Topology Optimisation to Support Preliminary Design

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Introduction

The design of lightweight and high performance parts lend themselves to the use of topology optimisation. To design manually, the intricate CAD (**C**omputer-**A**ided **D**esign) drawing required to produce a complex internal support structure requires a significant time investment from a skilled CAD designer. Alternatively, by designing the part using topology optimisation, those many weeks of manual drawing could be replaced, at least in part, with a few days of automatic design. These organic-like optimised designs can be readily manufacture using an additive manufacturing method, such as Selective Laser Sintering.

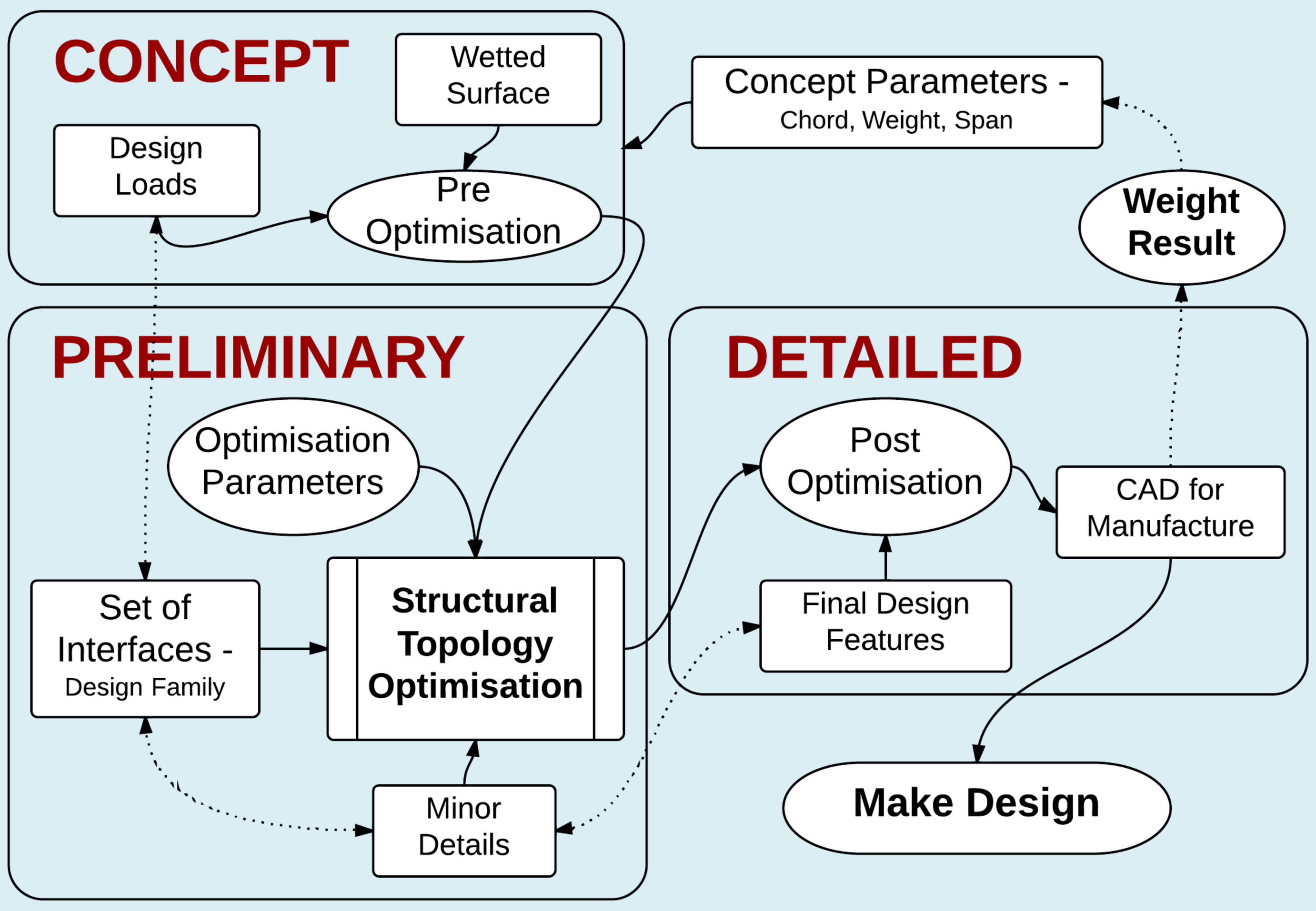


Figure 1: A typical design cycle using structural topology optimization for preliminary design

The Design Cycle

A typical design cycle contains three main stages: concept, preliminary and detailed design **(Figure 1)**. In the concept design stage, the concept parameters such as the shape, weight and span of the aircraft are considered and subsequently basic geometry is often produced. This geometry forms the basis of the preliminary design stage. By introducing a set of interfaces and design loads, topology optimisation can be used at this stage. This may require some manual adjustment post optimisation to add any final features and ensure the part is ready for manufacture. A **B**i-directional **E**volutionary **S**tructural **O**ptimisation (BESO[1]) algorithm has been written within this project to perform the topology optimisation. Structures optimised using this algorithm are shown in **Figures 2 & 3**.

