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Titanium alloy for a structural heat exchanger

26 March 2020

Problem statement

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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

Alchemite™ machine learning

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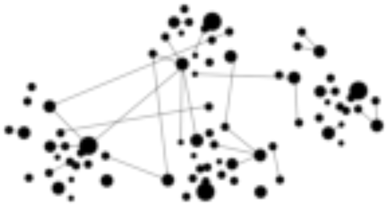
INGREDIENTS



PROPERTIES

Strength
Fatigue life
Conductivity
Elongation
Modulus

Training Alchemite™

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INGREDIENTS

PROPERTIES

100010011110
Strength
011100101010
101100100100
Fatigue life
101010010101
Conductivity
011101101010
100101010010
Elongation
101110101010
Modulus
010101010100
111011010111

Alchemite™ making a prediction

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INGREDIENTS

PROPERTIES

Strength
Fatigue life
Conductivity
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Modulus

Quality of predictions

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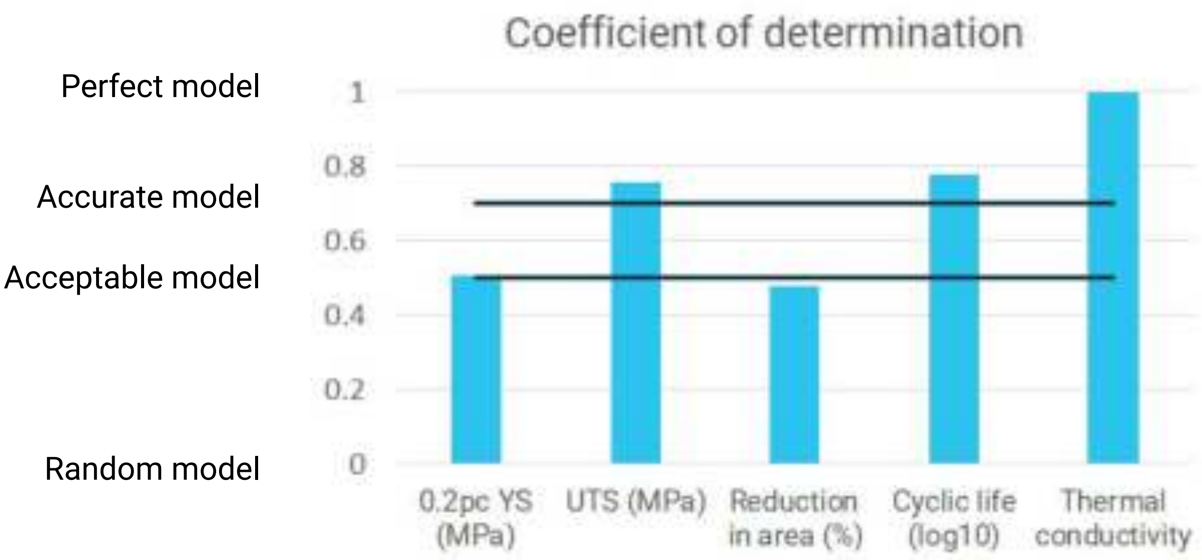
Augmented thermal conductivity experimental data with Wiedemann-Franz law and Nordheim’s rule

