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Reducing Risk Factors in the Workplace of the Laser System Operator

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***Abstract*—Laser processing of materials takes an increasing place in production processes. Improving the performance, improving the quality of processing is not a complete list of the positive aspects of the introduction of laser processing, but there are a number of points that need to be paid attention to during the operation of laser systems - these are issues related to safety. The following risk factors are specific to laser systems: firstly, the laser beam itself, effects on the organs of vision, direct thermal effects on the skin and tissues, secondly, harmful products resulting from the interaction of the laser beam and the material being processed. Aerosols, smoke and dust have different effects on the human body, especially on the respiratory system and the publication considers the risks associated with the release of harmful products during laser processing and the existing methods for reducing the concentration of harmful substances in the working area with specific examples.**

Keywords — Clean air, Safety, Nano particles, Laser processing.

I. Introduction

Industrial laser systems are becoming more widely used as they have high productivity, production processes become more efficient and largely automated. Increasingly, laser systems appear in educational institutions, in the youth technical creativity centers. On one hand, this is great, but on the other hand, as many years of experience have shown, entrepreneurs and laser system operators often have a low level of awareness of the risks and unwanted by-products which depend on the type of laser source; from the laser process; of the material type.

Depending on the application, these are harmful vapours, gases, aerosols, and solid particles. The negative impact will be not only on the person, but also on the laser equipment as well as the products may be damaged. Laser fume builds up firmly adhering layers of contamination. The danger of laser dust is often underestimated. Only effective air filtration can ensure safe working conditions and protect the health of the personnel of the enterprise in which the laser systems operate. The amount of harmful products during processing depends on the kind of technological process - drilling, cutting, welding, engraving or marking, as well as on the properties and composition of the material being processed, such as plastic, wood or metal. Fine dust and aerosols generated by laser processes are often smaller than 1 ***μm*** [1].

Impact on human health can manifest itself in different ways depending on the concentration of undesirable substances in the work area and on the individual characteristics of the human body. Manifestations of exposure to harmful substances can be expressed in inflammation and changes in the tissues of the respiratory organs, from allergies, and functional disorders of the lungs to lung cancer.

The classification of fine dust is based on the particle size (more precisely: on the aerodynamic diameter). Fine dust with a particle size of 10μm is respirable. These particles reach the bronchial area, as shown in Fig.1. In the case of fine dust, the smaller the dust particles, the more dangerous it is, as it can penetrate further into the lungs. Very fine dust can penetrate into the alveoli and clog them. Particles smaller than 1μm are extremely dangerous as they can penetrate very far into the lungs. [2]

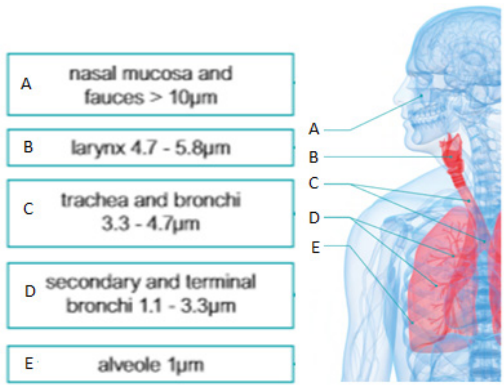

Fig. 1. Penetration of dust particles into the human body, depending on their size. [2]

The nanoparticles during inhalation overcome the lung blood barrier and enter the nervous system [3]. Depending on their chemical composition, they have further harmful effects. The health burden increases linearly proportional to the fine dust concentration. According to the information provided by the Laser Zentrum Hannover in the Laser safety database health burden increases linearly proportional to the fine dust concentration [4]. Information on the amount of emission in the process of laser processing is summarized in table 1. The EU Air Quality Plans aim for a maximum fine

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dust concentration of 40-50µg / m³ in the respiratory air. It should be contrasted with the fact that the fine dust concentration in laser processes is partly 100µg / m³ and more! [5]

The ISO committee who is responsible for the documents in the field of cleaning equipment from air and other gases. prepared new standards in accordance with research in this important area. This first edition of ISO16890-1, together with ISO16890-2, ISO16890-3 and ISO16890-4, cancels and replaces ISO/TS21220:2009, which has been technically revised.

