STAINLESS FOUNDRY & ENGINEERING, INC.

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Case Study of Water Quench vs. 13-Bar Nitrogen Vacuum Quench Jeanne Wagner 2017 SFSA T&O Background

Over the years Stainless has utilized vacuum heat treatment for investment castings to preserve the surface finish. Within the past 10 years, we have also utilized vacuum post weld heat treatment for weld repairs done on a machined castings to preserve the surface finish and the dimensional tolerances.

We had been hesitant to utilize vacuum heat treatment on the super austenitic castings, duplex, and nickel based castings because of concerns over cooling rate. We had experienced some corrosion test failures on some CN3MN castings. However, we found a heat treater that utilized a 13-bar nitrogen quench—this quench in conjunction with changing the solution annealing temperature, based on Professor DuPont's work, remedied the problem. In determining if we were capable of meeting NORSOK requirements for CE3MN in a 5 inch section thickness, we cast a 5 inch diameter x 13 inch tall bar and vacuum solution annealed the casting. We did tensile and charpy testing at the center of the bar (1/2T) and obtained passing results.

New Opportunity

With this history, when we were approached to make a 36" diameter washer-like brake disc casting out of a high strength low alloy steel. We turned to vacuum heat treating with a 13 bar quench to obtain the properties and limit distortion. Listed below are the chemical and mechanical requirements.

Element	Spec Range	Mechanical Property	Spec Minimums
C	0.22 – 0.27	UTS	1050 MPa min
Si	0.30 – 0.60	YS	900 MPa min
Mn	0.90 – 1.20	EL	8% min
P	0.015 max	Charpy @ -20C	27 J
S	0.015 max	Hardness	305 HB min
Cr	0.70 – 1.10		
Ni	0.90 – 1.30		
Mo	0.50 - 0.70		

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We did some trials to dial in the chemistry and the heat treatment utilizing a water quench and then completed a validation trial using a vacuum quench. The results looked good. We then set out to complete the first article.

The first article did not go as hoped. While the separately cast test bars met properties, the casting failed charpy. We re-heat treated a section in-house, water quenched and tested. We used our small lab furnace and water quenched in a 20 gallon tank. The results were improved, but still a little short on meeting charpy.

Test	Tensile			Hardness	Charpy @-20C			
Testing Spec	DIN EN ISO 10002-1			DIN EN ISO 6506-1	DIN EN ISO 10045-1			
Property	UTS (MPa)	YS (MPa)	EL (%)	HB	CVN-1 (J)	CVN-2 (J)	CVN-3 (J)	CVN (J) Avg
Spec Range	1050 min	900 min	8 min	305 min	27	27	27	27
TB (vac)	1069	993	12.5	339	32	46	37	38
Cast (Vac)	1054	929	9.2	338	23	24	14	20
Cast (WQ)	1097	1013	13.3	346	24	24	35	28

The next step for us was to determine if the specimen location also influenced the mechanical results. We did some additional sectioning and testing of the castings and found some variation in results. Along with the mechanical issues, we were also struggling with the MT requirement. We made some modifications to the rigging, poured 3 more castings, heat treated in vacuum, and completed the first article testing again. The second first article testing went better. The tensile and charpy did pass but did not do as well as the water quenched samples on the first heat.

Test	Tensile				Hardness	Charpy @-20C			
Testing Spec	DIN EN ISO 10002-1				DIN EN ISO 6506-1	DIN EN ISO 10045-1			
Property	UTS (MPa)	YS (MPa)	EL (%)		HB	CVN - 1	CVN-2 (J)	CVN-3 (J)	CVN (Avg
Spec Range	1050 min	900 min	8 min		305 min	27	27	27	27
TB (vac)	1067	1001	12		343	35	42	37	38
Cast (Vac)	1050	930	9		338	30	39	32	34

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Unfortunately the project was not continued because we could not meet the flatness requirement.

A number of months passed and the project was resurrected. We made two heats (6 castings) and tried vacuum quenching one heat and water quenching the other heat.

We only tested the test bars and have not completed first article testing at this time; however, in this instance we had better results with the 13 bar vacuum quench than the water quench.

Test	Tensile			Hardness	Charpy @-20C			
Testing Spec	DIN EN ISO 10002-1			DIN EN ISO 6506-1	DIN EN ISO 10045-1			
Property	UTS (MPa)	YS (MPa)	EL (%)	HB	CVN-1 (J)	CVN-2 (J)	CVN-3 (J)	CVN (J) Avg
Spec Range	1050 min	900 min	8 min	305 min	27	27	27	27
A (WQ)	1051	920	13	343	23	26	27	25
A (Vac)	1113	1012	11	369	34	37	39	37
B (Vac)	1220	1128	11	377	36	35	32	34

The vendor we used for the water quenching was not one that we have used in the past; however, we had visited their facility in the past and were impressed. We observed the quench and saw nothing wrong with it—less than 30 seconds into the tank, lots of agitation (more than our standard vendor). We were very surprised by the results.

In both heat treat methods, the castings and test material are stacked onto a heavy duty grate. Both methods must adequately remove the heat from the test material and the grate.

Conclusion

While the agitation in the commercial quench tank looked adequate enough, it obviously was not enough or not directed to the location of the bars adequately.