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



Predictions

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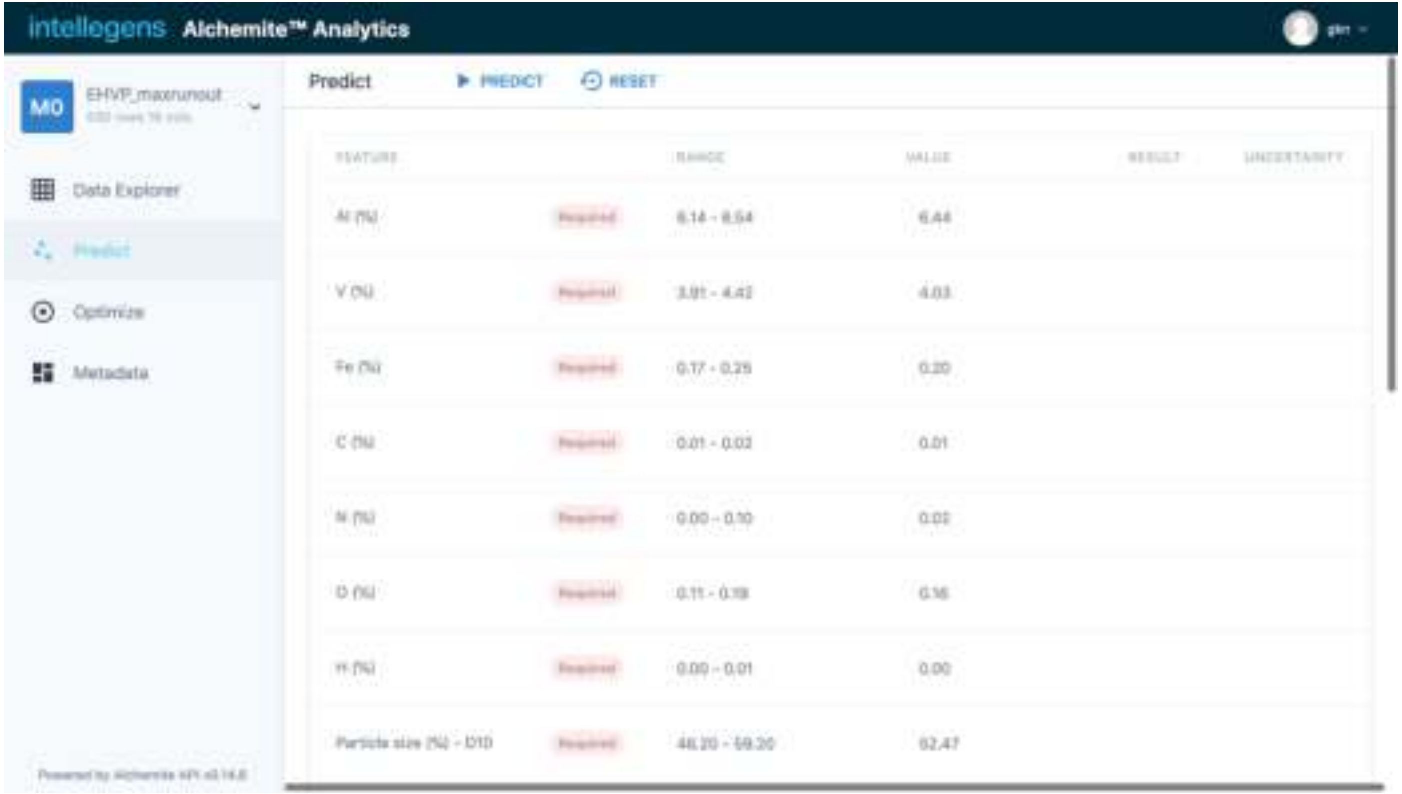

