EIM© ENVIRONMENTAL IMPACT MEASURING SOFTWARE

CONSIDERATIONS FOR CALCULATIONS

Jeanologia®
THE SCIENCE OF FINISHING

INTRODUCTION

In recent years, we have seen a growing commitment by brands and retailers to improve sustainability in production.

Among the motivations behind this constant push for a more responsible behavior are the stricter global legislations regarding chemical uses, waste water and fume emissions; the constant increase in the price of energy; water shortage issues in many areas of the world and the fact that the consumer is already starting to ask for better practices in apparel production.

As our industry and its major brands and retailers become more conscious of the impact of their activities on the environment, they are starting to look for alternatives that can truly fulfill ecological parameters on way or another.

EIM is the result of our aim to offer consumers an environmental friendlier product, starting from the understanding of where we are on the roadmap to sustainability to guide companies in the introduction of new technologies and processes, the selection of the right fabric and chemicals that can lead to a drastic reduction of the environmental impact caused by the garment finishing process.

EIM was developed by Jeanologia in 2009 as an internal tool to be used by Jeanologia engineers and designers. It proved to be a valuable resource for apparel brands and their garment finishing facilities, providing information that leads to more sustainable manufacturing practices. Aligned with Jeanologia's mission of transforming the textile industry, the EIM software is open to all of the garment finishing industry, regardless of the finishing technologies they use (including our competitors). Jeanologia's EIM platform standardizes the process with clear and transparent measurement criteria and rules and is priced affordably to scale access to the data in this valuable resource.

In this document we will define all the parameters used to calculate the environmental impact of a product, as well as all the considerations upon which the final EIM score is given.

OBJECTIVES

EIM has been created to provide laundries and garment finishers all over the world, not only Jeanologia's clients, with an instrument to help them build more sustainable processes.

THE TOOL WILL, AMONG OTHERS:

- Asses where the impact is higher and take the necessary actions to reduce the environmental footprint.
- Monitor that the actions are leading to the right direction.
- Compare different processes to make informed decisions.
- Motivate and accelerate the introduction of new finishing techniques that can lead to different levels of reduction of the environmental impact.
- Have a standard to measure the environmental footprint of the garment finishing stage of the process no matter where it is produced.
- Add a new decision element for buyers.

HOW IT WORKS

EIM measures environmental impact in four different categories: water, energy, chemical impact, and worker impact.

BASED ON A PROCESS (RECIPE) DESCRIPTION, THE SOFTWARE WORKS IN 3 STEPS:

1. Quantify impacts for each category.
2. Benchmark results against a define environmental threshold. Specific thresholds are available according to the kind of garment process being assessed (denim, garment dyeing, garment wash)
3. Classify process through a score based on equal weighting across all categories:

WATER CONSUMPTION l/kg	0 - 45	45 - 90	+90
ENERGY CONSUMPTION kwh/kg	0 - 2,50	2,50 - 3,60	+3,61
CHEMICAL IMPACT	0 - 33	34 - 66	67 - 100
WORKERS' HEALTH	0 - 13	14 - 29	+29

EIM v2 DENIM threshold

METHODOLOGY

To be able to assess the environmental impact of the wet finishing processes and make comparisons we have:

1. Established a primary hypothesis regarding number of garments being processed on every batch in washing, dyeing, and drying equipment.
2. Established the parameters that will be measured.
3. Defined a system to measure and classify this parameters.

DEFINITION OF THE ASSESSMENT PARAMETERS

a) Primary hypothesis:

Standard washing machine load to process: 100 kg of garments.

b) Parameters:

When assessing the garment finishing industry, there are multiple factors that might create an impact on the environment. Among all the possible sources of this impact we have set the focus on the three categories described below, since these are the ones that contribute the most to environmental pollution.

These four categories are:

b.1. Water consumption

b.2. Energy consumption

b.2.1. Electrical energy needed to run the machines.
b.2.2. Caloric energy needed to heat the water and air.

b.3. Chemical inputs:

Potential environmental impact, measured taking in consideration their effects on waste water (biodegradability, aquatic and soil toxicity).

b.4. Impact on worker health:

b.4.1 Potential hazards for the workers handling the chemicals due to their inherent toxicity
b.4.2 Potential hazards inherent to the operations the workers does (i.e: manual scraping, tagging, tyieng, etc...)

c) The environmental threshold

d) EIM score calculation - benchmark process classification

CONSIDERATIONS

b.1. Water consumption:

For each step a calculation of the quantity of water required has been made. The quantity of water consumed will vary depending on the liquor ratio (litres of water per kg of garments) defined for every step of the washing / dyeing process. The total quantity consumed in a complete wet garment process is the sum of the litres required for each sub-operation.

$$L : R = \frac{\text{LITER OF WATER YOU ENTER INTO THE MACHINE}}{\text{WEIGHT OF GARMENTS YOU ENTER INTO THE MACHINE}}$$

When using recycled water for one particular step, a correction factor will be applied. Only effective water usage is considered for the benchmark and final score calculation.

b.2. Energy consumption:

An accurate assessment of the total energy consumption requires a highly complex calculation. However, our main purpose has been to define a clear and logical system that allows us to measure and put a value upon the environmental impact of a process.

Regarding energy, there are two different kinds that are needed to complete a wet process.

b.2.1. Electrical energy needed to run the machines

b.2.2. Caloric energy needed to heat the water and air

b.2. Energy consumption:

b.2.1 ELECTRICAL ENERGY NEEDED TO RUN THE MACHINES

In order to calculate the quantity of electrical energy consumed by each machine, we have consider all elements that require energy, including pneumatic energy. We have considered:

Total running time: That is the time that the machine is running. Time dedicated to sub-operations where the machine is stopped, like filling steps, etc, will not be considered for this calculation.

Nominal power of the machine: Maximum energy that the machine will consume considering that it is working at his maximum power throughout the whole process.
If part or all the electrical energy needed in a finishing plat is self-generated by means of renewable energy sources, a correction factor will be applied. Only effective energy usage is considered for the benchmark and final score calculation.

WASHING MACHINES

Washing machines need electrical energy to turn the internal drum.
To define the nominal power, we have considered different non-extraction washing machines, with a nominal capacity of 350 – 400 kg from different suppliers. These types of machines are preferred to wet processed 100 kg of garments. The nominal power that we will adopt as an average of the machines existing in the market is: 18 KW

LASER

In a laser marking the energy consumed comes from the laser itself, the cooling system (chiller), aspiration, mannequin, etc.)

TUMBLER DRYER

The tumbler dryer needs electrical energy in two ways: to tumbler the dryer drum, and a fan to blow the air. Following the same criteria than before, the nominal power that is being considered for the drying operation is 24 KW (5 KW + 19 KW)

B.2.2. CALORIC ENERGY CONSUMED IN THE FINISHING PROCESS

To assess the caloric energy has been one of the complicate issues of this research. We have created our own assessment system based on the theoretical principles of the physics.

The definition of a calorie is the amount of heat required to raise the temperature of a gram of water 1°C at standard atmospheric pressure.

The quantity of required energy to heat the temperature has been calculated applying the following formula:

Heating energy required (Kcal) = (Tf-Ti)*L

Once the temperature is reached we need to keep it during a certain amount of time. The time will be different depending on the process step. To calculate the energy consumed in maintaining the water temperature, we have measured the rate at which the temperature dropped in semi-industrial and industrial machine, or conversely how often it was necessary to inject steam to preserve the same temperature. This calculation has been made at three different temperatures, 60°C, 80°C, 90°C, since these are the most popular temperatures within the processes being analyzed.

Based on the above water cooling graphics we have considered that to keep the water at:

- 60°C, we must inject steam every 15'
- 80°C, we must inject steam every 5'
- 90°C, we must inject steam every 1'

E(Kcal) = (Tf-Ti)*L

Where:

Tf: The temperature required for the specific steps of the washing / dyeing process.

Ti: The initial temperature, or the temperature that the water has when it is introduced into the machine.

This initial temperature not only will be different depending on the country where the garments are being process but also on the period of the year (summer or winter time). We have considered as a representative average 25°C.

L: The liters to heat are the total quantity of water that has been introduced into the machine.

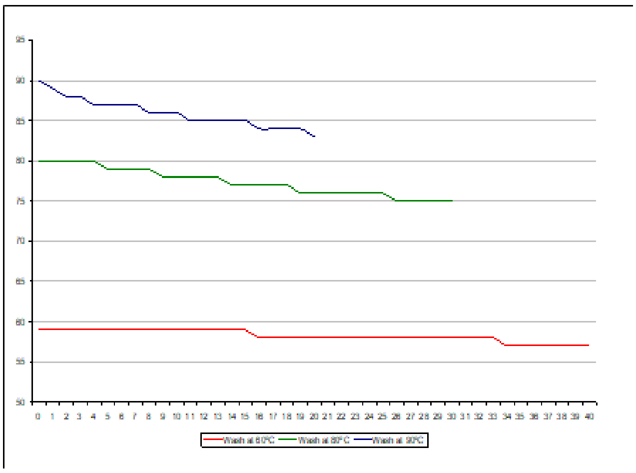


Fig.2: Cooling down graphic

b.2.3.

CASE STUDY - CALORIC ENERGY CALCULATION

Let’s imagine that:

- We need to wash 100 kg of garments at liquor ratio of 1:10.
- I need to introduce 1000 l of water into the machine.
- The water comes into the machine at a temperature of 25°C
- The required temperature for this process is 80°C
- I need the machine running for 30’ at 80°C

The total energy consumption to heat the water will be:

(25-80) x 1000 = 55.000 Kcal

To keep this water at 80°C, during 30’ we will need:

30/5 = 6 “steam injections”

That is, I need to increase the temperature from 79°C, to 80°C, six times, so I need:

(80-79) x 1000 x 6 = 6.000 Kcal to keep the water hot

The total energy that will be consumed for this particular process will be:

55.000 Kcal + 6000 Kcal = 61.000 kcal

Applying the conversion between Kcal and KWh (860 Kcal = 1KWh), we finally need 70,93 KWh.

There are many different chemical products that are required to be used in the garment finishing process. As a result of their use, chemicals can impact in different ways which include the following:

- Waste water effects directly with the chemical itself.
- Waste water effects with chemicals derived from the reaction with a chemical product within the textile goods and / or any other possible chemicals like colour, dyestuffs etc,
- Air quality due to emissions from the chemical itself.
- Air quality due to emissions resulting from chemical reactions with the textile goods.
- Exposing people to potential illness as a result of directly handling the chemicals.
- Exposing people to potential illness as a result of chemicals reactions with the textile goods and other chemicals previously applied to it.

The chemical impact is calculated taking into consideration the EIM CIS, a chemical impact score given each chemical to be used in a garment finishing process. EIM CIS, classifies and score chemicals as per their ZDHC MRSL conformance and the hazard assessment of each individual ingredients of a chemical product or a formulation.

EIM CIS works as platform of integration of two other important initiatives: ZDHC MRSL conformance and Screened Chemistry. Aligning EIM's metrics and methodologies with other industry standards for the classification and scoring of products will increase transparency, simplify the process for selecting safer chemical products, and facilitate more consistent and accurate communications to the marketplace.

To define the EIM CIS (chemical classification and scoring) methodology, Jeanologia has partnered with Scivera, an Enhesa Group company, who is a leader in providing chemical suppliers, chemical formulators, manufacturers, and brands across all industries with intelligence about the chemicals they are using in their products. By providing access to verified Chemical Hazard Assessments economically, Scivera helps their clients understand human and environmental health impacts and builds their capacity to make safer chemical decisions and safer products across global value chain.

EIM chemical database is formed by:

- Commercial formulations with at least ZDHC level 1 3rd party certificate.
- Commodities or basic chemicals.
- Generic chemicals based on functionalization such as enzyme, detergents, softeners, etc.
- Other special products such as pumice stones and its alternatives that are in fact not chemicals but can consider as such when describing a garment finishing process.

Chemicals available in EIM are classify and scored following the criteria described below.

WHO IS SCIVERA?

Since 2008, Scivera has been supporting consumer product brands and their global suppliers in building an enhanced understanding of the chemicals used or considered in products and formulations. Scviera developed the SciveraLENS platform to make data gathering and access to critical chemical hazard assessment information more accessible. SciveraLENS is a web-based platform that provides access to regulatory, scientific, and market-driven RSLs and comprehensive, verified chemical hazard assessments, scores, and insight. SciveraLENS supports safer sourcing, product development, and alternative ingredient selection decisions. In addition, SciveraLENS supports chemical formulation data gathering needed to better understand chemical ingredients and impurities in the supply chain while protecting proprietary business information.

EIM V2 chemical classification and scoring criteria

EIM CIS is represented by a color and by a number. The EIM CIS can go from 0 (most sustainable chemicals) to 100 (products of concern with environmental or human important hazards).

