

Titanium alloy for a structural heat exchanger

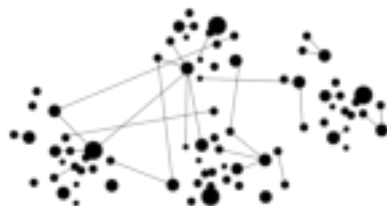
26 March 2020



Heat exchangers are becoming more important in aircraft

- AM enables light weight and high performance heat exchanger designs
- Potential to integrate heat exchanger function into structural components
- Titanium alloy Ti-6Al-4V is well developed to be used in the AM process and has excellent mechanical properties and corrosion resistance required for structural applications, but the thermal conductivity is relatively low
- Intellegens will seek a Titanium alloy composition with the highest thermal conductivity without reducing the original mechanical properties

INGREDIENTS



PROPERTIES

Strength
Fatigue life
Conductivity
Elongation
Modulus

INGREDIENTS



PROPERTIES

100010011110
Strength
01110011010
Fatigue life
101100100100
101010010101
Conductivity
01110101010
Elongation
101110101010
Modulus
010101010100
111011010111

Alchemite™ making a prediction

intellegens

INGREDIENTS



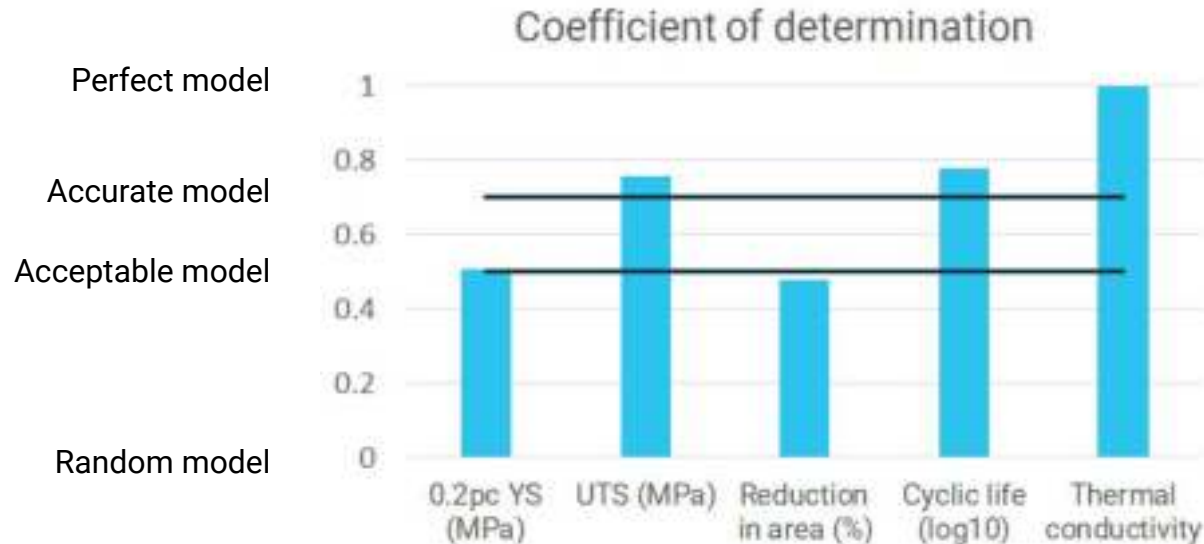
PROPERTIES

Strength
Fatigue life
Conductivity
Elongation
Modulus

Quality of predictions

Augmented thermal conductivity experimental data with Wiedemann-Franz law and Nordheim's rule

Accurately model yield stress, ultimate tensile strength, reduction in area, cycle life, and thermal conductivity



Predictions

intellegens Alchemite™ Analytics gpt

MO EHV_maxrunout 000 rows (0 cells)

