Product/Process Design

Using

Horizontally Structured Modeling

and

Virtual Machining
Agenda

- Introduction
- Product Design Applications
- Manufacturing Applications
- Further CAD/CAM Developments
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- Product Design Applications
- Manufacturing Applications
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**Product Design Applications**

**Traditional Feature Modeling Process**

Documented in Software Training Materials and Presentations

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**Definition of Feature Dependency**
A Relationship Between Features that Defines its Placement and Position to Other Features

- Structural Features are Not Independent

**Method:**
- Create/Position Features on features

**Limitations:**
- Parent/Child Feature Dependencies
- Can NOT independently reorder, suppress or delete features
Vertical Feature Modeling Demo
Vertically Structured CAD Model

Recommended by Commercial CAD/CAM Vendors

Created with Feature Dependencies
Function
Demonstration of **UNDESIRED** results when editing a vertically structured model.

Scenario:
Product engineering has determined that the extra RIB material is no longer needed and must be removed.
Because RIB is starting feature.
DELETE RIB FEATURE

UNDESIRED RESULTS
Horizontally Structured CAD/CAM Modeling

Delphi Methodology
- All features are placed on and positioned to datums
- ONLY Parent child relationship between features and datums

Benefits
- Enables easy feature manipulation
  - Reorder features, remove features, add features

Cartesian Coordinates
- Ex: Datum Planes

Primitive Feature
(example: (blank))

Form Feature
Horizontally - Structured Modeling Demo
Horizontally Structured CAD Model

Process Developed by

Independent Features
Function
Demonstration of **DESIRED** results when editing a horizontally structured model.

Scenario:
Product engineering has determined that the extra RIB material is no longer needed and must be removed.
DELETE RIB FEATURE

DESIRED RESULTS

DESIRED RESULTS

Model Navigator

Feature Name

horizontal_pmphs

- CYLINDER(5)
- FIXED_DATUM_PLANE(6)
- FIXED_DATUM_PLANE(7)
- FIXED_DATUM_PLANE(8)
- BOSS(10)
- RECTANGULAR_PAD(12)
- RECTANGULAR_PAD(13)
- BOSS(14)
- BOSS(15)

TOP WORK
### Product Implementation Benefits

<table>
<thead>
<tr>
<th>Product Design Activity</th>
<th>CAD Operator Functions</th>
<th>Productivity Improvement</th>
<th>Delphi Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create Models</td>
<td>20%</td>
<td>50% reduction</td>
<td></td>
</tr>
<tr>
<td>Detail Drawings</td>
<td>30%</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Edit Models</td>
<td>50%</td>
<td>90% reduction</td>
<td></td>
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</tbody>
</table>

- Increased Productivity
- Reduced Cost
- In-Sourced Work

Total CAD Operators ~70
Agenda

- Introduction
- Product Design Applications
- Manufacturing Applications
- Further CAD/CAM Developments
Previous Process (1)
Prior to 3D CAD/CAM

Product
3D CAD/CAM
SOLID MODEL

Manufacturing
RE-CREATE GEOMETRY
(2D CAD/CAM)

MANUFACTURING PROCESS SHEETS

HISTORY of the Process Sheet:
1. 2D CAD/CAM or Manual
2. Non Associative Models
3. Associative In-Process Models

• Process Sheets work is done outside in 2D CAD/CAM
  - 3D CAD/CAM Costly
  - Complex to learn/use
  - Resulted in loss of data integrity

Delphi Automotive Systems
First 3D CAD/CAM Process (2)

Product

3D CAD/CAM SOLID MODEL

Manufacturing

3D CAD/CAM SEPARATE SOLID MODELS (Not linked)

MANUFACTURING PROCESS SHEETS

- Process Sheet work in 3D CAD/CAM
  - Complex to learn/use
  - Cost disadvantage to Delphi
  - Redundant model creation
- Offered no real advantage
- Alternative method sought

Delphi Automotive Systems
Delphi Automotive Systems

Manufacturing Engineering
Integrated CAD/CAM Implementation

New 3D CAD/CAM Process (3) - Virtual Machining

Product

3D CAD/CAM PRODUCT MODEL

VIRTUAL PROCESS MODELS For Mfg.

