

Carondelet Division

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1671

Corrective Action Carondelet Division Corrective Action Type NCR Date 4-10-06 Revised **4-20-06** CA Originator C. Ruud Applies to: A-6 Coil

Description of Defect / Non-Conformance

Test bar from zone 1 failed elongation at -320 F. Result was 20% versus a minimum of 32%. The original set of three bars, Z-1, Z-2 and Z-3 were sent for testing. Z-1 failed for elongation, 26% vs 32% minimum and Z-3 failed for elongation 19% vs 32% minimum. All other results were acceptable. Retests were ordered. The second results were similar. Z-1 failed for elongation, 25% vs 32% minimum and Z-3 failed for elongation 13% vs 32% minimum, but broke outside the gauge length. The third set of bars was tested. Z-3 passed and Z-1 failed for elongation, 20% vs 32% minimum, but broke outside the gauge length. All other test results were acceptable. See attached test reports. A fourth set of 3 test bars were tested. All results were acceptable, but it is believed that they came from zones 1, 2 and 3.

Root Cause See attached report, with attachments.

Corrective Action Use A-6 as is.

Actual Completion Date Completed 4/20/06.

Signed: C. Ruud

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CC: B. Craig, J. Edwards, E.J. Kubick, J. Markham, J. Galaske

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Requirements provided by MetalTek International

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Testing Specialists for Aerospace, Automotive, and Material Testing Fields Locations in Voungstown, PA U.S.A. ~ Tel. (724) 537-3131 and Banbury U.K. ~ Tel. +44 (0) 1295 261211

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April 10, 2006 MetalTak Inte The Carondel B600 Comme	Attantion: Subject:	TENSILE I Requirem SOAK TIM SPEED OI	No. 22	A6 Z3 TENSILE Requirem	SOAK TIP	Coll Specime	A6 Z1	Requirer D - Ruptu месячески симили се меся гид. и на сами на сами и сами

Addendum to CA 1671 Effect of Solidification Microstructure on Tensile Properties of Stellaloy J. Edwards and C. Ruud, MetalTek International

Overview

The development of "Stellaloy" by MetalTek International commenced in 2003 with the modification of the base 316 material primarily for magnetic permeability requirements. Initial results demonstrated that this material is extremely robust mechanically at both ambient and cryogenic temperature ranges. Tensile properties gathered from integrally cast test specimens poured with the modules have shown variability. While most have far exceeded the specification minima, outliers have shown to demonstrate reduced elongation.

Background

Initial tests on the C5 casting showed that the elongation was lower in test bars associated with Zone1 than in other areas of the casting. Repeat tests showed the same result (Table I). Based on this result, the microstructure of the test specimen was examined and characterized compared to other test bars integral to the same modular coil casting. Results are shown in figures Lab report 05M1167, Figures 1, 2 and 3.

Similarly, testing of the A6 casting has shown a lower elongation in the test specimens associated with Zone 1. Testing was repeated in specimens from the same zone with reproducible results (25-26% elongation at 77K), although one test demonstrated a 20% elongation with breakage outside the gauge. Results of this test are shown in Table II and associated microstructures in Figures contained in WMTR#6-26780.

The tensile test variation seems to demonstrate correlation to microstructure with finer grains and heavily dendritic structures showing lower elongation. Other properties are generally well above specification for both samples.

The attached test specimens from the production coils are machined to a 0.350" diameter ("sub size" or SS) bar. The strain rate on the production components is 0.003 in/in/min to yield and 0.05 in/min/in to fracture.

Analysis

The test specimens are attached to metal feeders ("risers") in the modular coil casting mold. The attachment of these test specimens is largely determined by convenience due to accessibility of the feeder and orientation to a natural interface between mold components (cope, drag, and cores). Metal is introduced into the mold through a series of ceramic tubes from any of 3 ladles and mixes naturally upon entry into the mold cavity. Attached test specimens are filled by the molten metal at different temperatures and at different elapsed time from mold filling onset. The combination of elapsed time and geometric location of the attached specimens results in a range of solidification structures based on the superheat of the metal entering the specimen as well as the rate of heat extraction from the metal through the sand wall due to mold temperature surrounding the specimen (Table III). In general, cooler metal temperatures favor multiple nucleation sites while cooler mold temperatures promote nucleation at an accelerated rate on the mold surface. Hotter metal temperatures result in fewer nucleation sites and more growth of individual grains during solidification.

Results

- 1. The properties measured from attached test specimens vary; however, exceed the specification minima in most cases.
- 2. Isolated test bars have shown depressed elongation values of approximately 25-29%. Microstructural analysis of these test bars demonstrate that the microstructure is generally fine grained and may or may not contain heavily dendritic structure.
- 3. Test bar structure is the result of solidification physics of the test material and not associated with physical differences of Zone location.
- 4. Stellaloy continues to test well across a variety of microstructures at both 77K and RT.

Table III	High Metal Temperature	Low Metal Temperature
High Mold Temperature	Little incentive for	Multiple nucleation sites
	nucleation and low	within material, but little
	thermal gradients.	thermal gradient to mold.
	Large columnar grains.	Creates finely dispersed
		equiaxed structure within
		metal with little
		correlation to mold wall.
Low Mold Temperature	Strong dendritic structure	Multiple nucleation sites
	with multiple mold	with primary sites on
	surface nucleation sites.	mold walls.
	Relatively "fine"	Intraspecimen nucleation
	appearance of closely	as solidification
	spaced dendrites.	progresses. Broken
		dendritic with equiaxed.

April 19, 2006	
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Telephone: 724-537-3131 Westmoreland Mechanical Testing & Research, Inc. P.O. Box 388 Youngstown, Pa. 15696-0388 U.S.A. Westmoreland Drive Fax: 724-537-3151

WMTER is a technical leader in the material testing industry. Website: www.wmtr.com

CERTIFICATION

WMT&R Report No. 6-27410 P.O. No. 19386 Requisition No. 7580

Section 1 of 1

621-014 621-02

Madcap iterials Testing Labora

The Carondelet Division 1-55 Industrial Park 8600 Commercial Blvd. MetalTek International Pevely, MO 63070-1528

Attention: Jim Galaske

Subject:

All processes, performed upon the material as received, were conducted at WMT&R, Inc. in accordance with the WMT&R Quality Assurance Manual, Rev. 9, dated 4/1/2000. The following tests were performed on this order: MICRO and TENSILE

TENSILE RESULTS: ASTM E21-05

Requirements: UTS ksi (Min 95/Max ---) 0.2% YS ksi (Min 72/Max ---) 4D Elong. % (Min 32/Max ---) Modulus Msi (Min 21/Max ---)

SOAK TIME: 5 Minutes

SPEED OF TESTING: 0.003 in./in./min., 0.05 in./min./in. MATERIAL: Metaltek CF8MNMnMOD

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>	6W	0.09581698	2.15	1,40	0.1585	0.3511	9394	16180	24.8	8	¥	97.0	167.1	-320	D43606	22	æ
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AWR: A=ACCEPTABLE, U=UNACCEPTABLE, R=REPORT

Requirements provided by MetalTek International

Testing Specialists for Aerospace, Automotive, and Material Testing Fields Locations in Youngstown, 12A U.S.A. - Tel. (124) 537-3131 and Banbury U.K. - Tel. +44 (0) 1295 261211

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fenglie Supervisor April 19, 2006

Technical Services Managed

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