An Evaluation of Welding Processes to Reduce Hexavalent Chromium Exposures and Reduce Costs by Using Better Welding Techniques

Author: Keane, Michael J.

Source: Environmental Health Insights, 8(s1)

Published By: SAGE Publishing

URL: https://doi.org/10.1177/EHI.S15259

Open Access: Full open access to this and thousands of other papers at http://www.la-press.com.

Environmental Health Insights

Supplementary Issue: Occupational Health and Industrial Hygiene

An Evaluation of Welding Processes to Reduce Hexavalent Chromium Exposures and Reduce Costs by Using Better Welding Techniques

Michael J. Keane

Health Effects Laboratory Division, National Institute for Occupational Safety and Health, Morgantown, WV 26505, USA.

ABSTRACT: A group of stainless steel arc welding processes was compared for emission rates of fume and hexavalent chromium, and costs per meter length of weld. The objective was to identify those with minimal emissions and also compare relative labor and consumables costs. The selection included flux-cored arc welding (FCAW), shielded-metal arc welding (SMAW), and multiple gas metal arc welding (GMAW) processes. Using a conical chamber, fumes were collected, and fume generation rates and hexavalent chromium (Cr^{6+}) were measured. GMAW processes used were short-circuit (SC) and pulsed-spray modes. Flux-cored welding used gas shielding. Costs were estimated per meter of a 6.3-mm thick horizontal butt weld. Emission rates of Cr^{6+} were lowest for GMAW processes and highest for SMAW; several GMAW processes had less than 2% of the SMAW generation rate. Labor and consumable costs for the processes studied were again highest for SMAW, with those of several GMAW types about half that cost. The results show that use of any of the GMAW processes (and flux-cored welding) could substantially reduce fume and Cr^{6+} emissions, and greatly reduce costs relative to SMAW.

KEYWORDS: welding, hexavalent chromium, welding fume

SUPPLEMENT: Occupational Health and Industrial Hygiene

CITATION: Keane. An Evaluation of Welding Processes to Reduce Hexavalent Chromium Exposures and Reduce Costs by Using Better Welding Techniques. *Environmental Health Insights* 2014:8(S1) 47–50 doi: 10.4137/EHI.S15259.

RECEIVED: September 18, 2014. **RESUBMITTED:** November 13, 2014. **ACCEPTED FOR PUBLICATION:** November 14, 2014.

ACADEMIC EDITOR: Timothy Kelley, Editor in Chief

TYPE: Original Research

FUNDING: Funding was from the Health Effects Laboratory Division, National Institute for Occupational Safety and Health. The author confirms that the funder had no influence over the study design, content of the article, or selection of this journal.

COMPETING INTERESTS: Author discloses no potential conflicts of interest.

CORRESPONDENCE: mjk3@cdc.gov

Paper subject to independent expert blind peer review by minimum of two reviewers. All editorial decisions made by independent academic editor. Upon submission manuscript was subject to anti-plagiarism scanning. Prior to publication all authors have given signed confirmation of agreement to article publication and compliance with all applicable ethical and legal requirements, including the accuracy of author and contributor information, disclosure of competing interests and funding sources, compliance with ethical requirements relating to human and animal study participants, and compliance with any copyright requirements of third parties. This journal is a member of the Committee on Publication Ethics (COPE). Provenance: the authors were invited to submit this paper.

Introduction

Welding is a major occupation in the US and worldwide, and includes workers in manufacturing, construction, and a number of other industrial sectors; there are several million welders worldwide. Welding creates a number of hazards during operation, including physical agents such as extreme heat and ultraviolet radiation, as well as fumes and toxic gases. Antonini[1] reviewed occupationally related adverse health effects in welders, such as lung disease and possible neurological disease. The National Institute for Occupational Safety and Health (NIOSH) Work-Related Lung Disease Surveillance Report[2] indicates elevated mortality for welders because of pneumoconioses and lung cancers.

Assuring a safe workplace during most welding operations is generally well understood; industrial hygiene elements include helmets for eye protection, proper clothing for burn protection, and area and local exhaust ventilation for keeping fume exposures at acceptably low levels. But for welding stainless steels and similar chromium-containing alloys, it is a much more challenging situation. Hexavalent chromium (Cr^{6+}) and nickel in the fumes are potential carcinogens. Compliance with the 5 $\mu g/m^3$ OSHA permissible exposure level for Cr^{6+} is often exceedingly difficult; keeping exposures below the NIOSH-recommended 0.2 $\mu g/m^3$ level is even more difficult. Stainless steel welding can generate Cr^{6+} in the range of tens of thousands of parts per million in welding fume, and local or other types of exhaust ventilation can be difficult to apply or ineffective in certain situations.

Most welding (~45%) on ferrous metals is done using familiar shielded-metal arc welding (SMAW or stick). SMAW uses welding rods that have a filler metal rod coated with a flux mixture that provides a shielding environment to minimize degradation of the weld by atmospheric gases. Only a power supply, ground and electrode cables, welding rods, and an electrode holder are needed. But there are many other welding processes that can be successfully used in most situations. Gas metal arc welding (GMAW; often called MIG or MAG) uses a gas-shielded torch or gun, and the electrode is a consumable wire of the desired filler metal fed by a motorized feeder; shield gas is supplied from cylinders. Flux-cored arc welding (FCAW) is similar to GMAW, but the wire electrode has an internal flux material for weld shielding; the process may be used with or without an external shield gas.