MANUFACTURING PROCESS SHEETS

BENEFITS
• Maintain Data Integrity
• Reduced Annual Design Costs 50%
• Reduced Lead Time
• Control of Electronic Data

STATUS
• Implemented at all US Locations
• Implementing at Global Locations
**Traditional 3D Process Modeling (2)**

Ex: Multiple Files and Non Associative Solid In-Process Models

- **Operation 10.1**
  - Create Model
- **Operation 10.2**
  - Create Model
- **Operation 20.1, etc**
  - Create Model

**MPSS Program**

*Print Process Sheets*

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**Virtual Machining (3)- (requires horizontal modeling)**

Ex: Single File with Associative Solid In-Process Models

- **Product Casting Model**
- **Ref. & LINK**
- **Master Process Model**
  - *Horizontally Structured Features*
  - *Contains features for all Operations*

**Virtual In-Process Models**

*OP10.1, OP10.2, etc*

- **Create Process Sheets**
  - *Features Assigned to Operations*
  - *Drag ‘N Drop Functionality to reassign Features*
Virtual Manufacturing Process Modeling Demo
Virtual Machining Process Modeling

Developed by Delphi Automotive Systems

PART 1

Independent Process Modeling
PART 1
Demonstration of how product model changes update the manufacturing process models and process sheets.

Scenario:
The size of the Casting BOSS changes.
What is a Process Sheet?

A QS9000 required set of process documentation depicting either a part being machined or assembled. This information is displayed on the manufacturing line for the operators reference.
<table>
<thead>
<tr>
<th>OPER.</th>
<th>STATION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>--</td>
<td>BORE MAJOR CENTER DIAMETER</td>
</tr>
<tr>
<td>020</td>
<td>--</td>
<td>BORE INTERMEDIATE DIAMETER</td>
</tr>
<tr>
<td>030</td>
<td>--</td>
<td>BORE MINOR DIAMETER</td>
</tr>
<tr>
<td>040</td>
<td>--</td>
<td>DRILL (2) HOLES IN LOWER BOSSES</td>
</tr>
<tr>
<td>050</td>
<td>--</td>
<td>DRILL (2) HOLES IN CENTER PADS</td>
</tr>
<tr>
<td>060</td>
<td>--</td>
<td>DRILL (2) HOLES IN UPPER PAD</td>
</tr>
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</table>

Example of a Process Sheet
Remember the size of this BOSS
See OP001 SHT 1 for LEC

OP NAME: DRILL (21) HOLES IN UPPER PADS

PART NO.: 12345678

SECTION F-F

Φ 10.0
Delphi Automotive Systems

Product Casting

MASTER Process Model
Contains all Machined Geometry

Process Models
- Created from the MASTER
- Linked to the MASTER and Each Other
Production CASTING Change

Feature Dialog
Reattach

OK  Back  Cancel

Boss Feature
Production CASTING Change UPDATES ALL Process Models and Process Sheets
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CASTING Change UPDATED Process Sheet
Virtual Machining Process Modeling

Developed by Delphi Automotive Systems

PART 2
PART 2
Demonstration of how process changes update ALL process models and process sheets.

Scenario:
A HOLE that is currently located in Operation 60 now needs to be machined in Operation 20.
Sequence Change

Move HOLE Feature

Move HOLE Feature

Move HOLE Feature

Move HOLE to OP20
MASTER Change
UPDATES ALL Process Models and Process Sheets
HOLE moved to OP20
<table>
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<td>--</td>
<td>BORE MAJOR CENTER DIAMETER</td>
</tr>
<tr>
<td>020</td>
<td>--</td>
<td>BORE INTERMEDIATE DIAMETER AND (1) HOLE IN UPPER LEFT PAD</td>
</tr>
<tr>
<td>030</td>
<td>--</td>
<td>BORE MINOR DIAMETER</td>
</tr>
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<tr>
<td>060</td>
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<td>DRILL (1) HOLE IN UPPER PAD</td>
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**UPDATED Process Sheet**

HOLE now drilled in OP20
Drawing is OUT OF DATE
Current Implementation

Associated Master Product and Process Model

Delphi Automotive Systems

Vision

ProductCasting.prt

Cast.01.prt

Linked

Product01.prt

Finished Product
Model

Product Drawing

ProcessSheet.op000.a.ma.prt

Master Process
Model

Process Sheets

"SAVE AS"

Delphi Automotive Systems
Virtual Machining Comparison

Process Sheet Creation Time for EPS Epsilon Housing Machining

Savings for revisions in line with horizontal modeling
Agenda

- Introduction
- Product Design Applications
- Manufacturing Applications
- Further CAD/CAM Developments
Further CAD/CAM Development
(Work progressing at Delphi)

- AUTOMATED / KBE PROCESS PLANNING
  * Automated Machining Process Design

- MANUFACTURING PROCESS DOCUMENTATION
  * Horizontally Structured Modeling for Charted Parts / Alternate Operations

- MASTER MODEL (PRODUCT & PROCESS)
  * Virtual Concurrent Product/Process

- AUTOMATED MATH BASED TOOL DESIGN
  * Virtual Fixture/Tooling Design

- ASSEMBLY MOCKUP / SIMULATION

- RAPID TOOLING FABRICATION

- METAL REMOVAL PROCESS SIMULATION
  * Automated Machining Process Design

- NC/CMM TOOL PATH GENERATION
  * Automated Machining Process Design

- ANALYSIS