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Design Automation in the Conceptual Design of Airborne Wind Energy Systems

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For the development of a successful airborne wind energy (AWE) system, there is a need to have an accurate estimate of the final system's performance early in the design process. In order to increase the commercial value, a design should be optimized within the limits of the considered concept. In order to come up with a sound performance prediction of of a whole range of concepts, a combination of Multi-disciplinary Design Optimization (MDO) and Knowledge-Based Engineering (KBE) techniques are used. By these techniques, the process of finding a feasible and optimized design of a complete energy generating system can be largely automated. In this fashion, a large number of system concepts can be elaborated and compared accurately, thus generating the design knowledge that is sought before making any commitment to develop such a system in detail.

The proposed methodology uses KBE to capture the knowledge and experience that a human design engineer possesses and subsequently emulates it in an automated fashion. It typically works in a logical fashion, using rules and reasoning logic to make design decisions.

The focus of MDO is on the structuring of a design optimization that involves multiple distinct disciplines of a given to-be-designed product (e.g. aerodynamics, structures, control, etc.). It makes a complex design process more manageable by creating an effective division between different parts of the overall design problem, while maintaining consistency between them. The basis of MDO is numerical optimization, which is typically a heuristic trial and error method. In comparison to a rule based reasoning method, such an approach inherently requires more effort to come up with a design that is feasible. On the other hand, no preexisting design-knowledge is required to find this design, with the added bonus of finding a design that is also optimal within the imposed set of constraints.

The best results of the combined MDO and KBE approach in conceptual design automation are obtained by a combination of the two techniques that complement each other in an effective way. While the overall AWE system is a complex and novel combination of various components and sub-systems, actually a lot of these latter are very mature systems and well understood in terms of their design characteristics. For these lower-level designs, preexisting knowledge can be applied in a KBE fashion to efficiently find a feasible and close to optimal design solution. On an overall systems level, where such knowledge does not exist yet and complex systems interactions are at play, MDO-based processes would be more appropriate to find the optimum design point in a complex and unknown design landscape.

The implementation of innovative MDO and KBE design techniques will be described as well as their specific interaction in this framework. Tentative design results will be qualitatively presented for the various conceptual system architectures treated and recommendations will be made on successful candidates for further development.