

Cast Components for High Temperature CSP Thermal Systems

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Low-cost Components are Required for Gen 3 CSP Systems

- Components for Gen 3 systems are targeted for $>700^{\circ}\text{C}$ operation to achieve improved efficiencies
- High temperatures and harsh environments typically demand the use of high performance and more expensive Ni-based alloys (example: Haynes[®]230, Haynes[®] 282, or IN[®] 740H)
- Low-cost components are required to achieve to achieve the Sunshot goal of 6 ¢/ kWh

High Component Costs Are Due to Alloy and Processing Costs

- Both alloy cost and processing costs contribute to component costs
- Alloys such as Haynes[®] 282, or IN[®] 740H have excellent high temperature strength, creep and oxidation resistance
 - Relatively high materials cost due to high levels of Ni and Co

Alloy	Ni	Co	Cr	Fe	W	Mn	Mo	Nb	Al	Ti	Si	C
Haynes [®] 230	Bal (~59)	5 Max	22	3 max	14	0.5	2	0.5 Max	0.3	0.1 Max	0.4	0.1
Haynes [®] 282	Bal (~58)	10	20	1.5 Max	-	0.3 Max	8.5	-	1.5	2.1	0.15 Max	0.06
IN [®] 740H-S1	Bal (~50)	20	24.5	3 Max	-	1 Max	1 Max	1.5	1.35	1.35	0.15	0.03

- Multiple wrought processing steps required for fabrication of components such as seamless tubes

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



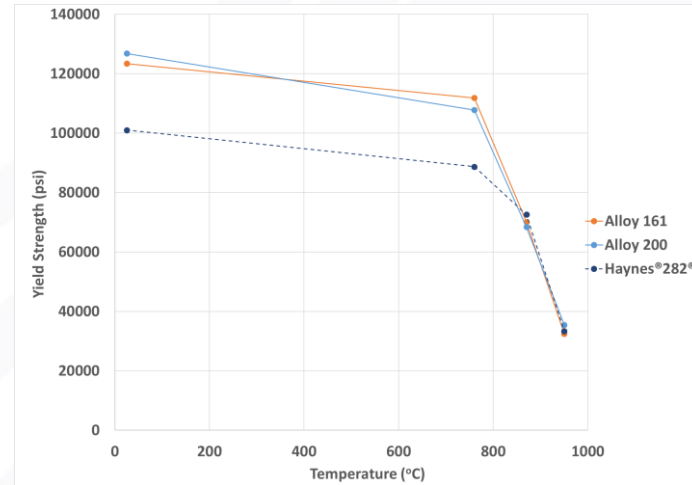
ORNL Alumina Forming Austenitic tubes fabricated using centrifugal casting in air (ARPA- E OPEN 2015)



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)

Use of Alternate Alloys May Offer Additional Cost Savings if Properties Are Adequate

- ORNL funded by EERE, Vehicle Technologies Program, has developed high strength alloys with Ni+Co ~ 50 wt. %
 - US Patents 9,605,565 B2, 9,752, 468 B2
- Creep properties in cast + heat-treated condition will be evaluated to determine if alloys will meet property requirements



Alloy	Ni	Co	Cr	Fe	Mn	Mo	Nb	Al	Ti	Si	C
Haynes®282	Bal (~58)	10	20	1.5 Max	0.3 Max	8.5	-	1.5	2.1	0.15 Max	0.06
IN®740H	Bal (~50)	20	24.5	3 Max	1 Max	1 Max	1.5	1.35	1.35	0.15	0.03
ORNL161	Bal (~46)	1	18	28	0.1	1.2	-	1.8	3.8	0	0.04
ORNL200	Bal. (~47)	2	18	26	0.1	0.75	-	2	3.5	0	0.03

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

Anticipated Outcomes

- Centrifugal casting process will be developed for selected alloys that meet high temperature mechanical property targets
- Mechanical properties of selected alloys in cast + heat-treated condition
- Provide information on suitability of alternate alloys
- Develop a supplier base for lower cost, cast components