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CAD Centric Use of Geometry for Tightly Coupled Analysis and Design

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ABSTRACT

Computer-Aided Design (CAD) systems have undergone several paradigm shifts over the past three decades in order to significantly improve their usefulness throughout the entire product development process. Now all CAD systems have abstracted geometric composition into Feature-based (parametric) construction. A major advantage of this generation of CAD systems is that the designer's intent can be incorporated into the CAD component.

Although there have been increases in the use of CAD models for simulation-based analysis, the knowledge and design intent that could be incorporated in a feature-based CAD model is rarely exploited in the downstream simulations. One of the root causes of this can be traced to legacy tools that are used for geometry handling and legacy codes configured to read in this geometric data. To compound these problems there is, at best, a loose integration of CAD and Computer Aided Engineering (CAE) through translators. After translation only the geometric information is available and any design intent encapsulated in the CAD models is stripped away.

CAD systems have become the *de facto* environment for product lifecycle management so there are other benefits of staying closely connected. Any CAE discipline that can integrate directly with CAD services can seamlessly be part of the entire development process (any discipline that is not may become marginalized in the enterprise). Therefore total use of CAD for all the simulation and design should be the goal. The benefits of full integration are the reduction in design cycle time through the possibility of a fully automated process that maintains a native model and avoids duplication. This is the context of the CAPRI software framework:
Seamless Geometry Import. This includes access to the CAD's geometry without translation using surface and curve evaluations as well as inverse evaluations (*snaps*). The analytic representation is also available as certain geometric primitives and a conversion to NURBS. A fully associative watertight triangulation completes the CAPRI view of the geometric components of the BRep (Boundary Representation).
Feature Tree Access for Design. All the major CAD systems support a suite of feature-based parametric abstractions for construction. This perspective allows for a simple and unified approach toward modifying geometry after the model has been initially constructed within the CAD GUI. When the CAD model is regenerated, the operation list (construction abstractions) is interpreted by the CAD system to sequentially build

the geometry of the part. This gives the operator the ability to construct a family of parts (or assemblies) by building that first instance. Many of the operations used in the construction can be controlled by parameters that may be adjusted. By changing these values, a new member of the family can be built by simply following the prescription outlined in the Feature Tree. In supporting this method of construction, a direct API can provide both simple and powerful access to the CAD system for driving design changes. The designer's intent can be transferred to the analysis and optimizers through the names assigned to parameters (and branches) as well as their association to positions in the Feature Tree.

Shape Design. The CAD perspective on the parametric building of parts is suitable for driving single-valued parameters, but is problematic for shape design where the definition is controlled by a large number of curve or surface points and parameters. But, incorporating shape design can be simply achieved by exposing certain spline curves as multi-valued parameters. The curves are extracted from the independent *sketch* features found in the CAD model. These curves are subsequently used in Features such as revolving about an axis, extrusion, blending and/or lofting along a guide. An optimization scheme, inverse design, or other shape-driving algorithm can readjust the points that define these curves. When the model is regenerated, the new part expresses the changed shape(s). This functionality is critical for shape design in general and specifically aerodynamic design.

Defeaturing & Solid Boolean Operators. These functions can allow for a single part to be used in multiple contexts. For example, structural analysis can be performed on the turbine blade then the blade part can be subtracted from a portion of the passage to provide the fluid domain. Defeaturing can be used to make the geometry appropriate for the analysis at hand.

If the engineering design knowledge, parameters, and process migrate to a modern CAD-based infrastructure the immense benefits of all of the tools found in the CAD environments can be utilized over the complete lifecycle of the product from concept to retirement. This can be achieved only by an investment in building robust CAD models that encapsulate the design upfront in the process. This is powerful and it ensures that all of the information about the product is contained in one place, rather than numerous data files and spreadsheets. The downside is that this conceptually simple process shift (move the complete design upstream) requires a change in current practices.

The CAD-based model should be generated as part the preliminary design phase and then can seamlessly transition to final design driven by high fidelity analyses. This greatly enhances the flexibility of the design process by extending the time period in which major design change can be made over the traditional design cycle. Upstream decisions tend to, early on, lock in the parameters most crucial to overall performance. The ability to easily return to a prior point on the design curve allows the engineer to improve the overall performance to a much greater degree than is possible by small permissible changes at a later time.

Although a parametric part may exist upfront in the design process, the analysis team is usually not equipped to exploit the feature and parametric capability due to the existing design process or limitations in the software tools. This has been due to lack of access to the CAD system or proper connectivity between the CAD system and CAE application, which can now be handled.