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Background

Personal protective equipment (PPE) for hand-held laser welding

With the advancement of laser technology, especially fiber lasers, laser material processing is becoming increasingly important. Hand-held laser welding in particular has experienced an unprecedented upswing in the recent past due to constantly increasing laser power combined with ever more compact designs. Precision, freedom from wear, speed, mobility and ease of operation are the key reasons for this. Due to the largely free movement of the end piece held in the hand, the correct use of suitable personal protective equipment (PPE) is of particular importance, irrespective of all technical protective and safety measures.

Standards and protection requirements

As with all laser applications, the physical properties of laser radiation, such as high power density and good focusability, pose a great danger to the user. Naturally, the eyes and skin are particularly at risk. Based on the EN 60825-1 standard, lasers are divided into so-called laser classes (1=low to 4=high risk) to classify the hazard potential, from which certain organizational measures and protection requirements are directly derived.

In Germany, lasers and laser products for private use may only be marketed in accordance with the Product Safety Act

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With the advancement of laser technology, especially fiber lasers, laser material processing is becoming increasingly important. Hand-held laser welding in particular has experienced an unprecedented upswing in the recent past due to constantly increasing laser power combined with ever more compact designs. Precision, durability, speed, mobility and ease of operation are the key reasons for this and with free movement of the hand piece, the correct use of suitable personal protective equipment (PPE) is of particular importance, irrespective of all technical protective and safety measures.

Standards and protection requirements

As with all laser applications, the physical properties of laser radiation, such as high power density and the ability to be focussed to an extremely small spot, pose a great danger to the user. Naturally, the eyes and skin are particularly at risk. Based on the EN 60825-1 standard, lasers are divided into so-called laser classes (1=low to 4=high risk) to classify the hazard potential, from which certain organizational measures and protection requirements are directly derived.

In Germany, lasers and laser products for private use may only be marketed in accordance with the Product Safety Act (ProdSG), lasers and laser

for private use may only be placed on the market if they comply with laser classes 1, 1M, 2 or 2M. Furthermore, according to the Occupational Health and Safety Ordinance on Artificial Optical Radiation (OStrV), competent persons must be appointed as laser safety officers when operating laser equipment of class 3R and higher. The laser devices used for hand-held laser welding even fall into laser class 4 and are therefore covered by these regulations.

The standards commonly referred to as laser safety standards EN 207, EN 12254 and EN 60825-4, on the other hand, deal with the laser resistance of certain protective products such as laser safety goggles (EN 207), temporary laser safety devices such as curtains (EN 12254) or machine enclosures and windows (EN 60825-4). The laser resistance (EN 207 and EN 12254), CE-certified by an independent testing institute in the form of protection levels (LB or AB values), helps the user to select the right protective product for the laser. EN 60825-4 offers greater scope for certification, as it determines the protective limit irradiation for a specific combination of laser power, spot size and time. However, this value can vary greatly for a different combination.

In general, the person operating the laser equipment is responsible for complying with the protective measures and, if necessary, appointing a laser safety officer. However, the manufacturer is responsible for the classification and marking of laser devices.

The most common applications of HLG are laser welding and laser cleaning. This means that the standards dealing with eye and face protection during welding and similar processes are also relevant. The two standards that deal with this protection, but have different focuses and areas of application, are EN 169 and ISO 16321-2.

EN 169 specifies the requirements for welding filters, in particular with regard to their optical properties, such as light transmission and protection against optical radiation, and is used specifically for the evaluation and classification of welding filters to ensure that they provide adequate protection against harmful radiation.

ISO 16321-2 is more comprehensive and covers additional requirements for eye and face protection devices used in welding and related processes. It is used when a more detailed evaluation of welding protective equipment is required that goes beyond the optical properties and also takes into account mechanical and material requirements. It includes aspects such as material requirements, mechanical strength and the design of the protective devices and ensures that the entire protective device meets the diverse requirements of welding.

ISO 16321-2:2021-03 specifies the following main requirements

- Protective devices must be made of materials that are resistant to optical radiation, flying particles and hot solids.
- Protective devices must meet certain optical and mechanical requirements to ensure adequate protection.
- The protective devices must have a high optical quality to avoid distortion and blurring.
- The devices must effectively block harmful ultraviolet radiation.
- The requirements for protection against infrared radiation must be met.
- Filters must meet specific light transmission levels to protect the eyes from intense light radiation.
- Automatic welding filters must meet special requirements to ensure that they adapt quickly and reliably to changing light conditions
- The protective devices must provide a sufficient field of vision to ensure the safety and efficiency of the user.
- Welding filters and other welding protection devices must be specially labeled to ensure that they can be correctly identified and used.

Health risks with hand-held laser systems

Hand-held laser devices (HLG) enable a new level of flexibility and quality in material processing. At the same time, however, the probability of unintentional, direct or indirect irradiation of the eyes, unprotected skin or the body increases, as does the risk of other secondary health hazards.

