Engineering: Summer in Germany-Darmstadt

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INTRODUCTION

The objective of this research project was to design, model, and manufacture a 1.7m column made of 3d printed steel that would support a large monitor. The column had to be both structurally stable and aesthetically pleasing. Side investigations included model optimization, tensile tests of 3D printed steel, and welding parameterization.

BASICS OF COLD METAL TRANSFER

The robot used for testing and printing had a functioning Cold Metal Transfer (CMT) system. CMT involves a work piece and a welding torch that are apart of the same electrical circuit. A filler wire is fed through the welding gun and heated via generous amounts of amperage. A droplet forms, and the residual heat melts the work piece so fusion can occur. CMT improves on prior methods by recognizing that when the current approaches zero, the droplet has come in contact with the weld pool. It then extinguishes the arc, retracts the electrode and moves foreword many times per second [Figure 1].

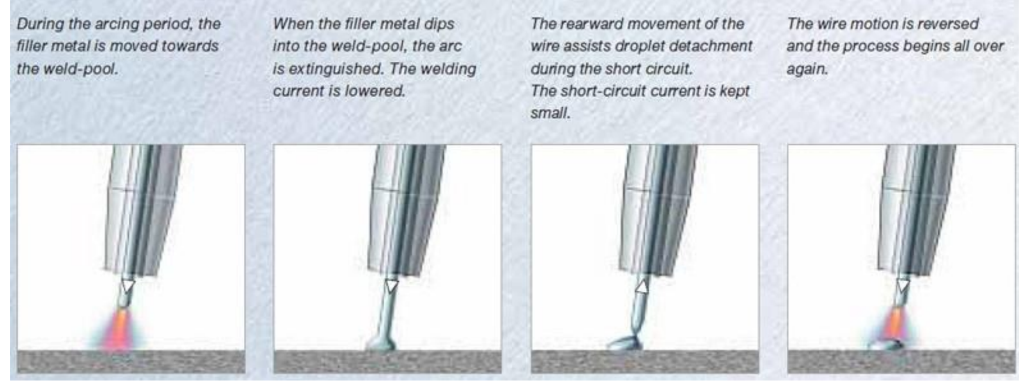
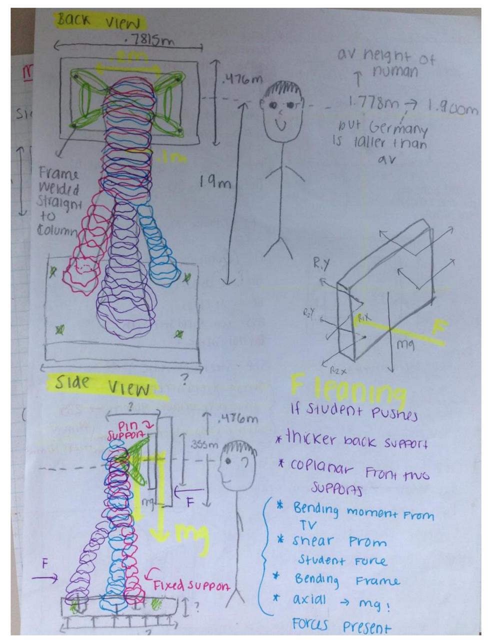


