Development of Robotic GMAW Workcell for Fabrication of Ti6Al-4V Machine Gun Receivers

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Introduction

The US Army is developing and fielding a number of vehicle and armament systems that use titanium. Due to the intent to transform the Army into a lighter, more transportable force, Army Research and Development facilities have incorporated titanium into the structure of many designs. The M240 machine gun is a 7.62mm gas operated machine gun that currently uses a riveted steel design for the weapon receiver. The total weapon weight of the steel design is 27 lbs. Designers have determined that by using Ti6Al-4V (Grade 5) titanium in the receiver, the total weapon weight could be reduced to 22 lbs—a total weight savings of 5 lbs. In order to implement this design change successfully in a high volume production environment and at an acceptable production cost, the titanium receiver would have to be welded by a robotic workcell. In order to accomplish this goal, a number of welding issues needed to be addressed, to include: development of titanium GMAW-P welding parameters, torch gas and secondary gas shielding issues, and wire feeding issues.

Procedure

The design of the titanium receiver uses slot and tang in slot types welds. Welds were grouped into three representative categories for weld process development, based upon unique weld joint geometries. Once welds were grouped, welding parameters were established for each weld type. The process of developing parameters began first with trading off wire diameter—0.035" or 0.045"—in bead on plate and test slot welds. After some exploratory work, 0.035" wire was selected for full weld parameter development. Weld parameters were first developed using bead on plate in order to establish acceptable arc conditions and weld penetration. Once an acceptable arc was established, test welds were performed in test slot configurations, measuring 25 mm long, with a 3mm root opening, and 45 degree chamfer in 3mm plate. Metallographic testing was performed to assess weld penetration and sidewall fusion. Once parameters were established, these were used to weld two prototype weapons having exact weld geometries of the actual receiver.

Lincoln Electric's WaveDesigner Software was used in the weld parameter development and was used to address welding parameters in the Lincoln PowerWave 455R welding power supply. Welding was accomplished using the Lincoln Electric 120iLT Gantry-mounted robotic welding system, modified to include a Binzel push/pull wire feed system, rotary wire straightener, and Linde ST-12 welding torch. Backing inert gas shielding was provided for welds where accessible.

Results

Basic weld parameters developed under this program are shown in table 1. These parameters were successfully used in all three categories of weld geometries, at varying linear weld travel speeds. Figure 1 shows a typical external weld profile. Figure 2 shows a typical weld cross section (cut, mounted, polished, and etched in Kroll's etchant).

Table 1 - Basic Welding Parameters

Wire Feed Speed = 235 IPM
Peak Current = 220 A
Step Off Current = 73 A
Background Current = 55 A
Peak Time = 1.0 ms
Background Time = 2.7 ms
Frequency = 200 PPS

Linear Travel Speed: 10-15 IPM
Torch Angle: 5 degrees push
Contact tip to Work Distance: ¾"
Shielding Gas: 75%Ar/25%He

In addition to metallurgical analysis of the welds, the welds were subjected to chemical analysis for interstitial composition. Analysis for oxygen, nitrogen, hydrogen, and carbon was conducted to assess adequacy of shielding gas coverage. Weld metal analysis indicated that interstitial element composition was below that of the base metal.

Figure 1

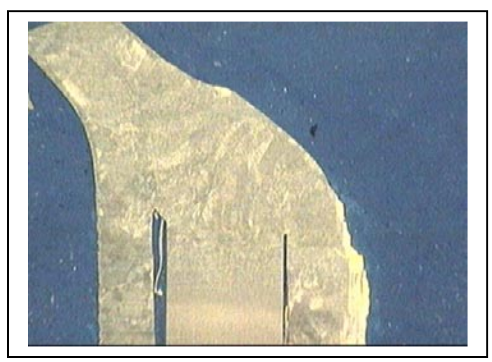

Figure 2

Discussion

Initial welding trials indicated that wire feeding was inadequate with equipment set-up as supplied by the manufacturer. Originally, no push/pull gun and no wire straightener were used. This resulted in a number of wire feed problems, particularly when using 0.035" diameter welding wire. The original torch supplied by Binzel was also determined to provide inadequate torch gas shielding for the welding of titanium. Therefore, a push/pull wire feed system, rotary wire straightener, and Linde ST-12 torch were added to the system. Addition of these features improved wire feeding, presentation of the wire to the weld joint, and overall weld shielding.

Since there are no baseline parameters for the GMAW-P welding of titanium, the goal was to develop functional parameters for the successful welding of prototype weapons for testing. The parameters developed under this program are considered are adequate for such a purpose, but more development is required to create a robust set of parameters for production and for commercialization of this welding technology. At the time of publication of this abstract, two functional weapon prototypes have been welded for firing testing. Weld process optimization will continue with the goal of creating a robust parameter set for production.

Conclusion

Two functional titanium 6Al-4V machine gun receivers were welded using a robotic welding workcell. Weld parameters were validated through metallurgical and chemical testing and the welds were found to be adequate for further weapon firing tests. ARDEC plans to further refine welding parameters for future prototype weapons and plans to implement a robust production process for the manufacture of titanium receivers pending successful firing testing of initial prototypes.