

Digital Prototyping for Golf Car Development

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ABSTRACT

This paper describes how three-dimensional (3D) solid models are used throughout the product-development process. The products described in the paper are gasoline- and electric-powered golf cars. In the product development process, 3D solid models are used to design components and assemblies, create engineering drawings, and construct finite-element models. For molded and cast parts, the solid model is the mathematical basis from which tooling is fabricated. The models are also used to develop technical illustrations in manuals and product service documents. Finally, engineering models have been adapted for marketing purposes to develop illustrations for brochures and animations for the company website.

INTRODUCTION

Computer-aided design (CAD) underwent a significant advance roughly 15 years ago with the introduction of 3D solid-based modeling. Prior to the use of solid models, CAD systems were based on wireframe representations of 3D geometry. With solid geometry, designers and engineers could better define the parts being developed, and could use the CAD system to estimate part mass, center of gravity and other physical characteristics.

As 3D modeling became widely adopted in vehicle design, engineering analysis software was updated to make use of CAD geometry for model generation. In the area of structural analysis, FEA code developers now offer auto-meshing capability and “workbench” software into which CAD geometry is imported, meshes are auto-generated and boundary conditions are applied.

In recent years, the growth of virtual engineering tools has expanded to include so-called lightweight solid models, such as the 3D CAD-neutral JT file format. JT data are ideally suited to viewing applications. Product Data Management (PDM) systems such as Siemens PLM's Teamcenter Engineering use JT images in their PDM viewer and Vis Mockup applications. The JT viewer in Teamcenter Engineering enables users throughout the company to view and manipulate parts, perform part searches and conduct “where-used” analysis.

ENGINEERING DESIGN AND ANALYSIS

COMPUTER-AIDED DESIGN (CAD) – In the development of a new golf car, the Product Management group specifies the product definition and styling direction based on data collected from Voice of the Customer (VOC) surveys and focus groups. Renderings and cross-section cuts of the vehicle body are provided by an Industrial Design (ID) firm. The Siemens PLM CAD program NX4 is used to create body surfaces, which are thickened to build 3D solid models suitable for manufacturing. Attachment points and structural elements are added to the 3D model. Draft is incorporated into plastic parts so they can be injection-molded. See Figure 1 for a view of the golf-car assembly.



Figure 1

Computer-Aided Design (CAD) model of electric-powered golf car

Structural components are designed and modeled in CAD. These include frame, suspension, brake pedals, cables, wiring harnesses, linkages, seats, and accessories. A view of the aft section of the golf car

showing electrical-system components is shown in Figure 2.

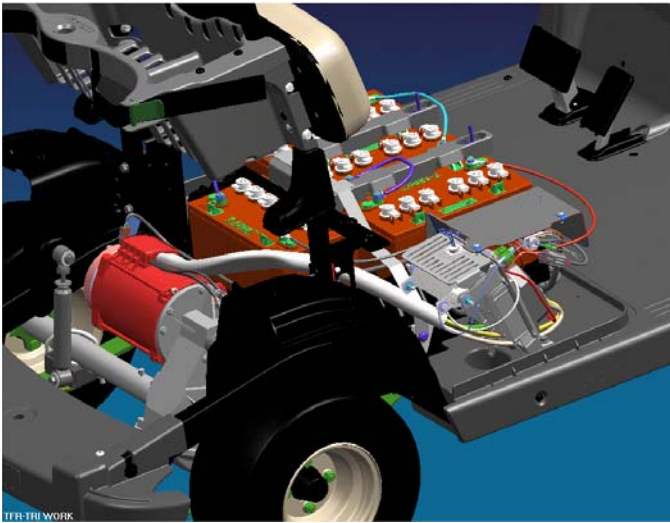


Figure 2

Electric-powered golf car with rear-body removed to show batteries, controller, motor and axle

Assembly Integration - The new golf car was designed using an automotive-industry practice called “Design in Body Position.” When designing a component part in body position, the part is created in the location and orientation that it occupies in the full vehicle assembly. The alternative to design-in-body position is to model a part at the coordinate system origin and then align or mate it to other parts of the vehicle.

