Survey and Assessment of the Safety of Laser Radiation Source Used in the Garment Industry

T.T.T. MAI[1], T.N. VO[2]

[1] Faculty of Environment and Labour Safety, Ton Duc Thang University, Ho Chi Minh City, Vietnam
[2] Branch of National Institute of Occupational Safety and Health in the South Vietnam

http://doi.org/10.29227/IM-2022-02-11

Submission date: 26-08-2022 | Review date: 13-11-2022

Laser power source is a new energy source that is being widely used in industrial production. Therefore, the issue of safety in the use and operation of equipment using this energy source needs to be concerned. In this research, we conduct a survey on the use of laser energy-emitting devices and machines in the garment industry to ensure safety when using and measure the laser power of the devices. This equipment at the working positions of employees is then compared with ANSI laser safety standards to consider the safety of workers when operating these devices, so that timely solutions can be taken to ensure safety when working with equipment that emits laser energy. Because there is currently no safety standard for using lasers in Vietnam, through the process of surveying and measuring laser radiation, we found that these devices always have potential dangers that can cause damage to the environment. workers during work.

Therefore, to ensure the safety of workers when working with these devices, we have also compiled a set of safety manuals for using laser energy to supply factories to ensure safety. Workers when working with these devices. We have also compiled a draft of the standard for safe use of industrial lasers to submit to the authorities in Vietnam for the promulgation of Vietnamese standards on the safe use of industrial lasers. With the fabric laser machine, the laser radiation intensity is from 233.0 $\mu W.cm^{-2}$ to 253.4 $\mu W.cm^{-2}$ and the average value is 245.3 $\mu W.cm^{-2}$. Laser Flexi-Pro machine, the laser radiation intensity is from 173.5 $\mu W.cm^{-2}$ to 196.0 $\mu W.cm^{-2}$ and the average value is 187.3 $\mu W.cm^{-2}$. Laser Jeanologia-Twin HS Machine, the laser radiation intensity is from 255.8 $\mu W.cm^{-2}$ to 279.2 $\mu W.cm^{-2}$ and the average value is 270.7 $\mu W.cm^{-2}$. Laser Flexi-Denim machine, the laser radiation intensity is from 189.4 $\mu W.cm^{-2}$ to 343.0 $\mu W.cm^{-2}$ and the average value is 292.8 $\mu W.cm^{-2}$.

Keywords: *garment industry, laser radiation, laser safety, laser machines, safety standard*

1. Introduction to laser sources and the health hazards of laser radiation

Laser stands for Light Amplification by Stimulated Emission of Radiation, which outlines the main facts of laser light generation. In the most simplified sequence, an energy source excites atoms in an active medium (gas, solid, liquid) to emit a particular wavelength of light. The generated light is amplified by an optical feedback system that causes the light beam to bounce back and forth in the operating medium to increase phase coherence until the emitted light is a laser beam. [1]

The health hazards of using industrial laser sources as well as other hazards are: [1]

- Damage to eyes and skin
- Electrical hazards
- Chemical hazard
- Compressed air
- Air pollution
- Liquid freezing
- Danger of fire

Hazard classification of laser sources: in Vietnam, there is no standard to classify the level of hazard of laser sources, so in this study, the research team used the American national standard ANSI (American National Standards Institute) for laser hazard classification. The ANSI Z136.1-2007 standard classifies laser hazard levels as follows: [1] These calculations are used to determine a factor defined as the Accessible Emission Limit or AEL which is the mathematical product of the Maximum Permissible Exposure limit (MPE) given in the Standard and an area factor computed from the defined term called the Limiting Aperture (LA). That is: AEL = MPE x Area of LA.

Limiting Apertures are dependent on factors such as laser wavelength and are based on physical factors such as the fully dilated pupil size (7mm) and beam "hotspots" (1mm).

For most all exposures to the skin and IR exposures to the eye lasting greater 10 seconds, the involuntary movement of the eyes and the body as well as heat conduction will average an irradiance profile over an area of about 10 mm^2, even if the irradiated body part is kept intentionally still. This equates to a size of about 3.5 mm.

Especially in the near-infrared, radiation is penetrating relatively deep into skin and due to scattering, the irradiance profile is averaged over corresponding dimensions. For wavelengths larger than 0.1 mm, an aperture size of 11 mm is specified, as smaller apertures would lead to inaccurate measurements due to diffraction effects.