Figure 1: CMT Process
www.digitalweldingsolutions.com/CMT.pdf

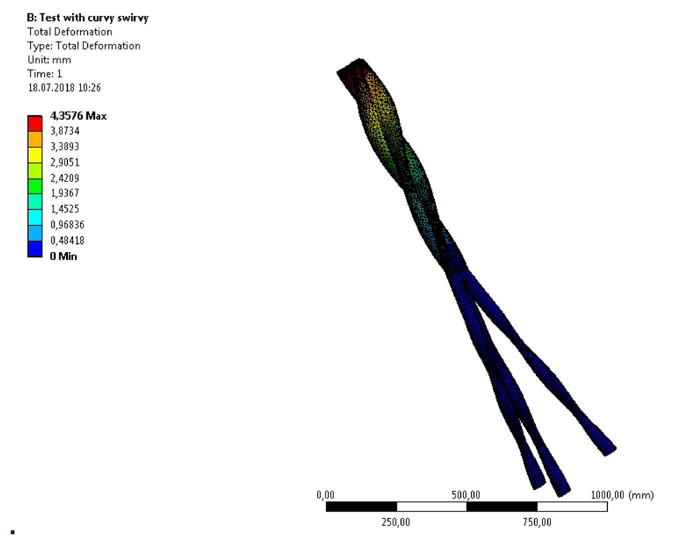
Extinguishing the arc has many advantages. There is more control of the process and less material splatter. This results in prints as thin as .3mm, with a lower porosity than alternative welding methods (www.sciencedirect.com/science/article/pii/S2214914717301022). CMT welding also uses less shielding gas, and has a higher success rate welding different materials together.

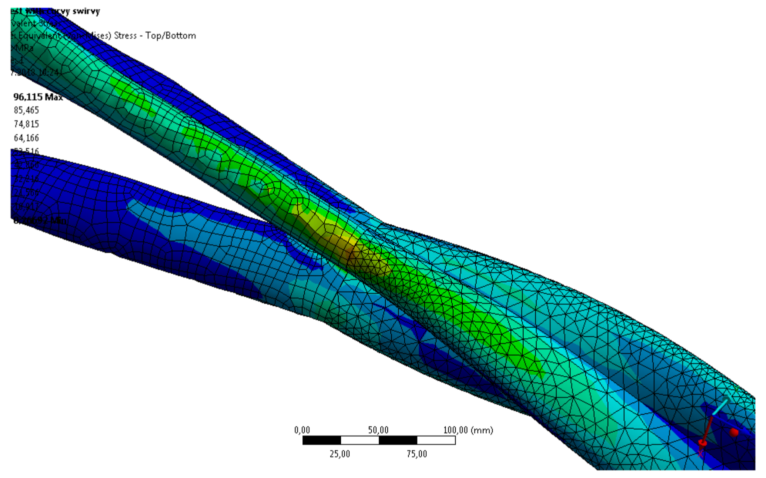
MODEL OPTIMIZATION



The first step was sketching a design and basic computations. The calculations included expected mass and bending moments from somebody 'leaning' on the monitor.

The second step involved parameterization in both Matlab and Grasshopper so that many iterations of Rhino models could be made. In this stage designs were eliminated based on aesthetics and base plate limitations. Any angle of convergence more than 10 degrees was determined unrealistic.

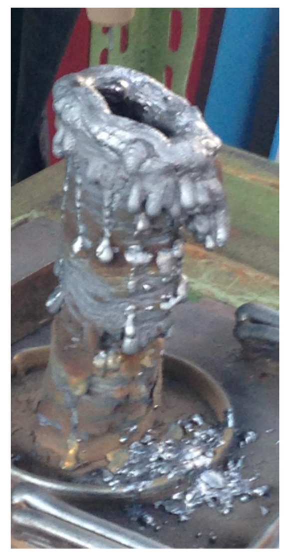


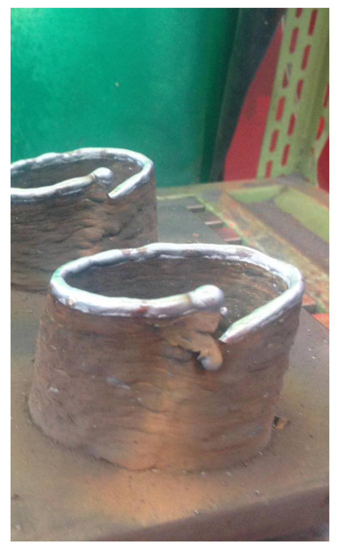


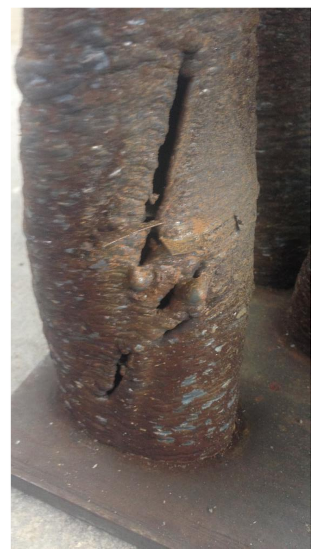
The third step involved putting dozens of designs into ANSYS Workbench 18.2 for finite element analysis. The designs were altered to reduce maximum deformation until below 5mm. This was done by increasing the radii of the ellipses, and coding the converged clover to grow with increasing length. The most location with the highest stress was the convergence point. This proved to be nerve racking because it is by far the most difficult section to manufacture.

