

The Air-Arc Interaction in Air Carbon Arc Gouging

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ABSTRACT

Air carbon arc cutting and gouging is a welding process that exposes workers to hazardous sound levels from 108–120 dB(A). Welders who perform the gouging process and other workers in close proximity to the process are at risk for noise-induced hearing loss.

To address this health risk, researchers at the National Institute for Occupational Safety and Health (NIOSH) investigated and identified the gouging process components affecting noise generation and researched methods for attenuating their effects. In the gouging process, an electric arc melts a portion of the metal workpiece and an air jet blows the melted metal out of the resulting gouge. The research revealed that both the arc and the air jet generate significant noise. Further, there is an interaction effect between them that increases noise generation. During gouging, when both noise sources are present, the sound power measured was 9 dB higher than the sum of each source measured alone.

NIOSH researchers investigated redirection of the airflow relative to the cutting torch, using a reconfigurable air nozzle to determine whether the air-arc interaction effect could be diminished. A-weighted sound power measurements of various configurations yielded a maximum reduction of 6 dB, illustrating that airflow redirection can reduce air-arc interaction noise.

1. INTRODUCTION

Air carbon arc cutting and gouging (hereafter referred to as “gouging”) is a process used by welders for a variety of metal fabrication and repair tasks such as cutting through metal, removing welds, repairing cracks, and removing hard facing on wear surfaces. This process exposes workers to hazardous sound levels ranging from 108 to 120 dB(A)¹⁻³. At these levels, noise exposures will exceed the NIOSH recommended exposure limit (85 dB(A) time-weighted average over 8 hours with a 3-dB exchange rate) in less than three minutes⁴. In 2008, there were an estimated 392,520 welders engaged in welding, cutting, soldering, and brazing in the United States, according to the Bureau of Labor and Statistics⁵, although not every welder performs gouging. It is estimated that roughly 10% to 90% of the welders at a given shop perform gouging tasks⁶ and other workers within earshot of the process can also receive hazardous noise exposures². Of the various tasks that welders perform, air carbon arc cutting and gouging was

found to be the loudest⁷, making it an important process to address in order to reduce noise exposure for welders.

As part of an investigation into methods to reduce hazardous noise from the gouging process, experiments were conducted in the NIOSH acoustic laboratories in Pittsburgh, Pennsylvania to determine which components of the process affected noise generation and how the process could be changed to reduce noise emissions. The air carbon arc cutting and gouging process involves an electric arc (positioned between a consumable electrode and the metal workpiece) which melts a portion of the workpiece, and a pressurized air jet that blows the melted metal, or slag, out of the resulting gouge, as shown in Figure 1. Figure 1 shows the manual gouging process, with the wand shown farther from the workpiece than usual for illustration purposes. The difference between cutting and gouging is the depth of the gouge with respect to the workpiece; although the same process is used for each, the cutting technique gouges completely through the workpiece. Both the electric arc and the air jet contribute to noise in this process.