Each laser class is based on these AEL thresholds:

- Class 1 lasers or systems cannot emit accessible laser radiation in excess of the applicable Class 1 AEL for any exposure times within the maximum duration inherent in the design or intended use of the laser. Class 1 lasers are exempt from all beam-hazard control measures.
- Class 2 lasers are CW and repetitively pulsed lasers with wavelengths between 0.4 μm and 0.7 μm that can emit energy in excess of the Class 1 AEL, but do not exceed the Class 1 AEL for an emission duration

Tab. 1. Biological effects of laser radiation [1]
Tab. 1. Skutki biologiczne promieniowania laseowgo [1]

Spectral Domain (CIE range)	Eyes effects	Skin effects
Ultraviolet C (200-280 nm)	Photokaretitis	Erythema (sunburn) Skin cancer Accelerated skin aging
Ultraviolet B (280-315 nm)	Photokaretitis	Erythema (sunburn) Increased pigmentation
Ultraviolet A (315-400 nm)	Photochemical cataract	Pigmen darkening Skin burn
Visible light (400-780 nm)	Photochemical and thermal retinal injury	Pigmen darkening Photosenstive reactions Skin burn
Infrared A (780-1400 nm)	Cataract and retinal burn	Skin burn
Infrared B (1400-3.000 nm)	Corneal burn, aqueous flare, cataract	Skin burn
Infrared C (3.000-1.000.000 nm)	Corneal burn only	Skin burn

less than 0.25 seconds and have an average radiant power of 1mW or less.

- Class 3R lasers have an accessible output between 1 and 5 times the Class 1 AEL for wavelengths shorter than 0.4 μm or longer than 0.7 μm, or less than 5 times the Class 2 AEL for wavelengths between 0.4 μm and 0.7 μm.
- Class 3B lasers cannot emit an average radiant power greater than 0.5 Watts for an exposure time equal to or greater than 0.25 seconds or 0.125 Joules for an exposure time less than 0.25 seconds for wavelengths between 0.18 μm and 0.4 μm, or between 1.4 μm and 1 mm. In addition, lasers between 0.4 μm and 1.4 μm exceeding the Class 3a AEL cannot emit an average radiant power greater than 0.5 Watts for exposures equal to or greater than 0.25 seconds, or a radiant energy greater than 0.03 Joules per pulse.
- Class 4 lasers and laser systems exceed the Class 3b AEL.

2. Evaluation procedure of laser sources safety and laser radiation instrumentation

2.1. Evaluation procedure of laser sources safety

(1) Purpose:

In this topic, the purpose of evaluating the measured data is to see if it is within the allowable limits of the standard, to ensure the safety of workers who have been working near these laser sources.

(2) Determine the measurement location:

In this study, the measurement position is determined by the author's group at the positions of workers standing closest to the source of the laser, and for laser generators using shielding equipment, the position measurement is defined as measuring when shielded and measured when not shielded.

(3) Take measurements:

After determining the measurement location, the measurement is carried out and at each measurement location, it is necessary to have a number of repeat measurements to ensure the accuracy of the measurement results.

(4) Data processing:

After having the measurement results at each location with the number of repetitions, proceed to process the measured data by averaging at each location to get representative data for each measurement location.

(5) Comment and evaluate data:

From the processing data, comments and evaluations are made against the allowed standards and solutions are given accordingly.

2.2. Laser radiation instrumentation

Measurement of laser radiation is carried out using a meter: Handheld Laser Power& Energy Meter Ophir – Nova II. This measure machine functions are:

- Monitoring of laser beam size
- Accurate tracking of beam position to fractions of a mm
- Beam position and wander
- All the other features of standard power/energy meters

3. Research results

We have surveyed and measured a number of laser emitting devices at a number of garment factories with the following survey and measured results:

3.1. Laser safety assessment results of fabric laser machine

Through the survey, it was found that these cutters are cutting machines using CO_2 lasers with a laser power of 130W, wavelength of 0.6μm and labeled as hazardous by the manufacturer as group IV. Therefore, it is necessary to have personal protective equipment for workers when working with these machines.

On each laser cutting machine of this type, the factory has stickers on the process of using the machine as well as the safety measures that need to be applied. In this table, there are 4 main contents:

A. General provisions,
B. Points to be checked before operating the equipment,
C. Steps to start and operate the machine,
D. End of operations.

The measurement was carried out at 03 fabric laser machines at the factory, because during the working process, most of the workers operating at these machines removed the protection, so the measurement was done when the machine was covered. and without cover, with measurement results as shown in the following table.

With the fabric laser machine, the laser radiation intensity is from 233.0 $\mu W.cm^{-2}$ to 253.4 $\mu W.cm^{-2}$ and the average value is 245.3±4.8 $\mu W.cm^{-2}$. It was found that the measured results, if compared with the evaluation standards for maximum exposure limits (MPE) for eyes and skin, are lower than the allowable standards. However, it is very dangerous for workers to often remove the protective cover when working, we have advised the factory on this content to ensure the safety of workers when working with these devices.

