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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



DRAFT International Standard

ISO/DIS 11553-2

Safety of machinery — Laser processing machines —

Part 2: Safety requirements for hand-held or hand-operated laser processing machines

Sécurité des machines — Machines à laser —

*Partie 2: Exigences de sécurité pour machines de traitement laser
portatives ou à commande manuelle*

ICS: 31.260; 13.110

Member bodies are requested to consult relevant national interests in IEC/TC 76 before casting their ballot to the e-Balloting application.

This document is circulated as received from the committee secretariat.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 172, Optics and photonics, Subcommittee SC 9, Laser and electro-optical systems in collaboration with IEC/TC 76, Optical radiation safety and laser equipment.

This second edition cancels and replaces the first edition (ISO/IEC 11553-2:2007), which has been technically revised with the following main changes:

- a) Several terms and definitions were modified or newly added;
- b) the covered hazards as well as the requirements concerning the hazards were added in more detail;
- c) [Table 1](#) was newly added in [Clause 6](#), and the previous [Annex A](#) was deleted;
- d) Several subclause headings were modified and several technical requirements were amended;
- e) Some of the lists were renumbered;
- f) Previous [Annex B](#) was modified and was renumbered as the new [Annex A](#);
- g) New [Annex B](#), [Annex C](#) and [Annex D](#) were added.
- h) [Annex E](#) was modified;
- i) new [Annex F](#) and [Annex G](#) were added.

A list of all parts in the ISO 11553 series can be found on the ISO website/IEC website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is a type-C standard as stated in ISO 12100:2010.

This document is of relevance particularly for the following stakeholder groups representing the market players with regard to machinery safety:

- a) hand-held or hand-operated laser processing machines (HLMs) manufacturers (small, medium and large enterprises); including manufacturers of sub/part machines such as devices or devices assembly related to laser radiation, as well as system integrators (small, medium, and large enterprises);

NOTE Devices or device assemblies are including but not limited to: guiding; shaping, delivery, protective, locking, control, enabling, limiting, impeding, switching, exhaust, stop, loading/feeding, scanning and warning devices.

- b) health and safety bodies (regulators, accident prevention organizations, market surveillance, etc.).

Others can be affected by the level of machinery safety achieved with the means of the document by the above-mentioned stakeholder groups:

- c) machine users/employers (small, medium and large enterprises);
- d) machine users/employees (e.g., trade unions, organizations for people with special needs);
- e) service providers, e.g., for maintenance (small, medium and large enterprise);
- f) consumers (in case of machinery intended for use by consumers).
- g) bystanders

The above-mentioned stakeholder groups have been given the possibility to participate at the drafting process of this document.

The machinery concerned and the extent to which hazards, hazardous situations or hazardous events are covered are indicated in the Scope of this document.

When requirements of this type-C standard are different from those which are stated in type-A or type-B standards, the requirements of this type-C standard take precedence over the requirements of the other standards for machines that have been designed and built according to the requirements of this type-C standard.

The purpose of this document is to prevent injuries to persons:

- h) by listing potential hazards generated by hand-held or hand-operated laser processing machines;
- i) by describing the risk assessment procedure for all relevant hazards;
- j) by specifying safety measures and verification procedures necessary for reducing the risk caused by specific hazardous conditions;
- k) by providing references to pertinent standards;
- l) by specifying the information which is to be supplied to the user so that they can establish proper procedures and precautions at the workplace.

Safety of machinery — Laser processing machines —

Part 2:

Safety requirements for hand-held or hand-operated laser processing machines

1 Scope

This document specifies the requirements for hand-held or hand-operated laser processing machines (HLM) and their components as well as assemblies. HLM is the machine in which laser radiation is generated, where the laser provides sufficient energy/power to cause a phase transition in a part of the workpiece and where the laser output or workpiece to be processed is guided manually or hand-held during the laser process.

HLM includes the laser device, beam-guiding device (e.g., mirror, fibre, lenses), beam-shaping device (e.g., telescope, focusing), and controls. The laser assembly as an integral part of the HLM or only the laser processing head is hand-held or hand-operated during the laser process.

This document does not apply:

- to laser processing machines which are remotely controlled by a manual controller (hand-operated controller), such as joy sticks, keyboard, etc., without touching a workpiece or a part mechanically connected with the laser processing head by using the hand(s) of the operator (user).
- to laser processing machines without a drive system which may not belong to machinery. And the laser processing apparatus without moving parts, which may not be considered as machinery in “Type C standard”.

NOTE “hand-operated laser processing machine” is synonymous with “hand-guided laser processing machine” in this document. Hand-operated laser processing machines often use manual force reduction means such as wheels, supports, etc., for manual positioning of the laser processing heads or the workpieces.

It is applicable to HLMs using laser radiation to process materials.

The purpose of this document is to draw attention to the hazards related to HLMs and to prevent personal injury. Depending on the application and the location/operating conditions of HLMs, a number of different significant hazards can arise. This document describes both the areas of hazards analysis and risk assessment as well as protective measures.

Requirements dealing with noise as a hazard are covered by ISO 11553-3.

This document deals with the specific hazards resulting from laser radiation arising in HLMs, when they are used as intended and under conditions of misuse which are reasonably foreseeable by the manufacturer.

This document does not apply to laser products or equipment manufactured solely or expressly for applications which are excluded from the scope of ISO 11553-1:2020. This document is not applicable for HLMs which have been manufactured before the date of publication of this standard.

HLMs include the following types:

- a) HLMs which are designed as all in-one laser assembly including the beam delivery/forming(shaping) system and optional features such as gas nozzles, material (e.g., powder, wire) feed system;

- b) HLMs where the relevant devices are connected by a beam guidance system (e.g., optical fibre) and power/control cables to an external laser assembly device and which includes only the beam delivery/forming(shaping) system and optional features such as gas nozzles, material (e.g., powder, wire) feed system;
- c) laser processing machines where the workpiece is manually moved under/relative to the laser beam (see informative [Annex A](#)).

The intended use of HLMs covers both:

- d) movement of the laser processing head (beam shaping device) by hand to move laser beam(s) over or relative to elements or workpieces to be processed, and
- e) movement of elements or workpieces by hand to be processed under/relatively to stationary laser beams as shielded.