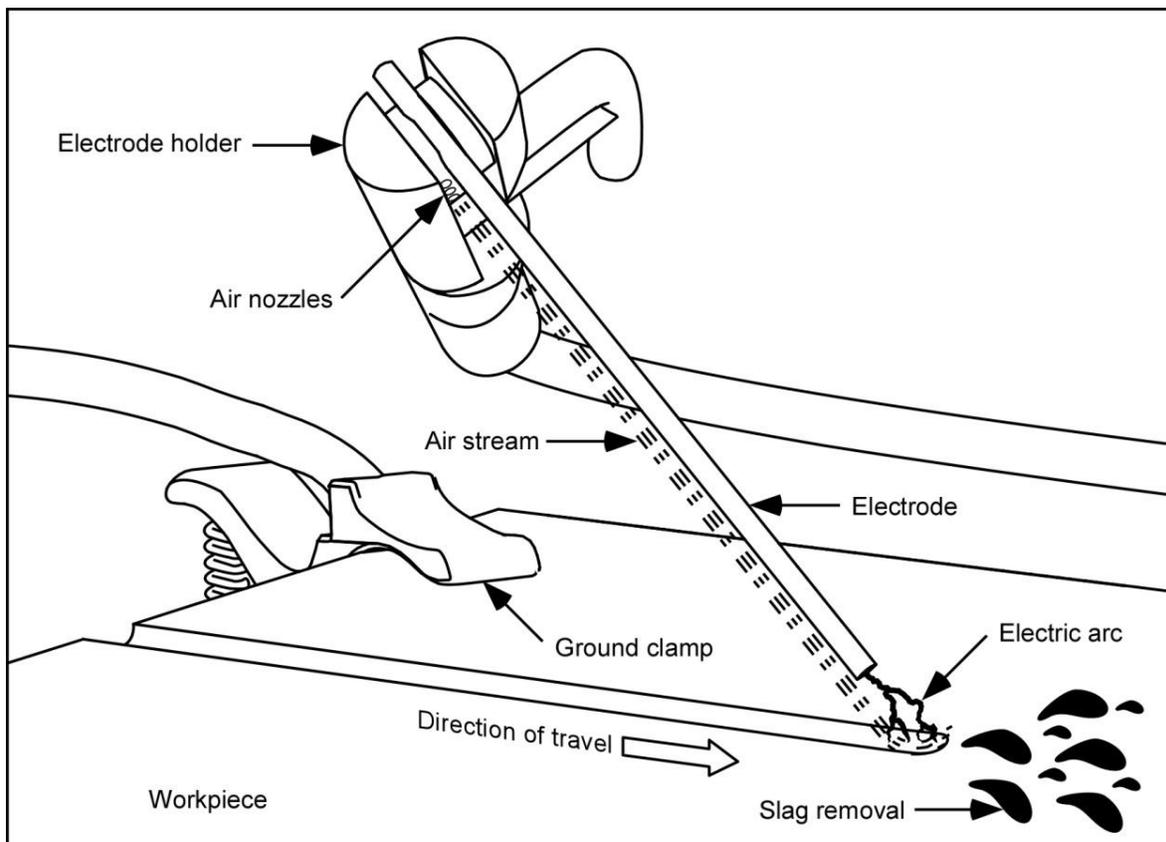


Figure 1: Schematic illustrating the manual air carbon arc cutting and gouging process.

The relative contribution of the arc and the air jet, as well as any interaction between them, will have implications for determining which noise control applications will be most effective. In particular, an interaction effect where the individual noise contributions of air and arc are not simply additive would indicate a potential opportunity for reducing overall noise without reducing airflow or the cutting effectiveness of the arc. An earlier study⁸ in 1980 by Kennedy, et al. of the sound pressures recorded 4 ft from the gouging tool discovered a potential interaction effect between the arc and the air, so the objective of the current study was to confirm the interaction effect and determine whether it can be diminished by redirecting the air jet.

2. EXPERIMENTAL SETUP

A test stand using an automated gouger was constructed, as shown in Figure 2, to ensure greater consistency of the test data than possible with the use of manual gouging. The gouger was mounted to a remote-controlled movable carriage which allowed for linear gouges at a constant set speed. For this testing, the carriage speed was kept constant at 76 cm/min, which was observed through prior investigations to be at the upper range of human gouging speed. The carriage and the test plates were affixed to a table. Standard test plates (1.27 cm × 15.24 cm × 122 cm) were used for each run. The test plates were made of SAE low-carbon steel because this type of steel is representative of the majority of mild steel that is gouged in the field. Electricity was supplied to the system by a Miller Dimension Series 652 power supply, which was set to 500 +/- 25 A in constant-current mode for all testing.

