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Analysis of the Harmful Effects of UV Radiation Generated During Welding

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Abstract

Arc welding produces several harmful health effects on the welder. The authors aimed to determine the intensity of ultraviolet (UV) radiation as a function of distance from the welding. The research focused on the UV radiation generated during the arc welding process as it is a widely used process in industrial practice today. During the experiment, several tests were performed on the gas metal arc welding process (GMAW). This procedure is also used automated in the industry, so research can help to designate a specific safety zone in an industrial area so that there is no need to separate the welder robot with a curtain, but at the same time be able to move around them. Where the production is not fully automated yet, it highlights the problems which cause possible damage to health and helps create safer working conditions.

Keywords*: ultraviolet radiation; arc welding; safety zone.*

1. Ultraviolet effects

Ultraviolet, in short, UV radiation, is electromagnetic radiation of a wavelength of between 100 and 400 nm (below that of visible light). The UV range can be further divided into UV-A between 315-400 nm, UV-B between 315-280 nm and UV-C between 280-100 nm **[1].** The main source of UV radiation on earth is solar radiation. The largest amount of ultraviolet radiation which reaches the earth's surface is UV-A radiation, most of the UV-B and all of the UV-C are absorbed by the stratospheric ozone layer. However, during arc welding, the device emits the entire spectrum of UV **[2].**

UV radiation strongly interacts with the molecules that make up living organisms, damaging them, so increased exposure to UV radiation poses a serious health risk.

Well-known examples of its acute health effects include keratoconjunctivitis and erythema.

UV-C radiation is absorbed by the cornea, UV-B and UV-A radiation is also absorbed by the cornea and the lens of the eye, and only a small amount of UV radiation reaches the retina **[3]**. Kerato-conjunctivitis is an inflammatory condition of the cornea, which is associated with unpleasant symptoms, such as pain, the feeling of a foreign body in the eye, blurred vision, sensitivity to light, tearing and eyelid spasms. The symptoms will disappear within 2 days **[4]**.

Erythema, i.e. skin redness, caused by UV radiation – is increased blood flow within the surface capillaries of the skin.

UV-B and UV-C radiation have a direct DNA-damaging effect. The body recognizes the damage and initiates several defence mechanisms, including DNA repair to reverse the damage, apoptosis and exfoliation to remove irreparably damaged skin cells, and increased melanin production to prevent future damage **[5]**.

UV radiation can induce many chronic processes in the body.

UV-B and UV-C radiation damage DNA directly or indirectly together with UV-A by creating reactive oxygen radicals. This causes premature skin ageing, loss of skin tone, and formation of wrinkles, metalloproteinases are induced, which cleave collagen, the structural protein that ensures the skin's elasticity [6].

Long-term exposure to UV radiation and the resulting DNA damage can have much more serious consequences than premature skin ageing. UV radiation is known to be carcinogenic, and damage and improper repair of special DNA sequences, so-called proto-oncogenes and immunosuppressor genes, can lead to the development of cancer [7].

UV radiation also induces immunosuppression, which aggravates the course of infectious diseases and further increases the likelihood of developing skin cancer [8].

UV radiation reaching the eyes is a serious risk factor for the development of serious diseases that cause vision loss, such as cataracts and macular degeneration [9].

1.1. Permissible level of UV radiation

The intensity of ultraviolet radiation to which a person can be exposed in a day is maximized by a given daily UV limit. According to the literature, this limit value is 3 mW/cm^2, which means that if the body receives a dose higher than this, it will eventually no longer be able to recover easily, thus increasing the degree of permanent damage to the cells. The example below can help to make it easier to interpret, if the UV measuring instrument measures a value of 0.001-0.002 mW/cm^2, it means that the person exposed to it can stay in the irradiated area for 30-60 minutes. This value can be modified based on whether the measured radiation falls into the UV-A, -B or -C range. Because different regions damage the body to different extents [3].

We can determine the intensity of ultraviolet radiation as a safety value that can be interpreted for the whole day. To calculate this, knowledge of the following formulas is required (1), (2):

$$E_{eff} = \sum_{180}^{400} E_\lambda \cdot S(\lambda) \cdot \Delta\lambda \quad (1)$$

$$t_{max} = \frac{3\ mJ/cm^2}{E_{eff}} \quad (2)$$

The first formula gives the radiation efficiency. The second is the daily limit of UV radiation. In the formula for the efficiency of radiation, letters mean the following: E_λ special radiation, W/(cm^2·nm); $S(\lambda)$ relative spectral efficiency; $\Delta\lambda$ is the center wavelength, nm. In the second formula, the value of 3 mJ/cm^2 corresponds to the daily permissible value. We can interpret this as being exposed to 3 mW/(cm^2·nm) UV UV radiation for 1 second during a day without harmful effects [10].