For example, a golf car assembly model might begin with the frame weldment. The frame would be modeled in its correct position and orientation relative to the vehicle coordinate system origin. Other components would then be designed in relation to the frame. When designing a part that mounts to the frame, such as the floorboard, the designer would import the frame weldment as a component of the floorboard using the absolute coordinate system. This orients the frame in body position. The floorboard would be built around the frame, which results in the floorboard also being in body position. All components that interface with or mount to the frame and floorboard would be designed following the same process.

When designing a new component, it is important to understand the part’s environment so that the appropriate clearances are maintained. Motion analysis may be required for moving parts such as suspensions, linkages, etc. Preliminary GD&T and GD&T-based tolerance stack analysis should also be performed in this phase of the project.

Note that at completion of the new component or assembly design work, all background (environment) geometry must be deleted from the new part before storing the part in the PDM system. This is critical for

maintaining an accurate CAD-based bill of material (BOM) in the PDM system. For example, if the frame were not deleted from the floorboard as described in the previous paragraphs, the frame would reside in the vehicle assembly in two places: in the CAD file of the frame and as background geometry in the floorboard.

The design-in-body position method enables designers to work simultaneously on interfacing component parts, using working files as background; all parts maintain their correct vehicle location.

Mating conditions work well with components like fasteners and brackets that must maintain a fixed relationship to features such as holes. When the orientation of the reference feature is changed, the mated part will be updated in accordance with the new orientation.

Using the body-position technique, if the location of a reference part is changed, other components will not automatically update to the new location, and will need to be manually moved to its new body position.

The primary disadvantage of using mating conditions is that the mating relationship may be lost if the reference part’s features are deleted or changed. If a designer is unfamiliar with a component or assembly in which mating conditions are used, it could require much effort to re-mate the components. The NX CAD program will generate an error message if a mating condition is broken, although it may allow the new file to be added. In this case, the location of the component with the broken mating condition may not be in its correct position.

CAD-Based Drafting - As is common practice throughout many industries today, the 3D CAD solid model is the basis for 2D drawing views. Drawing views and dimensions must be updated when the solid models are changed. Both detailed part (component) and assembly drawings are used in golf-car design.

In addition to being used in component-part and assembly drawings, installation drawings are also used in golf-car manufacturing to assist the manufacturing engineer in developing work procedures for the factory. Installation drawings usually include multiple views, and more-complex installations require multiple drawing sheets. Included in the installation drawings are details regarding fasteners, torques, lubricants, etc. The drawing views indicate the correct orientation and position of parts, as well as any special instructions for assembly. See Figures 3 and 4.

The installation drawing is not a procedural document. Installation drawings are used to document assembly operations for a particular system, subsystem, or accessory. The manufacturing engineer may choose to divide the assembly steps among multiple work cells or operators. The manufacturing engineer establishes the sequence of assembly operations. The sequence of

assembly steps is *not* defined on the installation drawing.