Predictions

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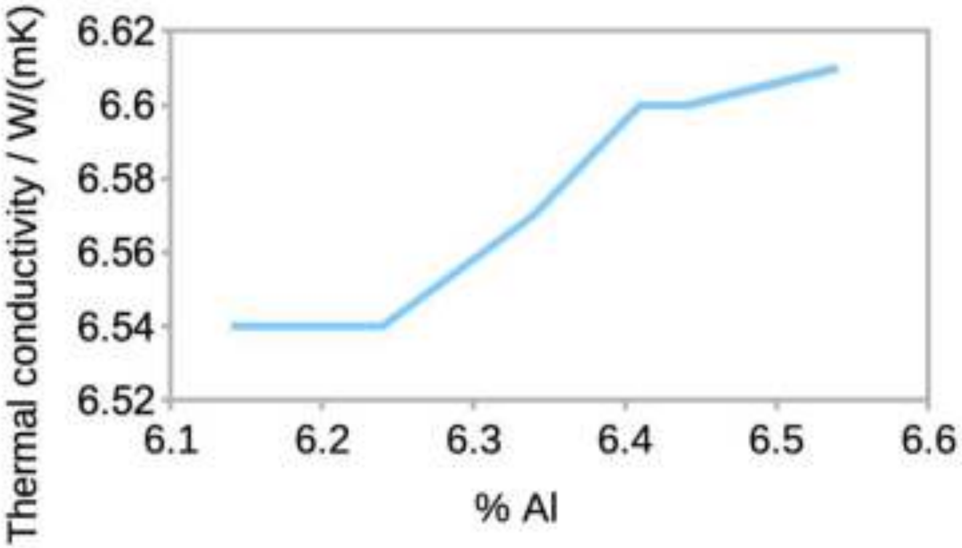
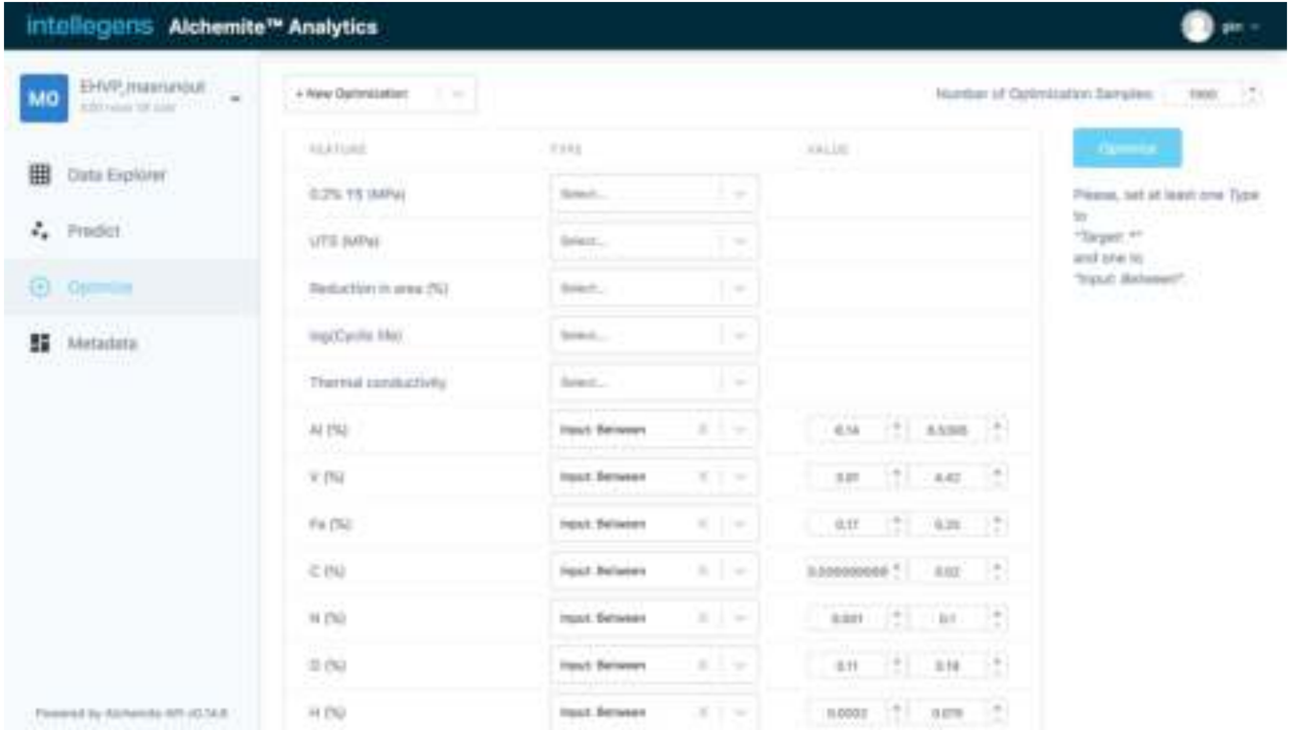
Test: increasing aluminum content should lead to increased thermal conductivity

Use default values for other parameters



Optimization

Target properties of default Ti alloy and then optimize them



Optimization

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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

