

SIEMENS



Power and Gas – Large Gas Turbines, Generators

UTSR Summer Fellowship: Siemens Energy

About The Fellow

- Student at the University of Florida
- Applying to graduate PhD programs this fall
- Graduating Spring 2017 with a BS in Materials Science & Engineering



Presentation Overview

- Data analysis
- Literature review
- Metallic foams proposal
- Highlights and reflections

Data Analysis

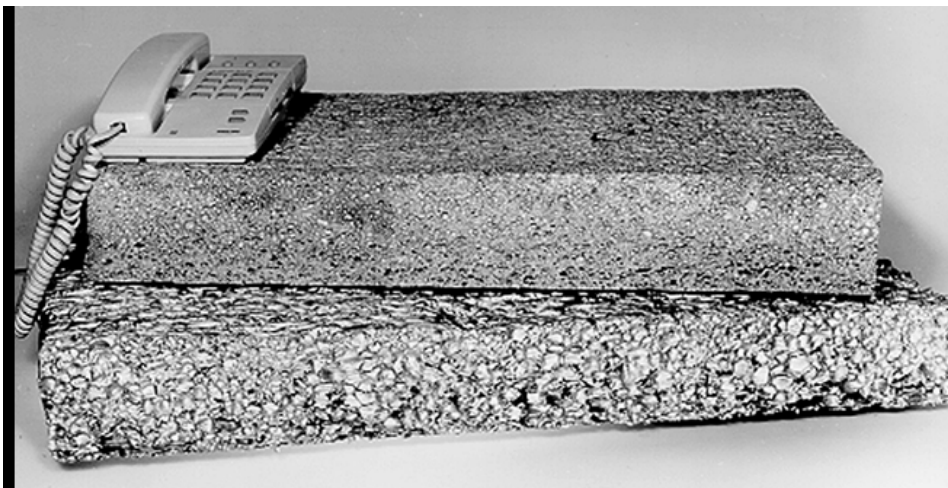
- High cyclic fatigue analysis
 - Haigh diagram
- Creep comparisons
- Erosion data analysis
- Digitizing

Literature Review

- Material comparisons
- Compositional search
- Data packages
- Overview of metallic foams

Metallic Foams Proposal

- Tasked with creating an experimental proposal for metallic foams



Source: J. Banhart, "Manufacturing routes for metallic foams", *JOM*, vol. 52, no. 12, pp. 22-27, 2000.



Source: "Composite Metal Foam", *Mae.ncsu.edu*, 2016. [Online]. Available: <http://www.mae.ncsu.edu/rabiei/CMF.html>. [Accessed: 03- Jun- 2016].

Metallic Foams Proposal

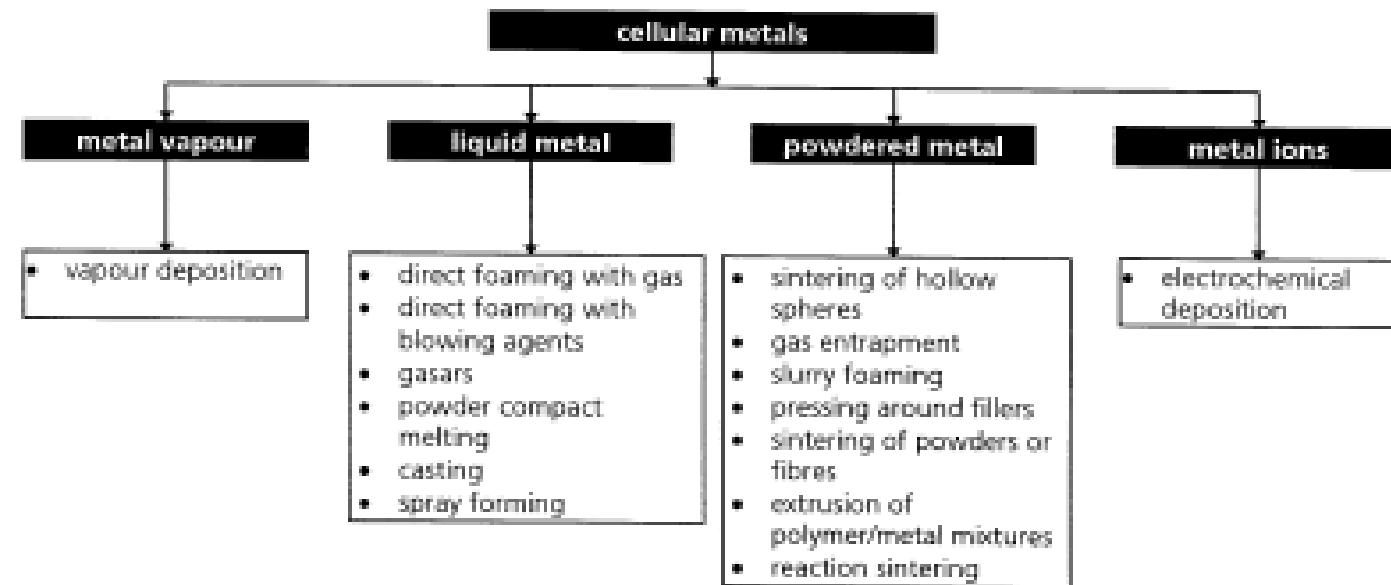
Background

- Developments in the industrial gas turbine (IGT) industry have been all about increasing efficiency
- Few studies on superalloy metallic foams
 - Focused on development rather than properties
- Proposed study intends on increasing the knowledge of the properties of superalloys as foams

