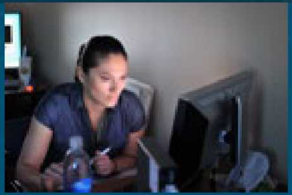
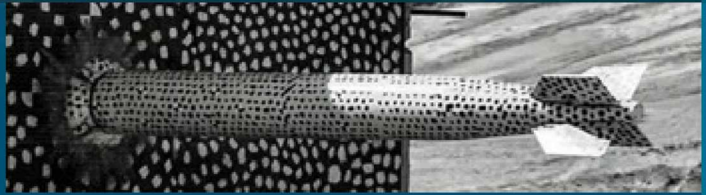
SAND2019-8641PE

Inconel X750 Spring Wire Characterization





Presented by

Megan Galdony

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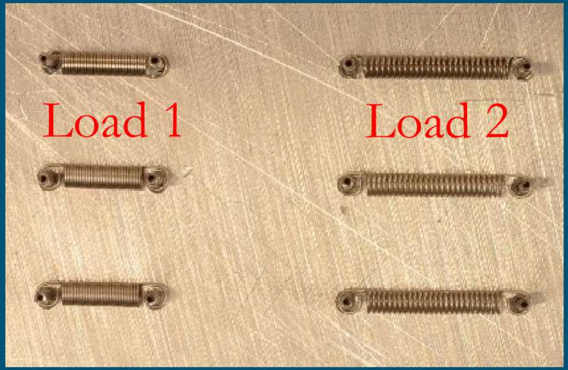
Background Information

Simply put, Sandia needs to make springs—very small springs.

How small?

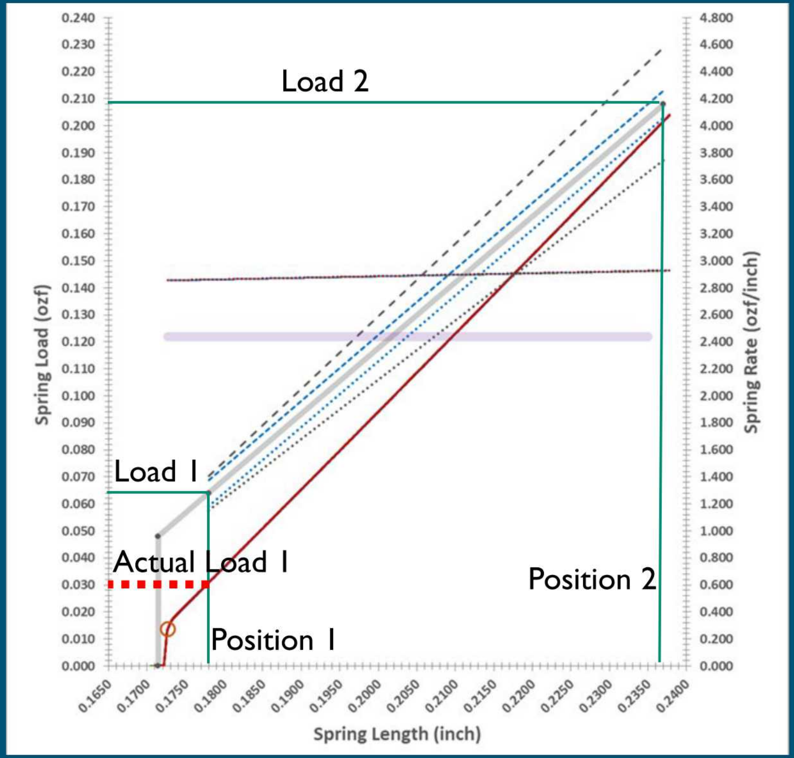
The springs (Inconel X750 spring wires) need to provide specific force values, which we will call "Load 1" and "Load 2" at positions 1 and 2.

