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Group A3 3 Catching the (arc)rays

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Abstract

The team attempted to explore the maximum safe exposure time to UV rays from welding. Comparison with the well known UV Index (UVI), and direct modelling, quickly found that pretty much any welding is far in excess of even the most extreme UVI ratings. Proposals were made for further papers, exploring more complex modelling and comparison techniques.

Introduction

In this short paper we will examine the effects of electric arc welding on exposed skin, specifically exposure times likely to result in sunburn-like effects. Most modern welding processes involve the use of an open electric circuit. By applying a high enough voltage across the gap between an electrode and a work surface (typically steel or aluminium), the electricity arcs across said gap. This in turn produces Joule Heating, as the flow of electrons exchanges energy with atoms in the gap, forming a plasma and in turn causing the surrounding metal to melt. Arc temperatures are typically in the 3200-13,200 °C range for welding [1].

Process Description

As well as strong infrared (IR) emission (causing the melting), there is a spectrum of electromagnetic radiation produced by welding processes, as well as many associated 'fumes' that fall outside the scope of this paper. This spectrum is caused by electrons within the plasma, formed by the arc, being excited in to higher energy states, before dropping back down to lower states, releasing energy in the process [2]. The high energies involved cause much of the energy released to be in the non-visible portion of the electromagnetic spectrum, typically ranging from the desired IR through the visible portion of light and further out into the ultraviolet (UV) portion of the spectrum.

The most common welding process is 'metal, inert gas, welding', commonly referred to as MIG welding. It uses the standard open-circuit of all electric welding processes but the arc itself is formed between a length of wire that is continually 'pushed' off a reel, towards the work piece. Both the work piece and the wire itself melt due to the arc, and the continuous pushing of the wire causes it to be deposited into or onto the work piece, forming a weld. As this process happens, an inert gas is blown into the work area to displace the air and prevent oxygen from reacting with the molten metal [1]. Typically the gas used is argon mixed with other trace gases that create technical effects well outside the scope of this paper.

Modelling

The amount of UV radiation produced by MIG-welding processes has been discussed at length by many academic articles over the years [3][5]. As such we decided to produce a basic model in RStudio, using known data [3] to demonstrate sunburn effects at set distances, this was done by comparing the UV produced by MIG welding against the well-known UV Index (UVI).

What rapidly became apparent was the complexity of the process and the various calculations independently required to create a useful model. To this end we decided to undertake an iterative modelling process. The eventual goal was to produce a model that could output maximum exposure times to the nearest second for particular arc-ray exposures, potentially at varying distances depending on the datasets available. However, the first goal was to create a model that simply translated exposure levels to the UVI and outputted the recommended maximum exposure time. The calculation is quite involved but for the very approximate conditions required for our preliminary model,

$$UVI = E_{er}\,(40\,m^2\,W^{-1}),\ [4] \qquad (1)$$

where E_{er} is the erythemal radiation, the part of the UV spectrum causing the most damage to living tissue. This value is then simply multiplied by 40 to translate it into a scale between 1-11 (for ease of public consumption). Our model then produced UVI ratings for a range of effective irradiance levels:

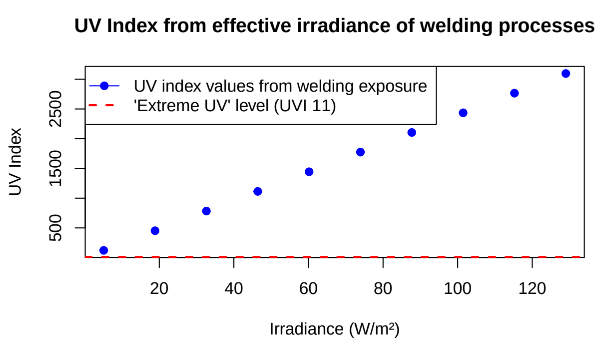

Figure 1: Modelled UVI values of the erythemal irradiance across a range of welding UV effective irradiance data

Conclusion

As can immediately be seen, the UVI index values generated by the model for real world UV exposure from welding are far in excess of the 'extreme' UVI value of 11. For UVI=11, recommended exposure is less than ten minutes, suggesting that for the entirety of the UVI values generated in the model, maximum exposure time would likely be in the seconds rather than minutes.

The final conclusion is that further work must be undertaken to fully calculate and model welding UV exposure. Incorporation of a more complex model is needed, rather than relying on the inadequate system provided by the UV Index. We thus intend to remove the comparison with the UVI entirely, replacing it with a calculation of exact energies predicted at set distances. By further investigating the exact physiological response of skin, we hope to calculate safe exposure times and create a more useful model.

References

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