Laser processing machines, where laser processing is performed with hand-held or hand-operated workpieces outside the fixed (neither hand-held nor hand-operated by the operator or user) laser processing machines are out of the scope of this document. Such a fixed laser processing machine is to be covered by ISO 11553-1.

HLMs are intended for the industrial use and can be only operated by trained and authorized personnel in indoor and/or outdoor environments/locations (e.g., cleaning of facades, statues).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3864 (all parts), *Graphical symbols — Safety colours and safety signs — Part 1: Design principles for safety signs and safety markings*

ISO 6385:2016, *Ergonomics principles in the design of work systems*

ISO 11145:2018, *Optics and photonics — Lasers and laser-related equipment — Vocabulary and symbols*

ISO/IEC 11553-1:2020, *Safety of machinery — Laser processing machines — Part 1: General safety requirements*

ISO/IEC 11553-3:2013, *Safety of machinery — Laser processing machines - Part 3: Noise reduction and noise measurement methods for laser processing machines and hand-held processing devices and associated auxiliary equipment (accuracy grade 2)*

ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 13732-1:2006, *Ergonomics of the thermal environment — Methods for the assessment of human responses to contact with surfaces — Part 1: Hot surfaces*

ISO 13849-1:2023, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

ISO 13850:2015, *Safety of machinery — Emergency stop function — Principles for design*

ISO 13857:2019, *Safety of machinery — Safety distances to prevent hazard zones being reached by upper and lower limbs*

ISO 14118:2017, *Safety of machinery — Prevention of unexpected start-up*

ISO 14119:2024, *Safety of machinery — Interlocking devices associated with guards — Principles for design and selection*

ISO 14120:2015, *Safety of machinery — Guards — General requirements for the design and construction of fixed and movable guards*

ISO 20607:2019, *Safety of machinery — Instruction handbook — General drafting principles*

ISO 26800:2011, *Ergonomics — General approach, principles and concepts*

IEC 60204-1:2016, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

IEC 60364 (series), *Low-voltage electrical installations*

IEC 60364-7-704:2017, *Low-voltage electrical installations - Part 7-704: Requirements for special installations or locations - Construction and demolition site installations*

IEC 60529:1989+AMD1:1999, *CSV, Degrees of protection provided by enclosures (IP Code)*

IEC 60825-1:2014, *Safety of laser products — Part 1: Equipment classification and requirements*

IEC 60825-4:2020, *Safety of laser products — Part 4: Laser guards*

IEC 61000-6-2:2016, *Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environments*

IEC 61000-6-3:2020, *Electromagnetic compatibility (EMC) - Part 6-3: Generic standards - Emission standard for equipment in residential environments*

IEC 61000-6-4:2018, *Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments*

IEC 61000-6-7:2014, *Electromagnetic compatibility (EMC) - Part 6-7: Generic standards - Immunity requirements for equipment intended to perform functions in a safety-related system (functional safety) in industrial locations*

IEC 62061:2021, *Safety of machinery — Functional safety of safety-related control systems*

EN 379:2003+A1:2009, *Personal eye-protection - Automatic welding filters*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in in ISO 11145, ISO 11553-1, ISO 12100, IEC 60825-1, IEC 60825-4 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

confined space

working area surrounded on all sides, or for the most part, by solid walls where they, on account of their confinement or containment of materials, preparation or equipment, augment or can augment particular hazards that considerably exceed the hazard potential normally prevailing at workplaces

3.2

disposal unit

equipment that captures and removes effluents and/or chemical pollutants (e.g., fumes, gases) and/or by products during laser material processing passing these on for filtration

EXAMPLE Capture devices, pipes, filtration systems, ventilation systems.

3.3

hazard area

danger zone

any space within and/or around machinery in which a person can be exposed to a hazard

Note 1 to entry: There may be several hazard areas (danger zones) on the same workplace depending on the types of hazards and relevant safety control measures against the hazards.

Note 2 to entry: For “laser hazard area”, see [3.6](#).

Note 3 to entry: Hazard area (danger zone) is not synonymous to “laser hazard area” and “nominal ocular hazard area (NOHA)”.

[SOURCE: ISO 12100:2010, 3.11, modified, Note 1 to entry, Note 2 to entry and Note 3 to entry added]

3.4

hand-held or hand operated laser processing machine

HLM

machine in which laser radiation is generated, together with essential additional facilities (e.g., cooling, power and gas supply) that are necessary to operate the laser, where the laser provides sufficient energy/power to melt, evaporate or cause a phase transition in a part of the workpiece and where the laser beam or workpiece to be processed is guided manually or hand-held during the laser process

Note 1 to entry: The HLM is synonymous with “laser unit”, see, [3.10](#).

Note 2 to entry: Generally, HLM can be divided in two representative types (Type 1 and Type 2) (see [Annex A](#)):

- Type 1: Machine equipped with a fixed laser assembly, where the workpiece is manually guided or manually positioned relative to the laser processing head (beam shaping device),
- Type 2: Machines equipped with a hand-held or hand-guided laser head (HLH) where the laser processing head is connected to a remotely located (i.e. external) laser device via a beam delivery system (e.g. fibre optical cable) or where the laser source is integral part of the hand-held device.

3.5

hand-held or hand-guided laser head (HLH)

component, which is hand-held or hand guided and contains the laser output/aperture

Note 1 to entry: The HLH can be equipped via an optical fibre with an external laser source or contain the laser system itself, which can be positioned or guided on the work piece surface or in a certain distance to the workpiece. Usually HLM comprises a housing/enclosure with optical elements for beam guidance and shaping, the operating elements, controls and indication elements (e.g., warning LED).

Note 2 to entry: The HLH can further comprise nozzle, feeder (gas/wire/powder), feed drive support, sensors/controls for contact or distance to workpiece, capturing device for fume and gas emissions.

Note 3 to entry: Depending on the equipment, the HLH can also be connected with feeding devices for wire, gas, cooling water, etc.

3.6

laser hazard area

area in which the laser radiation exposure of the eye and/or the skin exceeds the respective maximum permissible exposure values (MPEs), including the possibility of accidental misdirection of the laser beam

Note 1 to entry: To avoid ambiguities, information whether the laser hazard area is based on the eye or the skin MPEs should be added.

