ME 395 Introduction to Mechanical Design

Generation and Evaluation of Design Concepts

Stages in Design

- Problem Definition
- Information Gathering
- Concept Generation
- Evaluation of Concepts

Conceptual Design is then followed by Embodiment Design

Stages in Concept Generation

- Problem Decomposition
  - Physical Decomposition
  - Functional Decomposition
- Exploration of Solutions:
  - Brainstorming
  - Morphological Box or Chart

Creativity in Design

- Particularly important in concept generation
- Poorly understood
- Creative ideas emerge slowly often”half-baked”
- Aided by deliberate process
- “10% inspiration 90% perspiration” (Edison)

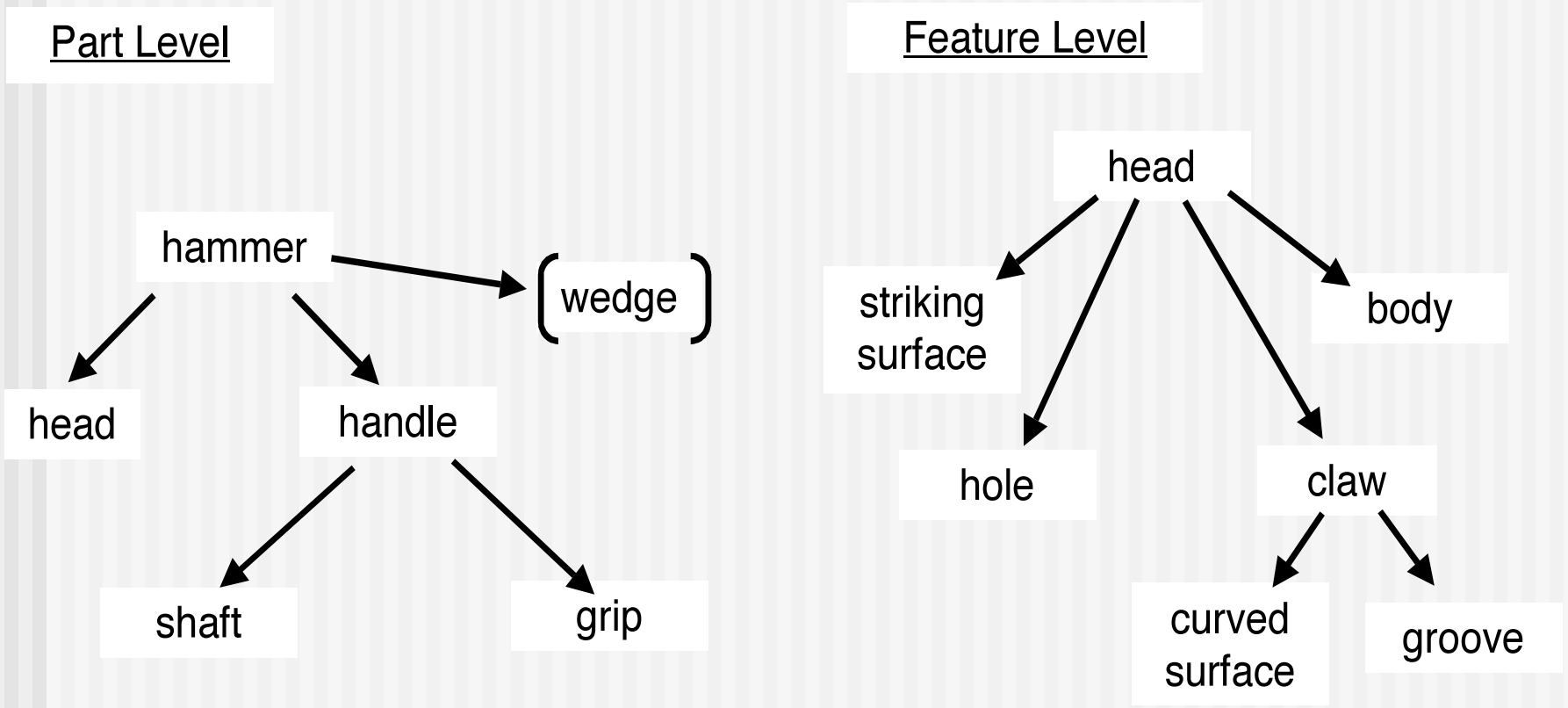
Enhancing Creativity

- Develop a creative attitude (self-confidence)
- Unlock your imagination
- Be persistent
- Develop an open mind
- Suspend your judgment
- Critical vs Creative thinking (Dieter pp 199)

Conceptual Decomposition

- Physical Decomposition
  - Breaks device into “chunks”
  - Closely related to design segmentation and to sub-assemblies
- Functional Decomposition
  - Separates and analyses functions that product performs
  - Treats flow of force, energy, material, information etc.