Tab. 2. Maximum Permissible Exposure (MPE) for Point Source Ocular Exposure to a Laser Beam [1]
Tab. 2. Maksymalne dopuszczalne narażenie (MPE) dla punktowego źródła ekspozycji oka na wiązkę laserową [1]

Wavelength λ (μm)	Exposure Duration t (second-s)	Maximum Permissible Exposure (MPE)	
		$J.cm^{-2}$	$W.cm^{-2}$
Ultraviolet			
0,180 – 0,400	-	-	-
Thermal			
0,180 – 0,400	10^{-9} – 10	$0,56.t^{0,25}$	-
Photochemical			
0,180 – 0,302	10^{-9} – 3.10^{4}	3.10^{-3}	-
0,302 – 0,315	10^{-9} – 3.10^{4}	$10^{200(\lambda-0,295)}.10^{-4}$	-
0,315 – 0,400	10 – 3.10^{4}	1,0	-
Visible			
0,400 – 0,700	10^{-3} – 10^{-11}	$1,5.10^{-8}$	-
0,400 – 0,700	10^{-11} – 10^{-9}	$2,7.t^{0,75}$	-
0,400 – 0,700	10^{-9} – 18.10^{-6}	5.10^{-7}	-
0,400 – 0,700	18.10^{-6} – 10	$1,8.t^{0,75}.10^{-3}$	-
0,400 – 0,700	10 – 3. 10^{4}		10^{-3}
Thermal			
0,450 – 0,500	10 – T_1		10^{-3}
Photochemical			
0,400 – 0,450	10 – 100	10^{-2}	-
0,450 – 0,500	T_1 – 100	$C_B.10^{-2}$	-
0,400 – 0,500	100 – 3.10^{4}		$C_B.10^{-4}$
Near infrared			
0,700 – 1,050	10^{-13} – 10^{-11}	$1,5.C_A.10^{-8}$	-
0,700 – 1,050	10^{-11} – 10^{-9}	$2,7.C_A.t^{0,75}$	-
0,700 – 1,050	10^{-9} – 18.10^{-6}	$5,0.C_A.10^{-7}$	-
0,700 – 1,050	18.10^{-6} – 10	$1,8.C_A.t^{0,75}.10^{-3}$	-
0,700 – 1,050	10 – 3.10^{4}	-	$C_A.10^{-3}$
1,050 – 1,400	10^{-13} – 10^{-11}	$1,5.C_C.10^{-7}$	-
1,050 – 1,400	10^{-11} – 10^{-9}	$27,0.C_C.t^{0,75}$	-
1,050 – 1,400	10^{-9} – 50.10^{-6}	$5,0.C_C.10^{-6}$	-
1,050 – 1,400	50.10^{-6} – 10	$9,0.C_C.t^{0,75}.10^{-3}$	-
1,050 – 1,400	10 – 3.10^{4}	-	$5,0.C_C.10^{-3}$
Far infrared			
1,400 – 1,500	10^{-9} – 10^{-3}	0,1	-
1,400 – 1,500	10^{-3} – 10	$0,56.t^{0,25}$	-
1,400 – 1,500	10 – 3.10^{4}	-	0,1
1,500 – 1,800	10^{-9} – 10	1,0	-
1,500 – 1,800	10 – 3.10^{4}	-	0,1
1,800 – 2,600	10^{-9} – 10^{-3}	0,1	-
1,800 – 2,600	10^{-3} – 10	$0,56.t^{0,25}$	-
1,800 – 2,600	10 – 3.10^{4}	-	0,1
2,600 – 1000	10^{-9} – 10^{-7}	10^{-2}	-
2,600 – 1000	10^{-7} – 10	$0,56.t^{0,25}$	-
2,600 – 1000	10 – 3.10^{4}	-	0,1

Tab. 3. Maximum Permissible Exposure (MPE) for Extended Source Ocular Exposure [1]
Tab. 3. Maksymalne dopuszczalne narażenie (MPE) dla przedłużonej ekspozycji oka na źródło [1]

Wavelength λ (μm)	Exposure Duration t (second-s)	Maximum Permissible Exposure (MPE)	
		$J.cm^{-2}$	$W.cm^{-2}$
Visible			
0,400 – 0,700	10^{-3} – 10^{-11}	$1,5.C_E.10^{-8}$	-
0,400 – 0,700	10^{-11} – 10^{-9}	$2,7.C_E.t^{0,75}$	-
0,400 – 0,700	10^{-9} – 18.10^{-6}	$5,0.C_E.10^{-7}$	-
0,400 – 0,700	18.10^{-6} – 0,7	$1,8.C_E.t^{0,75}.10^{-3}$	-
Photochemical			
For $\alpha \leq$ 11mrad			
0,400 – 0,600	0,7 – 100	$C_B.10^{-2}$	-
0,400 – 0,600	100 – 3.10^{4}	-	$C_B.10^{-4}$
For $\alpha >$ 11mrad			
0,400 – 0,600	0,7 – 10^{4}	$100.C_B.J.cm^{-2}.sr^{-1}$	-
0,400 – 0,600	10^{4} – 3.10^{4}	-	$C_B.10^{-2}W.cm^{-2}.sr^{-1}$
Thermal			
0,400 – 0,700	0,7 – T_2	$1,8.C_E.t^{0,75}.10^{-3}$	-
0,400 – 0,700	T_2 – 3.10^{4}	-	$1,8.C_E.T_2^{-0,25}.10^{-3}$
Near Infrared			
0,700 – 1,050	10^{-13} – 10^{-11}	$1,5.C_A.C_E.10^{-8}$	-
0,700 – 1,050	10^{-11} – 10^{-9}	$2,7.C_A.C_E.t^{0,75}$	-
0,700 – 1,050	10^{-9} – 18.10^{-6}	$5,0.C_A.C_E.10^{-7}$	-
0,700 – 1,050	18.10^{-6} – T_2	$1,8.C_A.C_E.t^{0,75}.10^{-3}$	-
0,700 – 1,050	T_2 – 3.10^{4}	-	$1,8.C_AC_E.T_2^{-0,25}.10^{-3}$
1,050 – 1,400	10^{-13} – 10^{-11}	$1,5.C_C.C_E.10^{-7}$	-
1,050 – 1,400	10^{-11} – 10^{-9}	$27,0.C_C.C_E.t^{0,75}$	-
1,050 – 1,400	10^{-9} – 50.10^{-6}	$5,0.C_C.C_E.10^{-6}$	-
1,050 – 1,400	50.10^{-6} – T_2	$9,0.C_C.C_E.t^{0,75}.10^{-3}$	-
1,050 – 1,400	T_2 – 3.10^{4}	-	$9.C_CC_E.T_2^{-0,25}.10^{-3}$