The exposure accumulates during the day and can quickly reach the limit without any protective equipment. It is worth mentioning here that as radiation spreads in the air, the amount of radiation decreases significantly depending on the distance. Also, during welding, the emission of the arc light wavelength changes as a function of the medium (shielding gas), according to the range in which the medium emits invisible or visible light [3].

2. Experiment

In the case of arc welding, UV radiation is an unavoidable source of inherent danger. For this reason, protective equipment is currently defined, for example: as covering skin surfaces with clothes or welding masks, shields or protective glasses. This protective equipment has been in use for many years and mainly focuses on absorbing and blocking UV light and only protects the wearer directly. In the welding halls, the individual welding stations are separated by curtains and screens, thus protecting the other welders. Our suggestion arose from the fact that knowing the given radiation intensity, a safety zone can be created while there is no need to completely cover the stations and workers could be able to walk between the welding robots following the designated routes without wearing protective gear.

2.1. The course of the experiment

Several articles have already been published in connection with this measurement. Our main goal is to measure the amount of ultraviolet radiation emitted during a given time and with the help of this, depending on the distance, specify a daily maximum value to which the body can be exposed. Adherence to this amount is important, as ignoring the recommendation can easily cause the problems described in the first part of this article.

The measurement was carried out with the help of a welding machine, on which both the welding values and the selection of gas mixtures could be easily controlled. The experiment aimed to define the effect of different gas mixtures on UV emission. Figure 1. shows a schematic representation of the experiment.

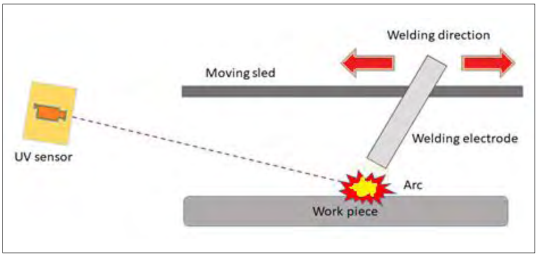

Figure 1. *Schematic diagram of the measurement.*

Table 1. *UV data as a function of distance*

Distance (m)	0.5	1	1,5
UV radiation mW/(cm²·nm)	1.1–2.3	0.34–0.6	0.095–0.2

During the measurements, we established that the individual shielding gas mixtures can influence the amount of ultraviolet radiation, but the exact measurement evaluations are still in progress. In addition, we carried out measurements to see how the UV emission might change in the case of other welding processes, and it was interesting to observe that in the case of TIG welding, with the same material and protective gas, we were able to measure much lower values, which is a positive thing, since this process is still a very widely used procedure performed by humans.

To be able to quantify our results further, Table 1 contains some measurement results. The measurement was made from several points and the distance changed due to the movement of the arc, so the values obtained are displayed as a range. The propagation of light can be demonstrated with the help of these data. The gas that we used as a shielding gas for the test was carbon dioxide (CO_2) which was carried out on S235 steel with SG2 yield material, with a feed of 7 m/min and a shielding gas dosage of 18 l/min and with the use of 171 A current.

The results clearly show how large a change in the intensity of ultraviolet radiation occurs depending on the distance. As the radiation spreads through the medium (air), it loses its ability to cause damage relatively quickly, so if the distances are correctly marked, the problem can be easily dealt with.

Searching the literature, we found a study where small experiments were carried out with the same shielding gas, and I would like to compare our results with them. The results of the research team “O., E. Otokpa, Y. B Usman” are shown in Figure 2 [11].

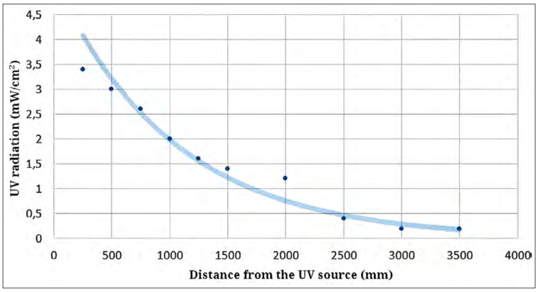

Figure 2. *Diagram of UV intensity as a function of distance.*

Although the diagram was made from experimental data with a similar shielding gas, the current used was higher. Thus, the nature of the UV propagation can be read from the diagram, but it is not fully compatible with our results.

3. Conclusions

Based on the current results of our research, we can say that the results of the trials support the proposition that depending on the distance, we can create a specific safety zone based on a knowledge of the shielding gas and the welding process. However, to determine the zone, it is necessary to know how much time a given worker will spend walking between the machines because even at a distance of 2.5 m, he can only spend a relatively small amount of time near the machines. In our opinion, perhaps it would be worthwhile to create a model with the placement of the machines, which makes it possible to calculate the route together with the speed of travel since on a large section of the route it would be further away.

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