Physical Decomposition e.g. Carpenter's hammer



Steps in Functional Decomposition

- State the most important function that the product serves
- Create descriptions of sub-functions
- Arrange sub-functions in logical order
- Refine (decompose) sub-functions as necessary

Functional Decomposition e.g. carpenter's hammer

Overall function:

Drives and pulls nails ?

(2 separate functions)

Driving nails - dynamic

Pulling nails - static

F D of hammer (cont.)

Functions of parts in driving nail:

- Head
  - Stores energy
  - Applies force to nail
- Shaft
  - Transmits force
  - Multiplies velocity
  - Absorbs shock
  - Provides guidance

F D of hammer (cont.)

Functions of parts in pulling nail:

- Head
  - Transmits torque
  - Applies force to nail
  - Applies reaction to wood
- Shaft
  - Accepts hand force
  - Multiplies force
  - Applies torque to head
  - Provides force feedback

F D of hammer (cont.)

Functions of features of head in driving nail:

- Body
  - Connects features
  - Stores energy (provides mass)
- Striking face
  - Transmits force
- Hole
  - Connects to shaft
- Claw
  - None?

F D of hammer (cont.)

Functions of features of head in pulling nail:

- Body
  - Connects features
  - Transmits force and torque
- Striking face
  - none
- Hole
  - Connects to shaft

F D of hammer (cont.)

Functions of features of head in pulling (cont.)

- Claw (groove)
  - Applies force to nail
- Claw (curved surface)
  - Applies force to wood