3.2. Laser safety assessment results of Laser Flexi-Pro machine

This is a device that uses a laser to burn on the surface of jeans to create the shapes required by the user, through the survey we found that these devices work very safely. because when operating, the entire process of laser emission is carefully covered, workers are not exposed at all, in some cases workers carelessly open or do not close the cover, the device cannot work. We have also conducted measurement of laser radiation when the machine is in operation at some locations where workers work around the machine with the following measurement results:

Laser Flexi-Pro machine, the laser radiation intensity is from 173.5 μW.cm^{-2} to 196.0 μW.cm^{-2} and the average value is 187.3±5.3 μW.cm^{-2}. Realizing that the measured results are in class 1 of laser sourse, it is a safe class for workers when working and operating these devices.

3.3. Laser safety assessment results of Laser Jeanologia-Twin HS Machine

Through the survey, we found that this device works quite safely and during the operation of the device, if someone enters the working area of the device, through the sensor system, the device will immediately stop working. However, when this equipment is operating without a cover, workers need to be careful not to intrude into the working area of the device to avoid the risk of accidents. We measure the intensity

Tab. 4. Maximum Permissible Exposure (MPE) for Skin Exposure to a Laser Beam [1]

Tab. 4. Maksymalne dopuszczalne narażenie (MPE) dla ekspozycji skóry na wiązkę laserową [1]

Wavelength λ (μm)	Exposure Duration t(s)	Maximum Permissible Exposure (MPE)	
		$J.cm^{-2}$	$W.cm^{-2}$
Ultraviolet			
Thermal			
0,180 – 0,400	10^{-9} – 10	$0,56.t^{0,25}$	-
Photochemical			
0,180 – 0,302	10^{-9} – 3.10^{4}	3.10^{-3}	-
0,302 – 0,315	10^{-9} – 3.10^{4}	$10^{200(\lambda-0,295)}.10^{-4}$	-
0,315 – 0,400	10 – 10^{3}	1	-
0,315 – 0,400	10^{3} – 3.10^{4}	-	10^{-3}
Visible and near Infrared			
0,400 – 1,400			
0,400 – 1,400	10^{-9} – 10^{-7}	$2C_A.10^{-2}$	-
0,400 – 1,400	10^{-7} – 10	$1,1.C_A.t^{0,25}$	-
	10 – 3.10^{4}	-	$0,2.C_A$
Far Infrared			
1,400 – 1,500	10^{-9} – 10^{-3}	0,1	-
1,400 – 1,500	10^{-3} – 10	$0,56.t^{0,25}$	-
1,400 – 1,500	10 – 3.10^{4}	-	0,1
1,500 – 1,800	10^{-9} – 10	1,0	-
1,500 – 1,800	10 – 3.10^{4}	-	0,1
1,800 – 2,600	10^{-9} – 10^{-3}	0,1	-
1,800 – 2,600	10^{-3} – 10	$0,56.t^{0,25}$	-
1,800 – 2,600	10 – 3.10^{4}	-	0,1
2,600 – 1000	10^{-9} – 10^{-7}	10^{-2}	-
2,600 – 1000	10^{-7} – 10	$0,56.t^{0,25}$	-
2,600 – 1000	10 – 3.10^{4}	-	0,1

Tab. 5. Parameters and Correction Factors [1]

Tab. 5. Parametry i współczynniki korekcyjne [1

Parameters/Correction Factors	Wavelength λ (μm)
$C_A=1,0$	0,400 – 0,700
$C_A=10^{2(\lambda-0,700)}$	0,700 – 1,050
$C_A=5,0$	1,050 – 1,400
$C_B=1,0$	0,400 – 0,450
$C_B=10^{20(\lambda-0,450)}$	0,450 – 0,600
$C_C=1,0$	1,050 – 1,150
$C_C=10^{18(\lambda-1,150)}$	1,150 – 1,200
$C_C=8,0$	1,200 – 1,400
$C_E=1,0$ $\alpha < \alpha_{min}$ *	0,400 – 1,400
$C_E= \alpha / \alpha_{min}$ $\alpha_{min} \le \alpha \le \alpha_{max}$ *	0,400 – 1,400
$C_E= \alpha^2 / \alpha_{max}.\alpha_{min}$ $\alpha > \alpha_{max}$ *	0,400 – 1,400
$C_P= n^{-0,25}$**	0,180 – 1000
$T_1=10.10^{20(\lambda-0,450)}$***	0,450 – 0,500
$T_2=10.10^{(\alpha-1,5)/98,5}$****	0,400 – 1,400