Metal Transfer Modes in GMAW

More than one mode of metal transfer from the electrode into the weld pool is possible with GMAW processes, in contrast to other arc welding processes. When using relatively low applied voltages, the process is called short-circuit (SC) GMAW. The electrode wire is in direct contact with the weld pool, and a portion melts, breaking the short and forming the arc, and the molten drop is transferred into the weld pool. When the applied voltage is raised and the shield gas contains a high percentage of argon, there is a transition to axial spray (AXS) transfer mode. Molten metal leaves the electrode wire tip and is transferred as a very fine spray into the weld pool. The technique is used primarily in flat or horizontal applications; overhead or vertical use may result in drip problems. There is a type of spray transfer known as pulsed axial spray transfer (AX-P), where current pulses are added to a steady-state background current; this allows the total current to periodically exceed the required transition current and permit spray mode. Pulsed-spray mode allows high-quality welds in any position with lower heat input, and has a very low fume generation rate.

The objective of this study was to identify welding processes with minimal fume and Cr^{6+} emissions, and also compare relative labor and consumables costs, providing information to develop strategies to minimize workplace exposures.

Materials and Methods

Welding was bead-on-plate using 0.045 diameter E308 electrode or 3/16 inch rods for SMAW. The welding plate was 1/2 inch thick, 22 inch diameter Type 304 stainless steel, which was rotated to provide travel rates comparable with good welds. Welding was done in a conical chamber that met American Welding Society specifications.[3] Fumes were sampled through a filter at the chamber top at 200 L/minute, weighed, and the material recovered for hexavalent chromium chemical analysis. Sample recovery, treatment, and analysis by ion chromatography has been described in earlier studies.[4,5] Four replicate welding runs were completed for each process, and three replicate samples were analyzed for Cr^{6+} from each process. Welds were inspected for proper appearance and redone if unsatisfactory.

Fume generation rates were calculated as fume mass collected per minute of arc time, and Cr^{6+} generation rates per meter of finished weld were calculated as the product of the fume generation rate (mg/minute), the reciprocal of the travel rate (m/min), and the fraction of the fume because of Cr^{6+} (ppm). Costs were calculated by adding relative labor costs per hour, shield gas costs, and electrode costs per meter of completed weld. Relative costs were estimated per meter length of a 6.3-mm thick horizontal butt weld, done on a boiler repair in a single facility using four techniques. The weld was a single-pass operation for all processes tested.

Results and Discussion

Hexavalent chromium emission rates for four processes are shown in Figure 1; the error bars displayed are standard errors for the replicate measurements. The relative costs in US$ are shown in Figure 2.

For SMAW, the equipment costs are the lowest, but fume and Cr^{6+} generation rates are the highest. Consumables are relatively average in cost. Labor costs (time per weld) are high.

The GMAW-SC processes have higher equipment costs, but much lower fume and Cr^{6+} generation rates, typically less than one-quarter of the SMAW rates. The labor and consumables costs are also lower than SMAW.

GMAW AX-P has higher equipment costs, but the fume and Cr^{6+} generation rates are lower than GMAW-SC. Labor and consumables costs are low, and welding is possible in all positions. Typical Cr^{6+} generation rates per meter of weld length are <2% of SMAW rates, and labor-plus-consumable costs are less than half the rate for SMAW.

Flux-cored processes can be used with typical GMAW welders, and fume and Cr^{6+} generation rates are less than SMAW, but higher than GMAW processes. FCAW has the important advantage that it can be used where there are coated or contaminated surfaces. Owing to the fast electrode feed rates and fast travel rates possible with FCAW, emission rates for FCAW can be comparable to some of the GMAW processes, although significantly higher than the lowest-emitting GMAW processes. Wire (electrode) costs are slightly higher than the solid wires used in all GMAW methods.

Overall, GMAW processes such as pulsed-spray are the most advantageous welding methods when they can meet the requirements of the welding task. The fact that labor costs per weld are significantly lower than SMAW is an important factor for persuading management to adopt these changes. Although equipment costs can be significantly increased, often welding equipment can be leased when especially challenging jobs are

