Taking off into a Knowledge-Based Composite World – Complementary Technologies that Radically Improve the Product Design Process

Authors: Judith Crockford, Phil Payne

Presented by: Julian Drake, Consultant

Knowledge Technologies International Inc.
City Center Office Park, North Building, Suite 295
26999 Central Park Boulevard
Southfield, MI 48076
Tel (248) 304 0024

http://www.ktiworld.com

The Automotive industry, like many others, is faced with the need to develop product in ever-shorter timescales. One area under constant review is that of composites, where investments in research and development have led to the availability of composite materials that might one day replace traditional materials for new and existing product designs. This paper discusses how a fusion of MSC Software and Knowledge-Based Engineering tools complement each other in a composites environment, and, drawing lessons learned from this Aerospace industry project, provide pointers that could have far reaching implications for Automotive design engineers worldwide.

KNOWLEDGE TECHNOLOGIES INTERNATIONAL

Introduction

The current CAD-Centric engineering process depends heavily on a designer's experience and his personal intuition. It makes very little use of knowledge other than that of the designer and his dexterity with the CAD tool. It addresses engineering performance, manufacturability and cost - usually after a great deal of the program budget and schedule has been expended as the project gets underway.

The KBE approach is to make the best engineering knowledge available, so that fully engineered product designs can be generated in little more than the computer runtime. This opens up great possibilities for design optimisation, and to give the designer the relative luxury of being able to compare and contrast design alternatives, as the case study will amply demonstrate. It enables the traditional design concept and design review activities - where the most significant decisions in the design process are taken - to be much more effective than in the CAD-Centric design process, where the time constraints and investment of building CAD models create a great reluctance to instigate product design changes.

This paper identifies the characteristics and benefits of a KBE Process. It shows how these characteristics have been used to bring benefits to Composite Product Engineering - in this case an Aircraft wing. The principles are equally applicable to any complex product engineering processes and in particular the automotive industry, where the designer's first proposal may not be the optimum solution.

KNOWLEDGE
TECHNOLOGIES
INTERNATIONAL

Current Engineering Practice – Situation Analysis

The Traditional Engineering Process

Traditionally, the engineering process has consisted of a collection of loosely integrated, sequential activities, where much of the engineering knowledge that has been acquired on previous projects must be rediscovered, relearned and applied.

This normally involves the following disciplines:

- Interactive tools, such as CAD systems, which will require the user to proceed through the design process in a time consuming sequence of low level steps, that contain no "engineering process intelligence", other than reliance on the capabilities and competencies of the CAD system operator.

- Analysis tools, such as FE, that provide extremely competent numerical capabilities to predict for example, deformations, stress levels, temperatures, fluid pressures and flows.

But:

- They are often quite separate from the design process and departmentally constrained.

- They require specialist engineers to set up and interpret the simulation process for feedback to the designers in a sequential fashion.

Improvements in Engineering Tools

Engineering software vendors have been improving their software to expand the extent to which their software can be used to automate parts of the engineering process, typically:

- CAD vendors have provided macro languages for programming sequences of CAD operations, so that drafting and geometry construction steps can be automated.

- PDM vendors have provided data management tools for the vast amount of product definition data created by CAD operators in the engineering design and revision process.

- Workflow vendors are providing tools for ensuring the smooth flow of information between participants in the engineering process.

- The MSC.Software Corporation provides tools, such as PCL for automating a great deal of specialist knowledge about the simulation process for a specific product.

- MSC.Acumen provides tools for deploying engineering simulation expertise behind an easy-to-use user interface. This enables engineers who are not FE specialists to execute complex FE analysis based on the expert's definition of the product simulation process.

In spite of the progress achievable through these tools, a great deal of engineering is still carried out manually. Where the engineering process behind these tasks is understood, the enormous cost and overhead of this human contribution is largely unnecessary, and frequently time constraints prevent re-engineering and product improvement early on in the design cycle.

KNOWLEDGE
TECHNOLOGIES
INTERNATIONAL

Current Engineering Practice - Design-Guesswork Driven Process

The improvements provided by CAD tools are primarily focused on helping the Designer to construct geometric models more quickly. Thus a CAD operator - whose primary concern is often geometry configuration – can create designs more rapidly. However, these designs are only a best approximation at the desired solution. The design model is then passed "over the wall" to other engineers to determine the performance, cost and manufacturability of the proposed design.