* 0,400 ≤ λ ≤ 1,400 μm: α_{min} = 1,5 mrad, α_{max} = 100 mrad

** Frequencies below 55 kHz (0.400 – 1.050 μm) and below 20 kHz (1.050 – 1.400 μm)

*** T_1=10 s, λ=0,450 μm ; T_1=100 s, λ=0,500 μm

**** T_2=10 s, α < 1,5 mrad ; T_2=100 s, α >100 mrad

Tab. 6. Measurement results of Laser radiation intensity at fabric laser machines

Tab. 6. Wyniki pomiarów natężenia promieniowania laserowego na maszynach laserowych do cięcia tkanin

No.	Machines	Measuring position	Laser radiation intensity ($\mu W.cm^{-2}$)	Average value	STD
1	Fabric laser machine 1	FLM 1.1.1	245.2	247.1	± 2.7
2	Fabric laser machine 1	FLM 1.1.2	250.2		
3	Fabric laser machine 1	FLM 1.1.3	245.9		
4	Fabric laser machine 1	FLM 1.2.1	234.1	233.9	± 0.8
5	Fabric laser machine 1	FLM 1.2.2	233.0		
6	Fabric laser machine 1	FLM 1.2.3	234.5		
7	Fabric laser machine 1	FLM 1.3.1	244.8	244.6	± 0.5
8	Fabric laser machine 1	FLM 1.3.2	244.0		
9	Fabric laser machine 1	FLM 1.3.3	245.0		
10	Fabric laser machine 2	FLM 2.1.1	252.4	251.9	± 0.8
11	Fabric laser machine 2	FLM 2.1.2	251.0		
12	Fabric laser machine 2	FLM 2.1.3	252.2		
13	Fabric laser machine 2	FLM 2.2.1	245.7	245.9	± 1.0
14	Fabric laser machine 2	FLM 2.2.2	245.0		
15	Fabric laser machine 2	FLM 2.2.3	247.0		
16	Fabric laser machine 2	FLM 2.3.1	244.8	244.7	± 0.4
17	Fabric laser machine 2	FLM 2.3.2	245.0		
18	Fabric laser machine 2	FLM 2.3.3	244.2		
19	Fabric laser machine 3	FLM 3.1.1	244.1	245.1	± 1.1
20	Fabric laser machine 3	FLM 3.1.2	245.0		
21	Fabric laser machine 3	FLM 3.1.3	246.2		
22	Fabric laser machine 3	FLM 3.2.1	246.2	245.8	± 1.4
23	Fabric laser machine 3	FLM 3.2.2	247.0		
24	Fabric laser machine 3	FLM 3.2.3	244.3		
25	Fabric laser machine 3	FLM 3.3.1	248.3	248.5	± 1.5
26	Fabric laser machine 3	FLM 3.3.2	250.1		
27	Fabric laser machine 3	FLM 3.3.3	247.2		
	Min		**233.0**		
	Max		**252.4**		
	Average			**245.3**	**± 4.8**

Fig. 1. Handheld Laser Power and Energy Meter Ophir – Nova II
Rys. 1. Ręczny miernik mocy i energii lasera Ophir – Nova II

Fig. 2. Fabric laser machine
Rys. 2. Maszyna laserowa do cięcia tkanin

Fig. 3. Laser Flexi-Pro machine
Rys. 3. Maszyna Laser Flexi-Pro

of laser radiation at locations around the machine with the following results:

In general, Laser Jeanologia-Twin HS Machine use class 1 laser source, safe for employees to work, but businesses need to regularly check and maintain these devices to ensure that the sensors are always in good working condition. Prevent workers from entering the danger zone when the equipment is in operation to ensure the safety of workers. Laser Jeanologia-Twin HS Machine, the laser radiation intensity is from 255.8 $\mu W.cm^{-2}$ to 279.2 $\mu W.cm^{-2}$ and the average value is 270.7±7.2 $\mu W.cm^{-2}$.

3.4. Laser safety assessment results of Laser Flexi-Denim machine

We have conducted a survey of the use status of this equipment and found that these devices are very safe during use, with full instructions and danger warnings for workers when working with the equipment. suffer this. However, we also found that the workers working here did not comply with the safety regulations when operating this equipment, not closing the cover when operating this is very dangerous for workers because Workers may have an accident due to the laser beams reflecting outward or accidentally entering the hazardous area while working. At the same time, we have measured the intensity of laser radiation at locations around the machine where workers work with the following results:

Laser Flexi-Denim machine, the laser radiation intensity is from 189.4 $\mu W.cm^{-2}$ to 343.0 $\mu W.cm^{-2}$ and the average value is 292.8±41.3 $\mu W.cm^{-2}$. The measured results of laser sources comply with class 1 according to the standard of being safe for users. But during the survey, we found that workers in enterprises still have not a high sense of the laser dangerous. Safety regulations on laser sources when operating, working with equipment that emits laser radiation such as using personal protective equipment, is not complied.