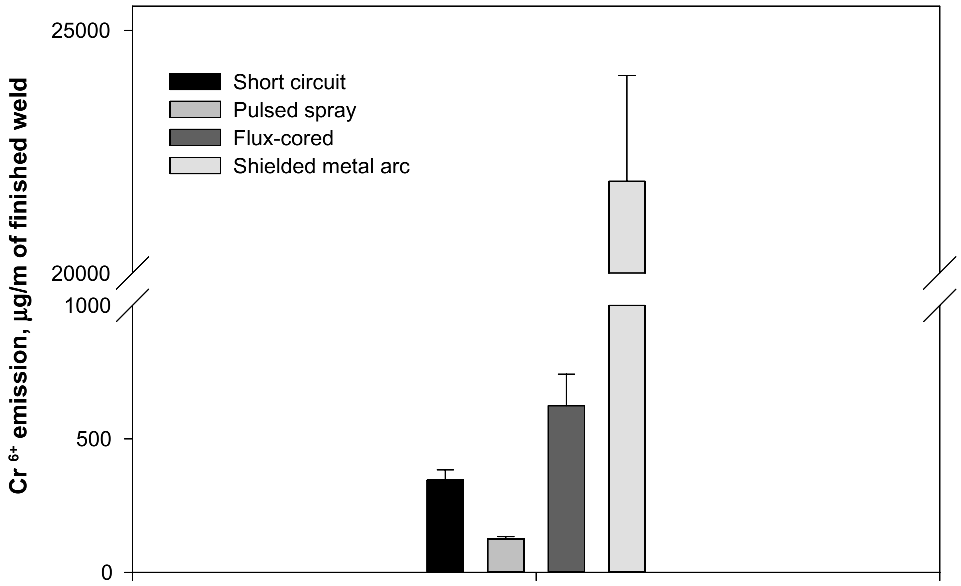

Figure 1. Hexavalent chromium emission rates for four welding processes.

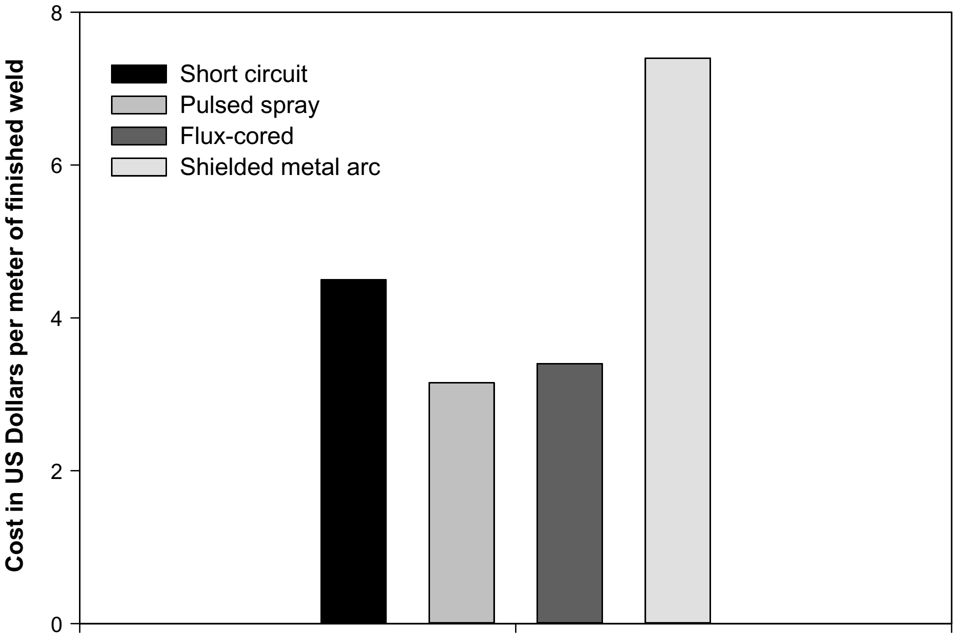

Figure 2. Labor and consumable costs for four welding processes.

anticipated. If pulsed-mode GMAW cannot meet the welding requirements, either GMAW-SC or FCAW will still provide reduction in fume and Cr^{6+}generation, and cost, relative to the commonly used SMAW process.

Disclaimer

The findings and conclusions in this paper are those of the author and do not necessarily represent the views of the NIOSH. The mention of any company names or products does not imply an endorsement by NIOSH or the Centers for Disease Control and Prevention, nor does it imply that alternative products are unavailable or unable to be substituted after an appropriate evaluation.

Author Contributions

Conceived and designed the experiments: MK. Analyzed the data: MK. Wrote the first draft of the manuscript: MK. Contributed to the writing of the manuscript: MK. Agree with manuscript results and conclusions: MK. Jointly developed the structure and arguments for the paper: MK. Made critical revisions and approved final version: MK. The author reviewed and approved of the final manuscript.

REFERENCES

1. Antonini J. Health effects of welding. *Crit Rev Toxicol*. 2003;33:61–103.
2. NIOSH. Work-related lung disease surveillance report 2007. DHHS (NIOSH) Publication 2008–143a. 2007. Available from: http://www.cdc.gov/niosh/docs/2008–143/default.html. Accessed December 7, 2014.
3. American Welding Society. *Laboratory Method for Measuring Fume Generation Rates and Total Fume Emission of Welding and Allied Processes (AWSF1.2:2006)*. Miami, FL: American Welding Society; 2006.
4. Keane M, Siert A, Stone S, et al. Selecting processes to minimize hexavalent chromium from stainless steel welding. *Weld J*. 2012;9:241S–6.
5. Keane M, Siert A, Chen BT, Stone SG. Profiling mild steel welding processes to reduce fume emissions and costs in the workplace. *Ann Occup Hyg*. 2014;58(4):403–12.