2015 NDIA GROUND VEHICLE SYSTEMS ENGINEERING AND TECHNOLOGY SYMPOSIUM
MODELING & SIMULATION, TESTING AND VALIDATION (MSTV) TECHNICAL SESSION
AUGUST 4-6, 2015 - NOVI, MICHIGAN

INTEGRATED PRODUCT AND PROCESS DEVELOPMENT FOR OPTIMIZATION OF PERFORMACE AND COST

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ABSTRACT

In development of next generation products, 80% or more of the downstream costs associated are committed during design phase. If we could predict, with reasonable confidence, the long-term impact of design decisions, it would open opportunities to develop better designs that result in tremendous future cost savings, often with no compromise in key performance objectives. Systems engineering is, by its nature, multi-disciplinary. The aim of Integrated Product and Process Development is to bring these disciplines together in order to assess various downstream implications of early design decisions, creating better designs, avoiding dead-end designs that are costly in terms of design cycle-time, and realizing designs that are manufacturable while achieving the performance objectives. The goal is to build a downstream value analysis tool that links all the conceptual design activities. This capability allows a designer to realize the long-range impacts of key up-front design decisions.

INTRODUCTION

Every modern industry always strives to develop newer, better, and more advanced solutions in a time efficient manner. Most of these solutions involve multiple disciplines with specific constraints and objectives. Deployment of a new competitive product involves decisions regarding performance, quality, manufacturability, and near-term and long-term costs. This needs in-depth knowledge of every discipline starting from the conceptual design basics, high fidelity model development for sub components, establishing relations between various components in the system, available manufacturing processes, and costs associated with production and deployment. In this paper, a workflow is presented to aid decision making process in the early design phase to demonstrate the advantages of such a workflow for a military application case. The Integrated workflow was implemented in the process integration and design optimization software, Isight [1].

PROBLEM DESCRIPTION

The objective was to choose an effective fan configuration for a typical fighter plane engine (Figure 1) to achieve specific mission goals.

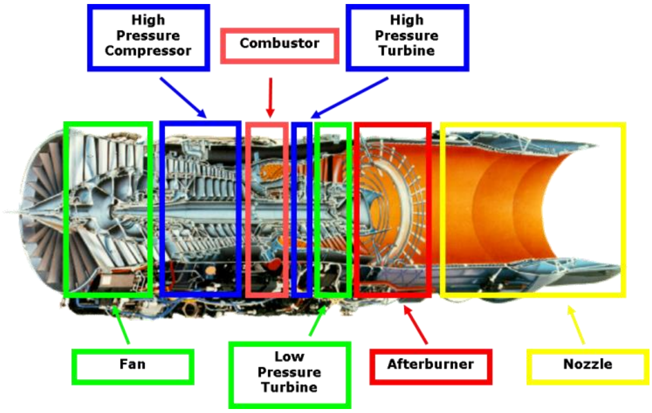

Figure 1: Typical fighter engine configuration [2].

It was assumed that there were two mission goals: suppression of Enemy Air Defenses/ Strike Mission, and low altitude attack mission. A total of 8 candidate fan technologies were chosen for assessment. The three subtasks in deciding which fan type to use were:

(a) Cycle and flow: engine performance was estimated based on engine thermodynamics criteria given certain key performance metrics, and an optimized fan blade geometry was chosen.
(b) Design and manufacturing: Depending on whether the design was feasible with respect to stress, strain,

and natural frequency criteria, the fan’s manufacturability was assessed.

(c) Production Cost: If the design passes the design and manufacturability stage, then the production cost for each design was estimated.

The following subsections describe the subtasks in more details.

Cycle and Flow

The cycle and flow task incorporated two public domain codes written by Jack Mattingly – ONX for generating thermodynamic cycle results and COMPR for performing flow analysis [3]. These two codes were interdependent and hence an iterative scheme was implemented such that the pressure ratio assumed prior to execution of ONX matched the pressure ratio estimated in COMPR. Additionally, the subtask was set up to optimize the cycle and flow solutions towards required objectives given certain constraints. Figure 2 shows the workflow for this subtask implemented in Isight [1].