KTI believes that this process is flawed for two reasons:

Designers are reluctant to rework their designs unless they have to, due to:

- Project schedule pressures
- Budget constraints
- Professional pride in their experience and the quality of work
- Reluctance to lose freedom in their day-to-day work

Many steps of the overall engineering process are expensive and time-consuming, limiting the opportunity for design optimisation – particularly:

- Design definition using a CAD system
- Manual calculations

The result? Lack of upfront product optimisation, where the majority of costs are incurred.

KNOWLEDGE
TECHNOLOGIES
INTERNATIONAL

Knowledge-based Engineering (KBE) for Business Improvement

The KBE Solution - Integrated Engineering : Automating "Known" Processes.

By contrast, KBE automates much of the design configuration process and puts product engineering at the heart of the design process. This automation is not "black-box" engineering, rather the execution of known engineering steps to evaluate design alternatives, providing engineers with information to make better decisions in the design process.

Integrated Engineering Ensures Reality

The ICAD® System was conceived to automate repetitive tasks and a framework for decision-making criteria, and thus provides a comprehensive KBE environment where rules and engineering process relating to any aspect of the design process can be combined. Hence, KBE processes can encompass all concurrent engineering considerations, producing fully engineered solutions. This enables design optimisation and comparison of design solutions to be executed using models that consider all aspects of the problem.

Limitations of a CAD-Centric KBE Environment

Much engineering knowledge is about the process of engineering a solution, not simply the resulting geometry. Even geometric rules are often best implemented during the development of the solution, rather than applied after the result has been created.

CAD-centric KBE has two particular weaknesses:

- The KBE objects are likely to be based on geometric results rather than the engineering process that creates the best overall design.
- The KBE objects are likely to be compromised by the breakdown of the overall product model into sub-assemblies and components whose model size and scope is suited to interactive CAD work by a single CAD operator.

Furthermore, during Conceptual Engineering, two aspects of the work in particular make a KBE system more suitable than a CAD system:

- *Loose Geometry Definition*: the product definition is often too nebulous for a CAD model to be an efficient basis of knowledge representation. KBE objects are generally much more suitable for representing abstract things such as product concepts, design calculations and engineering processes.

- *Manufacturing Engineering Participation:* arguably manufacturing engineers could make their greatest contribution to the profitability of an engineering product if they could carry out detailed manufacturing engineering during the conceptual and preliminary engineering phases of a product development. The reality is that they rarely have enough detailed information to guide the designers to the optimum overall solution

Finally, during the Detailed Engineering process, the product definition requires the rapid execution of well understood, but complex engineering processes, incorporating expertise from several engineering specialists. This large-scale engineering process automation for which ICAD is eminently suited provides two key advantages:

- The best corporate expertise can be applied to many design alternatives within hours, without error, regardless of the expertise of the user.

- The automation of a large amount of routine work, allows the engineering team to focus on engineering rather than project management and scheduling difficulties.

KNOWLEDGE TECHNOLOGIES INTERNATIONAL

The Importance of Scalability: Large-scale Knowledge-based Engineering Integration

The ICAD KBE environment is ideal for capturing and automating engineering knowledge, and integrating "islands of automation" within a large-scale engineering process. ICAD has the capability to deliver this vision due to a number of carefully constructed features of its KBE environment:

- A knowledge representation language which can efficiently represent any rule, expression or relationship (configuration, performance, component selection, manufacturing, etc).
- Facilities for efficiently defining, executing and testing rules.
- Tools for viewing and publicising the knowledge within the KBE objects.
- Tools for version management of the KBE objects.
- Software characteristics that enable it to cope very well with large models without disproportionate performance degradation.

Consequences of Scale Limitations in KBE Implementation

Without these characteristics, a KBE system would be limited to small scale knowledge capture, leaving the engineering process fragmented, and would present the Engineering Organisation with great difficulty in creating Quality Assured applications that will ensure consistency between the component applications.

Additionally, if the focus is to produce a suite of "user-assisting" applications, with no co-ordinating vision and architecture, it is likely that small KBE applications will only produce small-scale individual productivity benefits, and not
the much more business-critical benefits which can be achieved by developing KBE systems focused on overall objectives such as:

- Overall schedule acceleration
- Engineering error reduction
- Manufacturing and procurement risk reduction
- Best-in-class product engineering

KNOWLEDGE TECHNOLOGIES INTERNATIONAL

Knowledge - Present and Future

Expert Guesswork

Historically, it has been extremely important for experts to be able to make correct judgements about which design concepts to use, since by the time the calculations and design development have been done to prove their assumptions, the scope for change is often quite limited. Poor guesswork may lead to the cancellation of engineering projects that turn out to be non-viable. When a KBE system is used to integrate the design process with the performance simulation process, it becomes far less important to be able to "guess" correctly the first time, and more important to know how to find an optimum design solution. This is particularly true as market pressure forces engineering companies to produce better and better products, forcing them to improve on previous experience rather than simply repeat it. In this engineering climate, large-scale KBE provide a means of generating best current-practice designs rapidly and cheaply, allowing resource to be re-focused on design improvement.

