C. The Humping Phenomenon in High Speed GMA Welds

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Introduction

During high speed welding, the formation of humped weld bead profiles prevents users from achieving higher welding speeds in various fusion welding processes. The physical mechanism responsible for the formation of a humped weld is not well understood. As a result, many previous efforts to eliminate or suppress humping in various welding processes have been based largely on trial and error. In this investigation, the formation of humped Gas Metal Arc (GMA) welds was observed over a wide range of process conditions. Based on these observations, a phenomenological model of humping has been formulated and experimentally validated.

Procedure

To observe the sequence of events taking place during the formation of a humped GMA weld, a Laser Strobe Video system was used to obtain a clear view of the weld pool and the molten weld metal without the adverse interference from the welding arc. For the validation experiments, bead-on-plate welds were produced on 6.5 mm (¼″) thick cold-rolled mild steel plates with 22 mm contact-tip-to-work distance, 0.9 mm (0.035″) diameter ER70S6 wire, three different shielding gases (Argon, Mig Mix Gold™ and TIME™ gases), three welding positions (10° uphill, flat and 10° downhill) and three power levels (7.5 kW, 9 kW and 11 kW). These welds were made by a robotic GMA welding system using a wide range of preset welding speeds. For each set of process parameters, the maximum welding speed that produced a good weld bead was recorded.

Results and Discussion

During high-speed GMA welding experiments, when humping occurred, the weld pool surface was depressed by a combination of arc forces and the impinging stream of molten metal from the filler wire. The melted base metal and molten filler wire in the arc gouged weld pool was displaced along the fusion boundary from the leading edge toward the tail of the weld pool within a confined flow stream or wall jet. At the tail of the weld pool, the displaced molten metal accumulated forming a swelling (i.e., a hump), which was stationary relative to the workpiece. Meanwhile, the welding arc continued to move forward at the preset welding speed. As a result, the wall jet was elongated over an ever increasing distance between the welding arc and the swelling. Because of the smaller dimensions and thermal mass, the wall jet prematurely solidified and thereby choked off further backward flow of molten weld metal. This resulted in the formation of a hump and was followed soon after by the initiation and the growth of a new hump.

Based on the video images, without a strong backward momentum, the molten weld metal in the weld pool would not be able to flow and accumulate very far from the welding arc and thus humping would not occur. Therefore, the backward momentum of the molten weld metal is thought to be the physical mechanism responsible for the humping phenomenon. To validate this hypothesis, various shielding gases and welding positions were used as means to dissipate the backward momentum of the molten weld metal. From the experimental results, downhill welding allowed higher welding speeds than the flat position. In turn, higher welding speeds were possible in the flat welding position than uphill welding position. With downhill welding, the molten weld metal must work against gravity while flowing toward the back of the weld pool. As a result, the backward momentum of molten weld metal is reduced by gravitational force and thus higher welding speeds are possible as indicated by the experimental results.

For welds produced with Mig Mix Gold™ and TIME™ shielding gases, the weld bead profile was flatter and wider than those produced using Argon. For these welds, the area in which the molten filler metal droplets entered the weld pool was much smaller than the weld width. Thus, a larger portion of the molten weld metal must flow laterally towards the sides rather than towards the tail of the weld pool. As well, these welds had a larger liquid to solid interface than those produced using pure Argon. The larger liquid/solid interface provided extra viscous drag that further reduced the backward momentum of the molten weld metal. The lateral flow of molten weld metal and the extra viscous drag reduce the overall backward momentum of molten weld metal thereby allowing higher welding speeds when using the active shielding gases.

Conclusion

The humping phenomenon is caused by the strong backward momentum of the molten weld metal. To achieve higher welding speeds, the backward momentum of molten weld metal must be slowed down by changing controlling variables such as shielding gas and welding position.