Metallic Foams Proposal

Materials and Methods: Foam Production

- Siemens does not make their alloys in house
 - Production up to vendors
 - Pore size, porosity, density, composition
- Powder precursor route suggested; Could follow processing steps described in literature



Source: J. Banhart, "Manufacture, characterisation and application of cellular metals and metal foams", *Progress in Materials Science*, vol. 46, no. 6, pp. 559-632, 2001.

Metallic Foams Proposal

Materials and Methods: Experimental Design

- 125 samples of IN625
- Tested at 25°C, 500°C, 800°C, 1100°C
- Heat treatment with physical testing
- Metallography
- Mechanical testing

Ni	Cr	Fe	Mo	Nb (+Ta)	C	Mn	Si	P	S	Al	Ti	Co*
58.0 min	20.0- 23.0	5.0 max	8.0- 10.0	3.15-4.15	0.1 max	0.50 max	0.50 max	0.01 5 max	0.01 5 max	0.40 max	0.40 max	1.0 max

Composition of IN625. *if determined

Source: Special Metals. (2013, Aug 13). "INCONEL ® alloy 625" [Online] Available: <http://www.specialmetals.com/assets/documents/alloys/inconel/inconel-alloy-625.pdf>

Metallic Foams Proposal

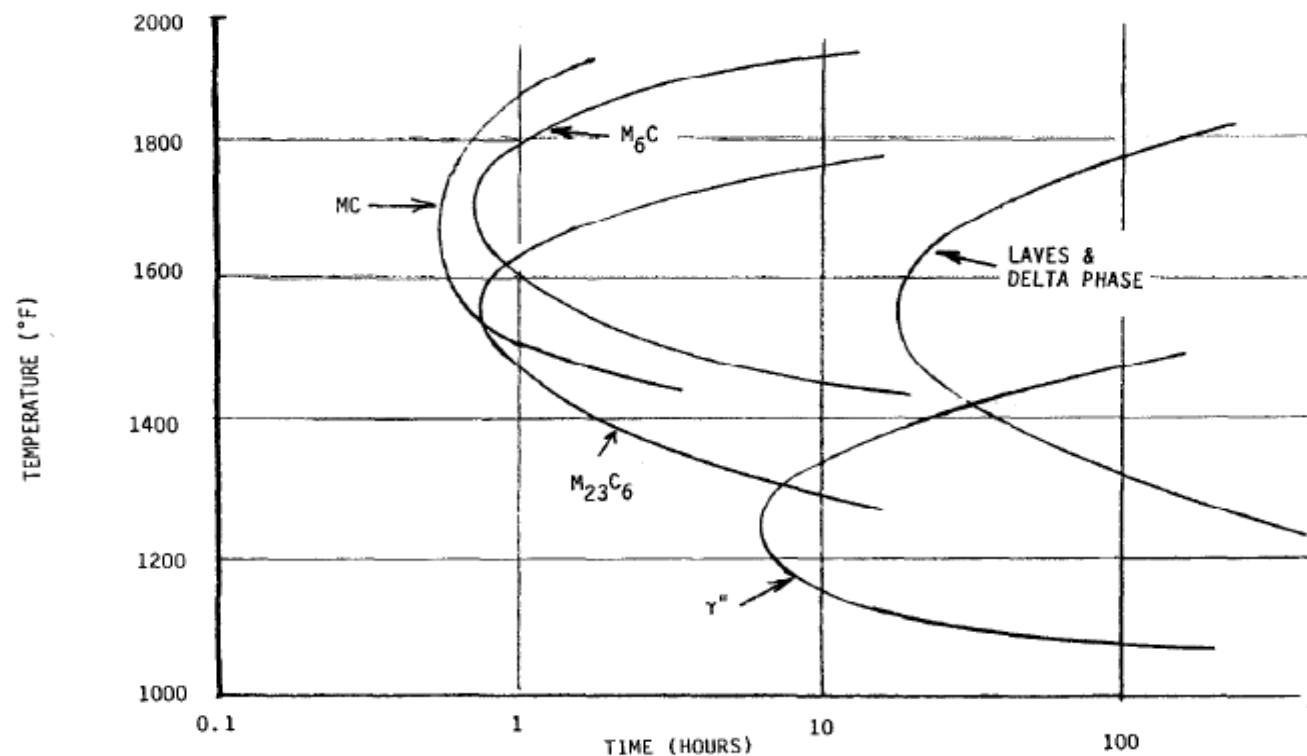
Materials and Methods: Test Matrix

Treatment Temperature (°C)		Samples							
		Heat Treatment & etc.	Creep Test			Tensile Test	Fatigue Test		
			100h	300h	1kh		1k c	10k c	100k c
25 (°C)		4	-	-	-	4	4	4	4
500 (°C)		4	5	5	5	4	4	4	4
800 (°C)		4	5	5	5	4	4	4	4
1100 (°C)		4	5	5	5	4	4	4	4