Note 2 to entry: See [3.11](#) for nominal ocular hazard area.

[SOURCE: IEC 60825-1:2014, 3.47, modified, Note 2 to entry added]

3.7

laser system

laser in combination with an appropriate laser energy source with or without additional incorporated components

[SOURCE: IEC 60825-1:2014, 3.51]

Note 1 to entry: See [Figure 1](#).

3.8

laser assembly

laser system together with specific, normally optical, mechanical and/or electrical system components for beam handling and forming

[SOURCE: ISO 11145:2018, 3.19.7, modified, “laser device” replaced by “laser system”, included “normally” and changed “beam guiding and beam shaping” to “beam handling and forming”]

Note 1 to entry: See [Figure 1](#).

3.9

laser device

laser where the radiation is generated, together with essential additional facilities (e.g., cooling, power and gas supply) that are necessary to operate the laser

[SOURCE: ISO 11145:2018, 3.19.6, modified]

Note 1 to entry: See [Figure 1](#).

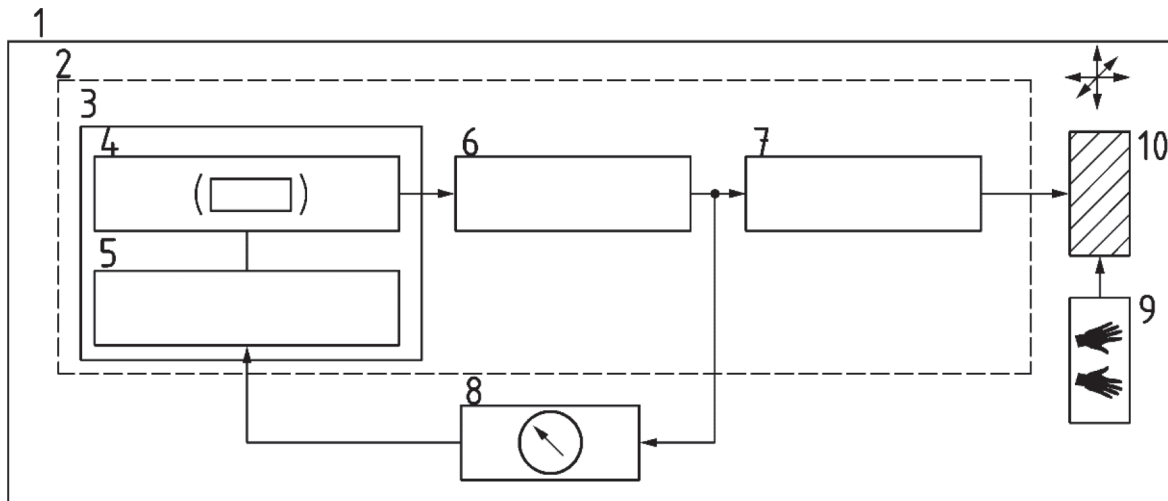
3.10

laser unit

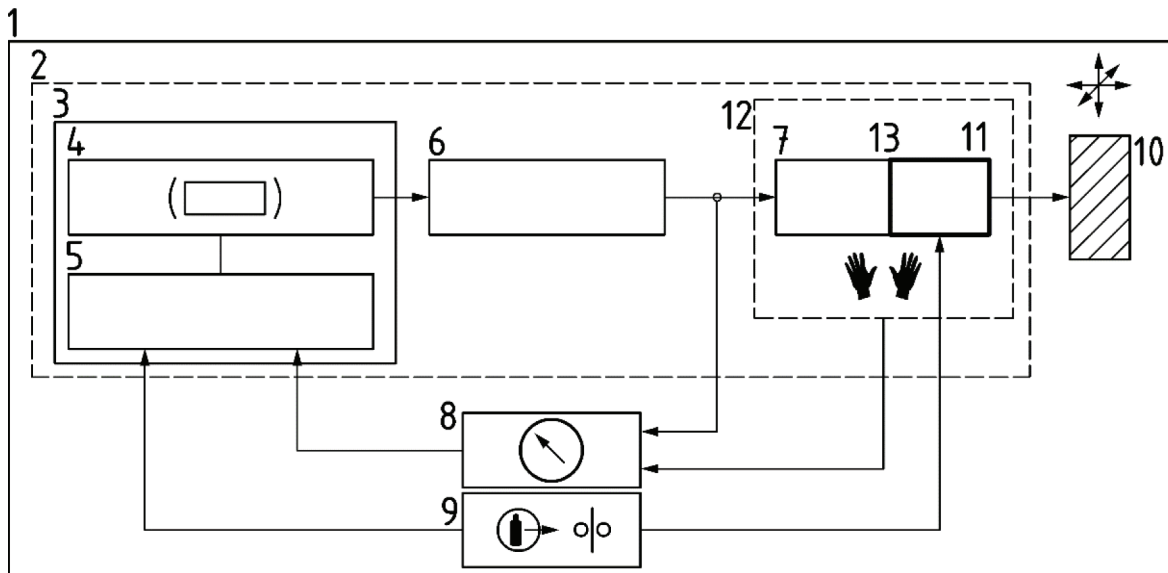
one or more laser assemblies together with handling units, measurement systems and control systems

[SOURCE: ISO 11145:2018, 3.19.8]

Note 1 to entry: See [Figure 1](#).



a) Hand-held, hand guided workpiece



b) Hand-held, hand guided laser head (HLH)

Key

1	laser unit (HLM)	8	measurement systems and control systems, including SRP/CS
2	laser assembly	9	hands of the operator
3	laser device	10	workpiece
4	laser	11	nozzle, feeder (gas/wire/powder), feed drive support, sensors/controls for contact or distance to workpiece
5	supply (power, cooling, gas)	12	hand-held, hand-guided laser head (HLH)
6	beam-guiding (mirrors, fibres, lenses)	13	HLH
7	beam-shaping device (telescope, focusing, wobbling)		

NOTE 1 This example is taken from materials processing.

NOTE 2 The safety equipment that is usually required is not included here.