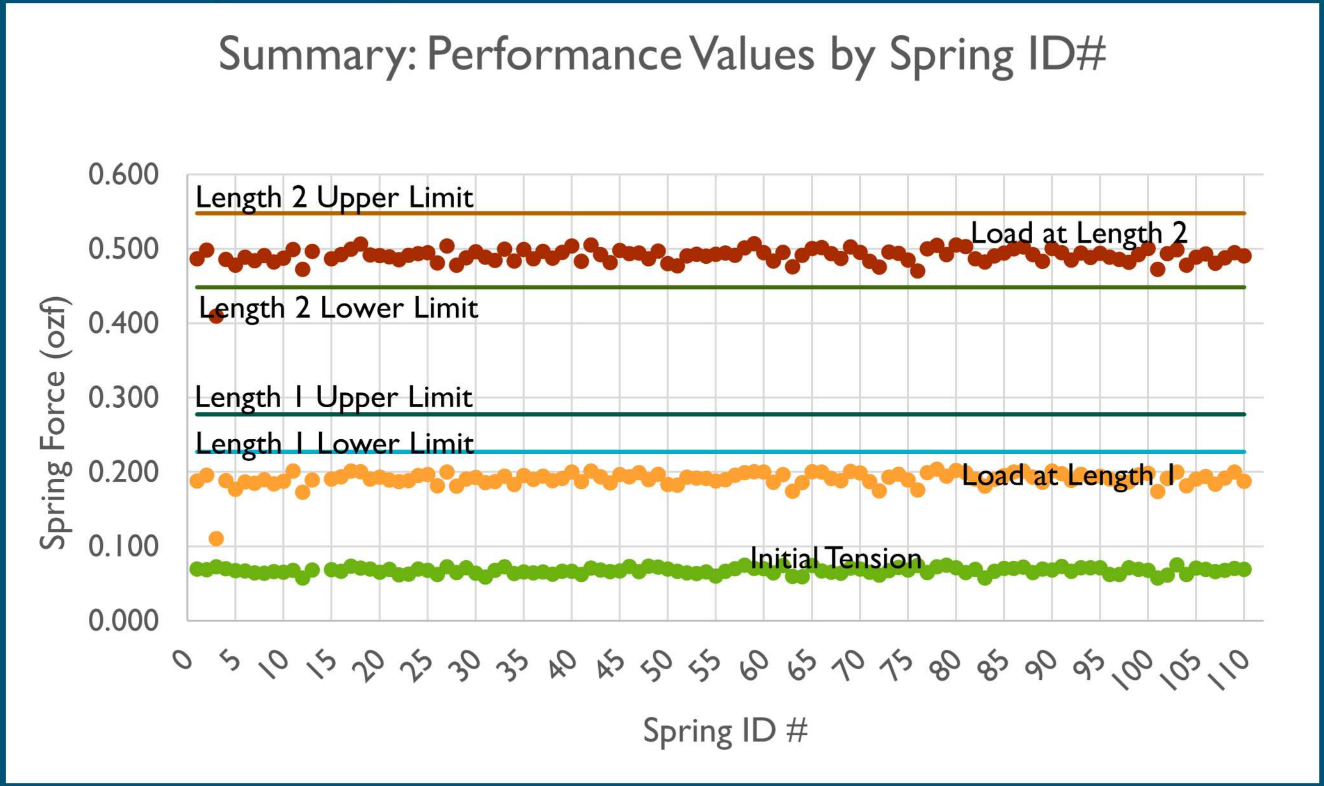


Problem

The problem that needs to be acknowledged here is that the springs cannot provide Load 1.

When the spring is pulled, its force goes up, passing under the first point and going through the second. What is supposed to happen is the line should pass through both points.





As can be seen, the spring force is consistently lower than needed for Load 1.

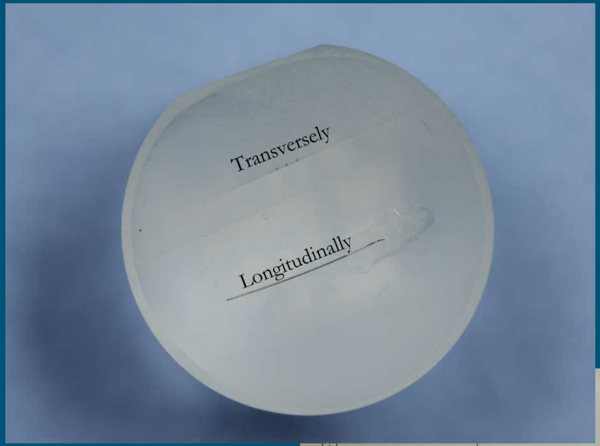
Question

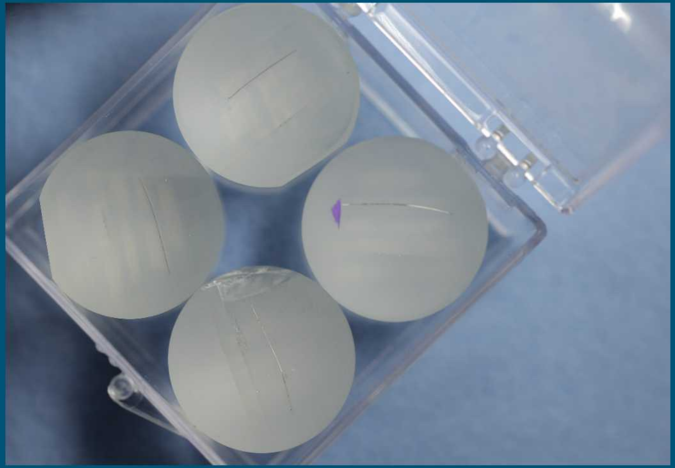
The question that's being asked is, why? Why does the spring go through Load 2's limits (between its minimum and maximum values) but not through Load 1's.