Metallic Foams Proposal

Materials and Methods: Heat Treatment, Physical Testing, Metallography

- Samples heat treated at 25°C, 500°C, 800°C, 1100°C. Held for 10hrs
- Density and porosity measurements
- SEM



Source: S. Floreen, G. Fuchs and W. Yang, "The Metallurgy of Alloy 625", Floreen, S., Fuchs, G. E., & Yang, W. J. (1994). *The metallurgy of alloy 625. Superalloys*, vol. 718, no. 625, pp. 13-37, 1994.

Metallic Foams Proposal

Materials and Methods: Mechanical Testing

- All tests run at 500°C, 800°C, 1100°C. Tensile and fatigue also run at 25°C
- Creep for 100, 300, and 1k hours
- Fatigue for 1k, 10k, 100k cycles
- Tensile

Metallic Foams Proposal Conclusion

- Previous studies on metallic foams generally found their properties to be less than their fully dense counterparts
 - Expect foamed IN625 to follow a similar trend
- Could still be implemented in an IGT

Highlights and Reflections

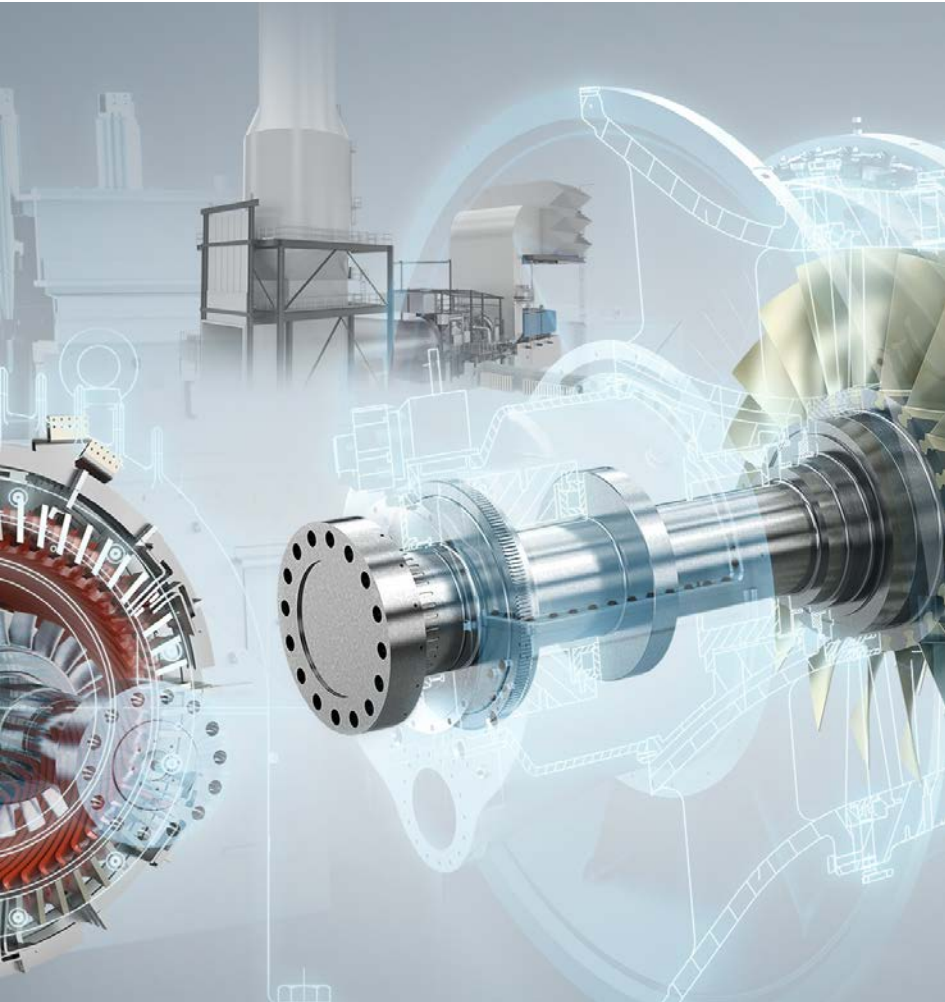
Highlights

- Tours
- Getting to know everyone
- After lunch walks

Reflections

- Live closer
- More consistent work flow
- Interactions with other interns

Thank you!



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