How to combine ML and ecodesign to find the best structure/material for sustainable aviation .

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I. Context

- The aerospace industry is evolving to reduce its environmental impact through lightweight structures

- Topology and material selection are key design variables for reducing mass and environmental footprint, creating a coupled optimization problem

- Currently, there is a lack of a comprehensive benchmark database that focuses on both mechanical performance and environmental impact of aerospace structures

II. Goals

- Develop a database on environmental impact

- Select strategic materials for aerospace structures

- Predict optimal mechanical and environmental performance for structures

III. SimJEB Library

- Simulated Jet Engine Bracket (SimJEB) is a public collection of crowdsourced topology optimised mechanical brackets

- 320 designs with the same interface and the same four bolts so they can be used for the same task.

- Design the lightest bracket with a maximum stress below the yield stress of Ti-6Al-4V across 4 load cases
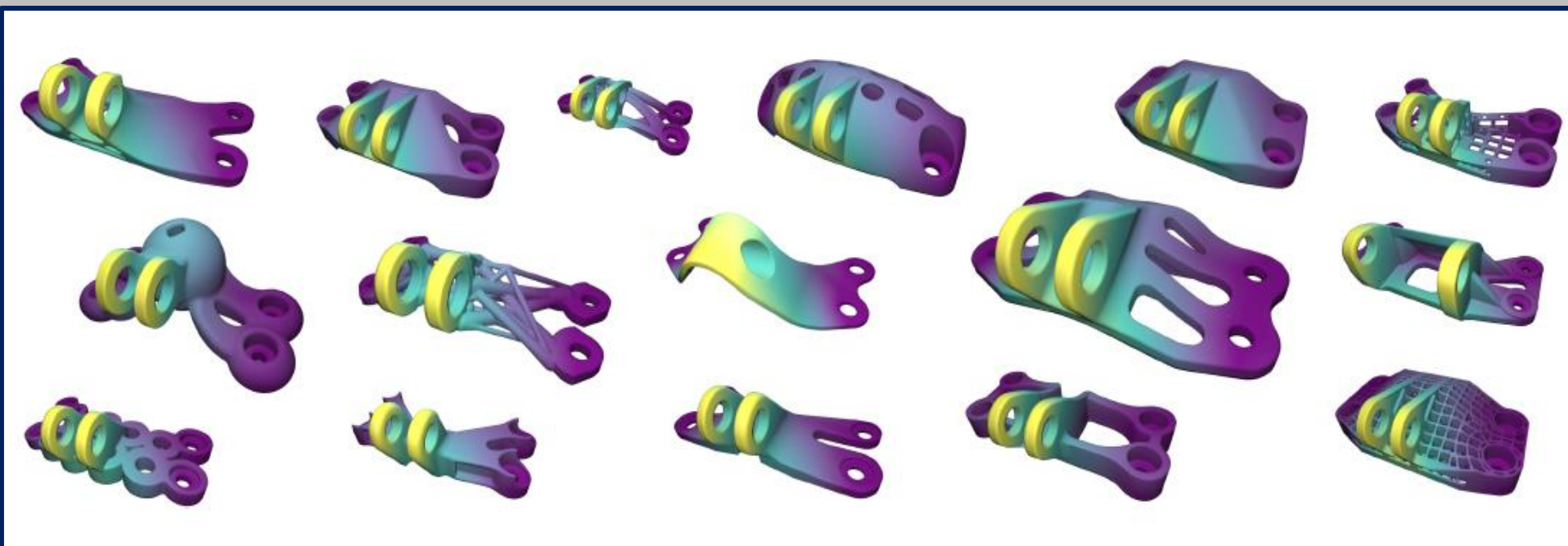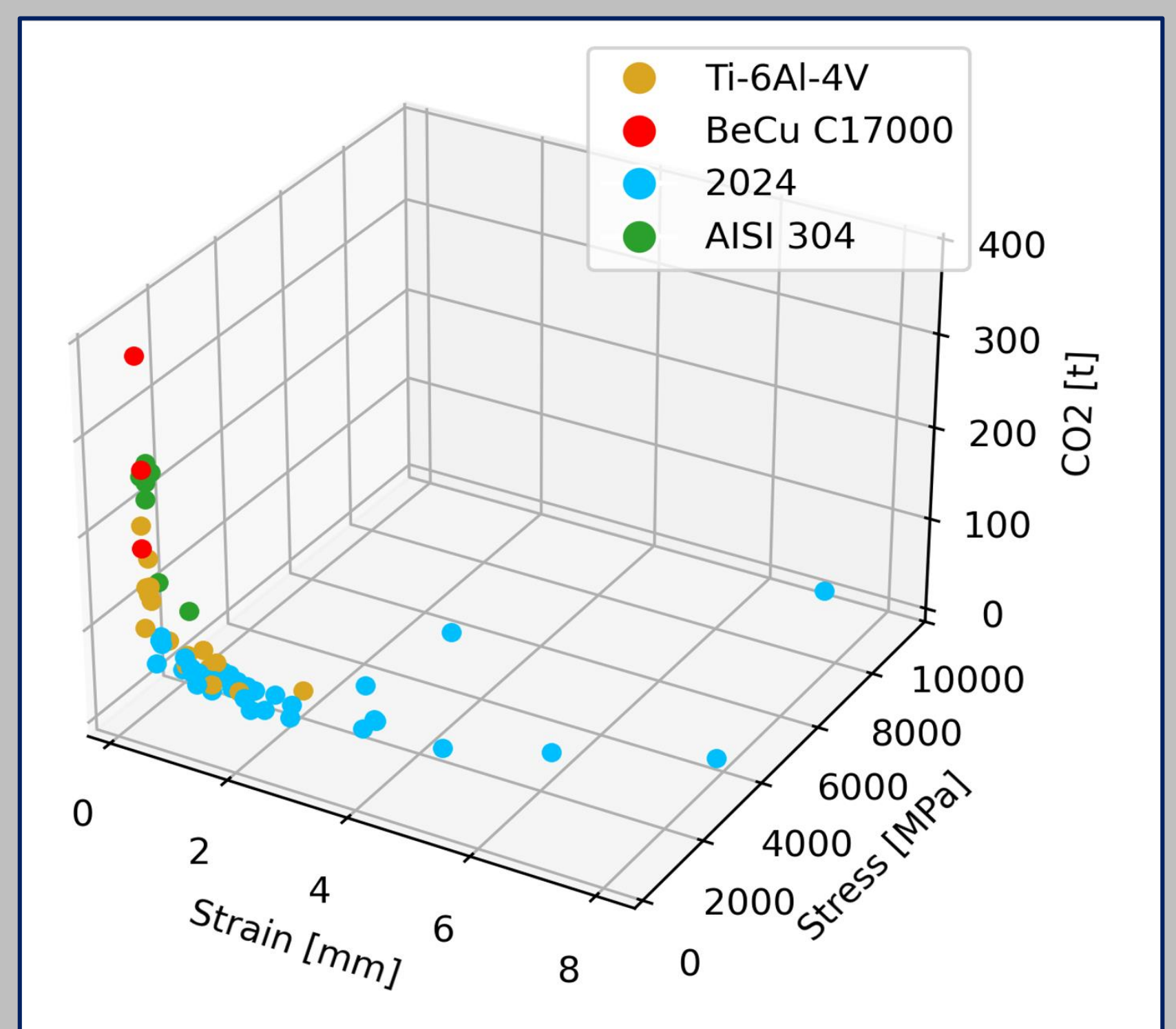