Figure 2: Mount Beam, with 12 load cases, designed using the in-house BESO implementation. Thanks to Rolls-Royce and Khosrow Rezaei for supplying the part geometry and load cases.

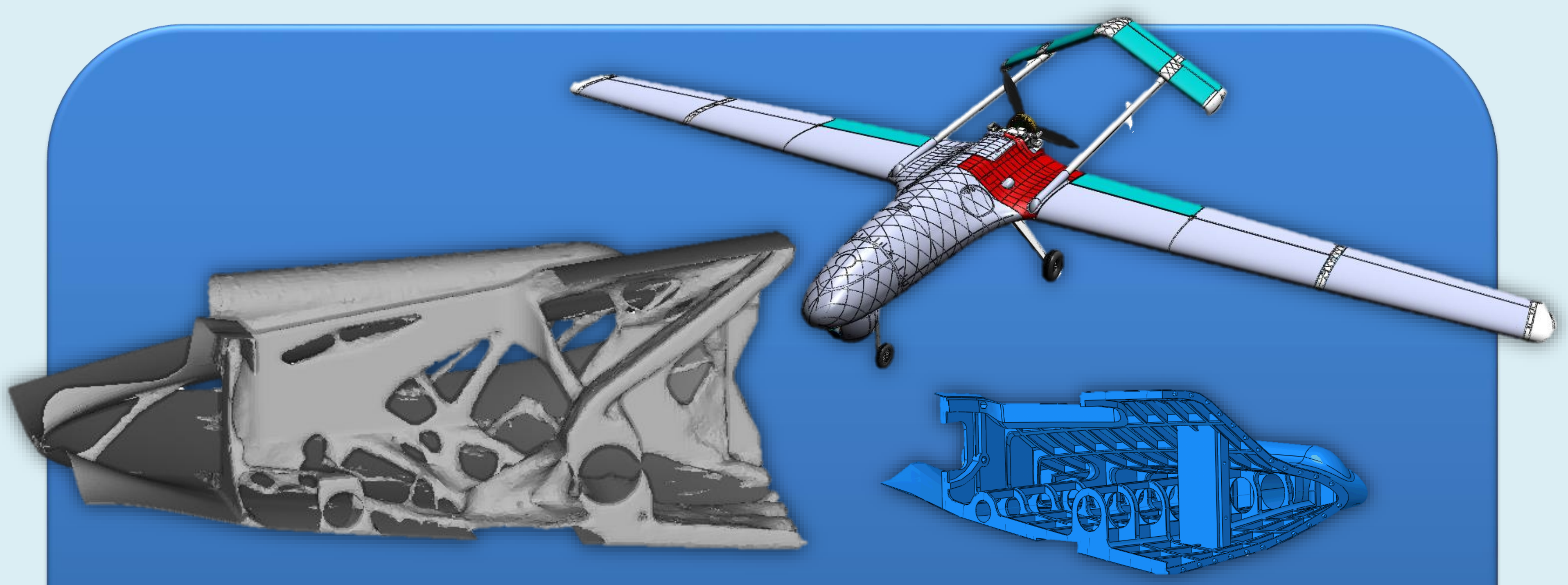


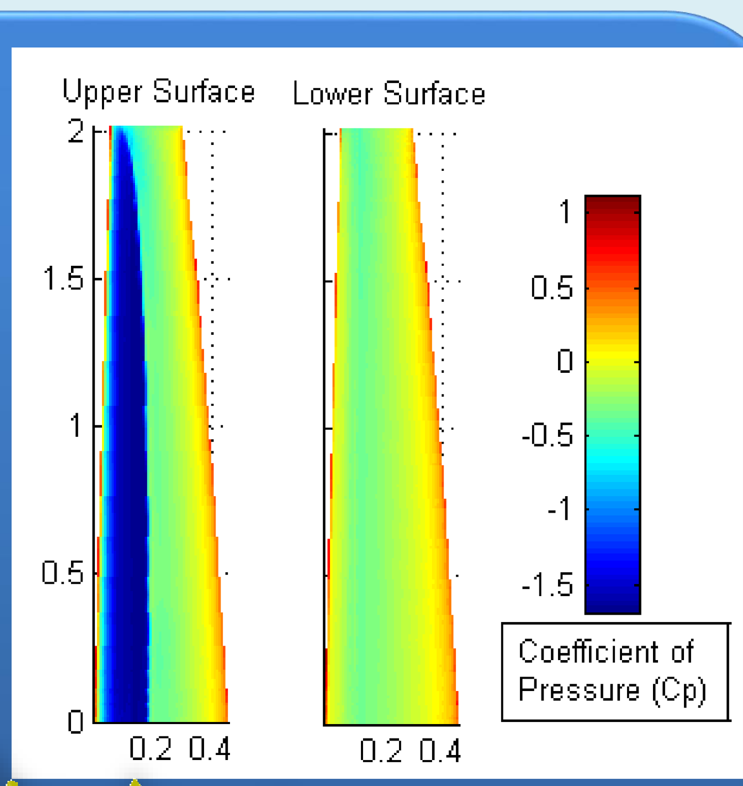
Figure 3: Rear section of an Unmanned Aerial Vehicle (UAV) fuselage designed using the in-house BESO implementation (left) against the manually designed part (right) and the complete UAV (above). Thanks to the University of Southampton DECODE (**D**ecision **E**nvironments for **CO**mplex **DE**signs) project for the UAV geometry.