One hypothesis we have is that some unexpected microstructural feature is interfering with the part's performance.

Method

How did we set up for this project? First, we had to mount the spring wires in epoxy. We had two different diameters of wires to work with, and we had to put them in longitudinally as well as transversely. We also had to do the same process again with the wires after they were heat treated.





Method (continued)

We also had to polish the mounts in order for the samples to be more easily seen through microscopes (the clearer, the better). Different grain-sized polishing cloths are used to polish mounts. For example, 9, 6, 3, and 1 micron cloths were used for the spring wires.

We also use an engraving machine to label our samples.

After polishing on the machine, samples sometimes even go through the vibratory to make the sample even more shiny.

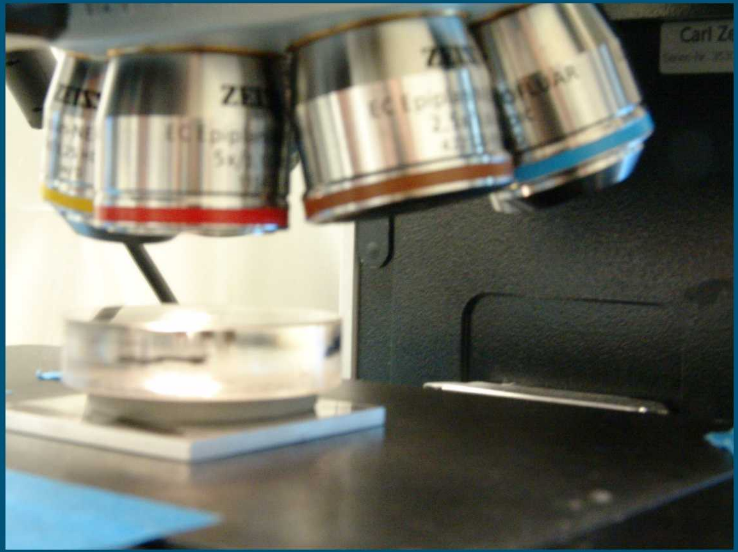
Method (continued)

Next, in order for them to look good for pictures, we needed to etch the samples.

Simply put, etching, which is the process of using strong acids to seep through the weaker parts of metal, is used to help the grains of metals become easier to see under the microscope.

Using a fancy microscope, we got many pictures of the samples (coming soon).

We also needed to take microhardness tests using a microhardness tester.



Background Data

We were given specifications for how the wires were supposed to be chemically formed, mechanically used, and heat treated, so one thing we checked for was that the wires we were sampling match all the requirements.

- We compared the chemical specifications with the actual chemical components of the wire.

TABLE 1 - Composition Specifications

Element	min	max
Carbon	--	0.08
Manganese	--	1.00
Silicon	--	0.50
Sulfur	--	0.010
Chromium	14.00	17.00
Nickel	70.00	--
Columbium	0.70	1.20
Titanium	2.25	2.75
Aluminum	0.40	1.00
Iron	5.00	9.00
Cobalt	--	1.00
Tantalum	--	0.05
Copper	--	0.50

Chemical Composition
for 0.0042

Instrument	Element	Concentration	
LECO	C	0.04	%
iCAP	Mn	0.08	%
iCAP	Si	0.03	%
LECO	S	<0.001	%
iCAP	Cr	14.87	%
iCAP	Ni	72.59	%
iCAP	Nb(Cb)	0.75	%
iCAP	Ti	2.43	%
iCAP	Al	0.64	%
iCAP	Fe	8.49	%
iCAP	Co	0.02	%
iCAP	Ta	<0.01	%
iCAP	Cu	0.06	%

Chemical Composition
for 0.003

Instrument	Element	Concentration	
iCAP	C	0.04	%
iCAP	Mn	0.05	%
iCAP	Si	0.01	%
iCAP	S	<0.001	%
iCAP	Cr	15.62	%
iCAP	Ni	71.55	%
iCAP	Nb(Cb)	0.76	%
LECO	Ti	2.37	%
iCAP	Al	0.71	%
LECO	Fe	8.81	%
LECO	Co	0.03	%
iCAP	Ta	<0.01	%
iCAP	Cu	0.05	%

Background Data (continued)

- We also checked that the tensile/mechanical properties between the requirements and actual samples were similar.