For a formulation to be included listed in EIM to have at list a ZDHC conformance level 1 third party certificate is required. Formulations compiling with this minimum requirement will be given a base score of 66 unless:

- The MSDS report content of a substance of concern in which case the score is increased to 89, 83, or 77 according to the ZDHC level (1, 2 and 3 respectively).
- The chemical has a ZDHC conformance level 2 or 3 in which cases the score will be reduce to 57 and 47 respectively.
- The chemical has a Screen chemistry score, or it goes through an equivalent hazard assessment done by a qualified and authorized service provider*. For chemicals having a screen chemistry score, the possible puntuations will be:
    - Preferred chemistry (SCS - 35-50):
        - EIM CIS = 9 (if ZDHC level 1)
        - EIM CIS = 5 (if ZDHC level 2)
        - EIM CIS = 0 (if ZDHC level 3)
    - To be improved (SCS – 34-20)
        - EIM CIS = 38 (if ZDHC level 1)
        - EIM CIS = 33 (if ZDHC level 2)
        - EIM CIS = 28 (if ZDHC level 3)

*Scivera

COMMODITY CHEMICALS:

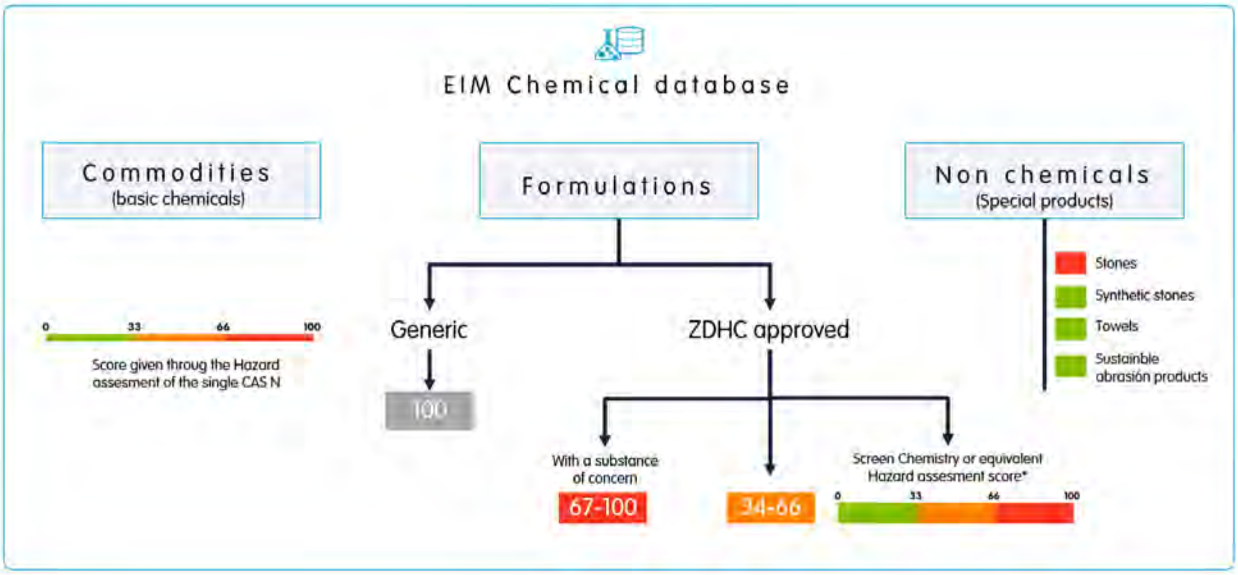
Commodity chemicals are scored differently than textile chemical formulations as the evaluation and score is based on a single CAS RN. Scoring is based on Screened Chemistry scoring rules (https://www.scivera.com/certifications/scv3/). Additional chemicals may be added to this list. The scores listed below are subject to change as assessments are updated. For the most current scores, users may view the SciveraLENS assessment.

COMMODITY CHEMICAL	EIM CIS
Acetic acid	47
Sodium Hypochlorite	37
Citric acid	18
Dextrose	18
Magnesium chloride	37
Hydrogen Peroxide	37
Soda Ash	18
Sodium Sulphate	18
Sodium Hydroxide (Caustic Soda)	37
Sodium Thiosulphate	37
Formic acid	37
Sodium Chloride (Salt)	37
Potassium Permanganate	100
Hydroxilamine	0
Stones (Pumice)	100
Sodium Metabisulfite	37
Peracetic acid	37
Acid - Phosphoric Acid	37
Acid - Oxalic Acid	37
Sodium Persulfate	100
Sodium Percarbonate	37
Sodium Perborate	37

EIM Chemistry Impact Scoring for Generic Chemical Formulation Categories

In some cases, a chemical product formulation used by a finishing facility is not listed on the EIM platform for selection. This might happen because the chemical being used does not have a ZDHC 3rd party certificate or because the chemical supplier has not yet had their chemical product screened and scored by Scivera for delivery to the EIM platform.

In these cases, the finishing facility has the option to select a generic equivalent to the chemical formulation by functional class. For example, if the formulation used is a silicone-based polymer softener, but the specific trade name product is not listed in EIM, the EIM user can select "Silicone-Softener" as the generic and a placeholder will be added to the recipe with a minimum score (Gray and 100) until the actual chemical formulation is available in EIM.



Uploading of commertial formulations in EIM can be done by Chemical suppliers throuhg a specifically avialble self EIM CIS calculation tool. To improved scores throuhg a hazad assesment Chemical suppliers can contact with the authorized Service providers (Scivera: support@scivera.com)

EIM chemical score calculation

To compute the EIM chemical impact score, an algorithm developed in collaboration with Sumerra is utilized. Sumerra is a advisory company with expertise in sustainability rating systems including data modeling and calculation.

The algorithm considers three factors: EIM CIS , quantity of each Chemical and total number of chemicals used.

In addition to the chemical impact, the system will also give breakdown information regarding chemicals used compiling with ZDHC conformance as well a breakdown of products used having a Screen Chemistry certicate.

ADDITIONAL CHEMICAL INFORMATION

ZDHC conformance

% of chemicals having a ZDHC certificate (level 1, 2 or 3)	% of commodity chemicals (Do not required ZDHC conformance)	% of commodity chemicals (Do not required ZDHC conformance)

Screen Chemistry Score

% of chemicals having Screen Chemistry Score	% of chemical without Screen Chemistry Score

SCORING METHOD

For the calculation of the chemical impact the following factor are being consider:

- A factor (W) that will consider the sustainability of the chemicals used in the recipe.
- A factor (Q) that will consider the total quantity of chemicals in a recipe.
- A factor (N) that will consider the number of unique chemicals in a recipe.

The score (S) will be the average of the three factor scores.

S = (W+Q+N)/3

The Sustainability factor will be a simple mean of the maximum EIM CIS score of the chemicals used in the recipe.

W = Weight Score = {csi, ...csn}

Where csi = EIM CIS Score for each chemical

For the quality factor (Q), each chemical in the recipe will be put in a cluster based on the EIM CIS score:

- Cluster 1 < 34
- Cluster 2 = 34 to 66
- Cluster 3 >66

Each cluster is weighted by a multiplier as follows.

- Cluster Multiplier 1 (CW1) = 0.5
- Cluster Multiplier 2 (CW2) = 1
- Cluster Multiplier 3 (CW3) = 3

The sum of the % of on weighted goods (o.w.g) in each cluster is multiplied by the number above and added together to generate a sum of weighted cluster scores (Wsum)

*Wsum = (∑{owgi...owgn}, cl=1)*CW1 + ∑{owgi...owgn}, cl=2)*CW2+ ∑{owgi...owgn}, cl=3)*CW3*

Where owgi = o.w.g. for each chemical in the cluster (cl)

n = number of chemicals in the cluster

Once the Wsum is generated we use the sigmoid function to create a sigmoid curve using a scaling factor (steepness of the curve) and a start value (point in curve where scale increases exponentially) for the designed curve and generate the Q factor.

Q = 100 / 1+e(-kq(Wsum-sq)*

Where Kq = scaling factor = 0.08

Sq = Start Scale = 20

For the number factor (N) the number of chemicals in each cluster (see above) are counted. Each cluster count is weighted by a multiplier as follows:

- Cluster Multiplier 1 (C1W) = 0
- Cluster Multiplier 2 (C2W) = 1
- Cluster Multiplier 3 (C3W) = 5

The count of each number in the cluster is then multiplied by the number above to generate a sum of weighted number scores (Nsum)

*Nsum = ncl1*C1W + ncl2*C2W + ncl3*C2W*

Where ncl1 = number of chemicals in cluster 1

ncl2 = number of chemicals in cluster 2

ncl3 = number of chemicals in cluster 3

Once the Nsum is generated we use the sigmoid function to create a sigmoid curve using a scaling factor (steepness of the curve) and a start value (point in curve where scale increases exponentially) for the designed curve and generate the N factor.

N = 100 / 1+e(-kn(Wsum-sn)*

Where Kn = scaling factor = 0.2

Sn = Start Scale = 20

Impact on worker health:

Garment finishing, especially denim finishing, can involve many different operations. Many of these operations are consequence of the industrialization of artisanal techniques and therefore are often done with domestic tools such as grinder, sandpaper, cutters, etc.

Any operations required on the finishing, and specially these manual operations, might have an impact in worker's heath. Risk of exposure to injuries and illness can be eliminate / minimized in a production plant by implementing the following controls:

a. Engineering controls: That is, eliminating the operation or substituting the equipment, the materials, or others to lessen the hazard.

b. Administrative controls such as writing operating procedures, exposure time limitations, etc.

c. Supplying the workers with appropriate personal protective equipment.

Hazard control and workers protection are highly dependent on the facility, the environment on which the operation is made as well as the person doing the operation. It is in consequence not possible to quantify through risk assessment standard methodologies the potential risk of finishing operation, however, all of the manual operations done in the garment finishing, has inherent ergonomic risk. Ergonomic health problems are one of the major causes of permanent health issues, and so the worker impact health EIM category aims to visualize this fact with the objective of reducing workers health by elimination or replacing those operations with higher inherent potential ergonomic risk.

WORKER IMPACT QUANTIFICATION CRITERIA

To be able to quantify operations according to its inherent ergonomic potential hazard risk, a deep analysis has been developed by a group of experts of “Ergonautas”, a department of the Polytechnics University of Valencia (UPV) specialized on ergonomics evaluation of workplace. Complete study made by “Ergonautas” is the annex 1 of the current document.

The “Ergonautas” study identifies common risk factors of the most common finishing operations and classifies it as low, medium, or high probable to appear. Taken conclusions of the report as a base, we have built a risk matrix taking into consideration the risk probability. To those risk factors with a low probability to happen, we have been given a punctuation of 0, when the risk factor is considered as probable, we have given a punctuation of 1 and when the risk factor is quite probable, the punctuation given is 2. Each operation has been given a total punctuation that is the sum of all risk probability. Table 1 bellow, is the risk matrix.

Table 1: Operations risk factor matrix

	Manual Scraping	Grinding With Manual Device	Grinding With Table Machine	Damages With Manual Device	Damages With Cutter	Automatic Damaging Machine	Spray	Sponging	3d Whiskers	Manual Tagging	Automatic Tagging	Laser Marking
Repetitive movements	2	0	1	0	2	0	2	1	1	1	1	0
Load handling	0	0	0	0	0	0	0	0	0	0	0	0
Force application	1	0	0	0	0	0	0	0	0	0	0	0
Force posture	2	2	2	2	2	0	2	2	2	2	1	0
Vibrations	0	2	2	2	0	1	0	0	0	0	0	0
Contact preasure	1	1	2	1	1	0	0	0	0	1	0	1
Thermal local environment	0	0	0	0	0	0	1	0	1	0	0	0
Noise local level	0	1	1	1	0	1	2	0	1	0	0	0
Atention and risk	0	1	1	1	1	0	0	0	1	0	1	0
Repetitivity and monotony	1	1	1	1	1	1	2	1	1	1	1	0
	7	**8**	**10**	**8**	**7**	**3**	**9**	**4**	**7**	**5**	**4**	**1**

EIM WORKER IMPACT SCORE CALCULATION

The EIM worker impact score is calculated as the sum of individual scores of each operation done in the finishing process according to its recipe description.

The environmental threshold:

Environmental threshold is the base for the benchmark and process classification in EIM.

In order to be able to classify the different finishing processes into processes of low, medium or high impact, we need first to define a threshold for every category.

The definition of the Environmental Threshold is different from every category.

Environmental threshold was developed following a defined methodology and based on certain considerations. As criteria for EIM category impact has been update, the environmental impact of every of the categories need to be as well revised. Furthermore, the positive evolution of the industry shows a different reality today. To prevent a negative blockage of progress (no need to improve if EIM said I am already doing well), as well as to an involuntary green washing, EIM threshold should be revised and aligned with industry today's reality. In addition to this, a clear and scientific methodology for environmental threshold revision and update need to be implemented.

The revision of the environmental thresholds as well as the definition of a methodology for Environmental threshold revision and update, if necessary, have been carried out by a third party: Sumerra.

WHO IS SUMERRA?

sumerra

Sumerra is a well-known consulting organization in the textiles, apparel and footwear industry that provides technical advisory services and program development and oversight to a number of organizations and industry groups. Sumerra uses an objective data-driven approach to establish program framework and benchmarks that ensures programs align, and evolve with industry progression. This approach works to fulfill Sumerra's mission of improving the industry as a whole and promoting safe conditions, worker's rights and environmental stewardship. For more information on Sumerra, please visit *www.sumerra.com*.

THE ANALYSIS OF THE DATA SHOWED THAT A REVISION OF THE ENVIRONMENTAL THRESHOLD WAS NECESSARY.

The first conclusion reached from this analysis showed a necessary revision of the Environmental threshold starting with an update of the benchmark unit. (from l and kwh / garment to l and kwh / garment produced).

In addition to the updated of the benchmark unit, since EIM can be used to measure impact of garment finishing process with great difference in resources such as Denim, garment wash and garment dyeing, environmental thresholds (benchmark) have been defined for each specific garment segment to have much more accurate comparison and drives motivation for continuous improvement.

Environmental threshold for water and energy

EIM V2.0 water & Energy Environmental threshold definition update based on initial methodology of benchmark against specific basic finishing processes:

EIM V2.0 DENIM

The basic finishing processes and steps follow to calculate the environmental threshold have been:

1. Identification of less impacting processes (Rinse (Dark) / Medium Dark).
2. Identification of more impacting processes (Stone/Enzyme bleach // Super Bleach).
3. Determine "Low impact threshold " as the average water & energy requirement for 1 kg of garment of less impacting processes.
4. Determine " medium impact threshold" as the average water & energy requirement for 1 kg of garment of all 4 processes.

Process Name	Garment Weight (kg)	Water (L/garment)	Energy (kWh/garment)
Rinse wash (less intensive wash 1)	1	30	2.16
Medium Dark wash (less intensive wash 2)	1	60	2.5
Light bleach (high intense wash 1)	1	120	4.34
Super Stone bleach (high intense wash 2)	1	145	4.78

EIM V2.0 GARMENT WASH

The basic finishing processes and steps follow to calculate the environmental threshold have been:

1. Identification of 2 basic washes (Softening / enzyme wash).
2. Calculate average water and energy requirements.
3. Determine the "low impact thresholds" calculated as the 30% improvement from the average of the 2 processes.
4. Determine high impact threshold as everything that goes above the 10% of the average.

Process Name	Garment Weight (kg)	Water (L/garment)	Energy (kWh/garment)
Enzyme Wash I	1	60	2
Basic Wash I	1	10	1.11

EIM V2.0 GARMENT DYIENG

The basic finishing processes and steps follow to calculate the environmental threshold have been:

1. Identification of 3 basic dyeing processes (Reactive, wash down, acid dyeing of polyamide (similar process applied to dye cotton with direct dyes).
2. Calculate average water and energy requirements.
3. Determine the "low impact thresholds" calculated as the 30% improvement from the average of the 2 processes.
4. Determine high impact threshold as everything that goes above the 10% of the average.

