Dissimilar GTAW Stainless Steel Welding

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Introduction

- Failure occurs in a tube-to-sheet weld that joins the heat exchange tube and the walls of commercial grade fryers.
- The large Coefficient of Thermal Expansion (CTE) of SS 304 causes enough stress to induce fatigue cracking during the high temperature cycles seen during service.
- SS 17-4 PH has been chosen as a replacement material for the heat exchange tube by the Henny Penny Corporation. It was chosen because it has a significantly smaller CTE and therefore greatly reduces the stress on the joint.

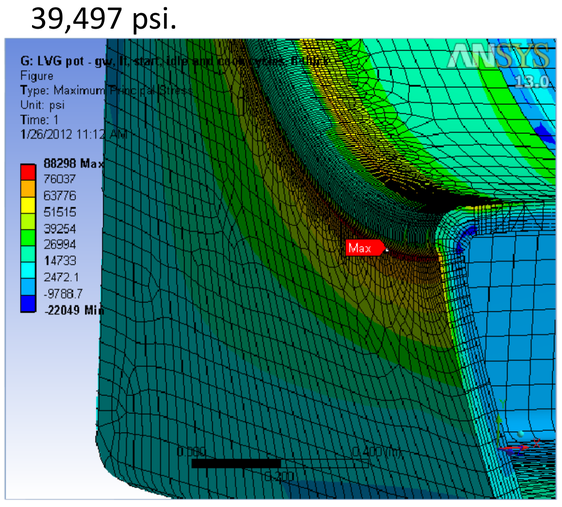
Material	Temperature Range (°F)	Mean Coefficient of Thermal Expansion (in/in/°F)
SS 304	32 - 1000	10.2×10^{-6}
SS 17-4 PH	70 - 800	6.3×10^{-6}

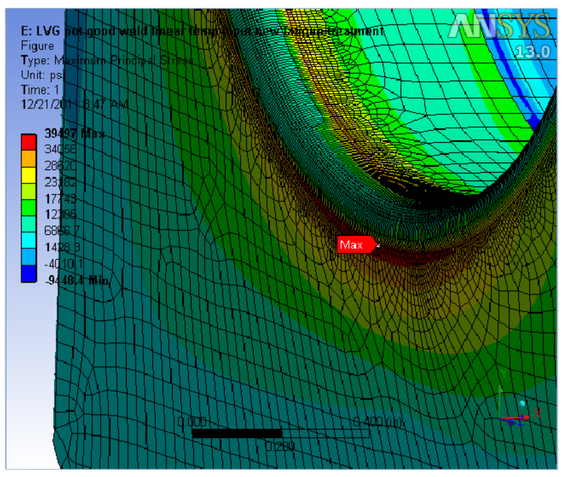
Objectives

- Optimize weld parameters and establish process windows to create sufficient welds for several combinations of SS 304, SS 17-4 PH, and SS 201.
- Evaluate the welded samples visually and with optical micrographs to ensure proper penetration, fusion and microstructure.
- Compile tensile testing results for all combinations of materials and compare them to ensure new SS 304 to SS 17-4 PH dissimilar joints provide sufficient strength.
- Consider complications that the dissimilar joint may cause including susceptibility to corrosion.

ANSYS Finite Element Analysis

- The engineering team at the Henny Penny Corporation completed FEA that supports that the replacement of SS 304 with SS 17-4 PH reduces the stress in the joint.
- The results showed that the stress in the joint can be reduced from 88,298 psi to 39,497 psi.





Welding Trials

- Welding Trials were completed using a GTAW Side beam welder with an automatic wire feeder.
- A fixture, similar to the ones used in manufacturing, was used to secure the plates during welding and apply backing gas to the welded joints.
- Successful welds with sufficient penetration were completed for all combinations.
- Upper and lower bounds were determined once successful welds were created.

Material 1	Material 2	Filler Material
304	304	316L
304	17-4PH	316L
201	17-4PH	316L
17-4PH	17-4PH	316L

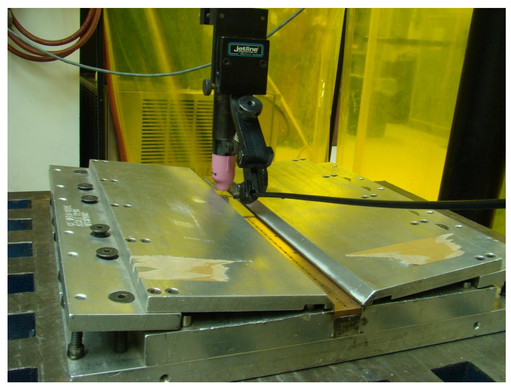


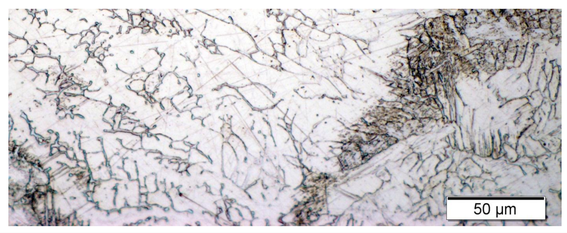
Table of Established Processing Parameters

