

MECH 3200 – 10S
Notes: Pahl & Beitz Chap.6

Conceptual Design

Prerequisite: Engineering Requirements (ER's)

- Result of Product Planning Process, or Quality Function Deployment

Process Steps:

1. Reduction of ER's to essential problem statement (simplification)
2. Adaptation of preliminary concept
3. Functional Decomposition, Functional Structure
4. Working principles for lowest functional level
5. Concept combination
6. Concept assessment and selection

Result: Principal Solution

1. Ready for Embodiment Design

Example: Means for stopping a long board in a narrow space

1. Product Planning
 - a. Users
 - i. Downtown finance worker
 - ii. AU student
 - b. Needs
 - i. Stop for emergency (traffic in front)
 - ii. Stop in constrained area (traffic around)
 - iii. Stop for fear (steeper than thought)
 - iv. Cost less than 25% of board price
 - v. Doesn't upset rider while stopping
 - vi. Easy to install
 - vii. As robust as board
 - c. Existing Alternatives
 - i. Drag foot
 - ii. Jump off
 - iii. Existing products
 - d. Engineering Requirements
 - i. Stopping surge force greater than 85 lbs.
 - ii. Stopping surge force less than 65 lbs.
 - iii. Stopping yaw moment - 150 in·lbs.
 - iv. Weight – 8 oz.
 - v. Drag - 10% of wheel rolling resistance
 - vi. Cost (this one might need to be a trade-off – see below)

- vii. Installation time 20 min. with 'household' (define) tools and misleading instructions
2. Reduction to essential problem statement
 - Stop board in a mild emergency while maintaining rider control using an easy-to-live-with add-on device
 3. Functional Decomposition
 - a. Apply retarding force
 - i. Generate controlling force
 - ii. Transfer controlling force
 - iii. Apply controlling force
 - b. Hold retarding force
 - i. Generate force
 - ii. React force to board
 - iii. Regulate force
 - c. Release retarding force
 - i. Return to free-wheeling
 - ii. Reset stopping system
 4. Working principles (each of these needs a sketch!)
 - a. Generate controlling force
 - i. Arm
 - ii. Foot
 - iii. Hydraulic
 - iv. Electrical
 - b. Transfer controlling force
 - i. Mechanical linkage
 - ii. Hydraulic
 - iii. Electrical
 - c. Apply controlling force
 - i. Hydraulic piston
 - ii. Lever
 - iii. Direct action
 - d. Generate force
 - i. Friction pair – board to ground
 - ii. Friction pair – board to rotating parts
 - e. React force to board
 - i. To board
 - ii. To undercarriage

- f. Regulate force
 - i. Control force regulation
 - ii. Lock and ablation
 - g. Return to free-wheeling
 - i. Spring return
 - 1. Mechanical spring
 - 2. Hydraulic spring
 - ii. Magnetic
 - iii. Manual disengage
 - h. Reset stopping system
5. Optional step – selecting working structures (rank and rate working principles)
 6. Combining Working Principles
 - a. Foot, mechanical, direct, board-to-ground, board, regulation, manual
 - b. Arm, hydraulic, piston, board-to-rotating, board, regulation, hydraulic spring
 7. Necessary Step – firming up the design. This is the big layout and calculate step, proving that the concept can meet the ER's (be sure to use lean calculation!). Might do some concurrent engineering here.

Tangent: Axiomatic Design

- i. Independence Axiom – the best designs result from concepts where each Functional Requirement (FR) is met independently by one (set of) Design Features (DF's). That way, the any FR can be adjusted by adjusting one DF, without affecting any other FR
- ii. Information Axiom – the best designs are those with the lowest information content (more broadly known as KISS)

Tangent: Incorporation of Analogies – Case 1108B: “there really hasn't ever been anything remotely like this!”