TABLE 4A - Minimum Tensile Strength, Inch/Pound Units

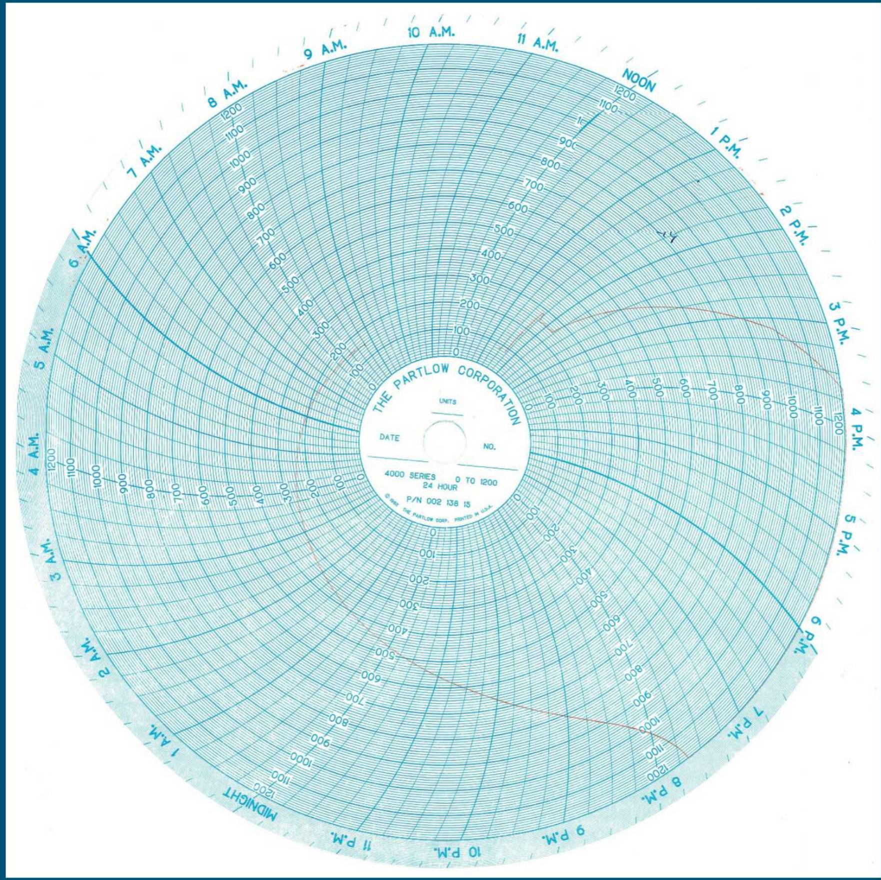
Nominal Diameter or Thickness Inch	Tensile Strength ksi
0.012 to 0.250, incl	220
Over 0.250 to 0.418, incl	200
Over 0.418 to 0.625, incl	180

	Specimen ID	Tensile strength [ksi]	Diameter [in]	Load at Break [lbf]
1	1	250.40	0.0042	3.465
2	2	248.82	0.0042	3.443

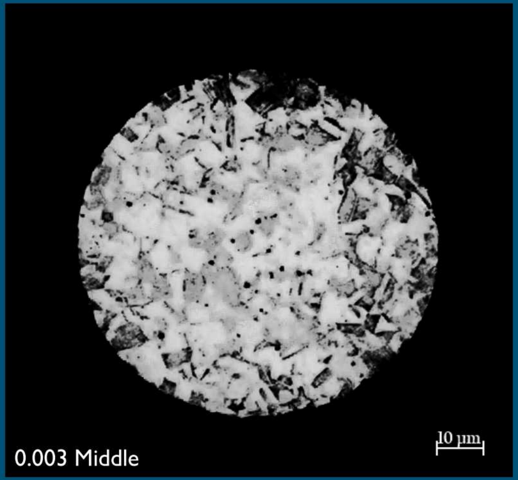
	Specimen ID	Tensile strength [ksi]	Tensile stress at Yield (Offset @ 0.2 %) [psi]	Diameter [in]	Load at Break [lbf]
1	1	370.35	338320.574	0.0030	2.617
2	2	365.21	349325.304	0.0030	2.581