Process Name	Garment Weight (kg)	Water (L/garment)	Energy (kWh/garment)
Polyamide dyeing 1:10	1	90	3.85
Reactive dyieng 1:10	1	120	3.78
Wash-down cationisation & dyeing 1:10	1	110	3.18

Chemical impact threshold

EIM chemical impact score is directly calculated as the EIM impact scale have been introduced in the EIM CIS calculation.

EIM CHEMICAL IMPACT SCORE IS:

0 - 33

34 - 66

66 - 100

ENVIRONMENTAL THRESHOLD FOR WORKER IMPACT:

Sumerra recommends the revision of EIM worker impacts to review environmental impact of this category,. However, due to the update of the quantification criteria, there is no data available yet.
The methodology defined to the definition have been approved by Sumerra as a good way to define a base line for the future data revisions and analysis.

1. Identification of most common effects that required manual operations
    - Whiskers and used area
    - Damages
    - Grinding of waist band, waist band and bottom
    - Whiskers and used area enhancement
2. Identification of available methods for each of the effect
3. Calculation of EIM worker health category impact of the lowest, highest and average risk possible combinations.
4. Green upper limit range of the Worker impact threshold will be the score of the lowest riks combination. Orange upper limit range, the score of the average risk combinations and the Red upper limit range, the score of the higgest risk combination.

Table 2 sumarizes the Environmental threshold calculation.

		EIM Operation Score	Low Risk	High	Med/ High	Med/ Low
Wiskers and Used Areas (1 operation)	Laser Marking	1	1			
	Manual Scrapping	7		7	7	7
Damages	Cutter	9		9		
	Pneumatic Griding device	8			8	
	Laser	1	1			
	Damage automatic machine	3				3
Grinding	Table griding machine	10	10	10	10	10
Effect	Sponging	4				4
	Spray	8		8	8	
	Laser marking	1	1			
			13	**34**	**33**	**24**
						29

5. The Worker impact environmental Threshold as per the methodology described is as follow:

Low Worker Impact	0 - 13
Medium Worker Impact	14 - 29
High Worker Impact	+29

Environmental threshold revision

For EIM to be aligned with industry progression, EIM environmental threshold should be revised and update when necessary.

According to Sumerra, a representative methodology for EIM threshold revision would be to use statistical analysis from the distribution of the data of a selected year and apply the 33rd and 67th percentile values as the Low and High Impact achievable thresholds.

Following this recommendations, the methodology and updated criteria adopted is as follow:

- EIM data to be analyzed at minimum every 2 years to evaluate need to update thresholds (EIM data from the most recent full year(s) of data. (one or two years if revision is done annually or every 2 years).
- Determine percentile values of the 33rd/67th %
- Threshold adjustment to be triggered when the 33rd/67th percentile values of the most recent year(s) are below 50% of the current threshold values.

EIM score calculation and Benchmark process classification

EIM score is the average of each category score.

Denim benchmarks consider the 4 category score however garment wash and garment dyeing do not include worker impact since this category is address to visualized impact of the dry process. Dry processes have a huge weight in denim finishing but nulle or almost nulle in garment wash and garment dyeing

Category scores are calculated as per the environmental threshold by transferring the category result into a bar from 0 to 100.

EIM scores goes from 0 to 100 therefore, the classification of the process into process of low, medium or high impact is done according to third the final score belongs to.

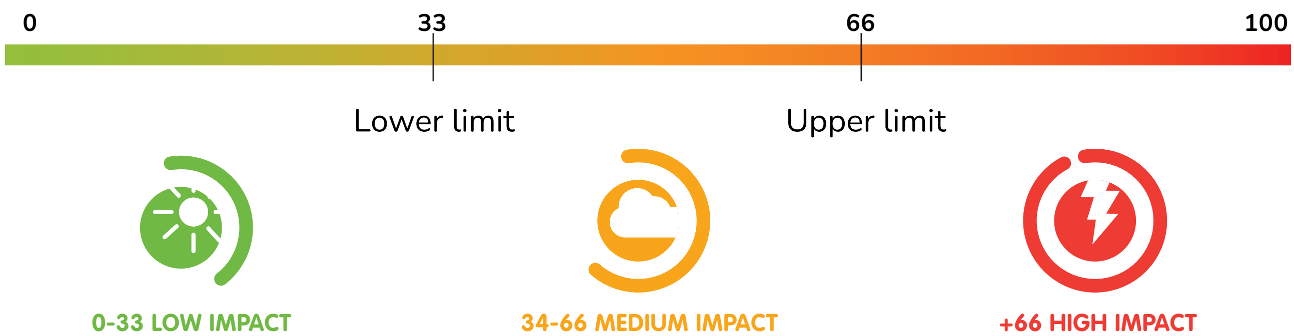
1
Calculation of process EIM score.

EIM scores is the average of category score.

2
Calculation of category score.

Tranferring score to a numerical bar from 0 to 100 according to category threshold.

3
Classification of the process in 3 categories according to EIM score result.

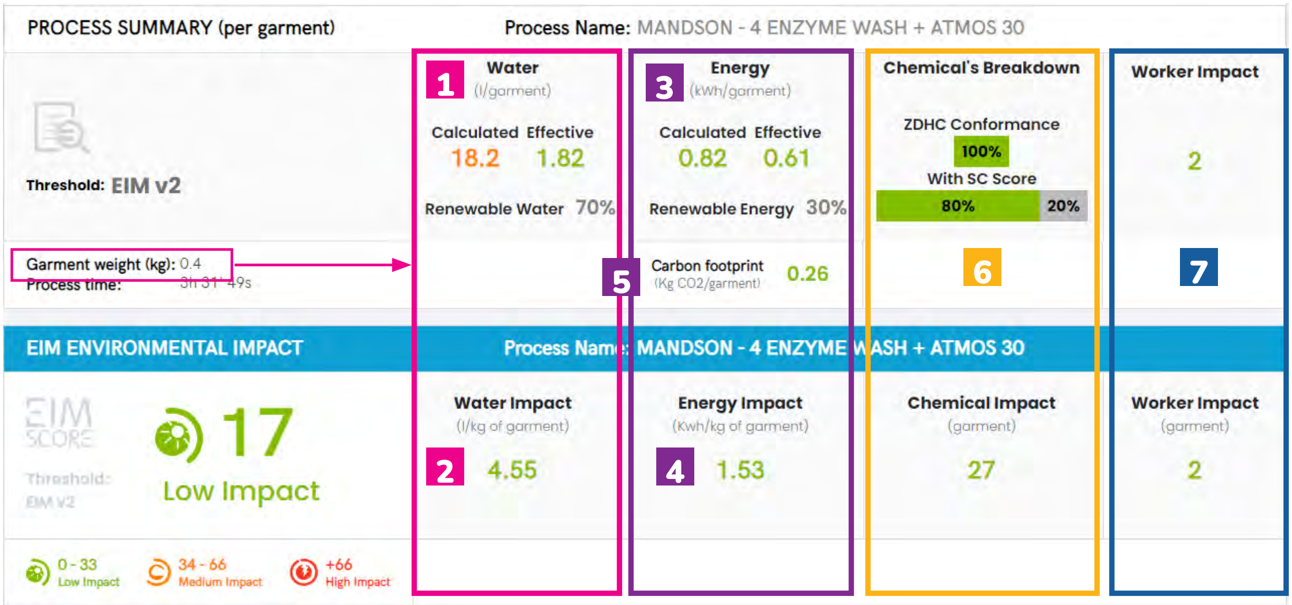


EIM is a great tool to gather data and be able to monitor progress, compare results and set targets.

EIM reports summarize the data related to the process described as well as the data necessary to calculate the score and be able to classify as per the selected EIM environmental threshold (benchmark).

The information supplies and how it is organized is detailed in the following picture:

KEYS TO INTERPRET THE REPORT



1 The **Calculated Water** is the water required to finish one garment according to the described recipe.
The **Effective Water** is the water used to finish one garment, so when re-using water, the % of re-utilized water will be discounted from the calculated one.
Both calculated and effective water are given in l/garment, therefore **Garment's Weight** is key to be able to calculate liters of water used to finish one garment.

2 The **Water Impact** is calculated from the Effective water used. The Effective water is normalized to 1 kg since EIM Benchmark is related to the l/kg used.
The Water Impact will be classified, and so coloured, as low (green), medium (orange) or high (red) impact according to the water threshold.

3 The **Calculated Energy** is the energy required to finish one garment according to the described recipe. The **Effective Energy** is the energy used to finish one garment, so when a % of Renewable energies are used, it will be discounted from the calculated one.
Both calculated and effective energy are given in Kwh/garment, therefore **Garment's Weight** is key to be able to calculate Kwh of energy used to finish one garment.

4 The **Energy Impact** is calculated from the Effective energy used. The Effective energy is normalized to 1 kg since EIM Benchmark is related to the Kwh/kg used.
The Energy Impact will be classified, and so coloured, as low (green), medium (orange) or high (red) impact according to the energy threshold.

5 The **Carbon footprint** is a first stimation calculated fromt he effective energy. An average energy mix factor is applied is applied to the electrical energy. The combustión factor is calculated considering gas and gasoil are the most frequent combusiton souces used in finishig plants.Both factors Will be revised annually according to oficial available data. (Current factor mix: 0,46 // Current factor for heatig energy 0,29)

6 Every chemical is given an **EIM CIS** (EIM Chemical Impact Score) according to its ZDHC MRSL conformance level and hazard. EIM CIS is represented by a number that goes from 0 to 100 and a color (green for preferred chemicals, orange for acceptable chemicals, red to identify those to phase out and grey for those there is not enough information for an accurate hazard assessment). EIM CIS is calculated by authorized third parties.

7 **Worker Impact** measures the impact on the worker health that operations they have to do to finish one garment. Operations are score according to the inherent ergonomic risk & factors of each operation have. The worker impact will be the sum of the score of all the operation done that shows this inherent hazard.

ENVIRONMENTAL
IMPACT
MEASURING
SOFTWARE

CONSIDERATIONS FOR CALCULATIONS

ANNEX I
-
Analysis of ergonomic risk factors in denim finishing operations

Jeanologia
THE SCIENCE OF FINISHING

Analysis of ergonomic risk factors in denim finishing operations

Responsibility

This report has been prepared by the Ergonautas research into occupational ergonomics group, which belongs to the Research and Innovation in Bioengineering Institute (i3B) of the Polytechnic University of Valencia (UPV) at the request of Jeanologia S.L.

The contents of the report have been prepared based on the information provided by Jeanologia S.L. on certain denim clothing manufacturing operations. The conclusions are based on the state of the knowledge and techniques relating to occupational ergonomic risk factors at the time of the preparation of the report. The UPV is not responsible for the inaccuracy of the information on which the report is based or for the lack of legality, reliability, usefulness, truthfulness, completeness or up-to-date nature of its content. This report is not a technical or legal guide, nor must it be used for any other purpose than information. The UPV is providing the report on an “as is” basis, without any kind of guarantee. The UPV cannot be held liable, with the limits established in the current legal system, neither indirectly nor secondarily, for damages of any nature arising from its use.

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Purpose

Achieving the desired finish and appearance of clothing manufactured with denim involves a series of processes and treatments known together as denim finishing. These processes include, among other things, certain types of washing of the garment or wear by mechanical, chemical or laser light means of areas of different sizes. In addition to certain health and safety risks in the operations involved in these processes, the workers carry out activities and tasks in which ergonomic risk factors may be present that affect their health.

According to the World Health Organisation (2019), musculoskeletal disorders are the main cause of disability in the world. The purpose of this report is to carry out a qualitative analysis of the ergonomic risk factors relating to these disorders that may be present in certain commonly performed operations in the denim clothing finishing processes.

The operations involved in these processes have a high variability in the way in which they are implemented and carried out in practice. For this reason, only the intrinsic characteristics have been considered of the tasks that pose an inherent risk, or those that are common or more widespread in their implementation and form of execution in production processes.

Therefore, this analysis is carried out on generic tasks in an attempt to establish the potential risk of the operations, so that it can serve as an *a priori* reference in the implementation of denim finishing production processes.

Scope and limitations of this study

This report includes an analysis of the ergonomic risk factors that can potentially be present in operations carried out in the denim finishing processes, considering these operations in generic form. That is to say, only taking into consideration the intrinsic characteristics of the tasks and not their implementation and form of execution in the production process. The objective is that the results of this analysis can be used as a prior reference, for example, in the selection of the most appropriate operations from the ergonomic point of view in the implementation of denim finishing processes. The ultimate aim is to contribute to the improvement of practices in occupational health and reduce risk in companies in the sector.

The aim of this report is not to make an ergonomic assessment of the tasks involved in denim finishing processes. The assessment of the presence of ergonomic risk factors in the performance of a task entails an overall analysis of the circumstances in which it is performed. In addition to knowing all the characteristics of the task itself, the workstation in which it is carried out, the organisational structure of the company, the work conditions and the characteristics of the workers that perform the tasks must also be analysed.

In the analysis included in this report, not all these characteristics have been considered, solely those inherent to the tasks. That is to say, those characteristics considered structural were analysed (characteristics that are highly likely to be present in any implementation of the task in a production process). Circumstantial characteristics, i.e.

those that depend on how the task is carried out or its actual implementation, have not been analysed or have been considered because of the likelihood of their existence.

Therefore, the scope of this analysis is necessarily limited and it can in no way be considered an ergonomic assessment of the analysed tasks, but an estimation of their potential risk. The actual risk will depend on the form in which the tasks are effectively put into practice. This report neither identifies nor includes all the risks that may be present in the facilities in which the tasks are performed, and risks may exist that are not mentioned or considered.

Moreover, this report does not consider the local standards, laws or regulations relating to work or health and safety at work, nor can it be used as a replacement for the obligations that these impose on companies.