ISO16890 consists of the following parts, under the general title Air filters for general ventilation:

- Part 1: Technical specifications, requirements and classification system based upon particulate matter efficiency (ePM)
- Part 2: Measurement of fractional efficiency and air flow resistance
- Part 3: Determination of the gravimetric efficiency and the air flow resistance versus the mass of test dust captured
- Part 4: Conditioning method to determine the minimum fractional test efficiency

The ISO 16890 series describes the equipment, materials, technical specifications, requirements, qualifications and procedures to produce the laboratory performance data and efficiency classification based upon the measured fractional efficiency converted into a particulate matter efficiency (ePM) reporting system. In Germany, the Technical Rules for Hazardous Substances (TRGS) reflect the state of the safety-technical, occupational-medical, hygienic and occupational-scientific requirements for hazardous substances with regard to marketing and handling. [9], [10]

Table 1. The fine dust concentration in laser processes [5]

	Process	Quantity	Aerodynamic diameter
Aerosols-emission	Removal of plastic	> 30mg / s	<0.12µm
	Welding of metal	> 9mg / s	
	Cutting of metal	> 100mg /s	
	Removal of paint	> 25mg / s	<0,23µm
Fine dust - concentration	Cutting of plastic	> 500µg /m³	<1.7µm
	Cutting of metal	> 300µg /m³	
	Welding of metal	> 2000µg /m³	

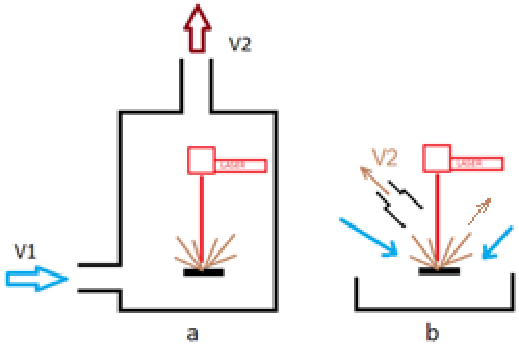

Fig. 2. Variants of the constructive implementation of laser systemsб closed a) and open b) systems

There are open and closed laser systems. Their main difference is that in the case of a closed system, it is possible to direct almost all the air from the laser working area to the filtration system; Fig. 2a, in this case, the flow of incoming air to the filtration system V2 and entering the working area V1 is almost equal, in an open or semi-closed system Fig. 2b, this is very difficult to draw. The air flow V2 that will be directed to the filter system will not be able to catch all the harmful emissions from the treatment zone.

It is necessary to note a few important points and technical solutions extraction systems. There is a relationship between the required air flow and the distance between the suction intake nozzle of the aspiration system and the material processing zone of the laser beam. Fig. 3 clearly shows that by reducing the distance to the treatment area by half, the air flow through the aspiration system can be reduced four times, with the same air cleaning efficiency in the operator’s working area. The required air velocity depends on the size and weight of the particles, as well as on the distance from the treatment point to the suction raster. This means that the same result can be achieved at lower cost.

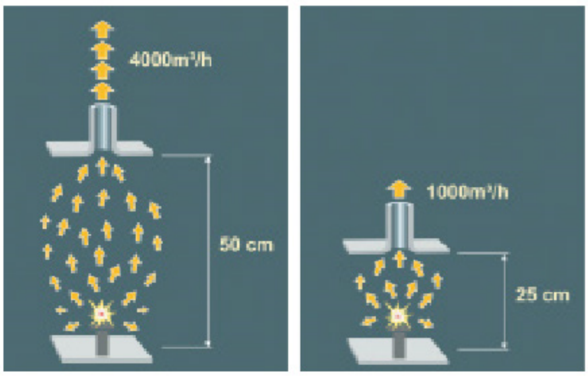

Fig. 3. Influence of distance to the required airflow [6]

The right design for collecting the contaminants is one of the most decisive factors for cost-effective, suitable dimensioning of the overall extraction and filter system this is clearly seen in Fig. 4 [7].