- Data Explorer
- Predict**
- Optimize
- Metadata

Powered by Alchemite 4.1.0 14.8

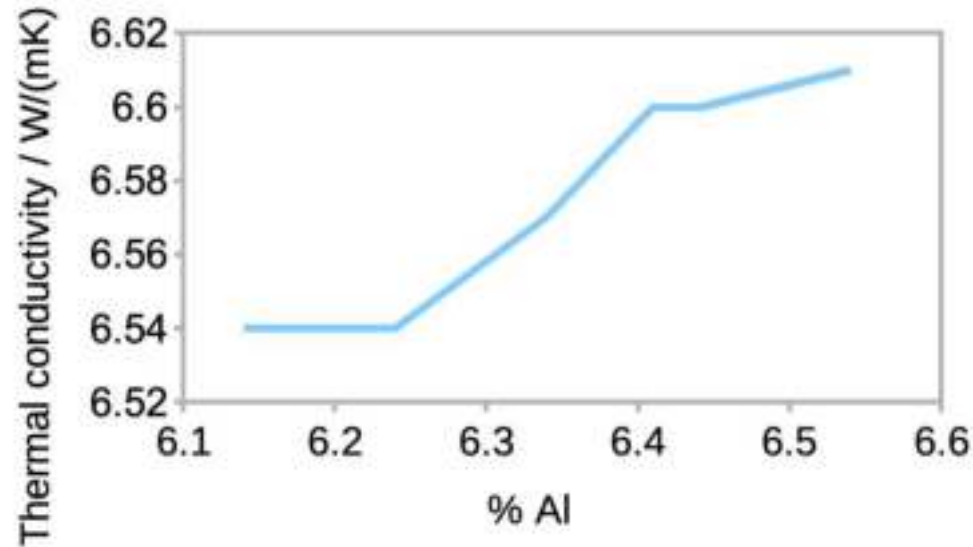
Predict ▶ PREDICT ↺ RESET

FEATURE	STATUS	RANGE	VALUE	RESULT	UNCERTAINTY
Al (%)	Required	6.14 - 8.54	6.44		
V (%)	Required	3.91 - 4.42	4.03		
Fe (%)	Required	0.17 - 0.29	0.20		
C (%)	Required	0.01 - 0.03	0.01		
N (%)	Required	0.00 - 0.10	0.00		
O (%)	Required	0.11 - 0.39	0.16		
H (%)	Required	0.00 - 0.01	0.00		
Particle size (%) - D10	Required	46.20 - 59.20	62.47		

Predictions

Test: increasing aluminum content should lead to increased thermal conductivity

Use default values for other parameters



Optimization

Target properties of default Ti alloy and then optimize them

intellegens Alchemite™ Analytics

MO EHV1_material 2023-08-01 10:00 AM

+ New Optimization

Number of Optimization Samples: 1000

Optimize

Please, set at least one Type to "Target" and one to "Input Achiever".

NATURE	TYPE	VALUE
0.2% TS (MPa)	Select...	
UTS (MPa)	Select...	
Reduction in area (%)	Select...	
log(Cycle life)	Select...	
Thermal conductivity	Select...	
Al (%)	Input Achiever	0.14 0.5305
V (%)	Input Achiever	0.01 0.42
Fa (%)	Input Achiever	0.11 0.20
C (%)	Input Achiever	0.00000000 0.02
N (%)	Input Achiever	0.001 0.1
O (%)	Input Achiever	0.11 0.18
H (%)	Input Achiever	0.0002 0.010

Powered by Alchemite™ API v2.14.0

Optimization

Use mean properties of known Ti-6Al-4V alloys as target

Property	Target
0.2% YS (MPa)	> 760
UTS (MPa)	> 776
Reduction in area (%)	< 57.8
log(Cyclic life)	> 3.57
Thermal conductivity (W/m/K)	> 6.52

Optimization



Use mean properties of known Ti-6Al-4V alloys as target

Property	Target	Optimized
0.2% YS (MPa)	> 760	844.2
UTS (MPa)	> 776	953.1
Reduction in area (%)	< 57.8	32.92
log(Cyclic life)	> 3.57	4.52
Thermal conductivity (W/m/K)	> 6.52	6.59