Ergonomic risks at work

Machinery, tools, equipment and chemical products are used in the processes involved in denim finishing. This means that there are health and safety risks to workers and the environment arising from deflagrations, poisoning, burns, inhalation of smoke, fibres, dust or chemical substances in suspension, electric shocks, falling and slipping. For their part, the ergonomic risks at the workstations associated with these processes can arise from the inadequacy of the physical and biomechanical conditions (dimensional, environmental, physiological, etc.), organisational and psychosocial conditions (hours, breaks, workload, remuneration, conciliation, etc.), as well as from individual factors or factors relating to the worker (anthropometry, pregnancy, training, illness, etc.).

In contrast to what happens with occupational safety risks, and to a lesser extent with health risks, ergonomic risks are characterised by the long time gap between the causes (the risks) and their consequences (the damage to the health of the worker). The risks to the health of the worker of unergonomic conditions at work usually occur due to the accumulation of small low intensity traumas over a long period of time. For this reason, it is very difficult to establish an immediate cause-effect relationship between the ergonomic risk factors and their consequences. This means that, generally, the risk perceived by workers is low and the consequences of these risks are unknown.

However, the magnitude of the consequences of the ergonomic risks on the health of workers is enormous. Together with mental disorders, work-related musculoskeletal disorders (MSDs) constitute the main cause of occupational disease and absenteeism at present (Fourth, Fifth and Sixth European Working Conditions Surveys, 2005, 2010, 2015). The high prevalence of MSDs has significant economic and social repercussions. Those affected have a reduced quality of life due to chronic pain, chronic fatigue and economic problems such as reduction of income as a consequence of taking sick leave and an increase in expenses on drugs and medical care.

Given the magnitude of this problem and the high economic and social costs, it is the responsibility of both public bodies and the companies themselves to promote strategies to reduce the presence of ergonomic risk factors at work. Reducing the incidence of work-related MSDs necessarily involves reducing the exposure of workers to ergonomic risk factors, by reducing the extent, duration and frequency of the risk. Reaching this objective involves properly fitting out or designing workstations to adapt them physically to the worker, adequate training of workers in order to achieve risk-free work performance and the organisational changes necessary to create a preventive culture in the company.

Ergonomic risk factors

The direct and most common consequence of the presence of ergonomic risk factors at work are work-related MSDs. According to the European Agency for Safety and Health at Work, MSDs are disorders affecting the body structures such as the muscles, joints, tendons, ligaments, nerves, bones and the circulatory system, caused or aggravated mainly by work and the effects of the environment in which it is carried out. MSDs mainly affect the back (especially the lumbar area) and the neck, although they are also common in the shoulders, upper limbs and lower limbs.

Some MSDs have well-defined symptoms such as, for example: wrist tendinitis (inflammation of the wrist tendons), carpal tunnel syndrome (irritation of the median nerve responsible for closing the index finger and half of the ring finger), epicondylitis (irritation of the tendon in the forearm muscles), or a herniated disc (displacement of a fragment of the intervertebral disc that compresses the adjacent nerve and causes pain). However, other MSDs have symptoms and signs that are not as well defined, such as myalgia (aches and functional deterioration of the muscles) or cumulative trauma disorders, which are injuries caused by continuous efforts or movements that affect the soft parts of the joints.

There are numerous risk factors that can be the cause of MSDs. The European Agency for Safety and Health at Work groups them into physical and biomechanical factors, organisational and psychosocial factors, and individual and personal factors. In a non-exhaustive list, among the physical and biochemical factors are: manual load handling (lifting, transport, pushing, etc.), application of forces, making repetitive movements, adopting forced or static postures, vibrations and environments with inadequate environmental conditions. Listed among the organisational and psychosocial risk factors are: work with a high psychological demand, lack of control over the tasks, little autonomy, low level of worker satisfaction, monotonous and repetitive work, and little support or social recognition. The individual risk factors, or those associated with the characteristics of the worker themselves, include: their medical history, anthropometry, physiology, physical capacity, age, gender, obesity, and smoking and other addictions.

Physical factors
• Manual load handling • Application of force • Repetitive movements • Forced and static postures • Direct pressure on tools and surfaces • Vibration • Inadequate thermal environment • Insufficient lighting • High noise levels
Organisational and psychosocial factors
• Working to very high standards, lack of control on the tasks carried out and little autonomy • Low level of work satisfaction • Repetitive and monotonous work at a high pace • Lack of support from colleagues, supervisors and managers
Individual factors
• Medical history • Anthropometry, physiology and physical capacity • Age • Gender • Obesity • Smoking and other addictions

Table 1. Ergonomic risk factors that potentially contribute to the development of MSDs

Furthermore, there are complex interactions between the ergonomic risk factors. For example, the application of a force that, due to its duration, frequency or amplitude, is not considered a risk in itself, but could be if applied while maintaining forced postures, is accompanied by localised pressure or is carried out in an inadequate thermal environment. Some of these interactions are less evident, such as those existing between organisational and psychosocial factors and physical factors.

Methodology

To carry out this study, an analysis team was formed consisting of four professionals with proven experience in occupational ergonomics, prevention of work-related MSDs and workstation ergonomic assessment techniques and methods. The process started with several meetings in which the procedures to follow to carry out the study were proposed and discussed, and the criteria to use and the risk assessment process were established.

For the study of the potential ergonomic risks in denim finishing operations, the analysis team started from a description of the generic configuration of these operations. That is to say, by establishing in the study content those characteristics of the tasks that will be present in the most common physical implementations in the production systems and focusing the analysis on these structural characteristics. Furthermore, it considered that the circumstantial aspects of the tasks, associated with their specific implementation in a particular work environment, had a common and standardised configuration. Thus, the analysis essentially focused on the extent of the ergonomic risks and considered the duration and frequency of the risks to be homogeneous.

For example, the time taken by a worker to carry out a particular operation over their working day depends mainly on the organisation of the production system (length of the working day, breaks, shifts and/or rotation of jobs). In the same way, the frequency at which the operation is carried out is conditional upon, in addition to its duration, the pace imposed by production. In this regard, this analysis is based on establishing a common 8-hour working day, the existence of adequate breaks in the activity and a pace of production that allows the operations to be carried out without time pressure.

Likewise, for the analysis, the characteristics of the workstations shown in Table 2 that may affect the actual ergonomic risk of the workstations were considered adequate:

Physical factors
Thermal environment o Temperature, humidity, air speed, changes in the thermal conditions, etc. General noise in the environment o Composite noise level over the day, number/frequency of impulse noises to which the worker is subjected. Lighting o Lighting level at the workstation, general lighting level, contrast between the luminance of the object to be observed and the background, glare, existence of natural lighting, etc.
Organisational and psychosocial factors
Working times o Daily and weekly working time, shift type, option to reject overtime, end of the working day at the established time, existence of breaks, etc. Health and safety o Compliance with health and safety legislation and standards, adequate maintenance of installations, machines and tools, training of workers on risk prevention, etc. Initiative, communication and relationship with management o Control of the pace of work, control of the quality of the finished product, influence of the worker on the quality of the product, impact of errors, adjustment of machinery used, persons with whom communication is established, standards with respect to communication, proximity of managers, frequency of instructions from managers, degree of hierarchical control, dependency on non-hierarchical higher category positions, existence of worker organisations, etc. Remuneration and social status o Adequate remuneration, need for knowledge or specific training, etc.
Individual factors
o Non-existence of prior or active pathologies, anthropometry considered in the design of the workstation, adequate physical and physiological capacity, smoking and other addictions, etc. o Adequate training for the task. o Correct use of personal protective equipment.

Table 2. Characteristics of the workstations, the organisation and workers considered homogeneous and optimal

More specifically, the following have been considered:

- that the usual recommendations as regards occupational health and safety are observed at the workstation and generally throughout the production process,
- that workers have the appropriate means for carrying out the operations (adequate machinery, installations, furniture and tools with optimal maintenance

and personal protective equipment suitable for the task and the anthropometry of the worker),

- that the workers have the necessary training, both for the technical performance of their tasks and for carrying them out in compliance with the health and safety at work recommendations,
- that the collection of materials and tools poses a negligible risk in the operation, since access to the materials is straightforward and the items are lightweight or there are support systems for load handling.
- that the garments awaiting processing is placed on trolleys, tables or bars at a height, distance and position suitable for facilitating access to them without the need for displacing, turning or twisting parts of the body.
- that the garments, once processed, can be placed on trolleys, tables or bars at a height, distance and position suitable for facilitating access to them without the need for displacing, turning or twisting parts of the body.

Based on the generic configuration of the operations and with the above assumptions regarding their actual implementation in the production process, the team has qualitatively analysed the potential presence of ergonomic risk factors shown below:

- Repetitive movements
- Manual load handling
- Application of force
- Forced and static postures
- Vibration
- Contact pressure with tools and surfaces
- Inadequate local thermal environment due to the analysed operation itself
- High noise levels due to the analysed operation itself
- Need for use of personal protective equipment
- Repetitive and monotonous work
- Level of attention required for the task and consequence of the risks of lack of attention

Repetitive movements

According to standard UNE EN 1005-5, a task is repetitive when it is characterised by being performed in repeated work cycles. That is to say, the repetitiveness is a characteristic of the task which means the worker who is performing the task is continuously repeating the same work cycle, technical actions and movements. A large part of denim finishing operations can be considered repetitive. They are characterised by work cycles in which perceptive or cognitive activities do not predominate and there are significant upper limb movements. Excessive intensity, duration or frequency of repetitive movements results in harmful effects to health, which are aggravated by the maintenance of forced postures, the exerted force or the non-existence of breaks that allow muscular recovery.

For the assessment of this risk factor in this study, the length of the working day, job rotation, the existence of breaks, the time devoted to other non-repetitive tasks and the pace of work have been considered constant and uniform among the operations. The technical movements and actions carried out in the operation, their type, frequency and duration, the existing recovery periods and the postures adopted (mainly analysing the shoulder, elbow, wrist and grips, as well as the presence of stereotyped movements) have been assessed.

Manual load handling

The manual handling of loads, which includes operations such as lifting, pushing, dragging and transporting, is related to MSDs principally in the dorsal and dorso-lumbar area of the worker's body. This is one of the most frequent types of MSDs. Handling a heavy load or handling a light load incorrectly results in mechanical moments that are transmitted through the body segments and can affect the structures and tissues of the locomotor system. Physiologically, tasks with repeated load handling can easily exceed the normal energy capacities of the worker, causing a premature reduction of their strength and increasing the likelihood of injury.

For the qualitative assessment of manual load handling in this study, influential aspects on the risk were observed, such as: the weight of the handled load, the posture adopted during handling, the displacement of the load or the distance covered with the load, the angle of the symmetry of the load with respect to the sagittal plane of the worker, the frequency and duration of handling operations and the type of grip on the load by the worker.

Application of force

The application of excessive forces or in inadequate conditions leads to musculoskeletal injuries due to joint, tendon or ligament overloading. This overloading can arise from excessive levels of effort and the duration and repetitiveness of it. In addition to injury, muscular overexertion can cause discomfort and fatigue.

Determining if an effort can be damaging is a complex task as it depends on numerous factors. On the one hand, there are psychological conditioning factors, such as the posture with which the effort is made, the muscle bundles involved or the duration, speed and frequency with which the movement is made. On the other hand, there are individual and demographic conditioning factors.

The analysis of the ergonomic risk due to the application of forces in this study has been carried out considering that the maximum isometric force made by the workers who carry out the operation is common to all. The intensity, frequency and duration of the exerted force has been assessed, as well as those circumstances that separate its application from the ideal situation: the position of the extremities and the trunk, the movement interval within the permissible ranges, the speed of application and the direction of application.

Forced and static postures

One of the risk factors most commonly associated with the appearance of musculoskeletal type disorders is excessive postural load. If inadequate postures are adopted continuously or repetitively during work, fatigue is generated and, in the long term, health problems may arise. Therefore, the muscular activity caused by static or dynamic postures, or due to sudden or unexpected changes in posture, must be assessed.

In the assessment of the postural load, this analysis has considered the postures adopted and estimates the variety, frequency, duration and deviation with respect to the neutral position of the different anatomical segments. Also assessed were the types of load grips, the existence of forces or loads applied suddenly, the static or dynamic character of the postures and the stability of the postures.

Vibrations and contact pressure with tools and surfaces

Vibration is an ergonomic risk factor that, in addition to discomfort, can cause disorders in the lumbar area, shoulders, neck and extremities. Moreover, the presence of vibrations during the task interacts with other risk factors to increase the hazard associated with applications of force, the adoption of poor postures or repeated movements. In addition to affecting the locomotor system, vibrations can cause negative neurological, vascular, sensory and psychomotor effects.

In general, the vibrations come from tools, machines or vehicles operated by the worker, or that are transmitted to their body through the ground or platform where they are located. Vibrations that affect the entire body or part of it can be distinguished. In the operations associated with denim finishing, vibrations in the hand-arm system are common due to the use of rotary tools.

The effects of the vibrations from the tools on the health of the worker depend on numerous factors, such as the frequency and amplitude of the vibration, the duration of exposure, the characteristics of the contact surface between the worker and the machine (dimensions, material, damping capacity, surface finish) and the pressure that must be exerted on the contact surface for the normal performance of the task.

The effects of the vibrations on the health of the worker depend, to a large extent, on the machines that produce them. The vibrations caused by the same type of tool can vary considerably depending on the model, the age, the state of preservation, maintenance or the way it is used. For this reason, the analysis carried out in this study has only assessed the likelihood of the existence of vibrations depending on the tools used, the frequency and relative duration of their use in the analysed operations. Furthermore, in addition to the local pressure exerted when handling manual tools, the pressure due to contact with other work surfaces has been assessed.

Thermal environment and local noise level and the need for the use of personal protective equipment.

In addition to causing discomfort, the lack of thermal comfort and a high noise level interacts with other ergonomic risk factors leading to an increase in the risk of the appearance of musculoskeletal disorders. The general thermal environment and noise level are those present throughout the working environment as a whole, and depend on numerous factors such as the weather conditions, ventilation systems, the plant size, the number and type of machines and tools in operation, among other things. In this analysis, the characteristics have been only assessed for those operations that determine the local thermal environment and noise level, i.e. in the environment in which the operation itself is carried out. The likelihood was considered, for example, of the existence of sources of noise from the analysed task itself due to the use of tools or machinery, or processes that generate heat, humidity or air movements that could cause local thermal discomfort.

Personal protective equipment, such as gloves, masks or glasses, is necessary to safeguard the health of workers in the performance of many denim finishing operations. The use of this equipment, although essential, may make the performance of some tasks more difficult and generate discomfort if its use is prolonged.

