PROCESS PLANNING, CAD/CAM & DFM

Product Development Cycle

Design
- Analysis
- Synthesis
- Design Parameters

Manufacturing
- CAM
- Production
- Quality control
- Packaging
- Shipping

2D Drafting v.s. Digital Playdo

Manufacture

- Market Research
- Conceptual Design
- Design for Manufacture
- Unit Manufacturing Processes
- Assembly and Joining
  - Welding
  - Bolting
  - Bonding
  - Soldering
- Factory, Systems & Enterprise
  - Machining
  - Injection molding
  - Casting
  - Stamping
  - Chemical vapor deposition
3 day prototyping by CAD/CAM/CAE

- Catia, Euclid, AutoCAD, ProEngineer
- Solidworks
- MasterCAM, PowerMill
- Moldflow, C-Flow, ANSYS, I-DEAS

Lecture objectives: laying foundation

Process planning
- Why process planning
- How do you do this
- Inputs and resources: Things to think about

CAD and CAM
- What are the key issues that make them important
- What you will do with these tools in lab

DFM
- Why is DFM important

Perspective on today’s lecture

What is process planning?
- Engineering activity that determines appropriate procedure for transforming raw materials into a final product as specified by engineering design.

What can we accomplish in one lecture?
- Impractical to cover all aspects of process planning in one lecture
- Understanding of what needs to be considered
- How to make a basic process plan
- Consider DFM

The big picture

Essential for timely information and material flow

These are essential for success in manufacturing

- Verification
- Testing
- Design
- Material
- Process planning
- CAM
- People
- CAD
- Equipment
Why process planning?

Structured approaches
- Certainty and repeatability
- Improve/optimize/troubleshoot
- Saving time and $ by avoiding mistakes
- Divide responsibilities

Introduction to process planning

Functional requirements
- Design specifications
- Manufacturing schedule

Constraints
- Mfg. Processes
- Process capability
- Training / skill

Introduction to process planning

Planning parameters / resources
- Equipment
- Space
- People
- Material

Real world vs. class projects
- Complexity of parts and number of parts
- Multi-people/plant/country activity
- You cannot do this “on the fly” with real products

Things to address

Process plans address:
- Type of manufacturing processes
- Sequence of manufacturing processes
- Manufacturing equipment
Things to address cont.

Process plans can be complex and cover more:
- Materials and material flow
- Testing of inputs/outputs
- Documentation/tracking
- Other resource interactions in the process system

Core steps of process planning

Starting process planning

Form a plan to create the geometry
- Break the formation of the part’s geometry into steps (operations)

Sketch can be very useful: Emulate the machine
- You are the machine and the pencil is the tool
- Always think, can it be made as you are sketching?
- Sketch the subsequent geometry you see after each operation

Example: Ford Duratec engine

COMPONENTS

ERROR

$\delta_a$ MAX = 5 microns

$J_L$  $J_R$

Block Bore $\delta_a$

Bedplate Bore $\delta_a$
Initial process planning

Flow charts are useful tools

Partial plan to form geometry for 2.3L Ford Duratec / 3.0L Jaguar engine:

- Note some steps/operations are missing. I've included the steps we will need for the example.

Use CAM or other tools to translate your plan for other resources

Iterated process plan

Partial plan to form geometry for 2.3L Ford Duratec / 3.0L Jaguar engine:

- Some things to think about when assigning equipment:
  - Is it capable (power, required degree of freedom/axes, stiffness, etc.)
  - Is it reliable (what is the mean time to failure and how does that affect the process)
  - Is it robust
  - Cost and pay back period
  - Service: set up and repair/maintenance
  - Does the tooling provide proper constraint

Equipment and tooling resources

Duratec manufacturing line
### Human resources

**Benefits:**
- Human resources are very flexible!!!
- Visual identification capabilities
- Dexterity and manipulation ability is good
- Knowledge and skill reservoirs

### Human resources cont.

**Limitation on assigning human resources**
- Cost: X salary by ~ 2 – 3 to obtain total cost
- Preparation: Training
- Health: Repetitive stress injuries
- Performance: Strength/loads/Speed
- Reliability
- Generally speaking, not repeatable

### Safety concerns

**What does this mean to process planning:**
- Designers, manufacturing personnel usually review the part for reasonable hazards (heavy weight, sharp edges, fragile, hazardous materials, etc.)
- This should be a specific part of the process plan!!!

### Material inputs

**The balance of material:**
- If you run out of material, you lose money, time, customers....
- Storing material cost money, space and time

**Means to route and control the flow of material**
- Tooling
- Pallets
- Robots
- People
- Conveyors, overhead cranes, automated guided vehicles, etc.
Material handling

The circulatory system of the process

Material handling failure = process failure

Considerations:
- Inspection/verification: know your inputs / trust but verify
- Multi-source: Redundancy
- Time sensitive: Food/beverage, etc. with expiration dates

Information inputs and handling

Means to transfer and manipulate information
- If you can not communicate, you can not control

Information routing is the “nervous system” of the mfg. process

If you do not have the right information at the right place/time, the process fails

How is this done?
- Computers
- Tags (including electronic devices) and paper documentation
- Human (not reliable)
- Phone

Considerations
- Inspection/verification
- Work tasks
- G Code

Evaluation and measurement

Evaluation/measurement
- Key issue: You need to know the state of your inputs and outputs if you want to control manufacturing activities
- If you can not measure it, you can not reliably manufacture it
- If your inputs vary, your outputs will vary
- Key issue: Understand sensitivity
Space resources

You will need space for:

- Tooling  Material  Work in progress  Inventory
- People  Machines  Conveyors  Testing
- Everything....

