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CSP Summit Presentation

Cast Components for High Temperature CSP Thermal Systems

Oak Ridge National Laboratory

Award # CPS No:34248

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Gen 3 CSP Systems Demand High Performance Materials

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- Components for Gen 3 systems are targeted for >700°C operation to achieve improved efficiencies
- Systems have to operate at high temperatures for long periods of time under relatively high stresses
  - Cross-cutting needs for multiple Gen 3 pathways
- Low-cost components are required to achieve to achieve the Sunshot goal of 6 ¢/ kWh

Candidate Ni-Based Alloys Are Expensive

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Alloy	Ni	Co	Cr	Fe	W	Mn	Mo	Nb	Al	Ti	Si	C
Haynes®230 (Heat 830587876)	Bal	2.38	22.14	1.55	14.24	0.53	1.3	0.0	0.39	0	0.37	0.1
Spec	Bal	5 Max	22	3 max	14	0.5	2	0.5 Max	0.3	0.1 Max	0.4	0.1
Haynes®282 (Heat 208278368)	Bal	10.18	19.39	0.79	0.06	0.08	8.53	0.0	1.52	2.22	0.06	0.062
Spec	Bal	10	20	1.5 Max	-	0.3 Max	8.5	-	1.5	2.1	0.15 Max	0.06
IN740H (HT3779J)	50.03	20.21	24.51	0.19	0	0.25	0.33	1.45	1.34	1.34	0.14	0.024
Spec	Bal	20	24.5	3 Max	-	1 Max	1 Max	1.5	1.35	1.35	0.15	0.03

- Alloys have high levels of Ni and in some cases Ni + Co

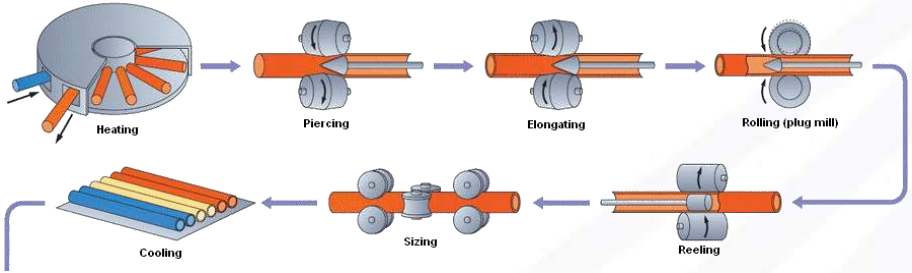
Casting Components Offers a Route for Cost Reduction

- Certain component geometries can be cast with cost savings
  - Example: Cylindrical objects (pipes) can be centrifugally cast
  - Complex valve bodies can be fabricated using the casting process
- Other benefits can be anticipated with castings
  - Customized material choice and component design, smaller order quantities, potentially lower lead-times
- ORNL has a history of successful development and collaborations on centrifugal cast components

ORNL Alumina Forming Austenitic tubes fabricated using centrifugal casting in air (ARPA- E OPEN 2015)

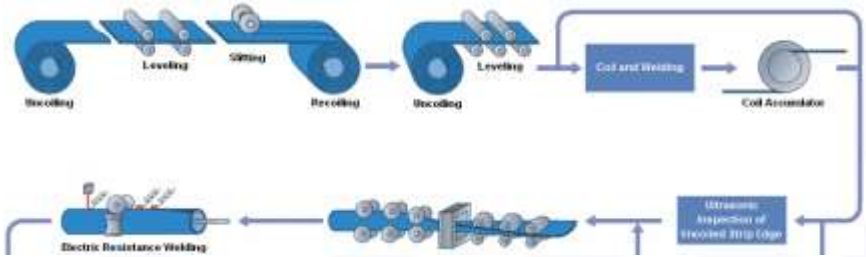
Furnace roll fabricated using centrifugal casting of ORNL alloy has been successfully operating in heat-treat furnace at 900° C for more than two years (ARPA- E OPEN 2015)

Centrifugal Casting of Smaller Vessels, Pipes, and Tubes Saves Manufacturing Cost Due to Reduced Steps



Plug Mill Process

Courtesy:http://www.wermac.org /pipes/pipemaking.html



Electric Resistance Weld Process

Courtesy:http://www.wermac.org /pipes/pipemaking.html

Single step Centrifugal Casting to Dimension (courtesy: MetalTek)

Cost savings and feasibility depends on size of tubing

Project Objectives

- Evaluate the feasibility of using a centrifugal casting process to lower manufacturing cost of piping fabricated using Ni-based alloys including Haynes®230, Haynes ® 282, or IN ® 740H
- Evaluate properties of cast and heat-treated alloys fabricated using this process
  - Investigate properties of alternate alloys with lower raw material costs
- Knowledge would be applicable to the design of piping, valve fittings, valve bodies along with those of turbo-machinery