Monotony, level of attention required for the task and consequence of the risks of lack of attention

If there is not sufficient variety in the content of the tasks to be carried out, and particularly if these are repeated in short cycles, the monotony of the operations may lead to boredom and demotivation of the worker. In certain circumstances, boredom, in addition to being a psychosocial risk factor in itself, may affect the safety of the worker. The monotony of a task causes a reduction in the level of attention. If the level of attention required for a monotonous task is high, the mental workload of the worker increases, especially if the risks associated with the lack of attention are significant and frequent.

To assess the monotony of the operations, the following were considered: their cycle time, the variety of the tasks to be carried out within them, their complexity, whether the worker could change the order or control the pace of the operations, the positive influence of the worker's interest in the quality of the product, if the skill and experience of the worker mattered, the need and possibility of verbal exchange with other workers or collaboration and team work.

The level of attention required for the task was assessed jointly with the consequence of the risks arising from a lack of attention. The fact that an operation requires a high level of attention is considered a risk factor if the consequences of not paying attention are significant from the production and/or safety point of view. To assess this, the following were considered: the complexity of the task, the duration of the work cycle, the accuracy required, the handling of small parts or tools, the need to record certain visual, touch or sound information, the existence of periods during which the level of attention can be relaxed, the difficulty in noticing possible defects, the significance of the risks that the lack of attention may entail and the frequency of these risks.

Risk assessment procedure and scale

After the criteria to be assessed were established, the analysis team determined the risk assessment scale and the assessment procedure. As has been indicated, the purpose of the analysis is not to carry out an ergonomic analysis of the tasks involved in the denim finishing processes, but a qualitative ergonomic risk assessment of the structural characteristics of the tasks that, with high likelihood, will be present in the most common implementations of the tasks in a production process.

For this reason, an ordinal scale was established with three levels for the assessment as shown in Table 3. This is a qualitative scale that indicates the probability of the presence of each ergonomic risk in each operation. As this is an ordinal scale, its three levels have an order of occurrence that increases with the probability of the presence of risk, however, the difference between two levels cannot be quantitatively established nor can arithmetic or quantitative operations be carried out with their values.

	Probability		
	Low	Medium	High
Colour code			
Description	The probability that a risk factor is present in the operation is low.	There is a certain probability that the risk factor is present while carrying out the operation.	There is a high probability that the risk factor may be present in the tasks that are part of the operation.

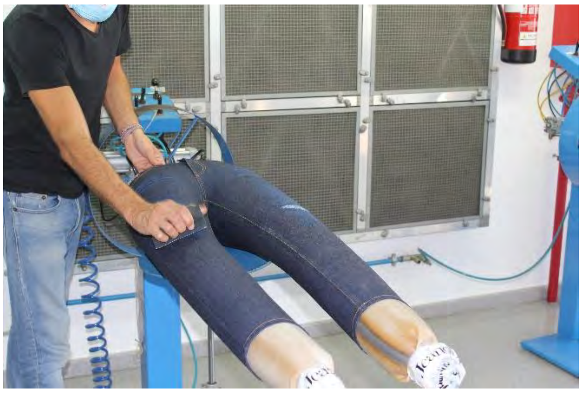
Table 3. Qualitative assessment scale for the presence of ergonomic risks

After the joint establishment of the criteria to use and the risk assessment process, each expert in the team independently analysed each of the operations in the denim finishing process included in this study, by analysing the information on them provided by Jeanologia S.L. After the analysis, each expert assigned a probability level for the presence of each risk factor using the scale in Table 3. Subsequently, the team shared and discussed the assessments made by each member to reach a consensus-based assessment.

Manual scraping

Manual scraping is an operation for removing or smoothing the colour of certain parts of the garment to give the fabric a worn-in appearance. Abrasive paper is used to achieve this by manually rubbing the desired areas. The operation can be carried out by placing the legs of the garment over a board or using pneumatic devices that inflate when the garment is placed on them (mannequins).

To carry out the operation, the worker must collect each garment individually. In the case of using boards, the worker places one of the legs over the board. Once the operation is completed on one of the legs, the garment must be taken off the board, the other leg placed on it and the process repeated. In the case of using pneumatic mannequins, the garment must be placed on the mannequin before inflating. Depending on the process carried out, sandpaper and chalk will be needed.



The work surface is usually horizontal in the case of using boards for the operation and vertical or horizontal when using mannequins. In the horizontal configuration, the boards and mannequins can be placed parallel or perpendicular to the sagittal plane of the operator. Once the garment is positioned in one of these configurations, the operator rubs the surface of the fabric with sandpaper.

When using boards, the worker uses one hand to hold the garment and prevent it sliding along the board during the sanding. Depending on the operation, the garment is held in place by resting one hand on the garment and applying pressure on the board or by gripping the garment. In the case of using mannequins, the worker uses one of their hands to prevent their movement or oscillation. Sometimes, if the process requires it, the worker must use chalk to mark the rubbing areas and achieve the desired finish.

Times: The working cycle is, in general, short, and mainly consists of the sanding tasks and placing the garment on the board or inflatable mannequin, and to a lesser extent of the collection of the garments, materials and tools.

Postures: The posture adopted during sanding depends to a large extent on the configuration of the operation. This can be done using a board, with the worker seated or standing, or a vertical or horizontal inflatable mannequin. These configurations are shown in schematic form in Figure 1.

Manual scraping with board, standing

Manual scraping with board, seated

Manual scraping with vertical mannequin

Manual scraping with horizontal mannequin

Figure 1. Schematic configuration of the postures adopted during *manual* scraping

Other than the configuration in which the task is carried out seated, the operation requires standing for long periods of time. To prevent a high postural load for this reason, there should be sufficient rest periods during the task in which the worker remains seated. The sanding operation requires accuracy and the application of force by hand. In the horizontal configurations, it is recommended that the working surface is located between the worker's waist height and elbow height, and in the vertical configuration between the worker's elbow and shoulder.

During sanding in the horizontal configurations, trunk and neck flexion is very likely and, especially when the operation is carried out seated, abduction of the arm that sands in order to improve the application of the force. In the vertical configuration, the likelihood of sustained trunk and neck flexion is lower, however, the vertical travel of the arm increases to reach the upper and lower parts of the garment.

The combination of long periods of standing, with sustained neck and trunk flexion, the limited variety of postures adopted in the application of force to grip and sand the garment raise the risk probability due to static and forced postures.

Load handling: Generally, the weight of the load handled during the operation is low, as it is limited to the weight of the garment itself and the items necessary for sanding. Handling is mainly carried out during the tasks of collecting and replacing the garments and tools at the start and end of the operation. An adequate configuration of the workstation should allow nearby access to these items without adopting forced or asymmetric postures, therefore the risk probability due to the manual handling of loads is low.

Repetitive movements: The operation is characterised by being performed in short repeated work cycles, therefore the technical actions and movements of the worker are repeated periodically, mainly movements of the upper limbs. The perceptive or cognitive activities that allow muscular recovery periods are not significant. During sanding, stereotyped flexion/extension movements of the upper arm and forearm are made which are repeated identically or very similarly within the work cycle with high frequency and with the application of force.

The risk probability due to repetitive movements is high, especially if there is no rotation of jobs, no frequent breaks, no time spent on other non-repetitive tasks or if the pace of work is high.

Application of force: There is no significant handling of loads or the exertion of strong forces during the execution of the task. However, while sanding the operator usually holds the garment by pressing on it to prevent it slipping, or grips parts of the fabric to sand certain areas. Light forces are also exerted to press on the sandpaper or to keep the mannequin in a suitable position for sanding.

Although none of the forces exerted can be considered significantly large, they are frequent and, depending on the length of the day in the workstation, carried out over a long period of time. Moreover, the forces are exerted by the upper limbs in a range of movements that can be wide, of moderate/high-speed, while maintaining postures that may be poor and with a difficult application direction. For this reason, although the application of forces is of low magnitude, the risk probability is considered medium.

Physical environment: Due to the characteristics of the operation, the likelihood of the existence of noise sources from the task itself or heat, moisture or air movement sources is low.

The use of abrasive paper to sand the garments can emit dust, fluff and fibres into the air, which can be harmful to the worker. Protective gloves, masks and glasses must be worn to carry out the task. Manual sanding of the garments does not cause vibrations, but direct contact between the skin and abrasive paper could be harmful to the worker. Moreover, pressure must be exerted on the abrasive paper for effective sanding.

Monotony, attention and risks: The variety of the content of the tasks carried out during the operation is low and the tasks are repeated in short cycles, therefore the monotony of the operation could cause boredom and demotivation of the worker. The complexity of the task is low, but requires a certain level of attention for the observation of small details, to see possible defects and to work over small areas. There are periods in which it is possible to relax the level of attention, such as when collecting or fitting the garments on the board or the mannequin. The skill and experience of the worker has an influence on the quality of the result. The task is carried out individually and there is no need for verbal exchange with other people for its performance. A lack of attention does not lead to significant frequent risks to the health of the worker or entail high economic costs.

Manual scraping

Risk factor	*Risk*	*Risk factor*	*Risk*
Repetitive movements	HIGH PROBABILITY	Manual load handling	LOW PROBABILITY
Application of force	MEDIUM PROBABILITY	Forced and static postures	HIGH PROBABILITY
Vibration	LOW PROBABILITY	Contact pressure with tools and surfaces	MEDIUM PROBABILITY
Local thermal environment	LOW PROBABILITY	Local noise levels	LOW PROBABILITY
Level of attention and consequence of the risk	LOW PROBABILITY	Repetitive and monotonous work	MEDIUM PROBABILITY

Table 4. Assessment of the ergonomic risk probability during manual scraping

Grinding (with hand grinder/wheel)

The purpose of grinding is to give certain parts of the garment the appearance of having been worn in. Abrasives tools such as grinding wheels or grinders are used during the operation. Grinding wheels are mainly used on the edges of the fabric and the grinders on the internal areas. Grinding is usually carried out on the edges and the openings of the pockets, the waist and hems. The operation must be carried out on a work surface, generally a table, which supports the garment and where the tools are fixed.

To carry out the operation, the worker must collect each garment individually. When using the grinder, the garment is placed in front of the worker in an appropriate position to access the application area. The garment is held in place with one hand and the fingers are used to keep the area of the fabric to be ground taught. The other hand holds and operates the grinder. Once the application is completed, the garment is put in another position and the process repeated.

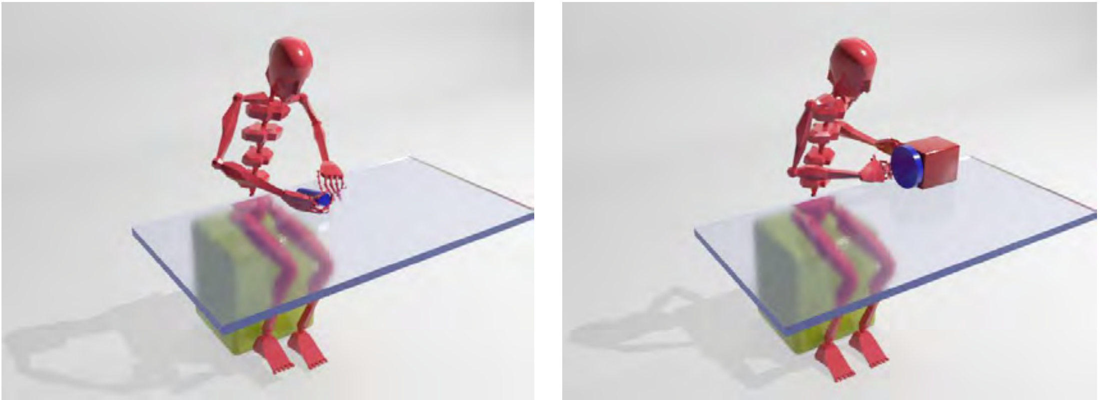
The grinding wheel can be placed in front of the worker, but it is also commonly placed to one side of the central working area in front of the worker. The worker holds the garment with both hands and grips the edges at both sides of the place to be ground and moves the fabric towards the wheel. Once the area has been ground, the worker gradually changes the gripped areas in order to cover the entire edge by repeating the operation. Once the process is complete, the worker starts the process again by collecting a new garment.

Times: The work cycle is short. The garment collection tasks do not take long, and the majority of the work cycle is used in the tasks of grinding and placing the garment in suitable positions for the use of the wheel or the grinder.

Postures: The characteristic postures during grinding are shown schematically in Figure 2. The position of the grinding wheel is shown to one side of the working area. Both in the use of the grinder and the grinding wheel, the worker can carry out the task standing or seated, remaining in these postures for long periods of time. To avoid a high postural load, there must be sufficient break times during the task, allowing the worker to walk and stretch if carrying out the task seated or to sit down if carrying out the task standing.

The use of the grinder is a task that requires a certain degree of precision, therefore it is recommended that the work surface is positioned slightly elevated. During grinding, trunk and neck flexion is very likely, as is a certain abduction of the arm holding the garment. If the wheel is located to one side of the work area, its use requires the worker to turn their trunk and the operation has to be carried out with both arms to one side of the sagittal plane. Arm abduction is not necessary, but there is neck flexion to observe the tool. In general, the application of force is not required.

The combination of long periods seated, sustained neck/trunk flexion and the limited variety of the postures adopted raise the risk probability due to static and forced postures.



Grinding with grinder — Grinding with wheel

Figure 2. Schematic configuration of the postures adopted during grinding

Load handling: The weight of the handled load during the operation is low, as it is limited to the weight of the garment itself and the grinder. The wheel remains fixed to the table. Handling is mainly carried out during the tasks of collecting the garments and handling the grinder during the operation. An adequate configuration of the workstation should allow nearby access to these items without adopting forced or asymmetric postures. The risk probability due to manual handling of loads is low.

Repetitive movements: The operation is carried out in repeated work cycles of a few minutes. There are no perceptive or cognitive activities in the task that allow muscular recovery periods. Stereotyped movements are made both in the use of the grinding wheel and when handling the grinder.

The range of movements is short and movements are repeated without the application of significant force, except in the case of the fingers during the use of the grinding wheel. To change the fabric edge area that makes contact with the wheel, the worker makes rapid flexions and extensions of the medial and distal phalanges of the index fingers and proximal and distal phalanges of the thumbs. After the change of area, some force is exercised with these fingers to keep the fabric in contact with the wheel.