3.5. Laser source safety manual

The safety manual for using laser sources was compiled by the research team into a system of safety solutions for each object with the following main contents:

- Management solutions
- Technical solutions
- About personal protective equipment
- Ensure radiation safety rules
- Training on OSH
- Taking care of employees' health
- General safety regulations for laser groups

3.6. Draft Vietnamese National standards for the safe use of industrial laser sources

Tab. 7. Measurement results of Laser radiation intensity at Laser Flexi-Pro machines
Tab. 7. Wyniki pomiarów natężenia promieniowania laserowego na maszynach Laser Flexi-Pro

No.	Machines	Measuring position	Laser radiation intensity ($\mu W.cm^{-2}$)	Average value	STD
1	Laser Flexi-Pro machine 1	LFP 1.1.1	193.2		
2	Laser Flexi-Pro machine 1	LFP 1.1.2	195.2	194.8	± 1.4
3	Laser Flexi-Pro machine 1	LFP 1.1.3	196.0		
4	Laser Flexi-Pro machine 1	LFP 1.2.1	187.3		
5	Laser Flexi-Pro machine 1	LFP 1.2.2	190.0	188.5	± 1.4
6	Laser Flexi-Pro machine 1	LFP 1.2.3	188.2		
7	Laser Flexi-Pro machine 1	LFP 1.3.1	188.6		
8	Laser Flexi-Pro machine 1	LFP 1.3.2	190.1	188.1	± 2.3
9	Laser Flexi-Pro machine 1	LFP 1.3.3	185.5		
10	Laser Flexi-Pro machine 2	LFP 2.1.1	176.3		
11	Laser Flexi-Pro machine 2	LFP 2.1.2	173.5	174.9	± 1.4
12	Laser Flexi-Pro machine 2	LFP 2.1.3	175.0		
13	Laser Flexi-Pro machine 2	LFP 2.2.1	186.3		
14	Laser Flexi-Pro machine 2	LFP 2.2.2	188.0	187.2	± 0.9
15	Laser Flexi-Pro machine 2	LFP 2.2.3	187.2		
16	Laser Flexi-Pro machine 2	LFP 2.3.1	183.5		
17	Laser Flexi-Pro machine 2	LFP 2.3.2	185.2	185.1	± 1.6
18	Laser Flexi-Pro machine 2	LFP 2.3.3	186.6		
19	Laser Flexi-Pro machine 3	LFP 3.1.1	191.1		
20	Laser Flexi-Pro machine 3	LFP 3.1.2	190.0	190.3	± 0.7
21	Laser Flexi-Pro machine 3	LFP 3.1.3	189.9		
22	Laser Flexi-Pro machine 3	LFP 3.2.1	187.9		
23	Laser Flexi-Pro machine 3	LFP 3.2.2	189.9	188.9	± 1.0
24	Laser Flexi-Pro machine 3	LFP 3.2.3	188.8		
25	Laser Flexi-Pro machine 3	LFP 3.3.1	188.7		
26	Laser Flexi-Pro machine 3	LFP 3.3.2	187.7	187.7	± 1.0
27	Laser Flexi-Pro machine 3	LFP 3.3.3	186.7		
	Min		**173.5**		
	Max		**196.0**		
	Average			**187.3**	**± 5.3**


Fig. 4. Laser Jeanologia-Twin HS Machine
Rys. 4. Laserowa maszyna Jeanologia-Twin HS


Fig. 5. Laser Flexi-Denim machine
Rys. 5. Laserowa maszyna Flexi-Denim

The research team has compiled a Draft Standard with 21 major contents and 6 attached appendices, arranged like the current standards of Vietnam. The main contents of the draft are as follows:

(1) Scope of application
(2) References
(3) Goals
(4) Terms and definitions
(5) Classification
(6) Harm of laser
(7) Causes of laser accidents
(8) Principle of measurement
(9) For Employers
(10) For employees

Tab. 8. Measurement results of Laser radiation intensity at Laser Jeanologia-Twin HS Machine
Tab. 8. Wyniki pomiarów natężenia promieniowania laserowego na Laser Jeanologia-Twin HS Machine