Process planning in 2.008 labs

<table>
<thead>
<tr>
<th>Embodiment</th>
<th>Plan execution</th>
<th>Translate plan</th>
<th>Execute plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sketches or CAD</td>
<td>Process Plan</td>
<td>Master CAM and/or G-Code</td>
<td>Machining</td>
</tr>
<tr>
<td>Sketch/idea Blueprint/</td>
<td>Planning</td>
<td>File exchange</td>
<td>Generate tangible</td>
</tr>
<tr>
<td>CAD</td>
<td>User input</td>
<td>G Code</td>
<td>Machine (i.e. mill)</td>
</tr>
</tbody>
</table>

CAD – More than just a drawing tool

It is important to understand what geometry/information management tools you have.

CAX = Computer aided x

The key issues:

- CAD is a based on a core/engine that utilizes mathematical representations to track, manipulate, and communicate geometry
- Importance: Easy to store/transfer information without error
**CAD – More than just a drawing tool**

**CAD is more than a drawing tool, it is a tool for:**

- Managing and manipulating surfaces/volumes
- Mathematical modeling and analyses (mass, moment of inertia)
- Create universal geometry formats that can be read by other geometry interpretation/manipulation tools (CAM, visualization software)

**CAM**

**CAM (Computer Aided Manufacturing) is used to:**

- Translates geometric representations into information you can use to instruct machines
- Generate G Code: Language used to tell machine tools what/when/where
- Coolant Movement Tools Spindles
- Makes forming complex surfaces a fast and easy process

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**G-code**

**N0027 G01 X175.25 Y325.00 Z136.50 F125 S800 T1712 M03 M08**

Statement Number 27 (N0027)

* a linear-interpolation motion (G01)
* to a position defined by (X175.25 Y325.00 Z136.50),
* with a feed rate of 125 mm/min (F125),
* and a spindle speed of 800 rpm (S800),
* using a tool Number 1712 (T1712),
* performing a c/w turn of the spindle (M03),
* and having the coolant on (M08).

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**Manual Programming**

**N001 G91**
**N002 G71**
**N003 G00 X0.0 Y0.0 Z40.0 T01, M06**
**N004 G01 X75.0 Y0.0 Z-40.0 F950 S717 M03**
**N005 G01 Z10.0 F350 M08**
**N006 G01 X110.0**
**N007 G01 Y70.0**
**N008 G01 X-40.86**
**N009 G02 X-28.28 Y0.0 I14.14 J5.0**

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CAM – Speaking in 1s and 0s…..

It is not practical to teach G Code and CAM in lecture
- You will plan a process in lab
- You will write G Code by hand (builds character)
- You will use MasterCAM in lab

Key Issue:
CAM is a tool for simplifying the transfer of geometric information into instructions for machines.
Reduce errors and time it takes to make parts!!!

APT – Automatic Programming Tool

APT developed at MIT in 1956.
APT II, APT III
- Identification statement
- Geometric Statements
- Motion statement
- Post-processor statement
- Auxiliary statement

“Manufacturable”

What makes something manufacturable?
- Depends on what is important
- Yes/no (can we make it or not)
- Acceptable cost, rate, quality, etc…
- Yield, complexity, adherence to design/mfg rules

DFM
Perspective on DFM

DF"x"
- Alphabet soup: DFM, DFA, DFQ, DFD, DFI, DFC, etc...

What DFMA is:
- Design and manufacturing activities that determine product design and manufacturing characteristics in order to obtain an acceptable level of “manufacturability” in a product assembly

What DFMA is not:
- Cook book design/mfg philosophy with rules to be blindly followed
- Optimization of parts in isolation

DFMA: Why and When

Why is DFMA important:
- Design architecture has significant effect on costs, quality, etc..
- Do it right the first time....
- Quality, rate and cost usually follow if DFMA is properly applied

When is DFMA used:
- DFMA should be applied early in the process and followed thru-out

Good designers always have DFMA goggles on

Design architecture

Architecture affects/determines part cost/complexity

DFM without DFA = local optimums and overall sub-optimality

Steps for DFMA
- Step 1: Design for assembly [ big picture, consider details ]
- Step 2: Selection of materials/processes/$ estimates
- Step 3: Design concept(s)
- Step 4: Design for manufacturing [ detail design ]

Tying PP and DFMA together

Embodiment | Plan execution | Translate plan | Execute plan
---|---|---|---
Sketch/idea | Feature generation | G Code | Machine (i.e. mill)
Blueprint/CAD | Planning | File exchange | Generate tangible
User input | CAM | |

Eliminate:

Minimize:
Number of parts

Decreasing the number of parts is a good strategy in general

Snowball effect of decreasing the number of parts
- Drawings/documentation
- Specifications
- Material/information routing
- Design time
- Vendors
- Inventory
- Overhead

DFM and process capabilities

Things which affect capability
- Part size ranges
- Tolerances
- Variation
- Surface finish
- Shapes/complexity
- Process limitations
- Materials

Design to take advantage of process capabilities

DFNA: Design for no assembly

Credit: Prof. Kota University of Michigan