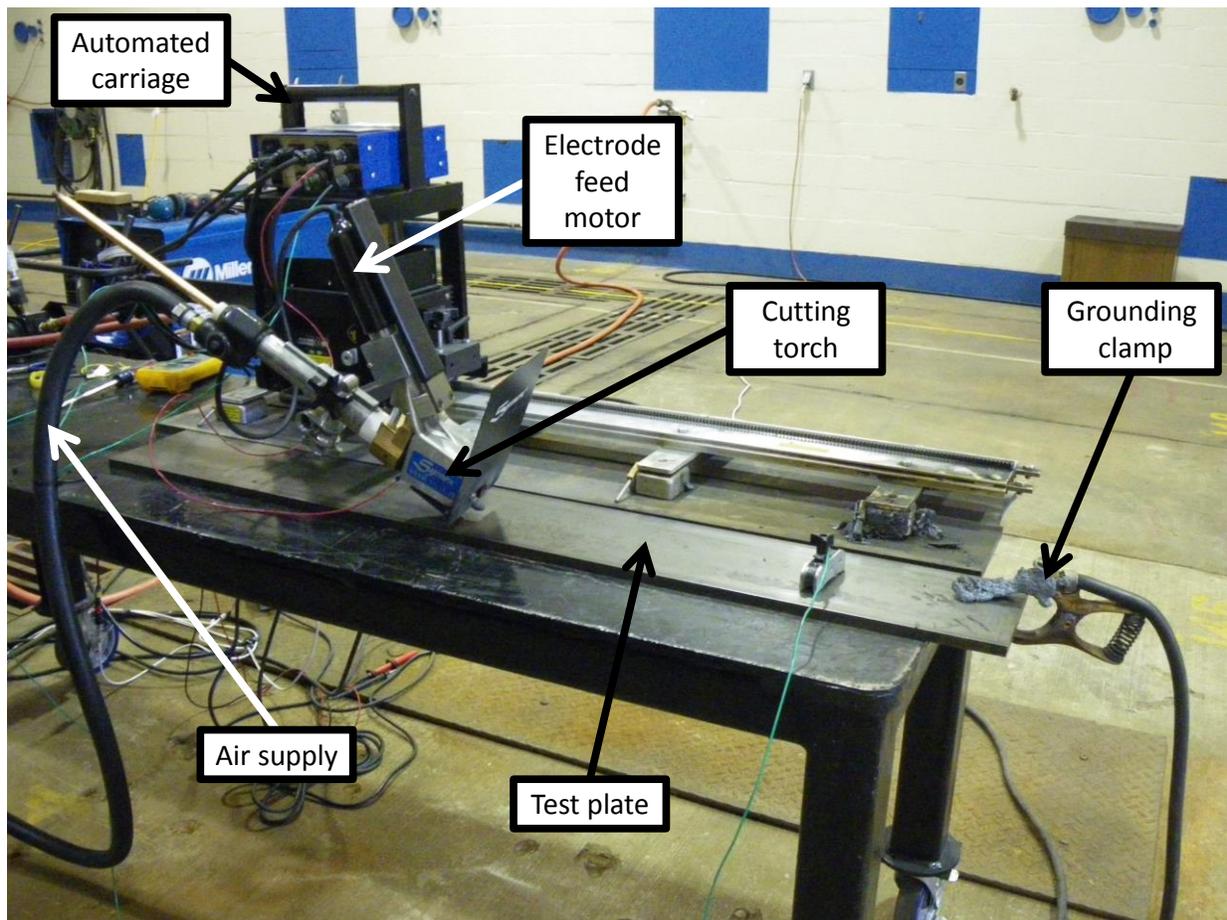


Figure 2: Test stand used for air carbon arc gouging experiments.

The automated gouger is responsible for controlling the electrode feed in order to maintain an electric arc between the electrode and the workpiece, the standardized test plate. The electrode feed controller was an off-the-shelf C.H. Symington Symex Automatic Star-Trac II Model 68881 unit, and was set to maintain the process voltage at 40 volts for all testing. The Symington unit senses the voltage drop across the arc and regulates the electrode feed rate to maintain a constant current.

Electrode parameters were another important factor to consider for ensuring test repeatability and validity of results. Round copper-coated carbon electrodes were used for all testing because these are the most commonly used in the field, and 1.27-cm-diameter electrodes

were chosen because they are commonly used for mining applications. An angle of 30° from the horizontal test plate was maintained consistently throughout the testing. Welders typically use an angle between 30 and 45 degrees when performing gouging. The air nozzle distance from the plate was kept constant at 7.6 cm, measured from the center of the nozzle exit to the plate along the angle of the nozzle.

The test stand also included instrumentation for measuring several operating parameters. Current was sensed with an amperage clamp placed around the positive line leading from the welding power supply. Voltage was measured between the electrified gouging torch and the test plate with a 30:1 voltage divider which fed the signal into the test data acquisition system. An air pressure sensor and an airflow meter were placed just upstream of the air supply to the cutting torch to monitor system pressure and airflow. For most testing, pressure was kept at a typical shop air pressure of 827 kPa with a tolerance of +/- 28 kPa. For comparison purposes, measurements of configurations with nozzle dimensions that varied from the stock air delivery system were run at the same airflow rate as the baseline system at 827 kPa.

Airflow direction and electrode rod angle were the main variables in this study. The airflow and electric arc were independently turned off and on to determine their effects on the overall sound power that was generated. Airflow direction was varied using an auxiliary air nozzle to redirect the flow.