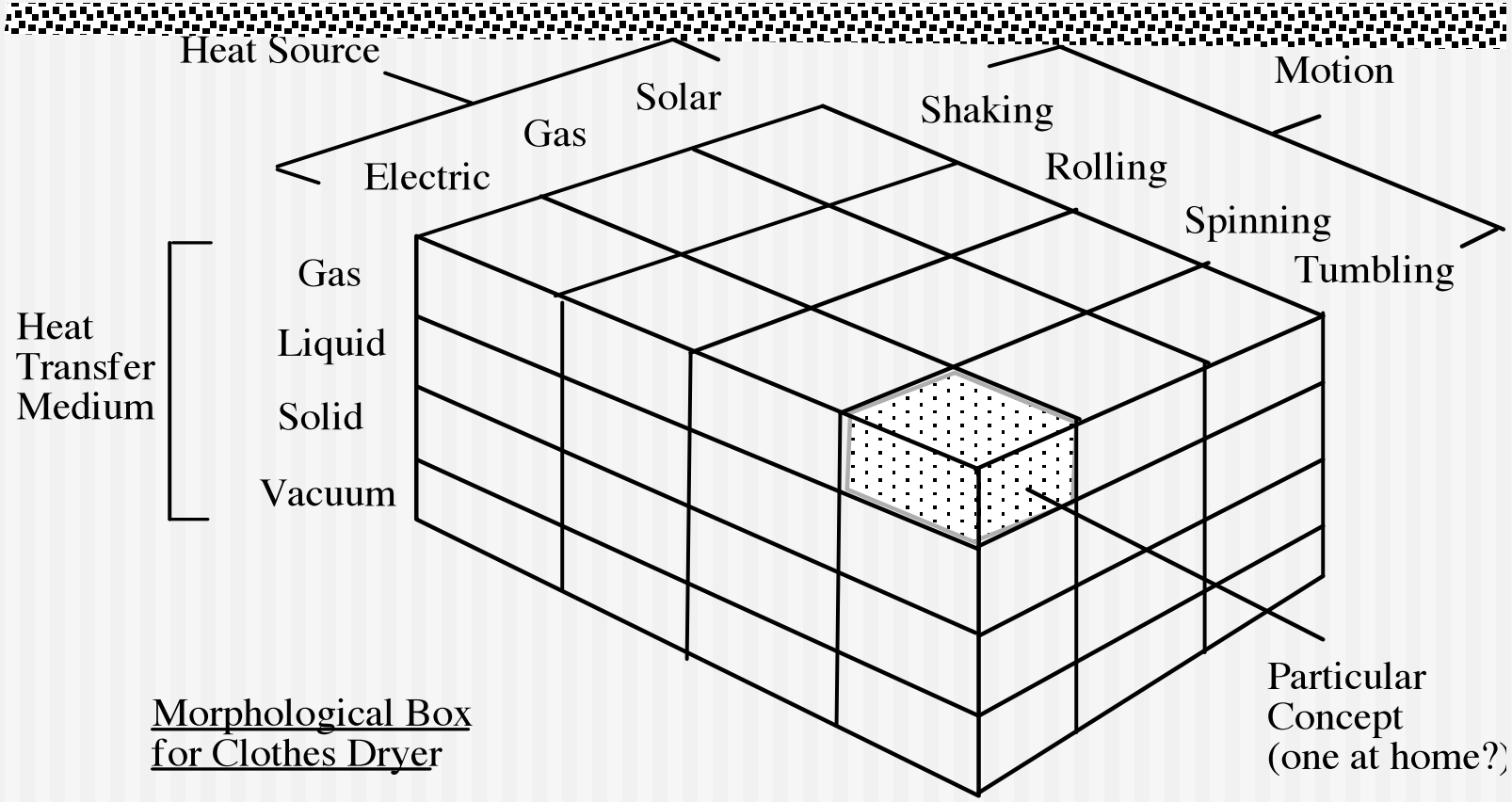
Generating Design Concepts

- Now starts the synthesis process
- Synthesis based on all analysis done to date
- Individual consideration of problem often initially better than team
- Brainstorming with team very effective
- Treatment of sub-functions separately then combination using morphological box or chart often work well

Morphological box

- Method of treating combinations of ways of satisfying sub-functions
- Discrete design space with one axis (dimension) per sub-function
- Can be used directly if small number of sub-functions or concept for their satisfaction
- Concept useful for more complex cases

Example of Morphological Box



Morphological Box for Clothes Dryer

Morphological Chart

- Used for more general case with many dimensions (sub-functions)
- See Dieter pp.235-236 for disposable syringe example

Axiomatic Design

- Uses to Axioms as basis for design:
- Axiom 1- Independence Axiom

  "Maintain the independence of functional requirements"
- Axiom 2- Information Axiom

  "Minimize the information content"

Concept Evaluation

- Used to pick best conceptual designs for future work
- Better evaluation at preliminary design stage
- Possible (non-exclusive) approaches:
  - Absolute filters (weeds out losers)
  - Rating process (ranks survivors)

Evaluation by Absolute Filters

Several possible criteria for evaluation:

- Feasibility of the Design
- Assessment of Technology Readiness
- Screening using Customer Requirements

Filtering based on Feasibility

Places designs in three categories:

- Not feasible (try to fix or abandon)
- Conditional (resolve condition)
- Feasible (keep for further development)

Filtering based on Technology

Design is Feasible if:

- Can be made with existing processes
- Critical functional parameters identified
- Sensitivity of parameters known
- Failure modes identified
- Existing hardware demonstrating above

Filtering based on Customer

Compares capability of product to meet each customer requirement and
places design in one of three categories:

- Meets all customer requirements
  (keep for further development)
- May meet all requirements
  (keep and try to fix)
- Clearly does not meet all requirement
  (abandon)

Concept Rating (Pugh)

Process steps:

1. Choose evaluation criteria
2. Formulate decision matrix
3. Clarify design concepts
4. Choose datum concept
5. Generate the matrix
6. Evaluate the ratings
7. Eliminate and refine concepts
8. Repeat steps 4 to 7 with reduced or modified list of concepts

Formulating the Decision Matrix

- Choose evaluation criteria (extent of coupling and information content could be two of the evaluation criteria)
- Enter criteria as rows
- Concepts are columns
- Same level of abstraction for concepts
- Use sketches if hard to describe

Clarifying Design Concepts

- Try to bring all members of team to same level of understanding of concepts
- Develop team ownership of all concepts

Choosing Datum Concept

- Select a concept as datum for initial evaluation
- Concept with which all others are compared
- Generally by nomination and voting
- Should be one of the better concepts
- For redesign, datum is original design

Generate the Matrix

- Each concept and is compared with datum under each criterion
- Three level scale:
  - Better (+ or 1)
  - Same (S or 0
  - Worse (- or -1)
- Usually involves useful discussion

Evaluate the Ratings

- Determine number of each rating for each concept (+'s, S's and -'s)
- Eliminate really bad concepts
- Be generous
- Consider moving good features of a concept to other designs
- Look at strengths of highly rated concepts
- Try to remove ambiguity

Reiteration

- Revise list of design concepts
- Establish new datum
  (usually the highest rated concept)
- Rerun the matrix, evaluate etc
- Plan further work as necessary