NOTE 3 Indication hand-held, hand-guided 

Figure 1 — Illustration of the terms laser, laser device, laser assembly, laser unit, HLH and HLM

3.11

nominal ocular hazard area

NOHA

area within which the beam irradiance or radiant exposure exceeds the appropriate corneal maximum permissible exposure (MPE), including the possibility of accidental misdirection of the laser beam

Note 1 to entry: If the NOHA includes the possibility of viewing through optical aids, this is termed as the “extended NOHA (ENOH)”.

3.12

nominal ocular hazard distance

NOHD

distance from the output aperture beyond which the beam irradiance or radiant exposure remains below the appropriate corneal maximum permissible exposure (MPE)

Note 1 to entry: If the NOHD includes the possibility of viewing through optical aids, this is termed as the “extended NOHD (ENOH)”.

3.13**nominal skin hazard area****NSHA**

area within which the beam irradiance or radiant exposure exceeds the appropriate maximum permissible exposure (MPE) for the skin, including the possibility of accidental misdirection of the laser beam

3.14**nominal skin hazard distance****NSHD**

distance from the output aperture beyond which the beam irradiance or radiant exposure remains below the appropriate maximum permissible exposure (MPE) for the skin

3.15**nominal hazard zone****NHZ**

space within which the level of the direct, reflected, or scattered radiation may exceed the applicable MPE and where exposure levels beyond the boundary of the NHZ are below the applicable MPE

[SOURCE: ANSI Z136.1:2014]

3.16**supply unit**

all devices that provide the process energies and operating material supply, direct to the point of action and are absolutely necessary for the operation of HLM

EXAMPLE Cooling system, power and gas supply.

4 Risk assessment**4.1 General**

The risk assessment comprises according to ISO 12100:2010:

- the determination of limits of HLM (see [4.2](#));
- the identification of hazards; (see [4.3](#) and [4.6](#))
- the risk estimation (see [4.4](#)); and
- the risk evaluation (see [4.5](#)).

The risk assessment is followed, if necessary, by risk reduction. This is an iterative process that results in an acceptable residual risk for the use of the HLM.

A risk assessment shall be done by manufacturer that thoroughly analyses HLM designs or manufacturing processes, early in the HLM development process, with the objective of finding and correcting potential design or manufacturing deficiency before the HLM gets constructed.

A risk assessment shall be performed:

- a) for all phases “life” (as applicable) of HLMs including all subcomponents; for examples see ISO 12100:2010;
- b) after each substantial modification of the HLMs by the person or organization responsible for the modification;
- c) for each use or operation, not included by the intended use but being reasonably foreseeable.

The risk assessment enables the systematic analysis and evaluation of the risks associated with HLM over their entire life cycle.

4.1.1 Types of HLM and special hazards

Generally, HLM can be divided in two representative types (see [Annex A](#)):

1) Type 1 HLMs (workpiece is guided manually under the laser beam)

Machine equipped with a fixed laser assembly, where the workpiece is manually guided or manually positioned relative to the laser processing head (beam shaping device);

2) Type 2 HLMs (HLH is guided manually)

Machines equipped with a hand-held or hand-guided laser head (HLH) where the laser processing head is connected to a remotely located (i.e. external) laser device via a beam delivery system (e.g. fibre optic cable) or where the laser source is an integral part of the hand-held device.

4.1.2 Special hazards with regard to types of HLM

Hazards of HLMs resulting from laser radiation are beyond the hazards mentioned in ISO 11553-1:2020 for ordinary laser machines because:

1) Type 1 HLMs

Machines equipped with a fixed laser assembly, where the workpiece is manually guided can be distinguished in open systems and shielded systems, where the hands are inserted through a hole of the laser radiation protective enclosure. (See also [Annex A](#), [figure A.3](#) and [A.4](#))

- a) the hands of the operator are near to the processing zone and therefore can be exposed,
 - by unintended exposure by the direct laser beam;
 - by specular reflected laser radiation;
 - by scattered laser radiation.
- b) if there are no laser filters in the oculars, the eyes can be endangered (if no laser goggles are worn),
- c) if the system is open, the eyes of the operator can be endangered (if no filter glass/shielding or no laser goggles are worn),
- d) open HLM systems can also endanger objects or other people in the vicinity of the workplace,
- e) especially for welding applications the fingertips (finger/hand) are exposed long term to UV-radiation, which can cause severe health risks.

2) Type 2 HLMs

- a) can easily be moved by workers to other workplaces (are portable);
- b) can be used in indoor and also outdoor applications;
- c) can be used on building sites, even on scaffolding at heights;
- d) can be easily changed for different applications such as welding, cutting and cleaning by changing the nozzle, the laser optics in the HLH or the feeder for additional material (wire feeder);
- e) allow the propagation of laser radiation in a very large spatial area or all directions respectively, which causes large NOHA (at least in foreseeable fault conditions);
- f) the hand-held laser processing head comprises beam guiding and beam shaping elements, which can (at least in foreseeable fault conditions) be misalignment, so that the housing of the HLH can be destroyed and laser radiation is emitted;
- g) the HLH can be connected to an external laser device via a flexible fibre optic cable, in foreseeable fault conditions laser radiation can be emitted from the fibre or fibre connectors;

- h) the operator is in close proximity to the process zone and therefore to the laser beam, which can cause high irradiance on the eyes and skin;
- i) the operator is in close proximity to the process zone and is affected by secondary radiation (UV-radiation, heat radiation) and generated fumes and gases;
- j) the third parties (persons) can easily get access to the laser area and be exposed by direct or specular reflected/scattered radiation and secondary radiation and fumes and gases if the HLM is not used in a proper shielded laser area.