Jet engine brackets [1]

IV. Methodology

Mat	E [MPa]	σ_{yield} [MPa]	CO_2 (prod) [kg/kg]	Energy [MJ/kg]	Water [L/kg]
BeCu C17000	$1,2\ 10^5$	483	5,25	71,0	300
Al 2024	$7,3\ 10^4$	165	12,5	220	250
Ti-6Al-4V	$1,1\ 10^5$	880	19,7	317	197
AISI 304	$1,9\ 10^5$	517	5,0	81	220

$$CO_{2,T} = CO_{2,prod} + CO_{2,life} = CO_{2,prod} + 98,8\frac{t\,CO_2}{kg}\ \ [2]$$

V. Results

- Pareto optimal solutions for structural design optimization using ML algorithms:

3D Pareto front

VI. Future Line of Work

- Develop of an open-source a HTML website to better visualise the obtained results
- Formulate a comprehensive figure of merit that integrates CO_2 emissions, energy consumption and water usage for each structure
- Include additional materials to further expand the database

1.Whalen, E., Beyene, A. and Mueller, C. (2021), SimJEB: Simulated Jet Engine Bracket Dataset. Computer Graphics Forum, 40: 9-17.
2.Luis Yepes Llorente, et al. "A Hybrid Machine Learning and Evolutionary Approach to Material Selection and Design Optimization for Eco-Friendly Structures." Structural and Multidisciplinary Optimization, vol. 67, no. 5, 1 May 2024