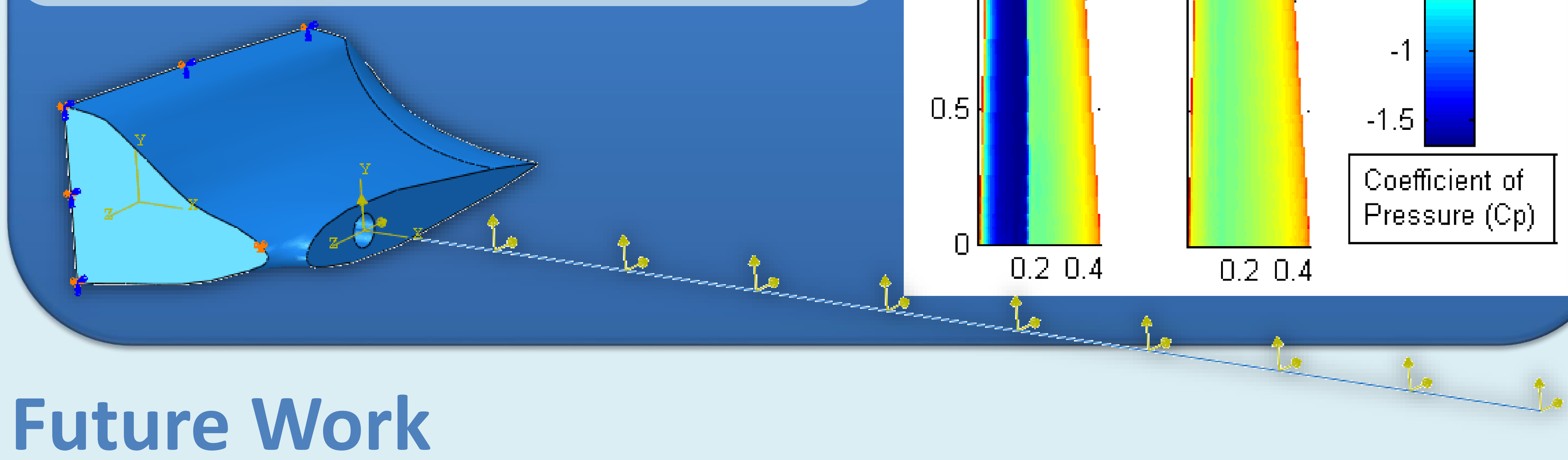
Improving Optimisation Accuracy

The quality of the optimised design is heavily reliant on the accuracy of the **F**inite **E**lement (FE) analysis used. The more accurate the load cases and boundary conditions, the better the final design. As such, the **F**ull-**P**otential (FP) method[2] is currently being used to generate accurate values for the load and drag along the spar as a result of the pressure generated on the wing (**Figures 4 & 5**). The aim is to gradually increase the complexity of the model before trade studies can be carried out to determine the estimated optimal fuselage weight for a given wing shape and size.

Figure 4 (Right): The pressure profile of the wing. Generated using FP analysis[2]

Figure 5 (Below): The subsequent FE model applying the lift and drag profile to the spar, which has been modelled using beam elements





Future Work

There are two main avenues of further work required for this project:

1. **Optimisation guidelines -** The development of a set of guidelines for the FE model and optimisation parameters required to achieve the best results when using topology optimisation to support preliminary design.
2. **Trade studies –** The application of the topology optimisation algorithm to trade studies to determine the effect of the wings on the required weight of the fuselage.

[1]HUANG, X. D., XIE, Y. M. & BURRY, M. C. (2006) A new algorithm for bi-directional evolutionary structural optimization. *Jsme International Journal Series C-Mechanical Systems Machine Elements and Manufacturing*, 49, 1091-1099.
[2]ESDU (2002) *Full-Potential (FP) Method for Three-Dimensional Wings and Wing-Body Combinations – Inviscid Flow Part 1: Principles and Results*. London: ESDU-02013.

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