4.2 Determination of limits of HLM

The definition of the limits of the HLM should include the following:

- 1) Application limits: It shall be determined if the HLM is intended to direct laser radiation towards the eyes, face and/or skin or not.
 - functional description, intended use, foreseeable faults and misuse;
 - description of the different types of application;
 - analysis of process sequences and manual operation/intervention;
 - description of interfaces;
 - power supply connections;
 - required and/or expected operator skills.
- 2) Limits related to machine components
 - required space/room for certain/intended application;
 - requirements for combining HLM components;
 - interfaces of HLM components including specifications.
- 3) Time limits
 - intended service life of the entire HLM and of each component;
 - process flow diagrams;
 - recommended maintenance intervals.
- 4) Other limits
 - suitability/compatibility for use under special environmental conditions (e.g., temperature, humidity, wind pressure);
 - properties of the materials intended to be processed;
 - hazards for the environment/third parties/bystanders.
- 5) Life phases and related tasks
 - assembly and installation
 - commissioning
 - use
 - maintenance/Servicing
 - decommissioning

— disposal

4.3 Hazards identification

The design of the HLM, the application and the location in which the HLM is operated decide the relevant hazards. It is necessary to identify the hazards associated with HLM and its application and to assess the risks in order to be able to identify appropriate protective measures and thus reduce the risk appropriately.

The manufacturer/designer shall carry out a hazard analysis which shall include all operating conditions:

- 1) Mounting, demounting and change of components of the HLM;
- 2) normal intended use and under condition of misuse which are reasonably foreseeable by the manufacturer. This includes all parameter-settings/ranges for the relevant HLM;
- 3) human interaction during the whole life cycle of HLM.

The manufacturer/designer shall carry out a hazard analysis which shall consider:

- 1) all components of the HLM (e.g., laser device, laser fibre, hand-held laser head, safety control) and their interaction;
- 2) all working sites, the HLM can be operated in (intended by the manufacturer).

A Significant hazard is a hazard which requires specific action by the designer to eliminate or reduce the risk according to the risk assessment. The list of significant hazards related to HLM given in [table B.1](#) in [Annex B](#) is a result of the identification of hazards and the risk assessment carried out as described in ISO 12100:2020.

NOTE A comparative list of the hazards being dealt with in this document is given in [Annex B](#). A list of other hazards, not being dealt in this document can be found in [Annex C](#).

Further hazards (e.g., confined spaces, noses, dazzling of persons) with HLM can be caused by special applications or conditions and by the interaction of the HLM with other machines and devices. These hazards shall be dealt with on an individual basis using hazards analysis and risk assessment for the specific application or conditions.

In the following, the significant hazards listed in [table B.1](#) ([Annex B](#)) are explained, hazards related to laser radiation are comprehensively conveyed.

4.4 Risk estimation

Estimate the risk for each identified hazard and hazardous situation with regard to the respective HLM and its applications. Estimate the severity and likelihood of occurrence of hazards.

4.5 Risk evaluation

Evaluate all the risks, which have to be considered with regard to the respective HLM and its applications and take the decision about the need for risk reduction.

NOTE Decision: "Risk adequately reduced?" is answered with "yes" or "no". If the decision is no, see chapter 5.

4.6 Hazards (significant)

Significant hazard is a hazard which requires specific action by the designer to eliminate or reduce the risk according to the risk assessment. The list of significant hazards related to HLM given in [table B.1](#) in [Annex B](#) is a result of the identification of hazards and the risk assessment carried out as described in ISO 12100:2020.

NOTE A comparative list of the hazards being dealt with in this document is given in [Annex B](#). A list of other hazards, not being dealt in this document can be found in [Annex C](#).

Further hazards (e.g., confined spaces, noises, dazzling of persons) with HLM can be caused by special applications or conditions and by the interaction of the HLM with other machines and devices. These hazards shall be dealt with on an individual basis using hazards analysis and risk assessment for the specific application or conditions.

In the following, the significant hazards listed in [table B.1 \(Annex B\)](#) are explained, hazards related to laser radiation are comprehensively conveyed.

4.6.1 Mechanical Hazards

Mechanical hazards can arise by breaking-up of components of the HLM during preparation and/or operation of the HLM.

Primary hazards arise if the mechanical hazard directly affects the operator or bystanders and are as follows but not limited to:

- contusion of finger, hand and/or foot, when parts of the HLM fall out of the hand contusion of finger/hand when positioning/holding the workpiece;
- retracting or catching by moving parts, e.g., the wire feeder, and pushing and stabbing by the wire, coming out of the nozzle;

Secondary hazards can arise if the mechanical hazard affects the functioning of components of the HLM, which causes malfunction and leads to further hazards e.g. emission of laser radiation, touching live parts e.g. when the hose package breaks and causes a laser fibre breakage and/or breakage of power supply.

Mechanical hazards can also arise, if components of the HLM have sharp edges or the workpiece (e.g., metal sheets) has sharp edges, since this can cause cutting injuries of the finger/hand of the operator.

4.6.2 Electrical Hazards

Electrical hazards can arise when live parts are touched. This is related to all live parts if the machine housing/insulation or cable are not properly designed or cable insulation is damaged.

If HLM are designed for outdoor applications, electrical hazards can arise by environmental conditions such as rain, humidity, etc.. These affects the isolation of the components and can cause Voltage on touchable housing parts).

4.6.3 Thermal Hazards

The laser beam material interaction can cause a significant temperature rise of the workpiece or an object which is irradiated by the laser beam.

Depending on the properties of the workpiece (e.g., flammable) or the materials in/near the process zone, this can lead to fire hazards. Process-gases, such as oxygen can support/promote the fire hazard.

Depending on the application and the workplace the HLM is used, the high power laser can also cause explosions, when the concentration of gases or dust in the workplace air is critical (lower explosion limit < C < upper explosion limit)

The high temperature of the workpiece in/after laser processing can also cause burns of unprotected body parts, mainly fingers, hand, in cases if the workpiece has not yet cooled down and is already touched by the operator.

Hot melt splashes can leave the process zone and endanger unprotected body parts (finger/hand/forearm/face) in the immediate proximity of the laser material process.

High temperatures of the workpiece can generate heat radiation. This radiation can affect unprotected body parts (finger/hand/forearm/face) in the immediate proximity of the laser material process).

4.6.4 Hazards by incoherent radiation

The laser beam material interaction can cause a plasma in the interaction zone (e.g. during welding). Due to physical effects, secondary radiation can be generated and can expose the operator in the immediate vicinity to the process or even bystanders and effects are accumulated.