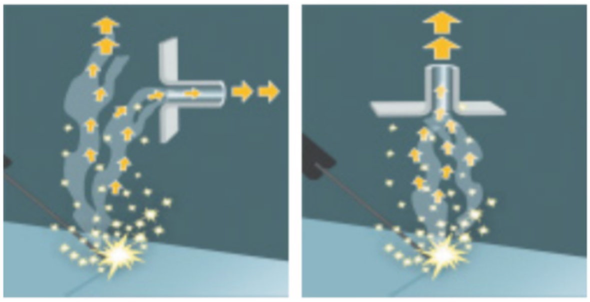

Fig. 4. Influence of hoods flanges forms to the effective extraction area. [7]

Depending on workplace and extraction situation, you can choose among various shapes and sizes of collection elements. The following figures illustrate the most important standard versions, this is seen in figure 6. In addition, the manufacturer designs customer specific versions, up to complete housing of the pollutant source [11]. Through skillful use of physical

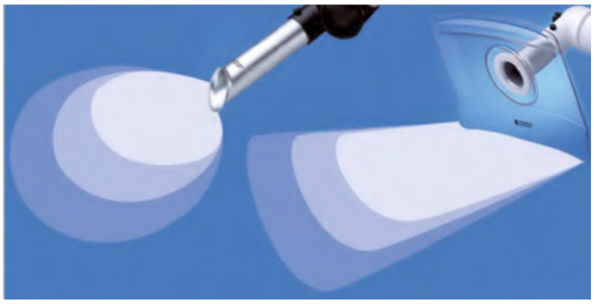

Fig. 5. Examples of the location of the suction raster [8]

laws, the low depth effect of the open detectors can be improved. These include: Most existing heat sources will cause upward thermal currents that can be used for local placement, example in Fig. 5, on the example to the right, the operation of the aspiration system will be more efficient.

Fig. 6. Collection elements [11]

Depending on the laser process, the kind of laser fumes can vary. Therefore, there are various filtering systems. Let us consider these systems on the example of ULT AG products. This is a saturation filter unit and a cartridge filter unit [12]. In both systems, the degree of cleaning allows you to return the purified air back into the work area. The cleaning level is in accordance with the current regulations in the European Union.

Saturation filter units:

- for low laser fume concentration;
- for sticky laser fume;
- for additional odour pollutio.

Cartridge filter units:

- for high laser fume concentration;
- for dry laser fume;
- for high demands on service life. [12]

When using a system consisting of filtering blocks, it must be kept in mind that the filters have a fixed life expectancy and will periodically need changing to ensure effective air filtration. Constructively, the system is visible in Fig. 7. Air filtration occurs gradually, from the beginning of the filters which cleans the air from large particles to the purge from the nano particles.

Cartridge filter units are mainly used to remove dry, intensive laser smoke continuously in fairly large volumes Fig. 8. They have long service life and low operating costs. The pollutants are collected on the surface of the filter cartridge. The filter cartridge is removable. They need to be systematically cleaned after a certain time period, the cartridge is cleaned with compressed air and dust is fully collected in dust collectors. Refined air is returned to the working area.

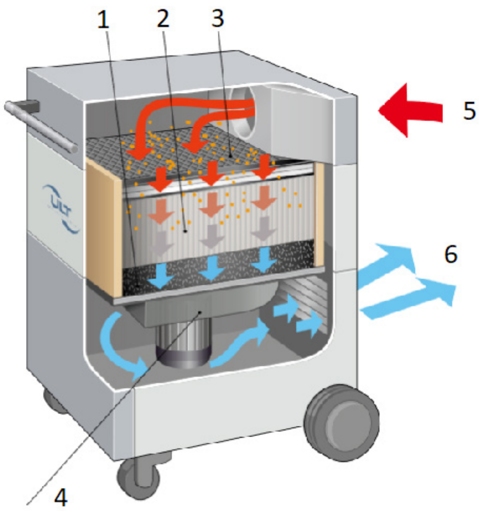

Fig. 7. Functional principle of saturation filter units , 1- activated carbon filter; 2- submicron particulate filter; 3- resublimation filter / spark protection; 4- fan; 5- process exhaust air; 6- purified air[12]