Ideal Welding Parameters (201 to 17-4 PH)	
Arc Length (Start Gap) (in.)	0.07
Travel Speed (In./min)	3-6
Current (Amps)	90-120
Wire Feed Speed (In./min.)	3-7
Observed Running Voltage (Volts)	11

Ideal Welding Parameters (304 to 17-4 PH)	
Arc Length (Start Gap) (in.)	0.07
Travel Speed (In./min)	3-6
Current (Amps)	90-120
Wire Feed Speed (In./min.)	3-7
Observed Running Voltage (Volts)	11

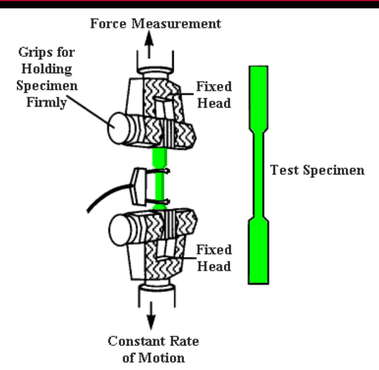
Metallographic Evaluation

- Metallography shows that established welding parameters yield sufficient penetration and complete fusion occurs.
- Solidification mode was determined to be FA (ferrite forms from liquid; some ferrite transforms to austenite) based on skeletal microstructure.



Tensile Testing

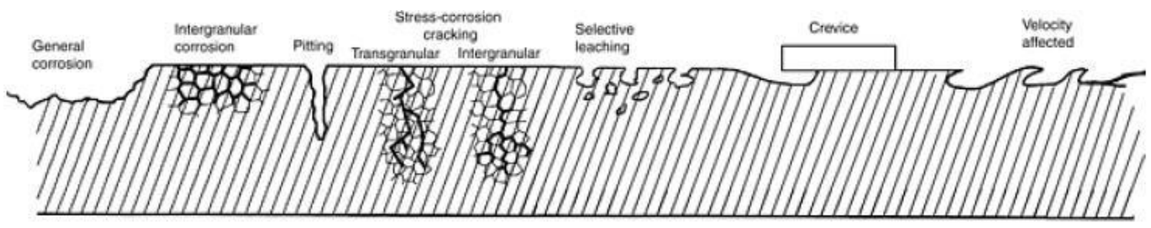
- Tensile Testing results show that new SS 17-4 to SS 304 joint exhibits comparable strength to the current SS 304 to SS 304 joint.
- The comparable strengths provide validation that the new material combination will provide sufficient strength in service.



	304 to 304		304 to 17-4	
	Weld #1	Weld #2	Weld #1	Weld #2
Elongation (%)	40	32.4	23.9	27.1
YS (psi)	60,000	60,500	64,000	64,500
UTS (psi)	97,000	92,500	96,000	96,000
Failure Location	HAZ 304	HAZ 304	BM 304	BM 304

Corrosion Concerns

- Corrosion is a concern due to the harsh chemicals that are used to clean the fryers throughout their life cycle.



- The SS 304 components that are currently used have no issues with corrosion.
- Based on an Oxalic Acid Etch Test per ASTM A262-10, the corrosion resistance of SS 17-4 PH is comparable to that of SS 304.
- The Oxalic Acid Test is not a conclusive corrosion test for 17-4 PH because its ability to test the corrosion resistance of martensitic stainless steels has been questioned in previous literature.

Oxalic Acid Etch Test of SS 304 – SS 304

Oxalic Acid Etch Test of SS 304-SS 17 - 4 PH

Conclusion

The results and investigation show that SS 17-4 PH can be successfully used to replace SS 304 for the heat exchanger tube in commercial grade kitchen fryers. SS 17-4 PH demonstrates similar welded characteristics as SS 304 while reducing the cyclical stresses on the system by more than half. While the final results for the tensile strength of the weld joints have not been completed, the researchers are optimistic that the SS 17-4 PH to SS 304 welds will demonstrate similar or better strength then the current SS 304 to SS 304.

Future Work

- Complete more invasive corrosion testing and compare the corrosion resistance of SS 17-4 PH to SS 304.

Acknowledgements

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