The spectrum of the secondary radiation covers wavelengths from the UV over visible to the NIR. The harmful effects depend on the wavelength spectrum:

1) UV-radiation

- eye: corneal inflammation, cataract of the lens, photokeratitis, conjunctivitis;
- skin: sunburn, accelerated aging, skin cancer, the effects are accumulated with the duration of the exposure;

2) Visible radiation

- eye: dazzling, flashing, photo retinitis;
- skin: darkening of pigments, burns;

3) NIR radiation

- eye: flashing, photoretinitis;
- skin: burns.

Depending on the HLM application and the power determining parameters of the process, local or national threshold limit values for incoherent radiation can be exceeded.

Information on the biophysical effects on the skin and the eye are given in IEC 60825-1 in [Annex D](#).

Information on how to assess hazards and reduce the risks arising from radiation emitted by machinery are given in EN 12198-1.

4.6.5 Hazards by laser radiation

4.6.5.1 General

Laser radiation is the physical type of energy transfer in which laser material processing is carried out with a HLM.

To process materials, the irradiance or the radiant exposure applied needs to reach such orders of magnitude, that a number of hazards can arise:

- primary hazards by the laser beam, include the direct laser beam, specular reflected laser beam and/or scattered laser beam;
- secondary hazards by interaction between laser beam and materials, include incoherent radiation, thermal hazards up to fire and explosion hazards.

Hazards that can arise by laser radiation can cause (but not limited to) the following (as function of the irradiance/radiant exposure):

- eyes: complete blindness, damage or partial damage of sight;
- skin: severe/deep burns, up to third degree burns, predominantly finger, hands, arms, but also legs, body, face, beard fires, etc.

The hazards related to laser radiation depend on the characteristics of the radiation. To analyse the hazards the knowledge of the power and wavelength determining parameters is essential.

For a hazard analysis and a risk assessment, the laser radiation emitted from a laser processing machine is characterized by including but not limited to the following:

- wavelength(s);
- laser output power or energy: CW power, or average power, peak power, and pulse energy;
- operating mode (CW, pulsed, Q-switch);
- beam profile (mode, energy distribution);
- beam quality codes: BPP, M^2 , K;
- polarization;
- foreseeable exposure limit (FEL) at the inner side of an enclosure and a laser guard;
- irradiance or radiant exposure at workplace or specified distance from HLM to the workplace;
- maximum foreseeable exposure duration.

To carry out a hazard analysis and identification with regard to hazards by laser radiation, this requires the following, however is not limited to:

- the hazard analysis shall include all applications, processes and parameter settings, that are possible with the respective HLM for the intended use and for foreseeable misuse;
- all components of a HLM shall be analysed as possible sources of laser radiation emission for the normal use and for foreseeable fault conditions (e.g., damage of fibre, optics in the beam delivery, damage of the housing of the HLH, malfunctions of the control/unexpected start-up);
- the hazard analysis shall consider all possible directions of movement of the HLH and the laser beam propagation associated with including misdirection.

4.6.5.2 Estimations of foreseeable exposure limit (FEL)

The optical properties (e.g., surface roughness and reflectivity) of the material exposed to the laser beam decisively determine the kind of reflection (direct/specular reflection or scattered reflection) and thus the risk level.

With regard to the workplace, and material processed, hazards by the direct laser beam, the specular reflected beam and scattered beam radiation shall be analysed and assessed to obtain estimations of the maximum foreseeable irradiance/radiant exposure or the foreseeable exposure limit (FEL) respectively:

- in typical distances where the operator works;
- in typical distances where the operator works with the HLH;
- and also at the laser guard for laser processing and resulting irradiance or the radiant exposure at a workplace close to or at a certain distance to the HLMs;
- in typical distances the laser hazard area is shielded by screens/walls or the NSHD and NOHD.

NOTE The definition of the foreseeable exposure limit (FEL) is given in IEC 60825-4. The definition can be applied also for other laser exposed objects than a laser guard.

Possible emission sources of unintended direct laser beams in foreseeable fault conditions, the laser radiation cannot be sufficiently coupled into the workpiece and can be unexpectedly highly reflected or misdirected and therefore propagate over significantly larger distances or areas.

Due to the large NOHA, especially in free workspace and surroundings applications without shielding the laser workplace with appropriate laser guards, third parties can be endangered by the laser radiation.

4.6.5.3 Possible emission sources of direct laser beam or due to specular reflection and divergent radiation due to scattered reflection

In foreseeable fault conditions in relevant devices, or beam delivery system including beam-guiding device and beam-shaping device (laser processing head), can cause an unintended emission of laser radiation.

4.6.5.4 Aperture

Possible emission sources of direct laser beam to be used or misdirected in normal operation for laser processing or to be used or misdirected during maintenance or servicing are including but not limited to the following:

- a) aperture of an embedded laser source (embedded devices);
- b) aperture of a beam guiding device (fibre optic cable, etc.) connected to the embedded laser source (embedded devices);
- c) aperture of laser processing head (beam-shaping device) for emitting laser beam to the workpiece;
- d) aperture of scanning optics for beam delivery to workpieces;
- e) auxiliary apertures of enclosed HLM for maintenance and servicing;

NOTE Possible beam propagation scenarios for the direct beam decisively depend on the application of the HLM and the laser beam guidance or deflection respectively.

4.6.5.5 Inadequate design or malfunction

Inadequate design or malfunction of laser component(s), equipment of HLM, or laser radiation protective measures, can also be the reason of laser radiation hazards due to emission of unintended laser radiation or a misguided laser beam, which are including but not limited to the following:

- a) damage of fibre optical cable;
- b) damage or malfunction of fibre connectors (e.g. not controlled by safety control);
- c) damage of passive optical elements (e.g. mirrors, lenses);
- d) misalignment of the beam path (due to inadequate optical elements, incorrect positioning, etc.);
- e) not properly working active beam guiding and shaping elements (e.g. optical modulators, zoom lenses, laser scanners);
- f) not proper designed HLH housing (the passive laser resistance or protective exposure limit (PEL) of the HLH housing is not sufficient to face the FEL);
- g) not properly working handling system (HLH) or drive supported positioning of the laser processing head;
- h) no or malfunction of positioning control between HLH aperture (nozzle) and workpiece (no contact) or distance control or malfunction or easy manipulation of these;
- i) if elements of the HLH (e.g., optical elements, nozzles) can be changed, to enable different applications (e.g., welding, cutting, cleaning), confusion and malfunction of elements can lead to laser hazards by unintended emission of laser radiation;
- j) elements (with (a) reflective surface(s)) inside the HLM including its beam delivery system;
- k) the workpiece holder (if workpiece is missing or moving);
- l) elements in the processing zone and at the HLM work space;
- m) elements inside the shielding (laser guards) for the workplace with the HLM (e.g. workpiece handling system, fume suction pipes, parts of laser guards); or

n) the workpiece during processing by the HLM.

