

利用人工智慧演算法建構鋁合金之機械特性模型 以用於積層製造

Constructing Mechanical Properties Model of Aluminum Alloy for Additive Manufacturing by using Machine Learning Approach

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Abstract

Aluminum alloys are widely used in industries such as aerospace and transportation. With the rise of additive manufacturing (AM), their application has expanded, but challenges remain—rapid solidification during AM often leads to non-equilibrium microstructures and cracking, reducing tensile strength. While modifying alloy composition can improve AM suitability, traditional trial-and-error methods are time-consuming and costly. In recent years, there is a growth of machine learning application in materials science and engineering. Machine learning has been considered as a powerful approach in deciphering complex physics and predicting materials properties. Hence, in this poster, we demonstrate the use of machine learning approach to establish a precise predictive model regarding mechanical performance associated with alloy composition and process conditions. Through this model and computational thermodynamics method, the goal of this study is to develop new formulations of Al Alloy suitable for AM.

Conclusion

- We successfully established Al alloy tensile strength model by using machine learning approach, and transformed model predicted-values based on data science to physical meaning.
- In the future, we will use computational thermodynamics methods to further screen suitable components and processes predicted by machine learning for additive manufacturing.

Acknowledgement

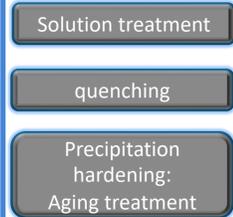
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Introduction

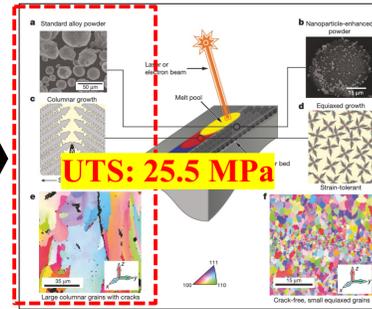
Development of aluminum alloy in additive manufacturing

Issue: Directly apply AM to Al7075

→ Significant loss of UTS



UTS: 538 MPa



Ref: Martin, J., Yahata, B., Hundley, J. et al. 3D printing of high-strength aluminum alloys. Nature 549, 365–369 (2017).

Issue: complex and multidimensional inputs, including:

- (1) alloy compositions
- (2) processing parameters (multiple aging heating process)

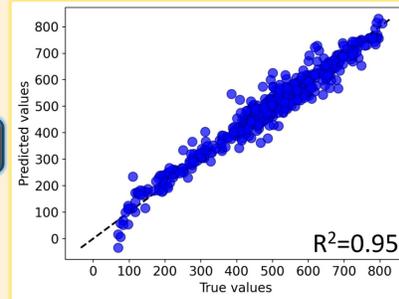
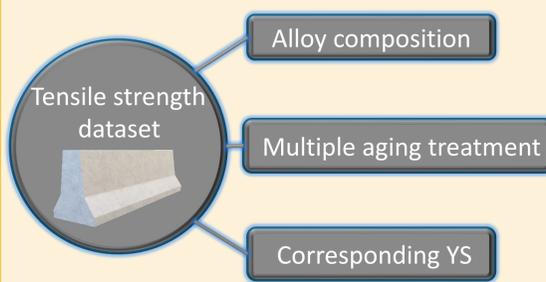
→ Difficult to receive mechanical properties via trial and error.

Solution: Modify alloy compositions, but such changes can also affect its mechanical properties.

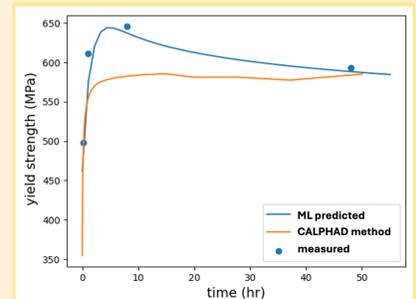
Strategy: Build up machine learning model for predicting mechanical properties of Al alloy.

Results and Discussion

Model of aluminum yield strength



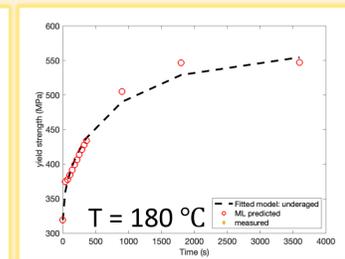
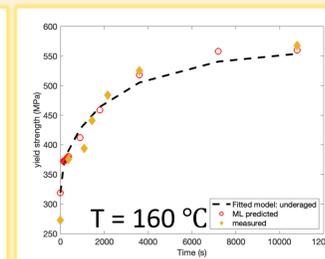
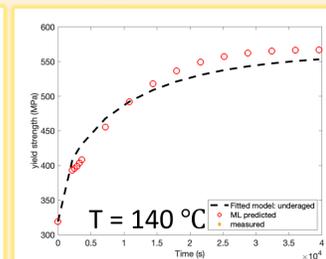
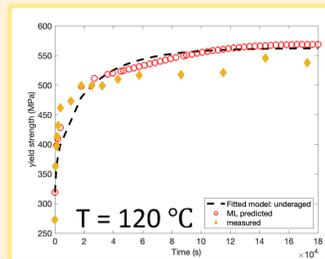
Model compared with CALPHAD



Physical model building based on ML-predicted yield strength

- Predict Al 7055 of yield strength (v.s time) aging at 120°C, 140°C, 160°C and 180°C respectively to fit Avrami equation: $f_r = 1 - \exp(-kt)$ and relation of $\sigma_{ppt} = C * f_r^{\frac{1}{2}}$ [2]

Ref[2]: Esmaeili, S., Lloyd, D. J., & Poole, W. J. (2003). A yield strength model for the Al-Mg-Si-Cu alloy AA6111. Acta Materialia, 51(8), 2243-2257.



- Besides, we fit physical models under over-aged conditions [2], and the choice of model depends on whether the particles are shearable or non-shearable.

$$\text{Overaged, shearable particles: } \sigma_{ppt} = C_2 r^{m-1};$$

$$\text{Overaged, non-shearable particles: } \sigma_{ppt} = C_3 r^{-1}$$

- Comparison of the experimental and modeling results using both shearable and non-shearable particle assumption.
- Overall comparison of the experimental and modeling results for yield strength aging at 160°C