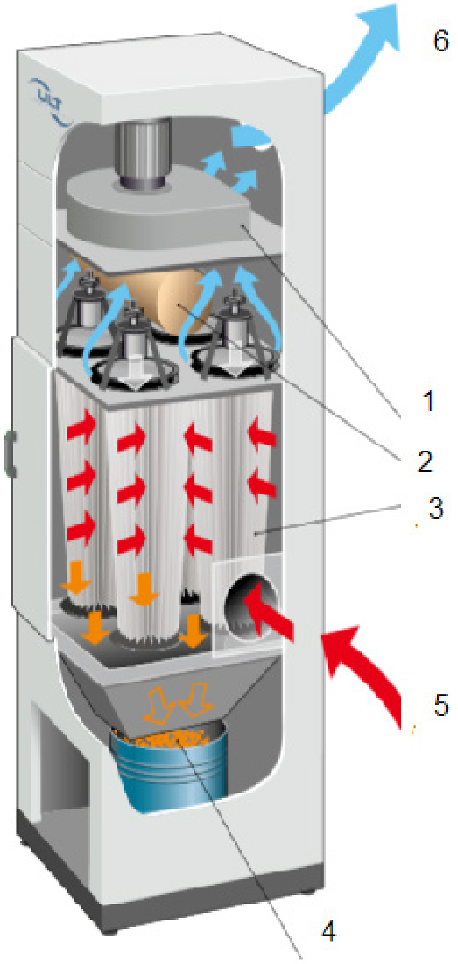

Fig. 8. Functional principle of cartridge filter units; 1- fan; 2- compressed air tank; 3- filter cartridges; 4- dust collector; 5- process exhaust air; 6- purified air [12]

II. Materials and methods

Air samples of fumes in the laser cutting were gathered from the breathing zone of the workers during the active work periods. Cellulose acetate membrane filters (Millipore, 0.45 mm) with a 37-mm open-face cassette were used as collectors. The flow rate was 2 L/min (GilAir sampling equipment was used), and the sample time varied from 55 to 90 minutes. The inhalable dust concentration was then calculated from the weight difference (method of gravimetry) of the filters before and after sampling, and the corresponding of air volume was done, too.

As well particle number measurements were done by "P-Trak Ultrafine Particle Counter" Model 8525 (particles size: 20 - 1000 nm) during metal laser cutting process.

The laser-cutting machine is equipped with closed fume extraction system.

III. Results and recomendations

The concentration of metal fumes in the work place air near by the laser cutting machine fluctuated in range from 0.40 to 0.56 mg/m3. The highest concentration of fumes was detected in the worker breathing zone, respectively 1.03 ± 0.15 mg/m3.

Working with metals makes an large part of the industry and nowadays one cannot imagine such manufacturing processes as metal processing, metallurgy and various manufacture auxiliary processes, for instance, maintenance of production equipment and work equipment without it. Employee who performs metal cutting and welding is subjected to series of harmful factors. Fumes consisting of various metal salts and oxides is released in work environment air; the presence of substances having especially adverse human health effects – cadmium, nickel, manganese, chromium (VI) – is possible. A safe limit value for welding aerosol fumes is 4 mg/m3, it is integrated in the Regulation of the Cabinet of Ministers No. 325/2007 "Work Safety Requirements when Working with Chemical Substances" (adopted on 15.05.2007, published in Latvijas Vēstnesis, 18.05.2007).

Total dust concentrations of metal fumes in work environment do not exceed safe limit value, however concentration in worker breathing zones where people are moving within the workshop is higher than in the work environment near the laser-cutting machine.

The particle concentration measurements were made during the technological process. In the laboratory measurements for clean room before the measurements in the workshop were done. The workshop gate was closed in period of "Conditions 1" and "Conditions 3'" during the working process. The gate was open for finished production transportation needs out of the workshop in the period of "Conditions 2", see measurement results in the table 2. The temperature difference between outdoor (+ 6 C°) and indoor (+ 24 C°) environment leads to air movement inside the workshop and particles from the surfaces, walls and ceiling areas moved down, and cause rapid increase of particle concentration in the breathing zone, see Fig. 9.