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Al

6.49%

V

3.99%

Fe

0.19%

C

0.01%

N

0.04%

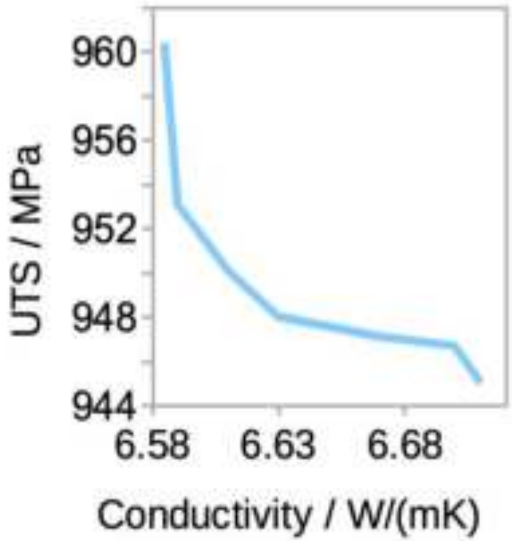
O

0.17%

H

0.00%

Pareto plots



Pareto plots

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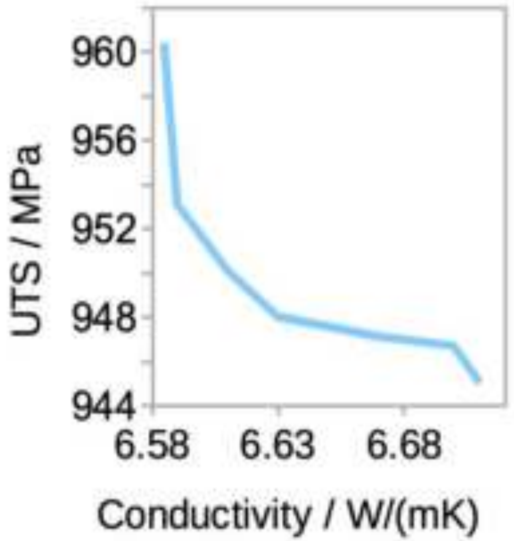
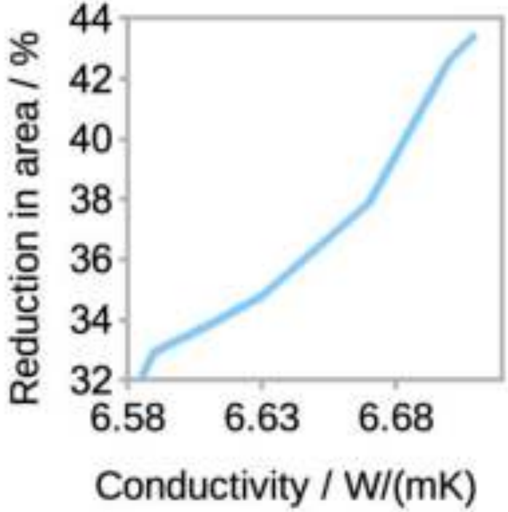
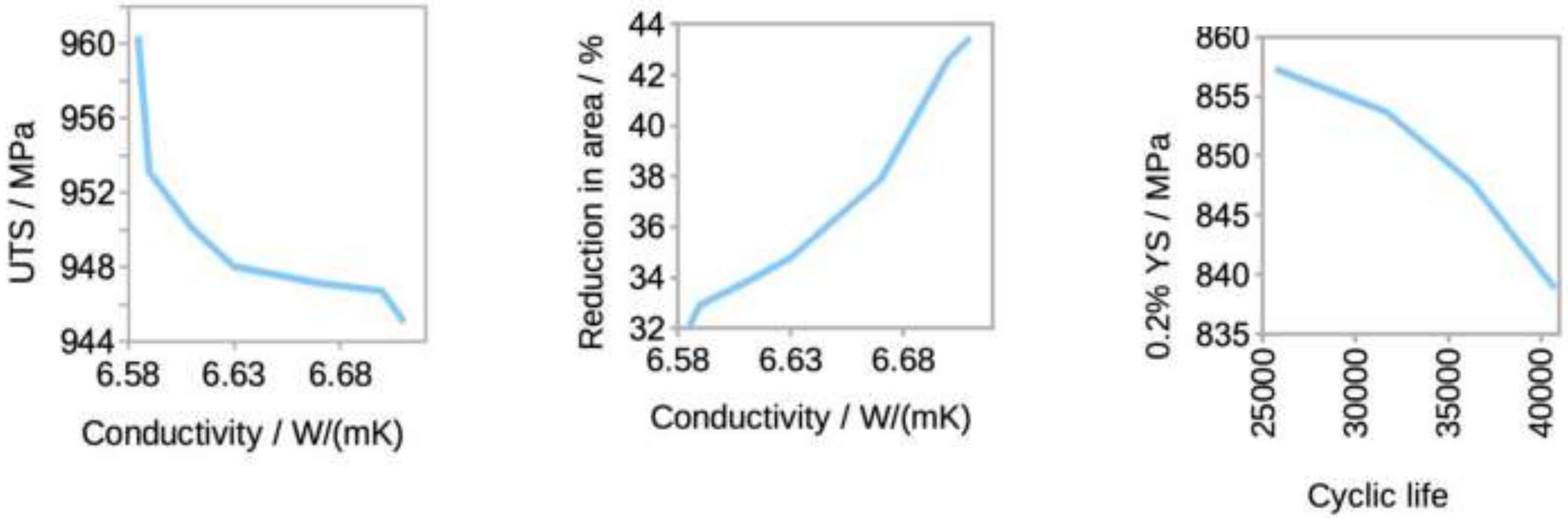




Pareto plots



Improving the predictions in phase II

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Analysis tool to explore and visualize design space

Report cyclic life rather than log(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