Approach

- Fabricate laboratory scale castings, develop heat-treatment processes and measure high temperature mechanical properties
- Verify high temperature mechanical properties using small industrial scale castings and down-select alloys for centrifugal casting trials
- Fabricate pipes using centrifugal casting and verify that target properties are met

Summary of Various Castings Completed

Laboratory Scale

Industrial Scale

Centrifugal

Technical Accomplishments

- Centrifugal cast tube of Haynes ®230

Technical Accomplishments

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- Centrifugal cast tube of Haynes ®282

Centrifugal Haynes®282 Ingots Were Subject to Two-Step Aging Heat-Treatments

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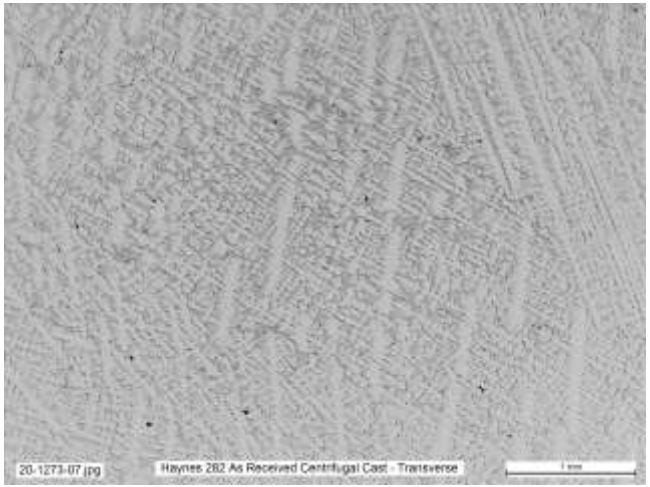
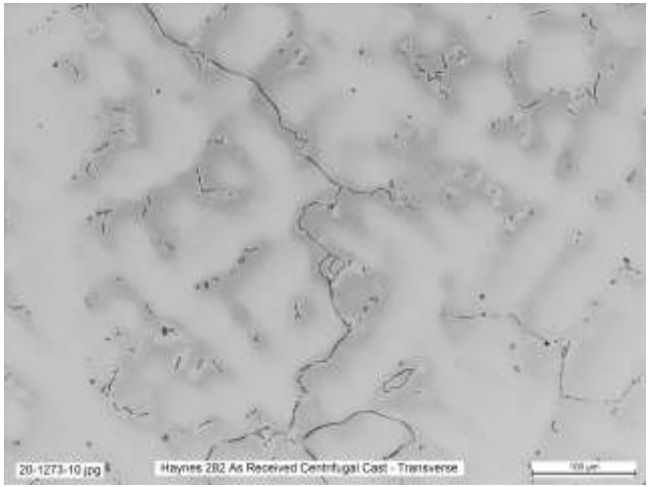
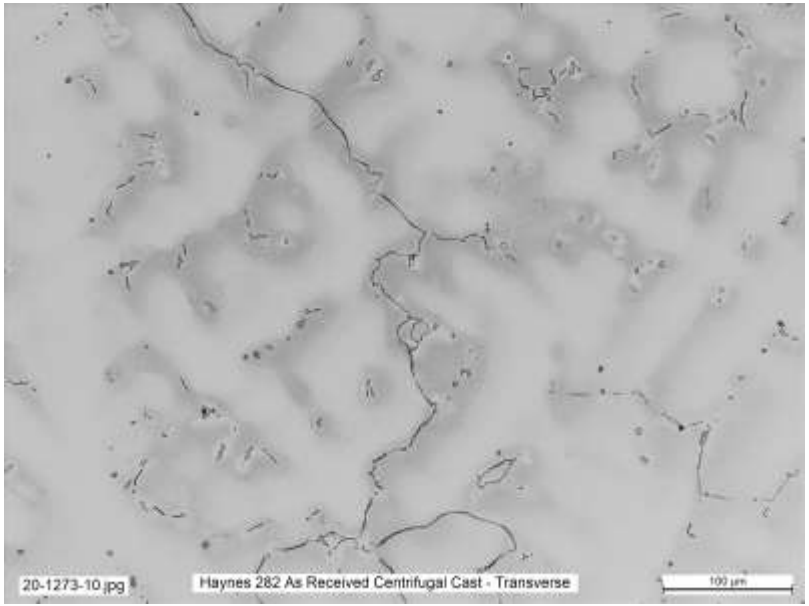
Alloy	Heat-treatment	Explanation
Haynes®282-HT3	Step #1: Homogenization: Ramp to 1093°C, hold for 8 hours, increase temperature to 1204°C, hold for 24 hours	Minimizes elemental segregation that occurred during solidification
	Step #2: Solution anneal: 1149°C for 1 hours, water quench	Prepares material for aging treatment
	Step # 3: Aging: 1010°C for 2 hours in inert atmosphere, air cool	
	Step # 4: Aging: 788°C for 8 hours, air cool	Two-step aging treatment for high strength

