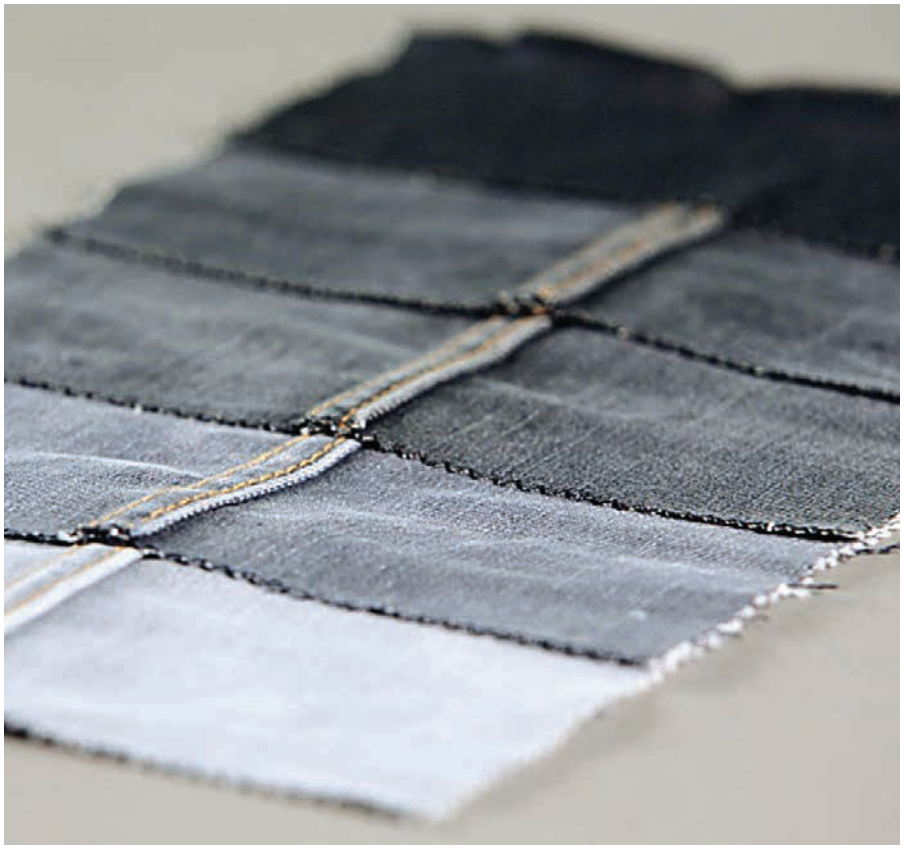
Stone washing is used on fabrics or garments to produce certain color or texture effects. When the stones come in contact with the fabric, abrasion occurs and superficial coloured fibers are removed.

Terms such as “deep stone” or “super stonewash” are an indication of how long the jeans have been stonewashed. The longer the wash, the lighter the color of the jeans.

Enzyme washing/biowashing: it is a process that uses enzymes to ‘stonewash’ jeans, it means to imitate the use of stones. The enzyme accelerates the superficial degradation of the fabric, exposing the white core of the color-dyed yarn. It is often used in conjunction with pumice stone to enhance the worn out look.

Jeans with repair effect

Jeans with patch effect



Denim fabric washed with hydrogen peroxide

Bleached effect: it is another chemical wash down treatment for the denim fabric. A sodium hypochlorite or potassium permanganate as strong oxidazing agent are normally used when the color is destroyed through chemical attack.

Due to ecological reasons, this kind of treatments will be progressively abandoned in the future.

As an alternative, chemical products like hydrogen peroxide are being used more and more often. This treatment is specially indicated for denim garments dyed with Diresul® RDT liq since the final look of the fabric is shiny and faded at the same time. This treatment can be considered as eco bleach because no hazardous substance remains in the denim fabric once it had been washed and dried.

Acid wash effect: a technique of washing jeans achieved by using pumice stones soaked in various chemicals during the stonewashing process. The visual effect is uneven.

Double color contrast is obtained after discharged oxidative treatment through combining stable/unstable sulfur dyes (Diresul® RDT liq range) with sodium hypochlorite or potassium permanganate.

Spray / pulverizing effect: the spraying of oxidizing products, pigments and resins on jeans, jackets, etc. It is supposed to create special effects and particular finishing on garments.

Permanganate effect along with some damage and a slight ozone treatment gives a vintage look (garment dyed with sulfur blue).

Ozone effect: as a new application technique, this treatment could be the most ecological fashion effect for the denim garment. The color, in the case of sulfur dyes (Diresul® RDT liq), keeps the initial cast but with a natural fading or bleached effect.

“21st century: sustainable fashion is a must”

9.4 Diresul® RDT liq as an Element of Final Distinction between Denim Articles. Special Finishing

Coating with Diresul® RDT liq

The concept of using Diresul® RDT dyes in the air knife coating head is very recent.

Archroma has developed this new process with the objective of continuing to offer clients articles of value-added differentiation.

The main advantages of this type of application are:

- Obtaining shades which range from very light to very intense ones;

- Wide range of shades;

- The use of resins is not required. Polymerizing temperature does not have to be reached, temperature sufficient for drying is enough;

- Pleasant handle after drying;

- Possibility of obtaining different effects after chemical wash-downs.

Overdyeing with Diresul® RDT liq

The continuous application process on the fabric is generally performed using the pad-steam or pad-Ox application systems or other, related processes. They are usually carried out on desized denim fabrics. As a result darker and dirtier shades are obtained. Diresul® Orange RDT or Diresul® Brown RDT dyes are used to obtain the dirty effect. Black dyes are used for very deep shades.

Spraying with Diresul® RDT liq

It is a new process of application with Diresul® RDT liq dyes carried out by pulverizing the dyeing solution.

As previously mentioned, in this type of application it is possible to obtain new look and effect on garment.

9.5 Other Archroma Global Ranges for Application on Denim

As a global company with high expertise in textiles, Archroma offers a wide scope of pigment dispersions, dyes and chemicals.

Printofix® Pigments

A high quality range of pigment dispersions for application on denim articles. They can be used for colored fabric finishing in the coating head (paste or foam application), as well as for colored finishing on garment form.

Indosol® Dyes

Complete range of Archroma direct dyes. They are generally used for dyeing tailored garments which are supposed to have a dirty look (slight change of the conventional blue denim shade in order to obtain a soiled and used appearance). Generally this overdyeing process is combined with subsequent wash down treatment.

Archroma introduces a complete range of colors for this application from bright to dull tones, although on denim articles they give a dirty look. They change the shade of the classic blue obtained with indigo or any other color such as sulfur dyes.

Archroma´s Denim Book was conceived to give an overview of the many processes and products currently involved in the manufacturing of jeans.

Denim, of course, is in constant evolution and new developments will surely influence the future of the industry.

ARCHROMA
LIFE ENHANCED

www.textiles.archroma.com
textile.specialties@archroma.com
www.archroma.com

ARCHROMA MANAGEMENT LLC
Neuhofstrasse
4153 Reinach
Switzerland

ARCHROMA GLOBAL DENIM CENTER
Pol. Can Estape
0755 Castellbisbal BARCELONA - Spain
www.advanceddenim.archroma.com
denimcenterBCN@archroma.com
Follow us on twitter @advanceddenim