Depending on the number of breaks in the task and the pace of work, the risk probability due to repetitive movements is considered low in the operations carried out with the grinder and medium when using the grinding wheel.

Application of force: There is no significant handling of loads or the exertion of strong forces during the execution of the task. When using the grinder, the operator usually holds the garment by pressing on it to prevent it slipping or uses their fingers to stretch the fabric when working on specific areas. When using the wheel, the fingers press the fabric onto the abrasive area.

As the applied forces are very low, with a short range of movement at moderate speed, the risk probability is considered low.

Physical environment: Due to the characteristics of the operation, the likelihood of the existence of heat, moisture or air movement sources originating in the workstation is low. There are noise and vibration sources from the tools used in the task itself, the intensity of which will depend on the model, age, state of preservation and maintenance of the tools. Vibrations can be especially significant during the use of manual grinders which must be held with force and over a large contact surface with the hand.

There is a risk of direct contact between the skin and the rotary abrasive surface which could injure the worker. The use of grinding wheels, grinders and other abrasive or distressing tools can emit dust, fluff and fibres into the air, which can be harmful to the worker. Protective gloves, masks and glasses must be worn to carry out the task.

Monotony, attention and risks: The variety of the content of the tasks carried out during the operation is low and the tasks are repeated in short cycles, therefore the monotony of the operation could cause boredom and demotivation of the worker. The complexity of the task is low, but requires a certain level of attention for the observation of small details, to see possible defects and to work over small areas. Periods in which it is possible to relax the level of attention are confined to those used when collecting or placing the garments in the work area. The skill and experience of the worker has an influence on the quality of the result. The task is carried out individually and there is no need for verbal exchange with other people for its performance. When handling manual abrasive tools, a lack of attention can lead to relatively significant and frequent risks to the health of the worker. Lack of attention does not entail high economic costs.

Grinding with hand grinder

Risk factor	Risk	Risk factor	Risk
Repetitive movements	LOW PROBABILITY	Manual load handling	LOW PROBABILITY
Application of force	LOW PROBABILITY	Forced and static postures	HIGH PROBABILITY
Vibration	HIGH PROBABILITY	Contact pressure with tools and surfaces	MEDIUM PROBABILITY
Local thermal environment	LOW PROBABILITY	Local noise levels	MEDIUM PROBABILITY
Level of attention and consequence of the risk	MEDIUM PROBABILITY	Repetitive and monotonous work	MEDIUM PROBABILITY

Table 5. Assessment of the ergonomic risk probability when grinding with the hand grinder

Grinding with wheel

Risk factor	Risk	Risk factor	Risk
Repetitive movements	MEDIUM PROBABILITY	Manual load handling	LOW PROBABILITY
Application of force	LOW PROBABILITY	Forced and static postures	HIGH PROBABILITY
Vibration	HIGH PROBABILITY	Contact pressure with tools and surfaces	HIGH PROBABILITY
Local thermal environment	LOW PROBABILITY	Local noise levels	MEDIUM PROBABILITY
Level of attention and consequence of the risk	MEDIUM PROBABILITY	Repetitive and monotonous work	MEDIUM PROBABILITY

Table 6. Assessment of the ergonomic risk probability when grinding with the grinding wheel

Destroy (with grinder, cutter and destroy machine)

The purpose of the destroy process is to create holes and worn and frayed areas in the fabric to give the garment a used appearance. To fray areas, the warp threads of the denim are destroyed while the weft threads are kept intact. In the case of holes, which can be different sizes, both the warp and weft threads are destroyed. When this process is carried out manually, each garment is given a unique appearance that differentiates it from the others. The process can be carried out using manual tools, such as pneumatic grinders, cutters or needles, or by using machines operated by the worker that carry out the distressing process with different degrees of automation.

In manual processes, it is usual for the worker to carry out the task seated and collect each garment individually. Sometimes chalk or other markers are used to delimit the areas of the garment to be processed. A leg of the garment is placed on a board on which the operation is carried out. When grinders are used, the board is usually located parallel to the sagittal plane in front of the worker. To make the cuts, the board is placed perpendicular to the sagittal plane.

Pneumatic grinders are applied on the surface of the denim to remove the denim cellulose. The garment is located in such a way that the area to be distressed is exposed to the worker. While one hand handles the grinder, the other holds the fabric underneath the board. Once the application is completed, the garment is put in another position and the process repeated. After this, compressed air can be used to remove the detached remnants and reveal the fabric weft.

When cutters are used, several cuts are made in the fabric in particular areas of the garment. After completing the process on the first leg, the garment is removed from the board and the other leg placed on it and the process is repeated. Once the garment is finished, the worker starts the process again by collecting a new garment.

In the processes in which destroy machines are used, the degree of automation of the process varies considerably. It is usual to use machines in which, after placing a leg on a board, the worker slides the distressing tool parallel to the leg without touching the garment up to the desired area. Once located in the appropriate area, the worker operates a control that places the distressing tool over the garment and makes contact with it. On the board on which the garment is placed, there are reliefs with patterns of the desired shape.

Times: The work cycle for destroying with a cutter is short, which increases with the use of grinders and destroy machines. The collection tasks take up little of the cycle time and the majority this is spent on the tasks of cutting and distressing and the placing of the garment in suitable positions for the process.

Postures: The most usual characteristic postures in the destroying processes with grinder, cutter and destroy machine are shown schematically in Figure 3. In the first two cases, the task is usually carried out sitting down, while the destroy machine is usually operated standing up.

The use of the grinder or cutter is a task that requires a certain degree of precision, therefore it is recommended that the work surface is positioned slightly elevated. In both cases, the existence of trunk and neck flexion is very likely. During grinding, the worker holds the tool with one hand and the garment with the other underneath the board. The arm that operates the grinder is abducted and the shoulder rotated.

In the cutting operations, the arm that handles the cutter is kept against the trunk, while the other arm, which holds the garment during cutting, is abducted. To correctly orientate the cut, the worker usually rotates their trunk and carries out rapid and repeated movements with the cutter.

The destroy machine is operated by hand with an abduction/adduction movement. In general, the application of significant force is not required in any of the three types of operations.

Destroying with the grinder or cutter combines long periods sitting down with sustained neck/flexions and little postural variety. The risk increases in the cutting operation due to the rotation of the trunk while moving with the cutter. The use of the cutting machine allows a greater postural variety and forced or static postures are not observed.

Destroy process with grinding machine | Destroy process with cutter | Destroy process with machine

Figure 3. Schematic configuration of the postures adopted during denim destroy process

Load handling: The weight of the handled load during the operation is low, as it is limited to the weight of the garment itself and the grinder. The weight of the cutter is negligible. Handling is mainly carried out during the tasks of collecting the garments and handling the grinder. An adequate configuration of the workstation should allow nearby access to these items without adopting forced or asymmetric postures. The risk probability due to manual handling of loads is low in the three types of operation.

Repetitive movements: The operation is carried out in repeated work cycles with a frequency that is usually high in the case of cutting. The use of the grinder or the cutting machine involves activities that allow periods of muscle recovery, such as the marking of the areas of the garment to be processed or positioning on the cutting machine. Movements are slow in both cases and the risk due to repetitive movements is low.

Muscle recovery periods during cutting are infrequent and stereotyped movements occur. The range of movements is equal to the length of the cuts to be made, they are carried out in a forced posture and at a high speed. Depending on the number of breaks in the task and the pace of work, the risk probability due to repetitive movements when destroying with a cutter is considered high.

Application of force: There is no significant handling of loads or exertion of strong forces during the execution of the three versions of the task. During cutting, the worker must exert pressure on the garment with the cutter, but the force is very low. The risk probability due to application of forces is considered low.

Physical environment: Due to the characteristics of the operation, the likelihood of the existence of heat, moisture or air movement sources originating in the workstation is low.

In the case of destroying using a grinder or destroy machine, there are noise and vibration sources from the tools used in the task itself, the intensity of which will depend on the model, age, state of preservation and maintenance of tools. Vibrations can be especially significant during the use of manual grinders which must be held with force and over a large contact surface with the hand.

There is contact pressure when using cutters, which must be firmly grasped to make the cut. Destroying garments can emit dust, fluff and fibres into the air, which can be harmful to the worker. Protective gloves, masks and glasses must be worn to carry out the task.

Monotony, attention and risks: The variety of the content of the tasks carried out during destroying is, in general, low, especially in the case of destroying with a cutter. The complexity of the operation is low, but requires a certain level of attention for the observation of small details, to see possible defects and to work over small areas. The tasks are carried out individually and there is no need for verbal exchange with other people for their performance. The skill and experience of the worker has an influence on the quality of the result.

When destroying with a cutter, the work cycle is particularly short. Combined with the low complexity of the task and its monotony, this could lead to boredom and demotivation of the worker. In this operation, a lack of attention does lead to significant frequent risks to the health of the worker as very sharp edges are used.

Destroy process with hand grinder

Risk factor	*Risk*	*Risk factor*	*Risk*
Repetitive movements	LOW PROBABILITY	Manual load handling	LOW PROBABILITY
Application of force	LOW PROBABILITY	Forced and static postures	HIGH PROBABILITY
Vibration	HIGH PROBABILITY	Contact pressure with tools and surfaces	MEDIUM PROBABILITY
Local thermal environment	LOW PROBABILITY	Local noise levels	MEDIUM PROBABILITY
Level of attention and consequence of the risk	MEDIUM PROBABILITY	Repetitive and monotonous work	MEDIUM PROBABILITY

Table 7. Assessment of the ergonomic risk probability during the destroy process with a hand grinder

Destroy process with cutter

Risk factor	*Risk*	*Risk factor*	*Risk*
Repetitive movements	HIGH PROBABILITY	Manual load handling	LOW PROBABILITY
Application of force	LOW PROBABILITY	Forced and static postures	HIGH PROBABILITY
Vibration	LOW PROBABILITY	Contact pressure with tools and surfaces	MEDIUM PROBABILITY
Local thermal environment	LOW PROBABILITY	Local noise levels	LOW PROBABILITY
Level of attention and consequence of the risk	HIGH PROBABILITY	Repetitive and monotonous work	HIGH PROBABILITY

Table 8. Assessment of the ergonomic risk probability during the destroy process with a cutter

Destroy process with destroy machine

Risk factor	*Risk*	*Risk factor*	*Risk*
Repetitive movements	LOW PROBABILITY	Manual load handling	LOW PROBABILITY
Application of force	LOW PROBABILITY	Forced and static postures	LOW PROBABILITY
Vibration	MEDIUM PROBABILITY	Contact pressure with tools and surfaces	LOW PROBABILITY
Local thermal environment	LOW PROBABILITY	Local noise levels	MEDIUM PROBABILITY
Level of attention and consequence of the risk	LOW PROBABILITY	Repetitive and monotonous work	MEDIUM PROBABILITY

Table 9. Assessment of the ergonomic risk probability during the destroy process with a destroy machine

Spraying

The purpose of spraying is to create bleached, lighter or brighter areas on the denim. For this, with the garments fitted on the inflatable mannequins in a vertical position, an oxidising agent solution is sprayed on the appropriate areas using a spray gun. The operation is carried out in a booth, whose configuration can change from one workstation to another. The number of mannequins may vary and they may remain fixed or move automatically while being sprayed. Generally, the booths have ventilation systems and a water circulation system for collecting excess sprayed liquid.

This task starts with the collection of the garment and its fitting on the inflatable mannequin. The worker inserts the tubes of the deflated mannequin into the trouser legs and pulls them up. Finally, the worker holds them at the top while the mannequin inflates. Once the garment is in place, the operator sprays the fabric using the spray gun held with one hand. The worker uses the other hand to fix the position of the mannequin or rotate it if both sides have to be sprayed. Finally, the mannequin is deflated and the garment is removed by the bottom part so the operation can be started again.

The workers remain standing throughout the entire process. Sometimes, two workers are assigned to the operation; it is common for one to carry out the task of fitting and extracting the garment from the mannequin, and the other performs the spraying. In this study, the case of the operation carried out by a single worker is analysed.

Times: Depending on the configuration of the booth and the number of workers assigned to the operation, the spraying work cycle is usually less than a couple of minutes. The collection tasks take up little of the cycle time, and the majority of this is spent on the tasks of fitting the garment on the inflatable mannequins and spraying.

Postures: Considering the operation carried out by a single worker, the significant postures in the spraying process are shown in schematic form in Figure 4.

After the collection of the garment, the worker fits the trousers on the mannequin by inserting the bottom of the inflatable tubes into the trouser legs. To do this, the operator must squat down and/or bend their trunk to a degree that depends on the length of the mannequin and its position. After sliding the trousers up over the tubes, the worker holds the trousers by the top during inflation. This requires them to keep their arms raised above shoulder level.

During the application of the spray, the worker holds the gun with one hand and moves to distribute the spray. Meanwhile, the other arm is used to rotate the mannequin and keep it in a specific position. To access the lower parts of the garment, the worker usually lateralises and rotates their trunk while keeping one hand on the top of the mannequin. The postures adopted for the extraction of the garment are less demanding. After the deflation of the mannequin, the worker can remove the trousers by sliding them downwards from the top.

During the operation, the adoption of forced postures was observed, mainly during the fitting of the garment on the inflatable mannequin, and the maintenance of static postures during the application of the spray. The postural variety is limited during the fitting of the garment and the holding of the spray gun. The postural load caused by the execution of the operation is considered high. If the operation is carried out over long periods, there should be sufficient breaks in the task during which the worker can sit down and stretch.

Fitting Fastening Spraying

Figure 4. Schematic configuration of the postures adopted during spraying

Load handling: The weight of the handled load during the operation is low, as it is limited to the weight of the garment itself and the spray gun. Handling is mainly carried out during the tasks of collecting the garments. An adequate configuration of the workstation should allow nearby access to these items without adopting forced or asymmetric postures. The risk probability due to manual handling of loads is low.

Repetitive movements:

During the execution of the task, upper arm and forearm circumduction movements are repeated in order to apply the spray. The risk due to the repetition of these movements will be proportional to the weight of the spray gun. In the case of the gun having a reservoir attached to it that must be supported by the worker's arm, the extra weight increases the risk of the repeated arm movements. The stages of the work cycle for fitting the garment on the mannequin and its later removal also involve movements of the arms, therefore they do not constitute a recovery period.