Microstructure of as- centrifugally cast Haynes®282® Shows Dendritic Structure

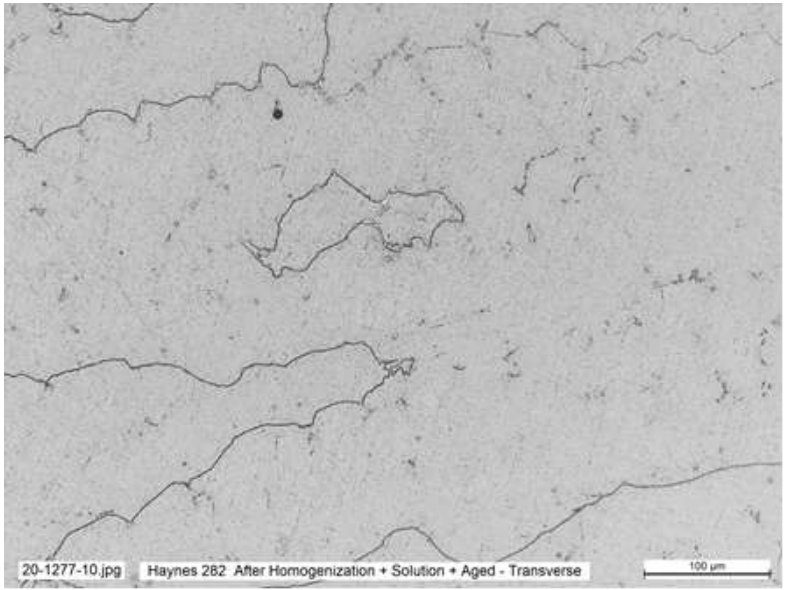




Homogenization was Achieved in Centrifugally Cast Haynes®282

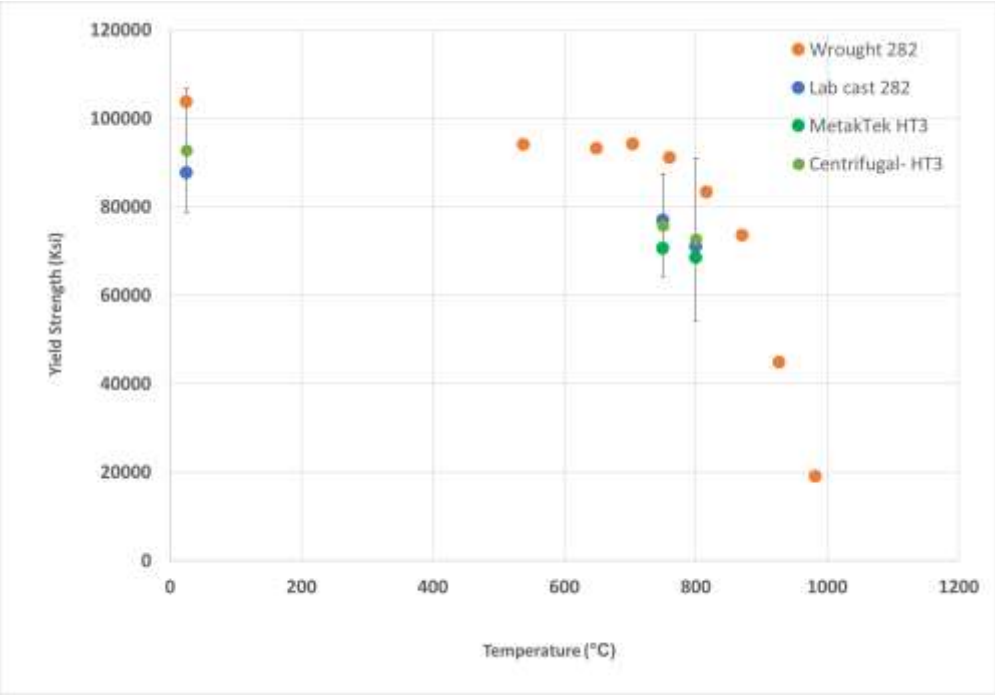


As-cast



As-cast + Homogenized+ Solution annealed + Two-Step aging

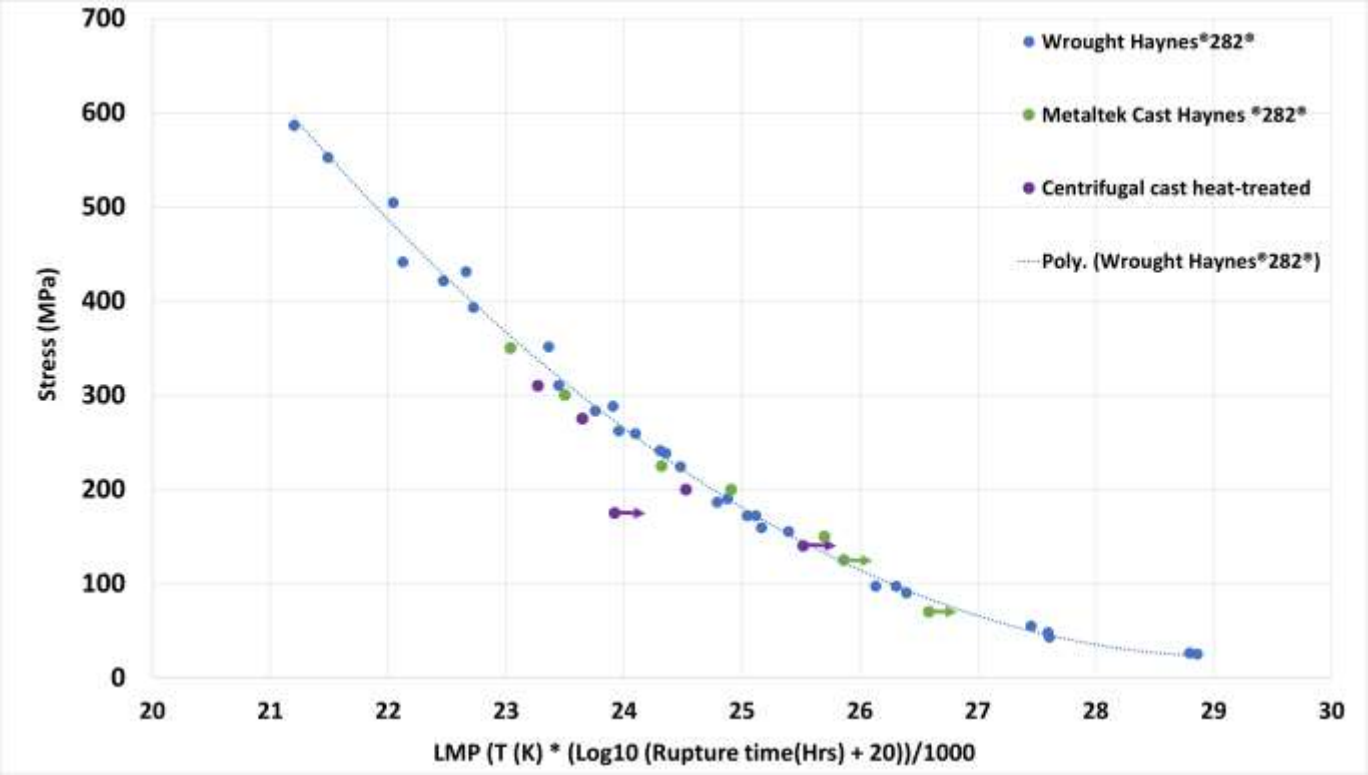
Milestone Requirements Are Satisfied by Haynes®282



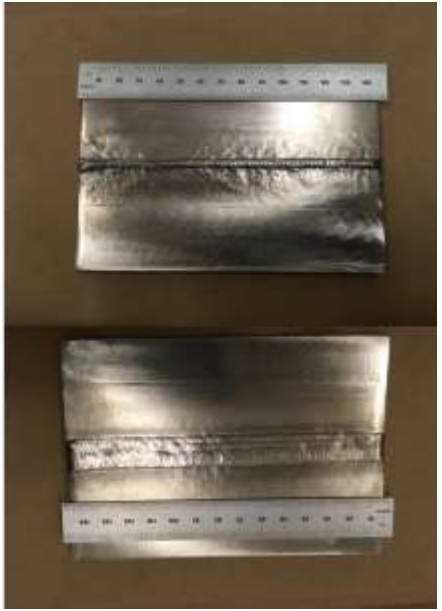
Alloy	Y. S. at 750°C (Ksi)	Y. S. at 800°C (Ksi)
Wrought Haynes®282	91.7	85.6
80% of Yield strength of wrought Haynes®282	***73.3***	***68.5***

- Yield strength of centrifugal cast + heat-treated Haynes®282 > 80% of wrought

LMP Plot Shows Creep Properties of Cast Haynes®282® Likely to Match or Exceed Wrought Haynes®282® at Expected Stress and Temperature Levels



Centrifugally cast material has been successfully welded



- Tensile and creep properties are under evaluation