No.	Machines	Measuring position	Laser radiation intensity ($\mu W.cm^{-2}$)	Average value	STD
1	Laser Jeanologia-Twin HS Machine 1	LJT 1.1.1	276.3	276.5	± 1.6
2	Laser Jeanologia-Twin HS Machine 1	LJT 1.1.2	275.0		
3	Laser Jeanologia-Twin HS Machine 1	LJT 1.1.3	278.1		
4	Laser Jeanologia-Twin HS Machine 1	LJT 1.2.1	278.9	278.3	± 0.5
5	Laser Jeanologia-Twin HS Machine 1	LJT 1.2.2	277.9		
6	Laser Jeanologia-Twin HS Machine 1	LJT 1.2.3	278.2		
7	Laser Jeanologia-Twin HS Machine 1	LJT 1.3.1	267.1	267.9	± 0.7
8	Laser Jeanologia-Twin HS Machine 1	LJT 1.3.2	268.0		
9	Laser Jeanologia-Twin HS Machine 1	LJT 1.3.3	268.5		
10	Laser Jeanologia-Twin HS Machine 2	LJT 2.1.1	255.8	256.2	± 0.5
11	Laser Jeanologia-Twin HS Machine 2	LJT 2.1.2	256.0		
12	Laser Jeanologia-Twin HS Machine 2	LJT 2.1.3	256.8		
13	Laser Jeanologia-Twin HS Machine 2	LJT 2.2.1	276.2	277.6	± 1.2
14	Laser Jeanologia-Twin HS Machine 2	LJT 2.2.2	278.0		
15	Laser Jeanologia-Twin HS Machine 2	LJT 2.2.3	278.5		
16	Laser Jeanologia-Twin HS Machine 2	LJT 2.3.1	265.7	266.3	± 0.8
17	Laser Jeanologia-Twin HS Machine 2	LJT 2.3.2	266.0		
18	Laser Jeanologia-Twin HS Machine 2	LJT 2.3.3	267.2		
19	Laser Jeanologia-Twin HS Machine 3	LJT 3.1.1	266.6	267.3	± 0.8
20	Laser Jeanologia-Twin HS Machine 3	LJT 3.1.2	267.0		
21	Laser Jeanologia-Twin HS Machine 3	LJT 3.1.3	268.2		
22	Laser Jeanologia-Twin HS Machine 3	LJT 3.2.1	267.3	268.6	± 1.1
23	Laser Jeanologia-Twin HS Machine 3	LFP 3.2.2	269.0		
24	Laser Jeanologia-Twin HS Machine 3	LJT 3.2.3	269.4		
25	Laser Jeanologia-Twin HS Machine 3	LJT 3.3.1	277.2	278.1	± 1.0
26	Laser Jeanologia-Twin HS Machine 3	LJT 3.3.2	278.0		
27	Laser Jeanologia-Twin HS Machine 3	LJT 3.3.3	279.2		
	Min		**255.8**		
	Max		**279.2**		
	Average			**270.7**	**7.2**

Tab. 9. Measurement results of Laser radiation intensity at Laser Flexi-Denim machine
Tab. 9. Wyniki pomiarów natężenia promieniowania laserowego na maszynie Laser Flexi-Denim

No.	Machines	Measuring position	Laser radiation intensity ($\mu W.cm^{-2}$)	Average value	STD
1	Laser Flexi-Denim machine 1	LFD 1.1.1	302.3	301.2	± 1.2
2	Laser Flexi-Denim machine 1	LFD 1.1.2	300.0		
3	Laser Flexi-Denim machine 1	LFD 1.1.3	301.2		
4	Laser Flexi-Denim machine 1	LFD 1.2.1	278.1	279.0	± 1.0
5	Laser Flexi-Denim machine 1	LFD 1.2.2	280.0		
6	Laser Flexi-Denim machine 1	LFD 1.2.3	279.0		
7	Laser Flexi-Denim machine 1	LFD 1.3.1	189.4	190.5	± 1.4
8	Laser Flexi-Denim machine 1	LFD 1.3.2	190.0		
9	Laser Flexi-Denim machine 1	LFD 1.3.3	192.0		
10	Laser Flexi-Denim machine 2	LFD 2.1.1	298.9	299.3	± 0.6
11	Laser Flexi-Denim machine 2	LFD 2.1.2	300.0		
12	Laser Flexi-Denim machine 2	LFD 2.1.3	299.1		
13	Laser Flexi-Denim machine 2	LFD 2.2.1	288.7	289.9	± 1.2
14	Laser Flexi-Denim machine 2	LFD 2.2.2	290.0		
15	Laser Flexi-Denim machine 2	LFD 2.2.3	291.1		
16	Laser Flexi-Denim machine 2	LFD 2.3.1	301.3	300.1	± 1.1
17	Laser Flexi-Denim machine 2	LFD 2.3.2	300.0		
18	Laser Flexi-Denim machine 2	LFD 2.3.3	299.1		
19	Laser Flexi-Denim machine 3	LFD 3.1.1	331.7	330.2	± 1.4
20	Laser Flexi-Denim machine 3	LFD 3.1.2	329.0		
21	Laser Flexi-Denim machine 3	LFD 3.1.3	330.0		
22	Laser Flexi-Denim machine 3	LFD 3.2.1	341.4	342.1	± 0.8
23	Laser Flexi-Denim machine 3	LFP 3.2.2	342.0		
24	Laser Flexi-Denim machine 3	LFD 3.2.3	343.0		
25	Laser Flexi-Denim machine 3	LFD 3.3.1	303.4	303.1	± 1.0
26	Laser Flexi-Denim machine 3	LFD 3.3.2	304.0		
27	Laser Flexi-Denim machine 3	LFD 3.3.3	302.0		
	Min		**189.4**		
	Max		**343.0**		
	Average			**292.8**	**± 41.3**