NOTE 1 Information on the assessment of Foreseeable Exposure Limits (FEL) and fault conditions of laser guards is given in IEC 60825-4:2006, Annex B. Also, the definition of the Protective exposure limit (PEL) is given.

NOTE 2 The generation of scattered radiation is determined significantly by the surface (optical properties) of the material to be processed or the coupling efficiency in this material respectively; also, the geometry of objects in the laser process zone affects the distribution of the scattered radiation.

4.6.5.6 Laser hazards regarding application

Hazards by laser radiation can result from special situations for the propagation of laser radiation depending on the application of the HLM. In the following, laser hazards are given for the most common applications:

1. Cutting:

direct beam: the beam can propagate through cutting kerf or (at the end of the sheet/cut) propagate past the work piece, even when the HLM is equipped with a touch control. This can lead to unintended exposure of legs (parts of the legs) or feet of the operator

Reflected beam: if the coupling efficiency of the laser beam is poor, radiation shares can be reflected (directly or scattered).

2. Welding:

direct beam: the direct beam can propagate through gaps (e.g. butt welding) or can be directly reflected (e.g. L-seam), if the coupling efficiency of the laser beam is poor (hazards similar to cutting).

3. Cleaning:

direct beam: the beam can propagate past the work piece (especially near edges); if the HLM is freely hand held, in an accidental situation, the beam can propagate everywhere in unintended directions. This can lead to unintended exposure of the operator or bystanders.

4. Marking:

direct beam: the beam can propagate past the work piece (especially near edges); if the HLM is freely hand held, in an accidental situation, the beam can propagate everywhere in unintended directions.

4.6.6 Hazards associated with materials and substances

4.6.6.1 Emission of hazardous materials and substances

Due to the laser material interaction, hazardous or objectionable levels of gases, vapours, fumes or dust, can be generated and pollute the HLM workplace. The levels of exposure to vapours, fume or dust can exceed the occupational exposure limits and occupational exposure standards for local control of substances hazardous to health.

- Chemical Hazards: These encompass a wide range of substances, including fluids, gases, mists, fumes, and dusts, which can pose health risks upon inhalation. Chemical hazards can cause respiratory irritation, lung damage, neurological effects, or other adverse health effects depending on the substance and exposure levels.
- Physical Hazards: Some substances may not necessarily be toxic but can still pose hazards due to their physical properties. For instance, fine dust particles or mists can obstruct airways or cause respiratory distress through mechanical means rather than chemical toxicity.
- Biological Hazards: In some cases, inhalation of biological agents such as bacteria, viruses, or fungi can also pose health risks in the workplace, leading to respiratory infections or other illnesses.

NOTE 1 Occupational Exposure Limits (OELs): These are typically established for various hazardous substances to provide guidance on safe levels of exposure in the workplace. OELs are set by national regulators.

NOTE 2 Examples of by-products of material processing can be found in Annex A of ISO/IEC 11553-1:2020.

4.6.6.2 Hazards due to contact with inhalation of harmful fluids, gases, mists, fumes and dust

Contact with inhalation of harmful fluids, gases, mists, fumes, and dust can pose significant health hazards to individuals exposed to them. These hazards can vary depending on the specific substances involved and the duration and intensity of exposure. Potential health hazards associated with inhalation exposure to these substances are given in the following listing:

- Respiratory Irritation: Many harmful fluids, gases, mists, fumes, and dusts can irritate the respiratory tract, leading to symptoms such as coughing, wheezing, chest tightness, and shortness of breath. Prolonged exposure may exacerbate pre-existing respiratory conditions such as asthma or chronic bronchitis.
- Chemical Toxicity: Some substances present in fluids, gases, mists, fumes, and dusts can be toxic to the respiratory system or other organs. Inhalation of these chemicals may cause acute or chronic health effects, including lung damage, organ toxicity, neurological effects, or even systemic poisoning.
- Allergic Reactions: Certain substances can act as respiratory sensitizers, triggering allergic reactions in susceptible individuals upon inhalation exposure. Symptoms can include asthma attacks, allergic rhinitis (hay fever), or skin rashes.
- Carcinogenicity: Exposure to certain chemicals found in fluids, gases, mists, fumes, and dusts can increase the risk of developing cancer over time. Carcinogens such as asbestos fibres, benzene, formaldehyde, and certain metal fumes are known to pose significant health risks through inhalation exposure.
- Asphyxiation: Inhalation of gases that displace oxygen in the air that are used in certain laser processes can lead to asphyxiation if concentrations become sufficiently high. Examples include nitrogen, carbon dioxide, and certain volatile organic compounds (VOCs) with low oxygen displacement potential.
- Pulmonary Fibrosis: Chronic exposure to certain particulate matter, such as silica dust or asbestos fibres, can cause pulmonary fibrosis—a progressive scarring of lung tissue that impairs breathing and can lead to respiratory failure.
- Infectious Agents: Inhalation exposure to biological agents such as bacteria, viruses, or fungi can lead to respiratory infections or other communicable diseases, particularly in healthcare or laboratory settings.
- Systemic Effects: Some substances can be absorbed into the bloodstream after inhalation exposure and can cause systemic effects beyond the respiratory system. For example, certain heavy metals (e.g., lead, mercury) or volatile organic compounds (e.g., benzene) can affect the nervous system, kidneys, liver, or other organs.