Sound power level tests were conducted per ISO-3743-2⁹ in a test chamber¹⁰ that was accredited by the National Voluntary Laboratory Accreditation Program (NVLAP) to ISO3741/ANSI S12.51¹¹. The test stand was placed in the center of the test chamber. Data were simultaneously recorded from 15 microphones arranged in a random distribution¹⁰. At least three 30-second recordings were made for each test condition until there were three measurements within 1 dB, and the resulting measurements were logarithmically averaged.

3. RESULTS AND DISCUSSION

A. Air-arc interaction

Our initial finding was that there is a significant interaction between the electric arc and the air jet in the gouging process. Table 1 shows results of our initial testing to determine the contributions of the two main noise sources in the gouging process—the electric arc and the air. All measurements were taken at 500 A, 40 V, and 827 kPa. As can be seen from Table 1, each noise source produces on its own a sound power of 112 dB(A). Theoretically, if these sources were independent, they would add up to 115 dB(A)¹². However, the measured sound power level when these sources are combined during normal gouging operation is 124 dB(A)—which means there is an air-arc interaction that increases sound power by 9 dB above the expected level. The finding that the air-arc interaction generates significant noise in the gouging system is consistent with results found by Kennedy et al. in 1980⁸. Although their sound pressure measurements show a diminished role for the arc noise on its own, the authors' study showed equal contributions of both arc and air sources through the use of sound power measurements.

Table 1: A-weighted sound power level comparison of gouging noise sources and operating levels, expected and measured.

Test Conditions	Sound Power Level, dB(A)
Air only	112
Arc only	112
Theoretical combination, independent sources	115
Measured level, combined sources	124

B. Interfering with the air-arc interaction

After determining that the greatest noise source in the gouging system is in fact the interaction between the arc and the air, the next step was to determine if this effect could be diminished. To accomplish this, a simple proof-of-concept test was performed to redirect the airflow at 45 and 90 degrees to the direction of travel of the cutting torch. The 90° nozzle configuration is shown in Figure 3. The nozzle was still aimed at the tip of the electrode at an angle 30° from the horizontal plane of the plate, and the nozzle tip was located 7.6 cm away from the plate along the angle of the nozzle, as in the baseline configuration. An auxiliary compressor was connected to the baseline nozzle to provide 97 kPa of air to cool the torch enough to prevent damage, per the manufacturer's recommendations. All measurements were taken in constant current mode at 500 A and 40 V. Because the auxiliary nozzle used for this testing was a different style and size from the baseline nozzle, the auxiliary configuration was set to match the airflow in the baseline system for comparison.



Figure 3: Auxiliary nozzle configuration, rotated 90° with respect to the gouging direction.

As can be seen in Table 2, the 45° auxiliary nozzle configuration reduces sound power by 4 dB when operated at the same airflow as the baseline nozzle configuration, and the 90° configuration reduces sound power by 6 dB. These results signify that it is possible to disrupt the air-arc interaction. However, rotating the airflow with respect to the gouge direction blows the slag across the gouge rather than out of it, allowing it to cool and solidify within the gouge. This results in a much shallower gouge than normal gouging and produces excess slag on the sides of the gouge. If a clean gouge is required, the excess slag would need to be removed later by grinding, chiseling, or some other additional procedure. Photographs of the resulting gouges are shown in Figure 4.

Table 2: A-weighted sound power level comparison of gouging system, baseline versus 45° and 90° auxiliary nozzle configurations.

Test Conditions	Sound Power Level, dB(A)
Baseline gouging system, 827 kPa, 1.26 m ³ /min	124
45° auxiliary nozzle, 1.26 m ³ /min	120
90° auxiliary nozzle, 1.26 m ³ /min	118



Figure 4: Visual comparison of resulting gouges from baseline and 90 degree auxiliary nozzle configurations.

4. CONCLUSIONS

There is a significant interaction between the individual noise sources of the air and the electric arc in the air carbon arc cutting and gouging process, as evidenced by the 9-dB difference in sound power level between regular gouging operation and the theoretical sum of each sound source measured alone. The data show that simply redirecting the airflow with respect to the direction of gouging can reduce the air-arc interaction sound power by as much as 6 dB. However, this is not a practical noise control solution for the gouging system because directing the airflow across the gouge results in a shallower gouge and leaves undesirable excess slag along the side of the gouge. Future studies need to investigate other possible orientations that will evacuate slag. These could include various nozzle types, orientations, quantities of nozzles and placements of nozzles.

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