Optimization

intellegens



Al

6.49%



V

3.99%



Fe

0.19%



C

0.01%



N

0.04%



O

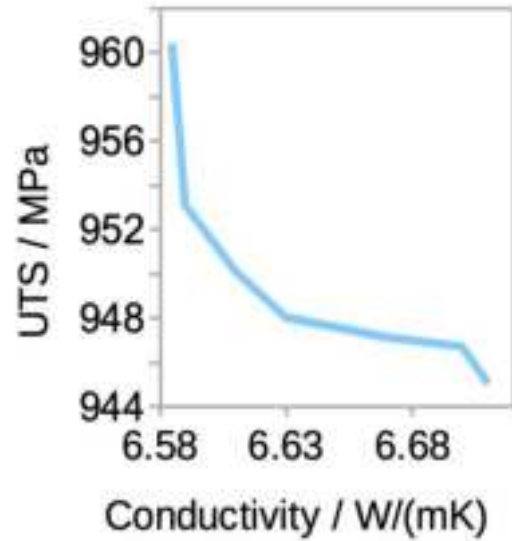
0.17%



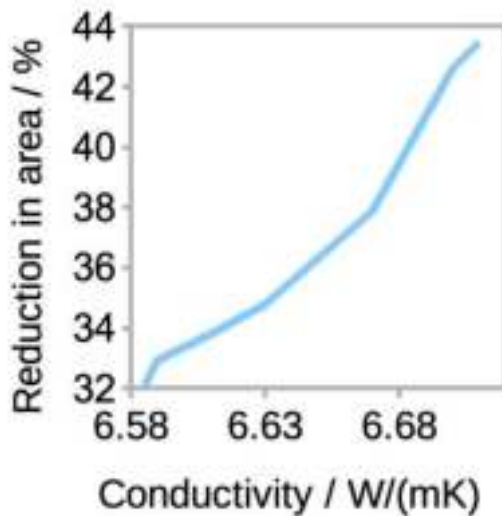
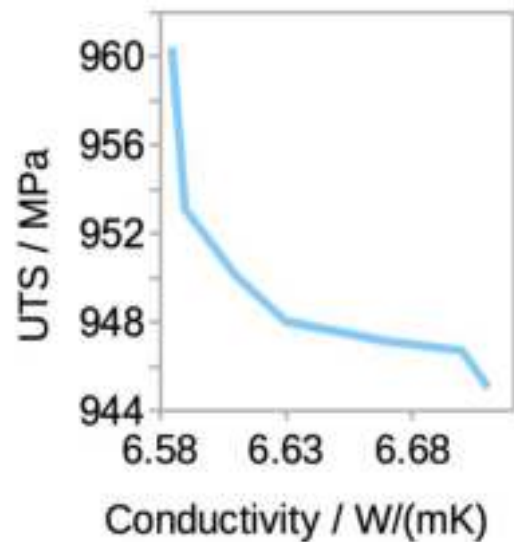
H

0.00%

Pareto plots

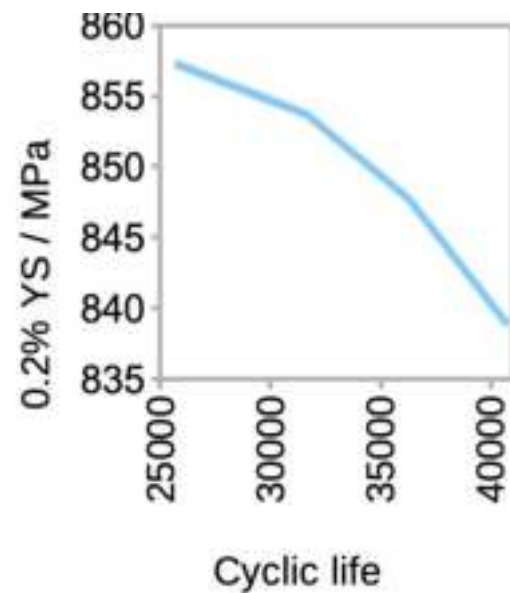
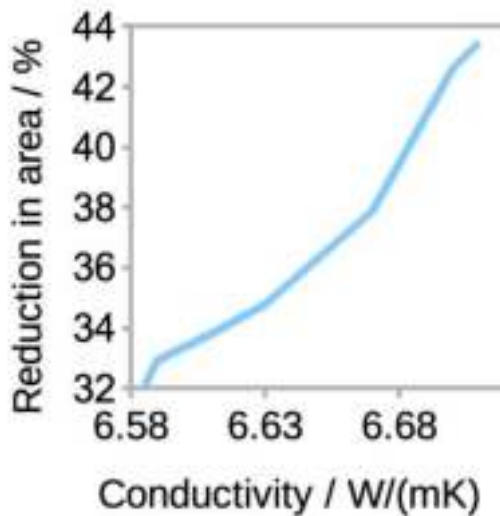
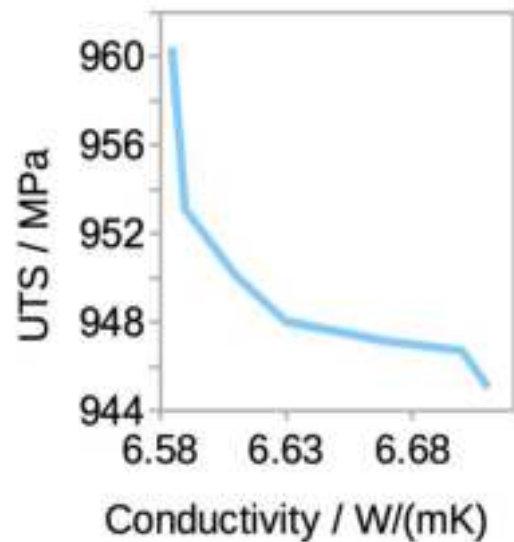


Pareto plots



Pareto plots

intellegens



Improving the predictions in phase II



Analysis tool to explore and visualize design space

Report cyclic life rather than $\log(\text{cyclic life})$

Collect more data on similar materials, consider phase behavior & porosity to exploit property-property correlations

Improve predictions of elongation and Young's modulus that are not accurately modelled using current data

Extend composition range to Commercially Pure Titanium for improved thermal conductivity

Determine the likelihood of ever being a Ti alloy that fulfils targets

Future steps



Titanium alloys are a case study for opportunity offered by machine learning

Lay the foundation to assess other alloy systems including copper and aluminum for suitability as structural heat exchanger

Apply Alchemite™ Analytics tool to other materials design projects within GKN