4.6.6.3 Fire

Fire hazards associated with laser processing can arise from various factors inherent to the operation of laser systems. In the following some common fire hazards are listed:

- Material Ignition: Laser processing involves directing a highly concentrated beam of light onto a workpiece. If the material being processed is flammable or combustible, it can ignite when exposed to the laser beam. This ignition can occur due to the heat generated by the laser or the interaction of the laser with certain materials.
- Ignition of Process Byproducts: Some laser processing operations produce byproducts such as smoke, vapor, or particulate matter, which can be flammable. If not properly ventilated or contained, these byproducts can accumulate in the processing area and create a fire hazard.
- Reflective Surfaces: Laser beams can be reflected off surfaces within the processing area, including the workpiece itself. If these surfaces are reflective and direct the beam towards flammable materials or combustible surfaces, they can cause ignition and lead to a fire.

- Overheating: Laser systems generate heat during operation, particularly in high-power applications. If the equipment is not properly cooled or if cooling systems fail, components within the system may overheat, increasing the risk of fire.

4.6.6.4 Explosion

While laser processing itself typically does not pose a direct explosion hazard, there are certain conditions and factors associated with laser systems that could contribute to explosion risks. In the following list are some potential explosion hazards associated with laser processing given:

- Materials Processing: Laser processing often involves cutting, welding, engraving, or drilling materials such as metals, plastics, or composites. Some materials, especially metals, can produce sparks or molten fragments during processing, which could potentially ignite flammable or combustible materials nearby.
- Flammable Materials: If the materials being processed are flammable or combustible, there is a risk of ignition and subsequent explosion if exposed to the laser beam or other sources of heat generated during processing.
- Dust and Vapor: Laser processing can produce dust, smoke, vapor, or aerosols as byproducts. If these byproducts are combustible or explosive in nature, they could create an explosion hazard if allowed to accumulate in sufficient concentrations.
- Process assist gases: Certain types of process assist gases, such as oxygen, if not properly controlled, can potentially leak or if excessively used can generate an atmospheric environment leading to an explosion risk, in the vicinity of the laser system.
- High Energy Density: Laser beams concentrate high amounts of energy into a small spot size, resulting in rapid heating of materials. If this energy is absorbed by volatile or reactive materials, it could lead to rapid chemical reactions or thermal decomposition, potentially resulting in explosions.

4.6.7 Hazards by disregarding ergonomic principles

4.6.7.1 General

Hand-held laser processing equipment presents several ergonomic hazards, which can lead to discomfort, injury, or long-term health issues for operators. Ergonomic hazards associated with hand-held laser processing equipment include:

- Repetitive Motion Injuries: Operators may need to hold the laser processing equipment in specific positions for extended periods, leading to repetitive strain injuries (RSIs) such as carpal tunnel syndrome or tendonitis.
- Awkward Postures: Holding the hand-held laser processing equipment in awkward positions or at arm's length can cause strain on muscles and joints, leading to discomfort or musculoskeletal disorders (MSDs).
- Heavy or Imbalanced Equipment: Hand-held laser processing equipment may be heavy or have uneven weight distribution, increasing the risk of muscle fatigue, strain, or dropping the equipment accidentally.
- Vibration Exposure: Vibrations generated by hand-held laser processing equipment can transmit to the operator's hands and arms, leading to discomfort, numbness, or circulation issues over time.
- High Force Requirements: Some hand-held laser processing equipment may require significant force to operate or manoeuvre, increasing the risk of muscle strain or overexertion injuries.
- Limited Visibility and Access: Operators may need to work in confined spaces or areas with limited visibility while using hand-held laser processing equipment, increasing the risk of awkward postures or accidental contact with hazardous surfaces.
- Heat and Radiation Exposure: Hand-held laser processing equipment can generate heat and laser radiation, which can cause discomfort or burns if operators come into contact with hot surfaces or direct laser beams.

4.6.7.2 Inadequate considerations of anatomy

Inadequate consideration of anatomy when designing hand-held laser equipment can lead to various ergonomic issues and potential health risks for operators. Here are some specific concerns related to anatomy that should be addressed in the design process:

- Hand Size and Shape: Operators have different hand sizes and shapes, and the equipment should accommodate this variability to ensure a comfortable and secure grip. If the handle is too small or too large, it can lead to discomfort, fatigue, or difficulty maintaining control during operation.
- Thumb and Finger Placement: The design should consider the natural positions of the thumb and fingers during operation to minimize strain and fatigue. Inadequate space or awkward positioning of controls can lead to thumb or finger discomfort and reduced dexterity.
- Wrist Alignment: The handle design should promote neutral wrist alignment to reduce the risk of repetitive strain injuries (RSIs) such as carpal tunnel syndrome. Excessive bending or twisting of the wrist can increase pressure on the median nerve and lead to pain or numbness.
- Pressure Points: Pressure points on the hand caused by poorly designed handles or grips can lead to discomfort, blisters, or skin irritation. Padding or contouring should be used to distribute pressure evenly and minimize the risk of pressure-related injuries.
- Muscle Fatigue and Overexertion: Prolonged use of hand-held laser equipment can lead to muscle fatigue and overexertion if the design requires excessive force or awkward postures. The design should minimize the effort required to hold and operate the equipment to reduce the risk of fatigue-related injuries.
- Range of Motion: Operators should be able to maintain a comfortable range of motion while using the equipment, without excessive reaching or stretching. Awkward postures can strain muscles and joints, leading to discomfort or musculoskeletal disorders (MSDs).
- Visibility and Access: The design should ensure unobstructed visibility of the laser processing area and easy access to controls, without requiring operators to adopt awkward or uncomfortable positions. Poor visibility can lead to eye strain, while restricted access can hinder precision and efficiency during operation.

4.6.8 Hazards due to malfunction of the control system

NOTE The control system is the key system for machinery, thousands of elements or components can cause malfunction of HLM. Hazards can arise when starting, stopping or changing operation mode, etc..

4.6.8.1 Malfunction of control system/control circuits

Malfunctions normally mean unexpected operation, such as unexpected start-up, unexpected stop, unexpected over speeding/spinning. The following lists some of the typical malfunctions of the control system (but not limited to the following):

- breaking-up during operation;
- uncontrolled movements;
- unexpected start-up;
- unexpected stop;
- unexpected over speeding/spinning;
- stop control cannot cut off the energy supply;
- automatic or manual stopping of the moving parts is impeded;
- drift of a part away from its stopping position;
- failure of restoration of energy supply after an interruption;