Process Improvement

The ability to rapidly re-engineer using KBE implementation of engineering processes, and the emphasis on design assessment, comparison and improvement almost inevitably lead to better engineering solutions to product design problems. The freeing of experts from team supervision, teaching and routine engineering work further enhances their ability to discover engineering improvements.

This improvement is crucial to competitive product engineering in the future.

Self Documenting Processes

The ICAD KBE system has an elegant rule language, allowing the user to use component, feature and characteristic names in a way that makes the rule references very clear. It also has facilities for automatically producing documentation of the rules and Knowledge Objects.

KNOWLEDGE
TECHNOLOGIES
INTERNATIONAL

Case Study: KBE Application - Aircraft Wing

Due to the proprietary nature of the work carried out, no precise details of the KBE implementation can be disclosed. However, the following description indicates the level of success achieved in applying KBE to automate the required engineering processes.

Metal Wing Design Process

KBE Step1

The overall wing design process starts with the aerodynamicist's definition of the wing aerofoil sections he requires. An ICAD KBE application imports this information and produces a smooth surface to the aerodynamicist's satisfaction between the controlling sections.

KBE Step 2

Preliminary design calculations must be carried out to determine the sizing parameters for the wing skin, machined stringers and ribs. Note: The skin thickness varies over the wing surface; the stringers are machined to minimum weight, changing thickness along their length, and the ribs are a complex machined component comprising of a stiffened web with lightening holes and flanges.

KBE Step 3

The ICAD KBE application passes the preliminary wing design definition, and additional commands to ensure appropriate idealisation to MSC.Patran using the MSC.Patran Command Language. The KBE application also defines the load application, as far as is necessary for MSC.Patran, and initiates the MSC.Nastran analysis.

KBE Step 4

The results of the wing performance simulation allow the KBE application to suggest appropriate adjustments to the user, and re-execute the analysis.

KBE Step 5

The KBE application provides a combination of automation and optional user interaction to complete the primary wing structure design down to the level of primary structure fasteners.

KBE Step 6

CAD solid models of the entire wing primary structure are produced.

KBE Step 7

Procurement and manufacturing information is produced, including:

- Definition of billets of raw material
- Definition of manufacturing geometry of the components (e.g. as machined, post-formed, etc)
- Jig and tool fixture designs

The entire process for a wing primary design now takes 4 people 6 weeks to run many iterations of the KBE wing engineering application suite, to scrutinise the results and to decide on the optimum engineering solution. Previously, just undertaking this design iteration took 20 people 6 months.

Composite Wing Design Challenges

Re-useable Metal Wing KBE Applications

Wherever the metal wing engineering and process was similar to the composite wing process, it was possible to re-use the KBE application objects.

Additional Complexities in Composite Structures Engineering

However, in a number of aspects, the design of composite structures is significantly different from metal structures. These differences include:

- Ability to tailor material properties to achieve optimum weight performance.

- Greater manufacturing tolerances. The curing process can induce significant distortion in composite panels if particular care is not taken over ply sequencing.

- Requirement to preserve mechanical properties through transitions in thickness, involving careful consideration of material continuity.

- Drape of composite cloths over doubly curved surfaces: this needs careful consideration since it affects fibre direction, and therefore material properties. Cloth materials may also wrinkle or require darts to achieve such surfaces. Surface contour has other effects including resin build up and movement of plies. Tape laying and other techniques require fine adjustment to achieve the desired results over contoured surfaces. The MSC.Patran Laminate Modeler can predict shear and fibre direction within each cloth, therefore highlighting potential distortion and deviation and subsequent downstream manufacturing problems.

- A significant range of materials, lay-up methods, component manufacture and assembly options.

Every valid best practice ply sequence is investigated to find the sequence giving best play continuity across the entire wing panel. Numerous possible configurations are considered in minutes, and prioritised according to knowledge and manufacturing preferences –

and the result of ply drape analysis using the MSC.Patran Laminate Modeler.

KBE Suitability for Evolving Knowledge

In addition to considering a wide range of materials and manufacturing methods, the engineering concepts were very new, and so best practice had not been determined. However, with ICAD it was possible to incorporate new ideas into the KBE application as they arose, testing their validity on the full wing design. When validated, the KBE tool was immediately available for quantified comparison of alternative product designs.