Depending on the number of breaks in the task and the pace of work, the risk probability due to repetitive movements during spraying is considered high.

Application of force: There is no significant handling of loads or the exertion of strong forces during the execution of the task. These are limited to the operating of the spray gun button and to the force necessary for placing the garments on the inflatable mannequin. Both are small. The risk probability due to application of forces is considered low.

Physical environment: Booths used for spraying usually have ventilation and suction systems, in addition to a water circulation device for the collection of excess spray. This can entail movements of air and increases of the relative humidity in the workstation environment. Furthermore, the use of spray guns, in addition to the ventilation and water circulation systems, can be sources of local noise in the workstation.

The existence of vibrations from tools or surfaces is not likely, nor are contact pressures with surfaces, tools and machinery. Spraying generates airborne particles, which can be harmful to the worker. Protective mask and glasses must be worn to carry out the task.

Monotony, attention and risks: The variety of the content of the tasks carried out during spraying is, in general, low. The complexity of the operation is low, but it requires a certain level of attention for the application of the spray on the appropriate areas. The tasks can be carried out individually or by more than one worker. The need for verbal exchange with other people during the task is not likely. The skill and experience of the worker has an influence on the quality of the result.

The task may be considered monotonous, but a lack of attention would not pose frequent or significant risks to the health of the worker.

Spraying

Risk factor	*Risk*	*Risk factor*	*Risk*
Repetitive movements	HIGH PROBABILITY	Manual load handling	LOW PROBABILITY
Application of force	LOW PROBABILITY	Forced and static postures	HIGH PROBABILITY
Vibration	LOW PROBABILITY	Contact pressure with tools and surfaces	LOW PROBABILITY
Local thermal environment	MEDIUM PROBABILITY	Local noise levels	HIGH PROBABILITY
Level of attention and consequence of the risk	LOW PROBABILITY	Repetitive and monotonous work	MEDIUM PROBABILITY

Table 7. Assessment of the ergonomic risk probability during the destroy process with a hand grinder

Sponging

The purpose of sponging is similar to that of spraying: to create bleached, lighter or brighter areas on the denim by the application of a solution of oxidising agents on some areas of the garment. While in the spraying operation the solution is applied by means of a spray gun, for sponging, sponges, brushes or cloths are used. This results in a less mechanical process which means the results are less uniform between different garments.

The operation can be carried out in different ways, the most common being the use of inflatable mannequins positioned vertically. This process starts with the collection of the garment and its fitting on the inflatable mannequin. The worker inserts the tubes of the deflated mannequin into the trouser legs and pulls them up. Finally, the worker holds them at the top while the mannequin inflates. Once the garment is fitted, the operator uses a brush, cloth or sponge to spread the oxidising solution on areas of the garment. The worker uses the other hand to fix the position of the mannequin or rotate it, usually holding the mannequin by the top. Finally, the mannequin is deflated and the garment is removed by the bottom part so the operation can be started again. The workers remain standing throughout the entire process.

Times: The cycle time for this operation is longer than that for spraying. The task requires more time due to the fact that it is a completely manual process. The tasks of collection and fitting of the garment on the inflatable mannequins take up little of the cycle time, the majority of which is spent on the application of the oxidising solution.

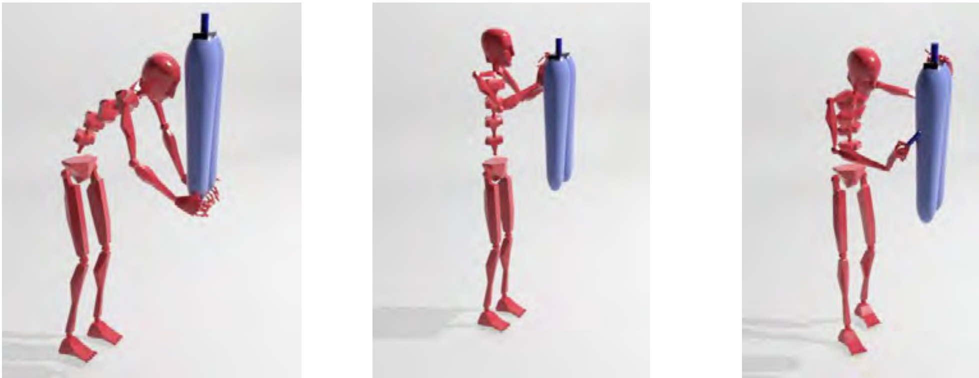
Postures: The significant postures in the sponging process are shown schematically in Figure 5. It was considered that the operation is carried out by a single worker.

After collecting the garment, the worker fits the trousers on the mannequin by inserting the bottom of the inflatable tubes into the trouser legs. To do this, the operator must squat down and/or bend their trunk to a degree that depends on the length of the mannequin and its position. After sliding the trousers up over the tubes, the worker holds the trousers by the top during inflation. This requires them to keep their arms raised above shoulder level.

Once the trousers are fitted on the mannequin, the worker applies the oxidising agent using a brush, sponge or cloth, by means of upper arm and forearm flexions and extensions. Meanwhile, the other arm is used to rotate the mannequin and keep it in a specific position, generally holding it by the top part with the arm raised. To access the lower parts of the garment with the brush or sponge, the worker usually lateralises or rotates their trunk while keeping the other arm raised. To access the lowest parts of the trousers, there may be significant flexion of the wrist.

The postures adopted for the extraction of the garment are less demanding. After the deflation of the mannequin, the worker can remove the trousers by sliding them downwards from the top.

During the operation, prolonged standing, the adoption of forced postures, mainly during the fitting of the garment on the inflatable mannequin, and the maintenance of static postures were observed. The risk probability due to a high postural load caused by the execution of the operation is considered high. If the operation is carried out over long periods, there should be sufficient breaks in the task.



Fitting | Fastening | Sponging

Figure 5. Schematic configuration of the postures adopted during sponging

Load handling: The weight of the handled load during the operation is not significant, as it is limited to the weight of the garment itself and the tool used (brush, sponge or cloth). An adequate configuration of the workstation should allow nearby access to these items without adopting forced or asymmetric postures. The risk probability due to manual handling of loads is low.

Repetitive movements:

During the execution of the task, upper arm and forearm flexion and extension movements are repeated. The stages of the work cycle for fitting the garment on the mannequin and its later removal also involve movements of the arms, therefore they do not constitute a recovery period.

The pace of the movements is not high; therefore, depending on the number of breaks in the task and the pace of work, the risk probability due to repetitive movements during sponging is considered medium.

Application of force: There is no significant handling of loads or the exertion of strong forces during the execution of the task. These are limited to the force necessary for fitting the garment on the inflatable mannequin, which is low. The risk probability due to application of forces is considered low.

Physical environment: Due to the characteristics of the operation, the likelihood of the existence of noise sources from the task itself or heat, moisture or air movement sources is low. Protective gloves, masks and glasses must be worn to carry out the task. The existence of vibrations from tools or surfaces is not likely, nor are contact pressures with surfaces, tools and machinery.

Monotony, attention and risks: The variety of the content of the tasks carried out during sponging is, in general, low. Although the complexity of the operation is low, it requires a certain level of attention for the correct application of the product over the appropriate areas, the skill and experience of the worker affects the quality of the finished product. The tasks are carried out individually or by more than one worker, but the need for verbal exchange with other people during the tasks is unlikely. The task may be considered monotonous, but a lack of attention would not pose frequent or significant risks to the health of the worker or consequences on production.

Sponging

Risk factor	*Risk*	*Risk factor*	*Risk*
Repetitive movements	MEDIUM PROBABILITY	Manual load handling	LOW PROBABILITY
Application of force	LOW PROBABILITY	Forced and static postures	HIGH PROBABILITY
Vibration	LOW PROBABILITY	Contact pressure with tools and surfaces	LOW PROBABILITY
Local thermal environment	LOW PROBABILITY	Local noise levels	LOW PROBABILITY
Level of attention and consequence of the risk	LOW PROBABILITY	Repetitive and monotonous work	MEDIUM PROBABILITY

Table 7. Assessment of the ergonomic risk probability during sponging

Tagging (manual tag / automated tacking)

The purpose of tagging is to create permanent folds in the denim. Its application is common on the waist, the hems and pocket corners on the trousers, although it can be used on any other area of the garment. To hold the folds, plastic or nylon tag pins are used and fitted with the help of manual or automatic tag pin guns. After undergoing a washing process, the tag pins are removed from the trousers and the folds are permanent.

It is usual for the worker to carry out the task seated and collect each garment individually. Once the appropriate area is determined, several folds are made in the fabric using the fingers, and the folds are fixed with tag pins. Then the process is repeated in another area of the garment until all the desired folds are completed.

The configuration of the operation depends to a large extent on whether manual or automatic tag pins are used. In the first case, the garments are placed on a table on a vertical support or directly on top of the legs of the worker. After making the fold, the worker uses the manual tag pin gun, holding it and actuating it by hand. The automatic tag pin machines are usually fitted on a table or workbench in front of the seated worker. After folding the fabric, the garment must be brought to the machine which fits the tag pins automatically.


Times: The work cycle is usually short in both configurations, and is slightly longer when carried out manually. The collection tasks take up little of the cycle time and the majority of this is spent on the fabric folding tasks.

Postures: The most usual characteristic postures in the manual tagging and tagging with automatic tag pin machines are shown schematically in Figure 6. Both procedures require the use of the fingers to make the fold in the fabric and to hold the fold while it is fixed. In both cases, there are frequent flexion/extension, rotation and lateralisation movements of the wrists, and the arms have to be kept raised in front of the worker for a large part of the work cycle. The postural variety is low, especially when using automatic tag pin machines.

In the manual tagging process, the worker must keep the fold in the fabric with one hand while operating the tag pin machine with the other. Depending on the location of the fold and the placing of the garment, the operation may require the worker to lateralise and/or rotate the trunk, or they may have to abduce the arm to conveniently access the fold in order to fix it.

The use of automatic tag pin machines means it is not necessary to adopt asymmetric postures, other than when collecting the garments. Furthermore, it allows the folds to be held with both hands which means less force need be exerted with the fingers. If the height of the machine is adequate, the worker will not have to frequently flex the trunk or neck excessively.

The low postural variety and the positions of the fingers necessary to fold the fabric mean the risk probability due to the adoption of poor, static or forced postures is considered medium in the case of the automatic tag pin machines. The postures of the trunk and arms adopted during manual tagging raise the risk probability to high.

Manual Tagging — Tagging with automated tacking machines

Figure 6. Schematic configuration of the postures adopted during tagging

Load handling: The weight of the handled load during the operation is low, as it is limited to the weight of the garment itself and the manual tag pin gun. An adequate configuration of the workstation should allow nearby access to these items without adopting forced or asymmetric postures. The risk probability due to manual handling of loads is low in the two types of operation.

Repetitive movements: The operation is carried out in repeated work cycles. In both types of processes, repeated, frequent and rapid movements of the fingers occur during the folding of the denim. These movements are carried out by exercising a certain force for the folding and holding the fold before fixing it. Depending on the number of breaks in the task and the pace of work, the risk probability due to repetitive movements of the fingers is considered medium.

Application of force: There is no significant handling of loads or exertion of strong forces during the execution of the two versions of the task. The most significant forces are those carried out with the fingers when making the folds and for operating the tagging machine. The risk probability due to application of forces is considered low.

Physical environment: Due to the characteristics of the operation, the likelihood of the existence of heat, moisture or air movement sources originating in the workstation is low. The tools and machinery used in the operation are not likely to be sources of significant noise or vibrations. There is a certain contact pressure when using the manual tag pin machines, which must be firmly grasped for use.

Monotony, attention and risks: The variety of the content of the tasks carried out during the operation is, generally, low. The complexity of the operation is low, but it requires a certain level of attention for the observation of small details, the making of the folds in the fabric and for the use of the fold fixing tools.

The tasks can be carried out individually and there is no need for verbal exchange with other people for their performance. The skill and experience of the worker has an influence on the quality of the result. The low complexity of the task and its monotony could lead to boredom and demotivation of the worker. When the tagging is carried out manually, a lack of attention does not pose significant frequent risks to the health of the worker. When using an automatic tag pin machine, the risks posed by a lack of attention are significant but infrequent.

Manual tagging

Risk factor	*Risk*	*Risk factor*	*Risk*
Repetitive movements	MEDIUM PROBABILITY	Manual load handling	LOW PROBABILITY
Application of force	LOW PROBABILITY	Forced and static postures	HIGH PROBABILITY
Vibration	LOW PROBABILITY	Contact pressure with tools and surfaces	MEDIUM PROBABILITY
Local thermal environment	LOW PROBABILITY	Local noise levels	LOW PROBABILITY
Level of attention and consequence of the risk	LOW PROBABILITY	Repetitive and monotonous work	MEDIUM PROBABILITY

Table 8. Assessment of the likelihood of ergonomic risks during manual tagging

Tagging with tacking machine

Risk factor	*Risk*	*Risk factor*	*Risk*
Repetitive movements	MEDIUM PROBABILITY	Manual load handling	LOW PROBABILITY
Application of force	LOW PROBABILITY	Forced and static postures	MEDIUM PROBABILITY
Vibration	LOW PROBABILITY	Contact pressure with tools and surfaces	LOW PROBABILITY
Local thermal environment	LOW PROBABILITY	Local noise levels	LOW PROBABILITY
Level of attention and consequence of the risk	MEDIUM PROBABILITY	Repetitive and monotonous work	MEDIUM PROBABILITY

Table 9. Assessment of the ergonomic risk probability during tagging with tacking machine

3D Whiskers

The purpose of whiskering is to create linear wear patterns and long creases in the garment similar to those that are created in clothing due to the adoption of different postures during everyday wear. It is common to do this in the hip area, the front part of the thighs, the pockets and behind the knees.

Whiskering may have relief (3D whiskers), or only surface marking on the fabric (2D whiskers). 2D whiskering is achieved by distressing the surface of the denim with sandpaper or abrasive rotary brushes. Sometimes templates are used with the shape of the marks placed under the fabric. 3D whiskers can be produced with the fabric impregnated with a resin solution. It is usual for the worker to carry out the task standing and collect each piece of clothing individually. The garment is placed on a manual ironing board or an ironing press. Then, the worker manually creases the appropriate area of the garment and steam irons the created crease to fix it. Generally, each piece of clothing requires the process to be repeated in other areas of the garment until the desired folds are completed.