TESTING

The average yield stress was 329 Mpa, and the test demonstrated a high porosity.

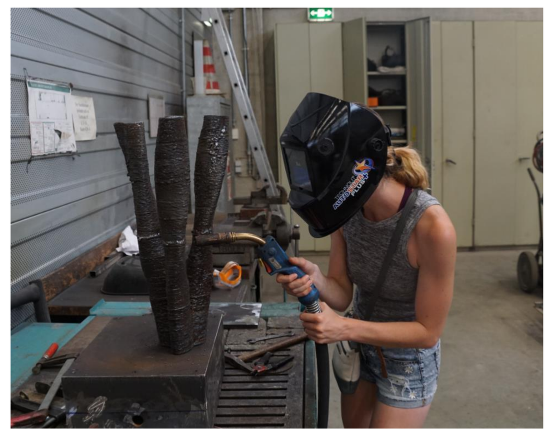






The success of the CMT welding process is dependent on numerous welding parameters such as wire size, wire feed rate, welding speed, choice of shielding gas, shielding gas flow rate, power, arc length, and torch position. Both the wire size and the shielding gas choice were constant because there was only one type available. The wire diameter was 1.2 mm and it was made out of steel. The shielding gas was Arcox 18, which is 82% Argon and 18% carbon dioxide. When welding steel, it is important to have an active gas like carbon dioxide. Other parameters--like shielding gas flow rate, power, arc length, and torch position--were kept constant to keep from complicating the experiment. The shielding gas flow rate was 11 L/min, the power was 1.0 Watts, the arc length was 2.0 units*, and the torch position was vertical. Wire feed speed (layer thickness) and welding speed were varied to observe print quality. The second test was still speed variation; however, this time the location of the speed shift was also studied. Changing speeds leads to uneven layers, which eventually results in the wire electrode being both too close and too far in one cycle. It proved beneficial to print at 330 mm/min and make minimal changes. The third test studied changing the layer thickness by changing the wire feed speed at a constant welding speed of 330 mm/min. The layer thickness started at 1.2mm and was increased to 1.5mm. The piece experienced material overflow because the thicker layer had nowhere to go when printed onto the thinner layers. The next test corrected this process by instead changing the layer thickness .1mm at a time. The final test on a single ellipse was done with a wire feed rate of 2.6 m/min, layer thickness of 1.4mm, and welding speed of 330 mm/min. It was successful until roughly 25 cm where the heat of the piece built up and the top melted. Single ellipse tests, while not a perfect representation of the final design, were useful for understanding the effects of changing certain printing parameters.

RESULTS AND ERRORS



After testing welding parameters, it was determined that the final project had to be printed in pieces. There was far too much variability to confidentially print all 1.7m at once. The manufacturing process chosen was breaking the design into four printed components; each printed on their own baseplate. The pieces were then sawed off and hand welded together. This is not only more applicable to real-world large scale metal printing, but saved hundreds of euro in baseplates because it was not damaged during the cutting process. The errors that may have occurred during the final print are due to coding limitations within the printer.

CONCLUSIONS

3D printing may be the way of the future, but because of the large amount of time it takes to print, it will most likely remain on a small scale. This summer's research concluded that even the best printers cannot match the speed of mainstream manufactured steel; however, 3D printing steel is great for smaller projects.

ACKNOWLEDGEMENTS

I would like to thank The Technical University of Darmstadt, my head supervisor Michael Drass, and my secondary supervisor Chris Costanzi. Without them I would not have been able to explore so many aspects of Engineering design.

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