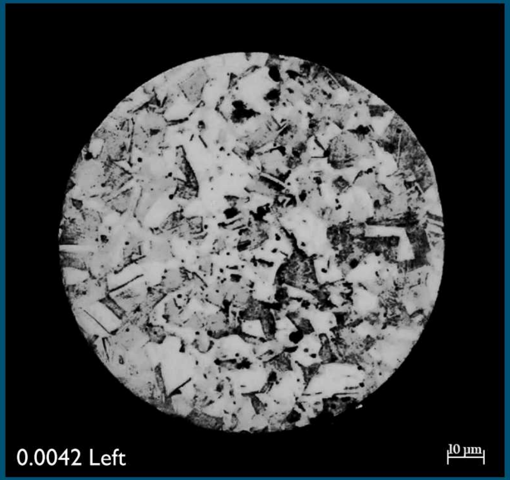
Background Data (continued)

- Lastly, we checked that the heat treatment was done correctly for this specific material by checking that the heat treatment diagram made during the process was accurate.

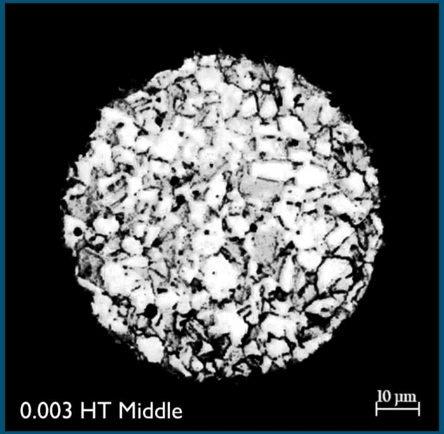


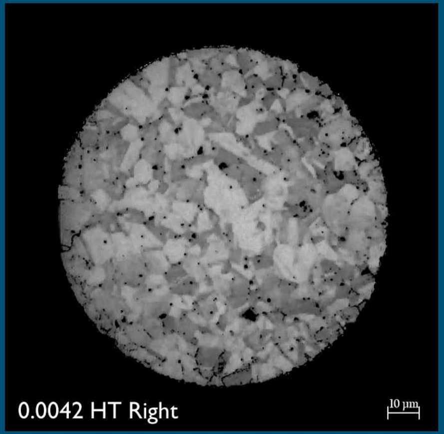
Collected Data

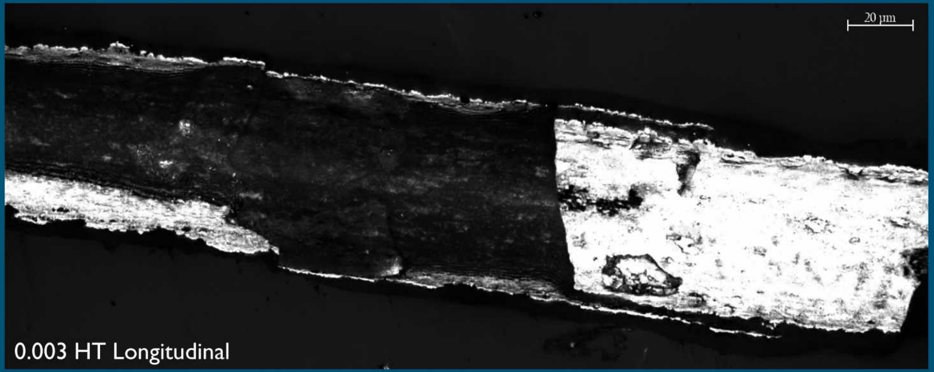




Not heat treated

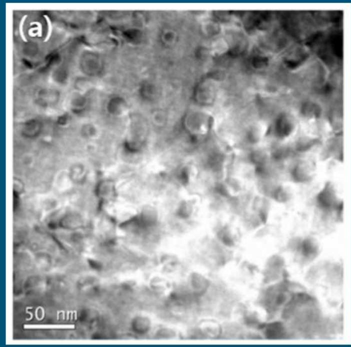






Heat treated

- Both have equi-axed grain structure, which means the not-heat treated wire has been recrystallized since it was drawn down into wire.
- The heat treated wire etched more evenly, which can mean that the microstructure contains less stress.
- The strength caused by the heat treatment is due to tiny precipitates that grow that we can't see optically.



Effect of cold drawing ratio on gamma prime precipitation in Inconel X-750 Ha, J.W. et al Mat Char 96(2014)1-5

Conclusion

- Fine wires are really hard to prepare.
- Chemical and mechanical properties of heat treated wire meet the specification.
- Heat treatment meets the specification.
- Grain structure is equi-axed.

Future work

- Microhardness testing
- Scanning electron microscope and/or transmission electron microscope examination to determine character of carbides.

Acknowledgements

Thank you, Lisa Deibler, Christina Profazi, Celedonio Jaramillo, and Alex Hickman!