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Proper Bead Sequencing for GMAW Additive Manufacturing

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Background

Gas Metal Arc Welding or GMAW often referred to as MIG welding, is a fast, user-friendly, multipurpose welding process suitable for new and experienced welders. It is an electric arc welding process that uses a continuously fed wire consumable electrode and shielding gas to protect the weld pool from contamination. With its versatility, it can be used across many metals with different thicknesses and in multiple positions.

All of these factors make GMAW a good choice for automated or robotic manufacturing processes, like additive manufacturing.

Additive Manufacturing (AM) with welding can also be referred to as 3-D printing with metal. It uses an industrial welding process and robot arms to deposit metal layer-by-layer to build, repair, or add features to metal components. The growing industry of additive manufacturing creates a pathway for new research involving metal alloy behavior, base metal and weld heat control, and how we can use this process to better other industries. AM is still so new and has many fine tuning issues that need to be covered. One of them being how weld bead layers should be ordered and what paths they should each have.

In our research of **GMAW Additive Manufacturing** we used a Lincoln Electric E-Cell robotic welder, with a travel speed of 10 in/min, a wire speed of 255 and the trim setting set to 1.01. The wire we used was 0.035" L-56 SuperArc and a FANUC ARC Mate 100i BE robot arm.

Motivation

We have pursued this topic of Proper Bead Sequencing for GMAW Additive Manufacturing to see how different welding sequences or toolpaths can affect the overall soundness of a weldment.

Objectives & Approach

-See how different welding sequences can affect the overall soundness of a one inch thick weldment made with **Additive Manufacturing**.

-To make our at home testing as similar to the experiment at OSU as possible, we made 4 toolpaths on draftsight for our robot to follow.

-After running all 4 toolpaths on the robot, we took the weldment to the bandsaw to cut it into smaller slivers for macro etching.

-We figured that macro etching would be the best way to test the weldment since we were wanting to see results of how much penetration and cold lapping could be between each layer.

-To know we have the proper bead sequencing, we looked at 5 main elements; weld height, weld speed, ending craters, start spots, and how flat each layer was after welding.

Conclusions

After observing both completed samples the second was more sound with more consistent measurements. The first had multiple spots of cold lapping throughout the diagonal layers, whereas the second only had one. We know that using the diagonal toolpaths just lead to overheating in opposite corners, so straight lines seem to work best. Having lines running in 2 directions works best in all factors especially heat input and consistency.

Future Work

After finishing our studies and looking over the final results, we could see that heat and wire input are major factors in this process. Too much of either can cause the whole weldment to fail, even just from a few small welds. If we were to run this experiment again we would focus more on starting colder and slowing the program down more to allow for small spurts of cooling throughout the layers.

Results & Discussion

Figure 1.1 Toolpath 1

Figure 1.2 Toolpath 2

Figure 1.3 Toolpath 3

Figure 1.4 Toolpath 4

Figure 1.1 is the first toolpath made with the robot. It is made up of many paths following the robot's Y-axis, along with two border passes to make sure the walls of the weldment are built up. Each pass within each layer is 0.1455" apart to allow for enough overlay on the beads.

Figure 1.2 is the second toolpath, this layer follows the robot's X-axis. Throughout this welding process we chose to start each layer when the weldment had reached around a 200 degree mark. This meant we would need to preheat at points in the experiment or let the weldment cool after welding. **Figure 1.3** is the third toolpath, it is made in diagonals starting in the bottom right corner and working towards the top left corner. This layer helped us to be more aware of the high heat input that the end of the diagonal paths were creating. After this layer, we decided to do some editing in our fourth tool path **Figure 1.4**. We changed the order of where the border would start and end, along with changing the amount of wire we were putting into each layer. The first border and internal passes of the first three paths were all at 255WFS and 10in/min travel speed. The last pass was made at 220 WFS and 10in/min. on each layer the second border was made at 200 WFS and 10in/min. This first experiment did not look the way we wanted after internal investigation, so we decided to do a second one with only toolpaths 1 and 2.