The work surface is usually horizontal. The ironing boards and presses are located in front of the worker, parallel to their sagittal plane. The fabric is creased using the fingers of both hands. If a manual iron is used, the operator holds the crease with one hand while reaching and using the iron with the other. In the case of using an ironing press, the operating control on the head must be used.

Times: The work cycle is, generally, short, and mainly consists of the placing of the garment on the ironing board or press and forming the creases. The cycle time spent collecting the garments is very short.

Postures: The worker remains standing during the entire operation. To prevent a high postural load for this reason, there should be sufficient rest periods during the task in which the worker remains seated. Figure 7 schematically shows the most characteristic postures adopted by the worker when using a manual ironing board.

Both during the creasing of the fabric and during ironing, if this is done with a manual iron, there is very likely to be trunk and neck flexion and a slight abduction of the arms. In the case of using an ironing press, this posture is only held while creasing the fabric.

Creasing   Manual ironing

Figure 7. Schematic configuration of the postures adopted during 3D whiskering

Creasing the fabric requires the use of the fingers to make the folds and to hold the fold while it is fixed by means of the steam iron. There are frequent flexion/extension, rotation and lateralisation movements of the wrists, and the arms have to be kept raised in front of the worker for a large part of the work cycle, although there is a support for them on the ironing board.

In the manual ironing process, the worker must hold the fold in the fabric with one hand while reaching for and using the iron with the other. Depending on the location of the fold and the placing of the garment, the operation may require the worker to lateralise and/or rotate the trunk, or they may have to abduce the arm to conveniently access the fold in order to fix it. The use of ironing presses means asymmetric postures do not have to be adopted.

The low postural variety, positions of the fingers necessary for folding the fabric and the arms during ironing, mean the risk probability due to the adoption of poor, static or forced postures is considered high. In the case of using an ironing press, the risk probability would reduce.

Load handling: Generally, the weight of the handled load during the operation is low, as it is limited to the weight of the garment itself and the iron in the case of manual ironing. An adequate configuration of the workstation must allow nearby access to the iron without adopting forced or asymmetric postures, therefore the risk probability due to the manual handling of loads is low.

Repetitive movements: The operation is characterised by being carried out in short repeated work cycles, therefore the technical actions and movements of the worker are repeated periodically, mainly movements of the hands and fingers. During folding of the fabric, stereotyped flexion/extension movements of the fingers are made which are repeated identically or very similarly within the work cycle with high-frequency and the application of a certain force.

The perceptive or cognitive activities that allow muscular recovery periods are not significant. The risk probability due to repetitive movements is medium, especially if there is no rotation of jobs, no frequent breaks, no time spent on other non-repetitive tasks or if the pace of work is high.

Application of force: There is no significant handling of loads or the exertion of strong forces during the execution of the task. In an adequate task configuration, the iron must be positioned so that access is straightforward and it is located near the worker. In the operations carried out with the ironing press, the worker usually exerts a light force downwards on the ironing head. The risk probability due to application of forces is considered low.

Physical environment: The existence of vibrations from the tools and machines used is unlikely. The use of manual irons or ironing presses that use steam is a source of heat and humidity in the workstation. Furthermore, these items can generate noise during steam output or the operation of the head of the ironing presses. The risk probability due to these environmental conditions of the workstation depend to a large extent on the number and concentration of similar workstations and on the general ventilation and air conditioning systems.

Monotony, attention and risks: The variety of the content of the tasks carried out during the operation is low and the tasks are repeated in short cycles, therefore the monotony of the operation could cause boredom and demotivation of the worker. The complexity of the task is low, but it requires a certain level of attention for the observation of small details. The skill and experience of the worker has a medium influence on the quality of the result. The task is carried out individually and there is no need for verbal exchange with other people for its performance. A lack of attention can result in burns from the hot elements of the ironing boards and presses.

3D Whiskers

Risk factor	*Risk*	*Risk factor*	*Risk*
Repetitive movements	MEDIUM PROBABILITY	Manual load handling	LOW PROBABILITY
Application of force	LOW PROBABILITY	Forced and static postures	HIGH PROBABILITY
Vibration	LOW PROBABILITY	Contact pressure with tools and surfaces	LOW PROBABILITY
Local thermal environment	MEDIUM PROBABILITY	Local noise levels	MEDIUM PROBABILITY
Level of attention and consequence of the risk	MEDIUM PROBABILITY	Repetitive and monotonous work	MEDIUM PROBABILITY

Table 10. Assessment of the ergonomic risk probability during 3D whiskering

Laser abrasion

The abrasion or marking of denim garments by means of laser seeks to create wear patterns on the fabric, remove or soften the colour in certain parts and, generally, give the garment the worn-in appearance achieved by other manual processes in an automated way. The shape of the wear pattern is defined by software for image editing, and a laser light targeted by means of lenses reproduces the pattern on the fabric.

The laser abrasion devices can have different degrees of automation and configurations. Sometimes there are automatic garment feed systems and, in other cases, it is the worker that carries out this task. The garments can be positioned horizontally on a table or vertically on a support that rotates in order to mark the fabric on both sides of the garment. The laser beam operates inside a booth that must be equipped with ventilation and particle and gas removal systems.

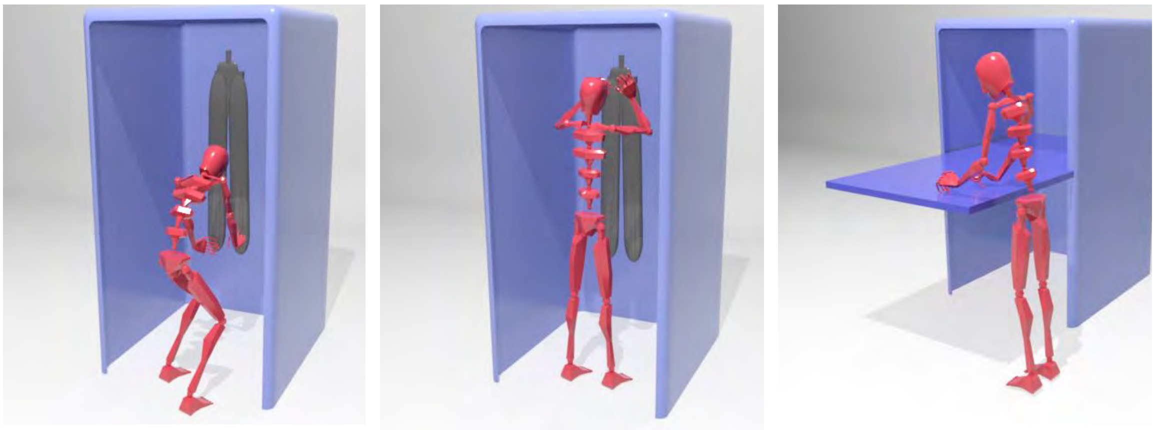
It is usual for the worker to carry out the task standing and collect each piece of clothing individually. In the vertical configuration, the worker introduces each trouser leg at the bottom of the holding device and lifts it towards the top to fix it. In the horizontal configuration, the operator places the garment on the table in the appropriate position. Then, the garment is inserted into the booth where the laser beam is applied.

Times: The work cycle is short. The cycle time devoted to collecting the garments is short. A significant part of the cycle time is used in placing the garment in the operation position. Once in place, the worker waits for the laser to act. Finally, the worker removes the garment from the support or waits for the automatic feed system to expel the garment.

Postures: The worker remains standing during the entire operation. To prevent a high postural load for this reason, there should be sufficient rest periods during the task in which the worker remains seated. Figure 8 schematically shows the most characteristic postures adopted by the worker. The first two images in the figure show the extreme postures adopted during the positioning of the garment on the support in a vertical configuration. The third image schematically shows the posture adopted by the worker when positioning the garment on the table in the horizontal configuration.

In the vertical configuration, the worker introduces the trouser legs at the bottom of the support. For this, the worker bends their trunk and, depending on the height of the support and of the worker, this may require leg flexion. Then, the worker extends their trunk and legs to lift the trousers over the support.

In the horizontal configuration, the worker extends the trousers over the table, which, depending on the height and width of the table and the stature of the worker, may make it necessary for the worker to bend their trunk to reach the furthest parts of it. In this case, there may be localised contact pressure between the edge of the table and the worker's pelvis.



Vertical configuration 1 | Vertical configuration 2 | Horizontal configuration

Figure 8. Schematic configuration of the postures adopted during laser abrasion

During the operation, the worker occasionally adopts forced postures, mainly during the introduction of the trousers onto the vertical support. However, the posture is generally dynamic and not held and there is postural variety. Although the operation requires standing for long periods, the worker has space to change posture and recovery time during the periods in which the laser is acting on the garment. The risk probability due to adoption of poor, static or forced postures is considered low.

Load handling: Generally, the weight of the handled load during the operation is low, as it is limited to the weight of the garment itself. An adequate configuration of the workstation should allow nearby access to these items without adopting forced or asymmetric postures. The risk probability due to manual handling of loads is low in the analysed configurations of the operation.

Repetitive movements: The risk probability due to repetitive movements is low. There are no significant stereotyped or repeated movements. There is a recovery period included in the work cycle time corresponding to the time that the worker waits for the machine to finish its task.

Application of force: There is no significant handling of loads or the exertion of strong forces during the execution of the task. The risk probability due to application of forces is considered low.

Physical environment: The existence of significant vibrations or noise from the machine is unlikely. The existence of ventilation and gas removal systems can cause local noise and local thermal conditions can vary slightly due to the presence of the laser beam which generates heat. However, the variation with respect to the overall noise and environmental conditions is not significant.

Monotony, attention and risks: The variety of content of the tasks carried out during the operation is low, but there are periods during which the worker can reduce their level of attention required for the task, therefore there is a reduced probability that the monotony of the operation causes boredom or demotivation of the worker. The task is carried out individually and there is no need for verbal exchange with other people for its performance. The use of a laser beam in the operation poses a significant risk for the worker due to the danger of burns or eye damage. However, the machine's automatic controllers and protection devices mean the risk probability is very low.

Laser abrasion

Risk factor	*Risk*	*Risk factor*	*Risk*
Repetitive movements	LOW PROBABILITY	Manual load handling	LOW PROBABILITY
Application of force	LOW PROBABILITY	Forced and static postures	LOW PROBABILITY
Vibration	LOW PROBABILITY	Contact pressure with tools and surfaces	MEDIUM PROBABILITY
Local thermal environment	LOW PROBABILITY	Local noise levels	LOW PROBABILITY
Level of attention and consequence of the risk	LOW PROBABILITY	Repetitive and monotonous work	LOW PROBABILITY

Table 10. Assessment of the ergonomic risk probability during laser abrasion

Ergonomic risk probabilities by operation

Table 11 shows the probability of the presence of different ergonomic risk factors analysed in this report in each operation. The risk probabilities were obtained by carrying out a qualitative assessment of the risks considering the most common characteristics of the operations in the production processes.

The probability of the presence of the risk has been assessed on a three-level ordinal scale. Low Probability indicates that the probability that the risk factor is present in the operation is low. Medium Probability expresses that there is a certain probability that the risk factor is present while carrying out the operation. High Probability indicates that it is likely that the risk factor is present in the tasks that make up the operation.

As this is an ordinal scale, its three levels have an order of occurrence that increases with the probability of the presence of risk, however, the difference between two levels cannot be quantitatively established nor can arithmetic or quantitative operations be carried out with their values.

Risk factor	Manual scraping	Grinding with grinder	Grinding with wheel	Destroy process with grinding machine	Destroy process with cutter	Destroy process with machine	Spraying	Sponging	3D whiskers	Manual tagging	Tagging with machine	Laser abrasion
Repetitive movements	HIGH PROBABILITY	LOW PROBABILITY	MEDIUM PROBABILITY	LOW PROBABILITY	HIGH PROBABILITY	LOW PROBABILITY	HIGH PROBABILITY	MEDIUM PROBABILITY	MEDIUM PROBABILITY	MEDIUM PROBABILITY	MEDIUM PROBABILITY	LOW PROBABILITY
Load handling	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY
Application of force	MEDIUM PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY
Forced postures	HIGH PROBABILITY	HIGH PROBABILITY	HIGH PROBABILITY	HIGH PROBABILITY	HIGH PROBABILITY	LOW PROBABILITY	HIGH PROBABILITY	HIGH PROBABILITY	HIGH PROBABILITY	HIGH PROBABILITY	MEDIUM PROBABILITY	LOW PROBABILITY
Vibration	LOW PROBABILITY	HIGH PROBABILITY	HIGH PROBABILITY	HIGH PROBABILITY	LOW PROBABILITY	MEDIUM PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY
Contact pressure	MEDIUM PROBABILITY	MEDIUM PROBABILITY	HIGH PROBABILITY	MEDIUM PROBABILITY	MEDIUM PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	MEDIUM PROBABILITY	LOW PROBABILITY	MEDIUM PROBABILITY
Local thermal environment	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	MEDIUM PROBABILITY	LOW PROBABILITY	MEDIUM PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY
Local noise levels	LOW PROBABILITY	MEDIUM PROBABILITY	MEDIUM PROBABILITY	MEDIUM PROBABILITY	LOW PROBABILITY	MEDIUM PROBABILITY	HIGH PROBABILITY	LOW PROBABILITY	MEDIUM PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY
Attention and risks	LOW PROBABILITY	MEDIUM PROBABILITY	MEDIUM PROBABILITY	MEDIUM PROBABILITY	HIGH PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	LOW PROBABILITY	MEDIUM PROBABILITY	LOW PROBABILITY	MEDIUM PROBABILITY	LOW PROBABILITY
Repetitiveness and monotony	MEDIUM PROBABILITY	MEDIUM PROBABILITY	MEDIUM PROBABILITY	MEDIUM PROBABILITY	HIGH PROBABILITY	MEDIUM PROBABILITY	MEDIUM PROBABILITY	MEDIUM PROBABILITY	MEDIUM PROBABILITY	MEDIUM PROBABILITY	MEDIUM PROBABILITY	LOW PROBABILITY

Table 11. Assessment of the ergonomic risk probability during denim finishing operations

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