HLGs are typically used to weld or clean metal sheets. Depending on the material (aluminum, copper, steel), the surface quality (smooth, rough, reflective) and the process parameters (speed, power), only a certain percentage of the laser power is available for the actual process during welding, for example, because a significant proportion is lost through reflection. Depending on the parameters mentioned, the initial reflection levels can be 65% for steel, up to 90% for aluminum and 88% to 93% for copper (Q1). This part of the laser radiation is reflected diffusely in the case of rough surfaces, but also directionally in the case of reflective or polished surfaces.

The laser beam is also predominantly reflected directionally by the cold workpiece, which can lead to a high optical power density in the reflection, particularly during the start phase of the welding process. During the process, the risk shifts towards diffuse reflection due to absorption and the associated heating of the workpiece.

Diffuse or directional reflected radiation is therefore unavoidable. The greatest possible care and a large distance between the face and the welding spot are therefore particularly important. Another hazard for unprotected areas of skin (face, hand) is UV or blue light, which is emitted in spherical form directly from the plasma generated by the laser.

The laser radiation absorbed in the workpiece causes the material to heat up. Depending on the specific welding situation, it may become too hot to be held with bare hands. It is therefore always advisable to secure the workpieces accordingly, which is also preferable from a quality point of view. In addition, the above-mentioned hazards from direct or diffusely reflected laser radiation, emissions from the plasma and any flying sparks also apply to the unprotected skin of the hand.

A further, secondary hazard concerns the respiratory system of the person welding. The microparticles produced by the laser welding process pose a considerable risk to the respiratory tract. The typical particles are of a very small size, most of which are even respirable and can be carcinogenic (e.g. when welding stainless steel). Suitably dimensioned extraction is a mandatory technical protective measure in addition to PPE (see also the Hazardous Substances Ordinance and TRGS 560 and TRGS 528).

As the operator is directly involved in the welding process, he is exposed to particular risk factors for his health. In addition to the technical measures mentioned as examples, such as extraction systems, holders and shielding, the use of personal protective equipment is prescribed by law (OStrV) when working with HLGs, as only this combination can guarantee occupational safety.

PPE for hand-held laser systems

Laser safety goggles

As with all laser applications, eye protection is one of the most important aspects when selecting PPE. The simplest solution is to use laser safety goggles.

Most manufacturers of laser safety eyewear offer corresponding calculation programs that help to calculate the required protective effect and suggest suitable eyewear (e.g. eyepro from laservision). Important parameters in the calculation are the operating mode, the wavelength, the optical power and, crucially, the spot size of the laser beam on the goggles in an emergency. This estimation is particularly critical, as the power density together with the absolute power is decisive for the resistance of the glasses and therefore their resistance time.

Most lasers for hand-held laser welding have a center wavelength of 1070-1080 nm and a continuous wave power (cw) between 2 and 3 kW. This results in a typical protection level of D LB6 or D LB7, with a tendency towards D LB8, which the goggles must at least meet at this wavelength.

As the plasma generated during the welding process emits broadband light, i.e. in the entire spectral range from UV to IR, the selected filter must also have an additional blocking effect against these parts of the spectrum and, in order to avoid glare as far as possible, the daylight transmission must not exceed certain values. Even if the plasma light generated by the laser is less intense than in conventional welding processes, the standards for welding protection filters EN 169 and ISO 16321-2 specify limit values for broadband attenuation in various spectral ranges. Unless explicit reference is made to the welding protection standards, only the laser protection requirements are considered below.

Figure 1: Laser safety goggles as over-glasses

Correctly dimensioned laser safety goggles then also offer safe protection for the eyes from the primary laser radiation and the plasma glow with HLGs. However, the face outside the cover area of the goggles remains unprotected. To protect the face as well, the laser safety goggles can be easily combined with a conventional welding helmet. The goggles guarantee standard-compliant laser protection, while the helmet protects the entire head against scattered radiation from the laser and plasma light.

Laser safety visors

Another option, which also offers a much larger field of vision, is the use of a complete visor with a large laser safety lens. This is typically made of the same polycarbonate filter material as the comparable laser safety goggles but offers a much larger coverage area. This not only protects the eyes, but also the entire face.

By selecting the VLT of the filter pane, the brightness of the plasma can be taken into account to

a small extent. Optionally, it can also be combined with additional laser or welding goggles.

Figure 2: Laser safety visor FS1 from laservision

In addition to the protective effect, wearing comfort also plays an important role when deciding on such a visor solution. A secure fit, maximum freedom of movement, easy adjustability in height and width and the lowest possible weight are decisive parameters.

Functionality and kinematics are no less important for longer, relaxed working. The weight should be balanced both in the working position and in the parking position of the visor so that additional, excessive strain on the neck is avoided. The widest possible, multi-adjustable carrying system (e.g. uvex Spiderneck) helps here. A scratch-resistant coating on the outside of the lens and an anti-fog coating on the inside are essential for the typically harsh welding environment.