(11) Management solutions
(12) Occupational risk management of laser radiation exposure
(13) Signs and warnings
(14) Training and supervision
(15) Technical solutions
(16) Personal protective equipment
(17) Ensure radiation safety rules
(18) Taking care of employees' health
(19) Laser safety measures in case of equipment setup
(20) Laser safety measures in case of adding new components
(21) Laser safety measures in case of maintenance

4. Conclusion

We have conducted a survey of devices using laser energy in enterprises with the results as presented. From the survey and measurement results at enterprises, we also have basic data on the situation of using equipment with laser energy sources in garment enterprises in Vietnam. We have also developed documents on "Safety instructions for using laser sources" and developed "Draft standards for safe use of industrial lasers". These documents serve safety work in garment enterprises as well as industries using equipment that emits laser energy and in safety management in Vietnam.

Literatura – References

1. American National Standards Institute , American National Standard for Safe use of Lasers (ANSI Z136.1-2007), 2007
2. International Electrotechnical Commission – IEC, Safety of laser products – Part 1: Equipment classification, requirements and user's guide 60825-1 Edition 1.2, 2001-08, 2001
3. University of Virginia, Guidelines on Laser Safety, October 2004
4. Northwestern University, Office for Research Safety; Laser Safety Handbook ;
5. Eksplorasi denim menggunakan laser flexi pro untuk produk men's modest wear, Elsi Yuningsih, Widia Nur Utami Bastaman, Fakultas Industri Kreatif, Telkom University, Bandung, Indonesia e-Proceeding of Art & Design : Vol.6, No.2 Agustus 2019, Page 1759:
6. https://ehs.oregonstate.edu/laser/training/laser-hazards

Badanie i ocena bezpieczeństwa źródła promieniowania laserowego stosowanego w przemyśle odzieżowym

Źródło zasilania lasera to nowe źródło energii, które jest szeroko stosowane w produkcji przemysłowej. Dlatego też należy zwrócić uwagę na kwestię bezpieczeństwa użytkowania i eksploatacji urządzeń wykorzystujących to źródło energii. W ramach przedstawionych badań przeprowadzono ankietę dotyczącą wykorzystania urządzeń i maszyn emitujących energię lasera w przemyśle odzieżowym w celu zapewnienia bezpieczeństwa podczas użytkowania oraz pomiaru mocy lasera urządzeń. Sprzęt wykorzystywany na stanowiskach pracy został porównany z normami bezpieczeństwa lasera ANSI. Uwzględniono bezpieczeństwo pracowników podczas obsługi tych urządzeń, tak aby można było na czas przyjąć rozwiązania w celu zapewnienia bezpieczeństwa podczas pracy ze sprzętem emitującym energię lasera. Ponieważ obecnie w Wietnamie nie ma norm bezpieczeństwa dotyczących korzystania z laserów, w procesie badania i pomiaru promieniowania laserowego stwierdzono, że urządzenia te zawsze stwarzają potencjalne zagrożenia, które mogą spowodować szkody w środowisku pracy. Dlatego, aby zapewnić bezpieczeństwo pracownikom podczas pracy z tymi urządzeniami, opracowano również zestaw instrukcji bezpieczeństwa dotyczących wykorzystania energii lasera do zasilania fabryk w celu zapewnienia bezpieczeństwa pracy. Opracowano również projekt normy dotyczącej bezpiecznego użytkowania laserów przemysłowych w celu przedłożenia stosownym władzom w Wietnamie w celu wdrożenia ogłoszenia wietnamskich norm dotyczących bezpiecznego użytkowania laserów przemysłowych. W maszynie z laserem tkaninowym intensywność promieniowania lasera wynosi od 233,0 $\mu W.cm^{-2}$ do 253,4 $\mu W.cm^{-2}$, a średnia wartość to 245,3 $\mu W.cm^{-2}$. Maszyna Laser Flexi-Pro charakteryzuje się intensywnością promieniowania lasera od 173,5 $\mu W.cm^{-2}$ do 196,0 $\mu W.cm^{-2}$, a średnia wartość to 187,3 $\mu W.cm^{-2}$. Laser Jeanologia-Twin HS Machine - intensywność promieniowania lasera wynosi od 255,8 $\mu W.cm^{-2}$ do 279,2 $\mu W.cm^{-2}$, a średnia wartość to 270,7 $\mu W.cm^{-2}$. Maszyna Laser Flexi-Denim - intensywność promieniowania lasera wynosi od 189,4 $\mu W.cm^{-2}$ do 343,0 $\mu W.cm^{-2}$, a średnia wartość to 292,8 $\mu W.cm^{-2}$.

Słowa kluczowe: *przemysł odzieżowy, promieniowanie laserowe, bezpieczeństwo laserowe, maszyny laserowe, norma bezpieczeństwa*