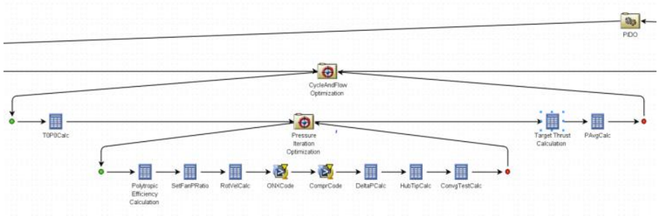

Figure 2: Cycle and flow subtask implemented in Isight.

Design and Manufacturing

Once a feasible solution was obtained in the cycle and flow subtask, the design was then passed onto the design and manufacturing subtask for evaluation. This task executed the design and manufacturing codes. The design code had its own internal optimization scheme to determine design characteristics such as blade thickness. The final design was then propagated to assess manufacturability of the blade. Figure 3 shows the subtask implemented in Isight [1].

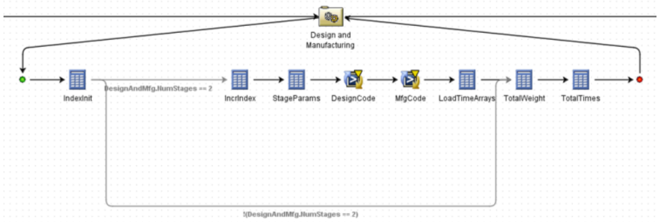

Figure 3: Design and manufacturing subtask implemented in Isight.

Production Cost

The last subtask in this workflow was analyzing the production cost of the various candidate technologies so that one with best return of investment could be chosen. The cost code consisted of a Microsoft Excel workbook that worked on pertinent time and weight values generated from the design and manufacturing codes. Figure 4 shows this subtask implemented in Isight [1].

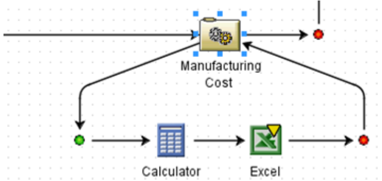

Figure 4: Cost subtask implemented in Isight.

Solution Execution

The design space encountered in this project was extremely complex and discontinuous. Optimization techniques often have difficulty converging in such a complex space. In such cases, exploratory techniques perform better but they require more time for execution. Often times the design exploration gets trapped into invalid/infeasible zones. It is also very important to start from a feasible design point to make sure that the design exploration will move forward instead of diverging or going out of bounds. The design variables were monitored while the design process was in progress to make sure the exploration was continuing in a valid range and if necessary, the formulation was adjusted and bounds were tightened.

FUTURE TASK

The phase I of the workflow involved the design part of the process only. The next phase is to develop a workflow to incorporate deployment, operation and maintenance costs to realize the downstream costs associated with the design. The conceptual workflow with all the essential components is shown in Figure 5.

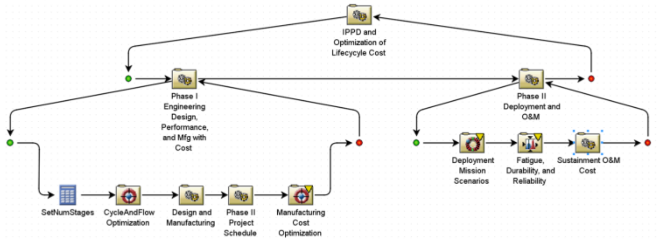

Figure 5: Complete process integration workflow.

The current design process implemented in this work incorporated codes that are based on theoretical and simplified approaches. They do not take into account the effect of blade size and shape on the aerodynamics and they do not allow changing blade twist, axial length of a stage, and angle or shape of the axial flow path. However it is important to substitute the simplistic models with high fidelity analyses approaches including fatigue and durability analyses for making reliable design decisions. Additionally, the current workflow performs deterministic analysis only. It is important to incorporate probabilistic analysis schemes in the work so that the design decisions can be made with confidence. Hence the Phase II of the project is to incorporate high fidelity analysis approaches along with probabilistic schemes so that the full implication of making a design decision on future products can be realized during the design phase and a reliable decision can be made with confidence.

REFERENCES

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