Recommendations for Automotive Application of KBE: Large-scale Process Automation

The Aerospace examples demonstrate that together with the MSC software for Material Data and Engineering Simulation, ICAD's KBE Environment has the capability to integrate and automate huge engineering processes, enabling the user to control and direct the process. Consequently, we believe that KBE is an appropriate technology for enabling significant improvements in Automotive Engineering, through engineering process implementation that integrates:

- Product configuration
- Performance simulation
- Component and system level design
- Conceptual and detailed design definition
- Manufacturing engineering

This integrated design, simulation and engineering knowledge environment promotes rapid vehicle configuration generation, and idealisations for:

- Chassis design
- Performance simulation (typically stress, dynamics, crash, thermal, CFD)
- Consideration of many more design options in a given period

KBE also promotes problem avoidance and design improvement by:

- Application of "best practice" KBE models.
- Reduction in human error.

- Identification of known problems by KBE implementation of best practice
- Problem resolution and improvement by rapid engineering iteration
- Quantitative comparison of design alternatives.

In summary, the KBE application will either use the best arrangement it finds, or allow the user to choose from a set of valid possibilities. If the user wishes to choose the solution he will be presented with summary information based on the results of each choice. With this (qualitative) information, making the right choice will be much easier and require much less user assumptions at the design stage.

KBE as a design and process improvement methodology for Automotive Design

To date, ICAD has been used for a wide range of automotive applications, including:

- Occupancy packaging
- Rear vision systems
- Driver visibility and wiper design (contact area, arm and motor), Windshield detailed design
- Wheel envelope, ground clearance, suspension, floor pan and related vehicle configuration design
- Body panel detailed design (closures)
- Vehicle chassis structure
- Electrical system design
- Exhaust manifold and exhaust system design
- Inlet port design; Piston design
- Bumper design
- Headlight design
- Flywheel design
- Pulley design
- Tooling design

KNOWLEDGE
TECHNOLOGIES
INTERNATIONAL

About The KBO Environment

KTI's The KBO Environment™ with 'ICAD® Built In' is the advanced Knowledge-Based Organization (KBO) software tool for the intuitive management of complex processes. It enables a KBO to harness product definitions along with the knowledge base of its experts, product rules, performance data, legislative and safety codes and design best practices. It automates product development from concept to production. KTI's KBO technology has been proven in countless process automation applications for world-leading companies in automotive, aerospace and manufacturing industries providing the most advanced knowledge deployment environment and regularly provides returns on investment of over 100% and productivity gains in excess of 50%. The KBO Environment is a new family of KTI's Knowledge-Based Products comprising several inter-operative elements:

- Knowledge-based Process Modeller (KPM) — Comprehends, initiates, controls and dynamically monitors complex and even fragmented enterprise-wide processes
- Knowledge Server — Easily captures and serves knowledge with ('ICAD Built In')
- Knowledge Portal — Intelligently searches for, delivers and archives knowledge
- Knowledge Browser — An intuitive environment to access and integrate your KBO applications
- Knowledge Backbone — Integrates distributed heterogeneous knowledge sources

About KTI

KTI is the technology powerhouse behind the knowledge revolution and the world's most successful provider of software and services empowering the Knowledge-Based Organization (KBO). KTI's technology allows enterprises to capture their Intellectual Capital and deploy it intuitively to control complex processes. The benefits are compressed time scales, huge cost savings, enhanced creativity and optimized products, resulting in 'audited', documented, repeatable and fully understood processes and best practices. KTI's technology is now considered by many companies to be a vital asset in the drive to constantly improve their offer and keep ahead of the competition. Using KTI's software, global market-leading companies in aerospace, automotive and other manufacturing industries have become pioneers in creating customer-driven products, right first time – every time.

Registered in Luxembourg the company operates from offices across the United States, Europe and Asia. KTI's world-wide client base includes Airbus Industrie, BAE SYSTEMS Airbus UK, AP Parts, Benetton Formula 1, Corus, Daelim, Fiat, Ford, GM, IPTN, Jaguar Cars, Lotus Cars, Pratt & Whitney, Ricardo, Rolls-Royce, Sikorsky, Tata, Trico and many others. For more details see: www.KTIworld.com. **Note:** KTI initiated and is prime sponsor of the KBO conference. Sponsors have included Sun, Hewlett-Packard and Silicon Graphics. For details on the recent European KBO conference in Paris, and future Conferences, see: www.KBOworld.com