Table 2. Number of particles in the operator zone

Conditions	Concentration of particles in the air, pt/cc			
	Min	*Max*	*Average*	*Median*
Clean room	733	791	762	763
Conditions 1	8510	11600	9916	9845
Conditions 2	12100	45700	24548	22500
Conditions 1'	6510	17500	9934	9250

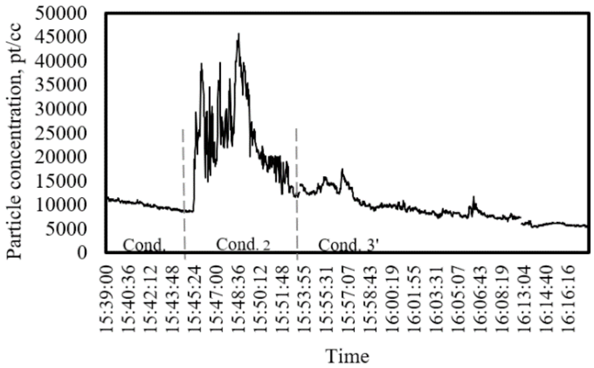

Fig. 9. Particle concentration during working process

According to literature, metal fumes consist predominately of particle agglomerates smaller than 1 μm. This means that most of the fumes are respirable [13]. Lehnert et al. (2012) indicate that the welding process is the major determinant of the exposure to particles in different size fractions, however in welding processes it can be observed that there is a large number of small - sized particles including ultra fine particles [14]. Typical workplace air is usually a mixture of these groups and the convection currents, work equipment and air ventilation systems keep the dust in a mobile state preventing the sedimentation of smallest particles [15].

Inhalation is considered to be the primary route of exposure for dusts with smaller particles, which have greater potential for harmful effects on human health as they reach alveolar level. Special attention should be paid to finding that the smaller fractions of dust from the metal industry contained toxic metals at nano-size (such as Zn, Mn, and Cr) [16,], [17], [15].

It is particularly essential to identify and determine the concentration of the smallest size dust particles with little mass, if there are any, as they could be found in the air in suspended state for prolonged periods and their effects on human health are particularly harmful.

References

[1] Jakschik St., Blei St., Laser fumes in femtosecond laser processes – product, process and environment considerations, ULT AG, ILK Dresden, https://www.ult.de

[2] https://www.tbh.eu/en/shortlinks/downloads.html

[3] https://www.ult.de/images/content/download/02_geraeteserien/LAS_extraction_filtration_laser_fume_2016_en_web.pdf

[4] https://www.lzh.de/de/publikationen/lasersicherheit

[5] Laserbearbeitung,datenblatt/dbl_tb_laserbearbeitung_dbl_deutsch.pdf

[6] Meissner St., Why Extraction and Filtrationn tehnology is important; ULT GmbH https://www.ult.de

[7] https://www.tbh.eu/en/shortlinks/downloads.html

[8] VDMA, Allgemeine Lufttechnik, Erfassen luftfremder Stoffe, www.luftreinhaltung.vdma.org

[9] TRGS 900 Grenzwerte in der Luft am Arbeitsplatz – „Luftgrenzwerte

[10] TRGS 901 Begründungen und Erläuterungen zu Grenzwerten in der Luft am Arbeitsplatz,

[11] https://www.ult.de/images/content/download/03_absaugearme/ULT_extraction_arms_capturing_elements_flextractor_en.pdf

[12] https://www.ult.de/images/content/download/02_geraeteserien/LAS_extraction_filtration_laser_fume_2016_en_web.pdf

[13] Jenkins, N.T., Pierce, W.M.-G., Eagar, T.W. (2005) Journal of Welding, October, 156-163.

[14] Lehnert, M., Pesch, B., Lotz, A., Pelzer, J., Kendzia, B., Gawrych, K., Heinze, E., Van Gelder, R., Punkenburg, E., Weiss, T., Mattenklott, M., Hahn, J.U., Möhlmann, C., Berges, M., Hartwig, A., Brüning, T.; Weldox Study Group. Ann Occup Hyg. (2012), 56(5), 557-567.

[15] Pavlovska, Z., Martinsone, Z., Vanadzins, I., Martinsone, I., Seile, A., Sudmalis, P.,2016. Occupational exposure parameters for characterization of nanoparticu-late matter toxicity: metal versus wood processing. Process Saf. Environ. Prot.102, 230–237.

[16] Peixe, T.S., de Souza Nascimento, E., Schofield, K.L., Arcurid, A.S.A., Bulcão, R.P., 2015. Nanotoxicology and Exposure in the Occupational Setting. Occup. Dis. Environ. Med. 3, 35–48

[17] O'Shaughnessy, P.T., 2013. Occupational Health risk to nanoparticulate exposure. Environ. Sci. Process. Impacts 15, 49–62.