Laser welding helmets

The Panoramaxx laser safety welding helmets from Optrel, for example, which were developed in cooperation with laservision, achieve a higher level of laser protection of D LB7 in the coverage area in accordance with EN 207 and are therefore comparable to high-quality laser safety goggles with glass filters. This family of three helmets differs primarily in terms of the filter used.

In addition to a purely passive plastic filter, two versions are also available with an auto-darkening filter installed in addition to the laser filter made of plastic or coated infrared filter glass. The advantage of these two hybrid solutions is that these helmets are certified for both laser welding and conventional welding.

Various designs from different manufacturers are currently available on the market in all price ranges and with different levels of protection. As with the visor solution described above, the wearing comfort and field of vision of welding helmets is also a decisive aspect for the acceptance of PPE.

Most welding helmets have a rectangular protective filter which, due to its geometry, tends to have a greater distance to the eye and therefore creates a restricted field of vision. For use as a laser welding helmet, only an additional laser safety filter is often integrated. In contrast, the filter design of the Panoramaxx helmets from Optrel, which has a cut-out for the nose, enables an up to 6 times larger field of vision by positioning the filter directly in front of the eye.

Figure 3: Hybrid helmet for laser and conventional welding from Optrel

As the corresponding laser safety filters also have this geometry, the field of vision is also significantly larger during laser welding than with helmets with a rectangular filter.

Figure 4: Laser safety screen from laservision for Optrel PANORAMAXX helmet

In comparison between welding helmets for conventional welding and hybrid solutions or pure laser welding helmets, these helmets are often somewhat heavier due to the additional laser filter. It is therefore particularly important here too to ensure a good retention system that can be adjusted in many directions. The Optrel Isofit headgear is one of the most flexible systems on the market.

Figure 5: Isofit Headgear

Respiratory protection

The microparticles produced during welding are particularly harmful to the lungs. Various measures must be taken to avoid this risk.

Figure 6: uvex FFP3 mask

The size of these particles is between 0.1 and 1 micrometer. Particles of this size can penetrate deep into the respiratory tract and be harmful or carcinogenic. The simplest and most widespread measure, the installation of an appropriate extraction system with filters, has already been mentioned. As this is often not sufficient or not possible in terms of space, appropriate respiratory protection PPE must also be worn.

The selection, use and application of respiratory protection PPE is described in the PPE Usage Ordinance (PSA-BV) and DGUV Rule 112-19012, among others. These standards also ensure that PPE complies with current safety requirements.

Passive respirators such as FFP2 and FFP3 provide basic protection against particles and vapors. FFP3 masks offer a higher level of protection than FFP2 masks and should be preferred if the concentration of harmful substances is higher.

Active PAPR systems (Powered Air-Purifying Respirators), on the other hand, offer even better protection as they actively filter the air and supply clean air to the wearer. These systems are particularly useful in applications with high exposure to pollutants or for longer working hours, as they reduce breathing resistance and increase wearer comfort.

Figure 7: optrel Swiss Air PAPR system

In general, PAPR systems should be preferred if the working conditions are particularly stressful, if there is a high level of emissions or if the wearer has health restrictions that make breathing through a passive mask difficult. In addition to welding helmets that already have such a system integrated or can be retrofitted with it, there are also stand-alone systems that can be combined with the aforementioned PPE products (visor, helmet, goggles). It is important here that neither the original protective effect nor the functionality are negatively affected by the combination. In general, however, the use of an extraction system is also mandatory here.

Hand and skin protection

As described above, laser welding poses a risk not only to the eyes and secondarily to the lungs, but also to the skin. The DGUV therefore explicitly points out the need for suitable protective clothing and gloves when using HLGs in its Information 203-093 Chapter 5.4.2. To minimize the risk of injury, it is recommended to wear closed, flame-retardant clothing (e.g. welding protective clothing). Most manufacturers of protective clothing (e.g. uvex) offer suitable protective clothing and gloves in various designs and qualities as standard.

Figure 8: Welding gloves Hexarmor

Summary

The market for hand-held laser systems is growing dynamically due to their precision, versatility, ease of use and cost-effectiveness. Advances in laser technology and increasing demand in various industries are also contributing to this growth.

At the same time, this technology has a high risk potential for the user, so that occupational safety and in particular the use of personal protective equipment (PPE) is of particular importance. Safety goggles, protective gloves and flame-retardant clothing are essential to ensure comprehensive protection. In addition, respirators such as FFP2 and FFP3 as well as active PAPR systems protect against hazardous particles generated during laser welding. Due to the complexity of the requirements, the selection of PPE should always be based on a thorough risk assessment and also include the protection of the surroundings and other people in the work area.

Q1:J.Helm, Dissertation Prozessstabilität und Prozesseffizienz beim Laserstrahlfügen, Aprimus Verlag 2022