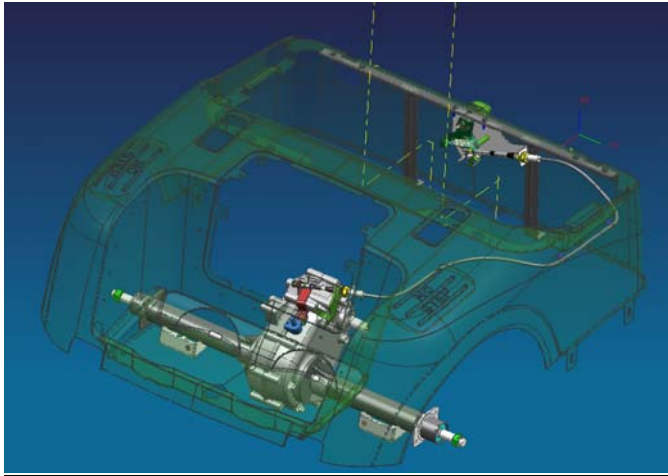


Figure 3

The solid model used for creating an installation drawing

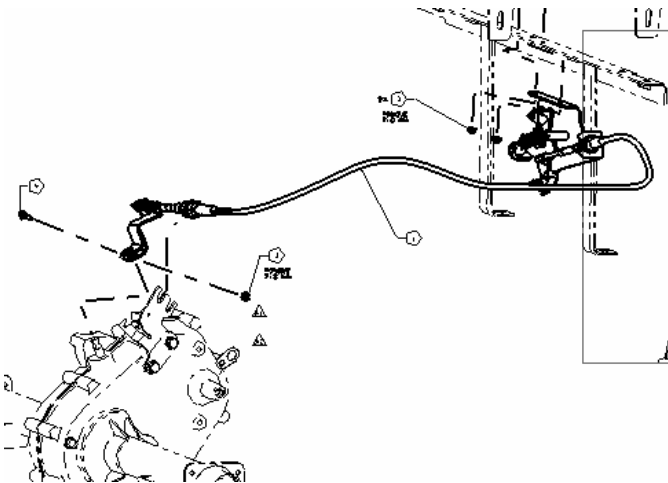


Figure 4

Drawing view for the forward-neutral-reverse selector and cable installation

FINITE ELEMENT ANALYSIS (FEA) - Finite element methods are widely used for structural analysis. The geometry required for FEA may be imported from a CAD program or created within the FEA software itself. The geometry to be analyzed may be a single component or a subassembly. The CAD geometry may be imported into FEA directly via a link between the CAD and FEA software. The geometry also may be imported from several other CAD-neutral file formats, such as Parasolid, STEP, and IGES. When importing geometry from the native CAD files, a number of dimensional parameters may be brought into the FEA program for optimization simulation. The geometry and boundary conditions must then be established in FEA based on the best engineering knowledge and judgment to assure FEA success.

Figure 5 shows the golf-car front cowl FEA model in the ANSYS Workbench interface. The key dimensional parameters are defined in this program. Depending on the project requirements, thermal, structural or fatigue analysis may be required. Based on the FEA results, the design is either approved or further improvement is suggested.

FEA is very effective in accelerating the product design and development process, from preliminary design through prototype testing and production. FEA has also proven effective in root-cause analysis of failures for reliability design.

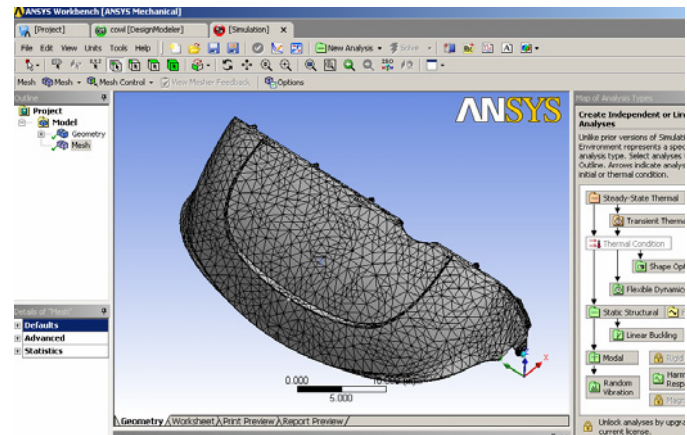


Figure 5

Golf car front cowl mesh for FEA

DESIGN REVIEW AND CHANGE MANAGEMENT

DESIGN REVIEW - Three-dimensional CAD solid models are used in the vehicle and subsystem design reviews. In the design review meeting, a designer or engineer uses the CAD program to present specific parts or assemblies. The presenter may add or remove parts from assemblies, and modify colors and lighting to illustrate parts of interest for the design review team. Technical issues such as fit-up and function are addressed. Aesthetic considerations, such as body design, colors, and textures may also be discussed.

The design review encompasses several other tasks unrelated to the part or assembly models, including drawing reviews, DFMEA, DVPP&R and other topics. These items are outside the scope of this paper.

CHANGE MANAGEMENT - Employees from departments throughout the company act as reviewers and approvers in the Change Request (CR) and Change Notice (CN) processes. The PDM system Teamcenter Engineering includes workflow functionality for routing tasks to employees based on his or her group and role. Because not all employees have access to CAD software, or have the skills necessary to use it, Teamcenter Engineering is used to enable visualization of 3D parts and 2D drawings. Further, the system provides the capability for change requestors to mark-up