Aero-structure Cost Estimation and Optimization Integrated KBE System

Background
This research focuses on thermoplastic aero-structure cost estimations, relevant sensitivity analysis and optimization studies. Thermoplastic components, as a new generation of composite aero-structures, are specialized with their low-cost, less maintenance properties. The cost model based on component geometry and production process is performed to verify this viewpoint. Along with the cost estimation, in order to gain the insight between cost value and its inputs, the sensitivity analysis is conducted to illustrate the influence of the cost driving parameters. Moreover, the design optimization involves cost performance is critical to aerospace industry, therefore, optimization studies based on sensitivity information are being investigated. The overall application is built based on a Knowledge Based Engineering (KBE) system, so-called Design and Engineering Engine (DEE), the cost model, sensitivity analysis and optimization process are embedded within DEE for the practical application development.

Research Objective
In order to involve cost performance into conceptual design phase, it aims at developing Thermoplastic aero-structure cost estimation, sensitivity analysis and design optimization within KBE system.

Progress and Future Steps
According to the implementation, it shows KBE approach is able to cope with the complexity of design rules and parameterized product geometry. Design knowledge in terms of product, process and cost is captured within the KBE system. Those knowledge is also reflected on the disciplinary views of the master geometry. Initial cost result shows the cost of thermoplastic stiffened-panel can benefit from cost-effective manufacturing processes. More accurate results will be obtained according to detailed data inputs and accurate CERs. At this stage, this research has developed a detailed procedure to estimate the cost in fast and modular paradigm, which works as a tool enabling cost engineers to concentrate on the final cost other than detailed cost estimating process. Moreover, it enables designers to get an overview of the product associated with shape, production and cost properties. Modularized sensitivity analysis will be developed to feed the optimization work flow. Verified optimization results are required to illustrate the capability of this application.

Publications

Research Methodologies
-Integrating cost analysis into conceptual design phase
The overall implementation couples the cost estimation model within DEE (Fig.3). As a KBE system, which is able to assist aero-structure conceptual design, the DEE allows the cost engineer to capture formalized knowledge and structured data from the design and manufacturing aspects. The Capability Modules (CM) associated with Multi-Model Generator (MMG) is developed for parameterized product model and cost estimation pre-processing; cost, weight and structural analyses are disciplinary performance analysis tools which provide inputs for cost involved optimization studies.

Developing cost estimation tool using genetic-causal technique and KBE technique
For cost estimation, an automated pre-processing is performed in order to generate producible geometry and the detailed data required by Product Breakdown Structure (PBS) and Bill Of Materials (BOM). Once the BOM is derived, the cost calculator takes each BOM item as the input to performing calculations and exporting results. The cost calculator is based on Cost Estimation Relationships (CERs) involving shape, material and production factors as cost causes. Fig. 4 shows an example of cost estimation processes during stiffened-panel design. The design is benefited from the cost estimation in terms of development time and effort. In addition, it helps benefit to the general performance of the aero-structures from a life cycle and total value perspective.

Developing sensitivity analysis and design optimization considering aero-structure cost
As an essential step of optimization study, sensitivity analysis is capable to provide gradient information as well as the impact of the design parameters w.r.t. the design performance. The implementation of cost sensitivity analysis is under development. It will be based on target function and constraints, using advanced and efficient derivative computation to derive the sensitivity. Accordingly, the optimization studies in terms of minimizing production cost, Direct Operating Cost (DOC) are investigated.

Relevant Projects
The TAPAS Project
Objective: The Thermoplastic Affordable Primary Aircraft Structure (TAPAS) project aims at the development of primary structural parts and the research into corresponding technologies. (Fig.1 & Fig.2)
Related research aspects:
Thermoplastic aero-structure production cost estimation; Cost modelling integrated KBE system.

Fokker-TUD project
Objective: Improve the component design process by enabling cost and weight sensitivity studies on the design proposal phase for aircraft moveables. (Fig.2)
Related research aspects:
Cost estimation pre-processing; Cost sensitivity analysis.

Fig.1 TAPAS Project wing box productions

Fig.2 TAPAS Project and TUD-Fokker Project Aero-structures

Fig.3 Adapted DEE for Aero-structure Cost Analysis and Optimization Studies

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Publications

Fig.4 Example of Automated Cost Estimation Process for Aircraft Stiffened-panel