- Refer to AU Vet School, Large Animal Clinic, Male Bovine Manure Removal Unit (LAC – MBMRU)
8. Assessment
 - a. Decision matrix, v. needs, with +,0,- scale (or just +,-)
 - i. Absolute scale
 - ii. v. datum
 - b. Decision matrix, v. needs, weighted, with 0-10 scale (confidence adjusted)
 - c. Decision matrix, v. objective tree, weighted, with 0-10 scale (confidence adjusted)
 - d. Trade-off – development of optimality function

Another example: Problem – improve productivity and smoothness of drywall taping. Intuitive concept/premise – device to spread joint compound and tape in one pass. [reference: Magrab, E.B., *Integrated Product and Process Design and Development*, CRC Press, 1997]

1. Product planning

- a. Users
 - i. Worker
 - ii. Contractor
 - iii. Homeowner
 - iv. Distributor
 - v. Tool rental center
 - vi. Manufacturer
- b. Needs (functional requirements – FR's)
 - i. FR_1 Load joint compound
 - ii. FR_2 Load tape
 - iii. FR_3 Dispense tape and joint compound uniformly and smoothly to wall
 - (1) FR_{31} Dispense tape simultaneously with joint compound
 - (2) FR_{32} Provide joint compound to dispenser
 - (3) FR_{33} Dispense joint compound uniformly
 - (4) FR_{34} Apply tape and joint compound smoothly to wall
 - (5) FR_{35} Separate tape from roll
 - iv. FR_4 Unload tape
 - v. FR_5 Unload joint compound
- c. Axiomatic design features (DF's) or design parameters (DP's)
 - i. DP_1 Joint compound loading system
 - ii. DP_2 Tape holding device
 - iii. DP_3 Tape and joint compound dispensing device
 - (1) DP_{31} Tape dispensing device
 - (2) DP_{32} Means to move joint compound through system
 - (3) DP_{33} Joint compound dispenser
 - (4) DP_{34} Tape and joint compound wall application device
 - (5) DP_{35} Tape severing device
 - iv. DP_4 Tape unloading device
 - v. DP_5 Joint compound removal system
- d. Alternative solutions
 - i. Manual, multi-step process
 - ii. Inexpensive tool (150 \$), results worse than a careful manual job
 - iii. Expensive tool (1650 \$), results meet functional needs
- e. Engineering requirements (a bit extensive – more like a “Product Design Specification”)
 - i. Quantity
 - (1) 20,000 units per year
 - ii. Cost
 - (1) Retail price: 500 \$
 - (2) Manufacturer's price (direct and indirect manufacturing cost): 200 \$

- (a) No new manufacturing facilities required (this is an organization-specific requirement, of the type Pahl & Beitz often focus on)
- (b) Minimize number of manufacturing operations; time and cost of each manufacturing operation
- (c) Familiar materials

iii. Performance

- (1) Tape inside corners
- (2) Tape joints in any orientation
- (3) Tape joints without leaking joint compound
- (4) Taped joints will require no additional smoothing
- (5) Tape will not break prematurely
- (6) Compound will flow evenly across tape/wall
- (7) Will work with both paper and fiberglass tape, with tape widths varying between 1.5 and 2.5 in, tape thicknesses varying between 0.005 and 0.007 in
- (8) Work with thick or thin viscosity compounds
- (9) Dispense tape at 6 in/s

Why 6 in/s?

- Average room $16 \times 12 \times 8$ ft, drywall sheets 8×4 ft, \Rightarrow 20 sheets per room
- Tape 1 short edge & 1 long edge \Rightarrow 240 ft per room
- 8 rooms per house \Rightarrow 1920 ft per house
- 1 house per hour \Rightarrow 1920 ft/h = 0.533 ft/s = 6.4 in/s
- Above not precise enough to support more than 1 significant figure accuracy

- (10) Dispense joint compound at $2 \text{ in}^3/\text{s}$

Why $2 \text{ in}^3/\text{s}$?

- 2.5 in tape, $\frac{1}{8}$ in thick layer of joint compound, 6.4 in/s \Rightarrow $2 \text{ in}^3/\text{s}$ joint compound volumetric flow rate

iv. Time scale

- (1) In market by (pick date)

v. Size

- (1) Total device easily transported by one person
- (2) Hand-held part of device smaller than $29 \times 16 \times 12$ in

vi. Shipping

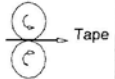


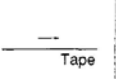



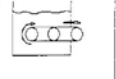


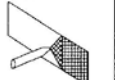

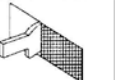
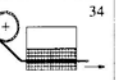
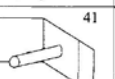
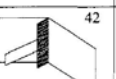
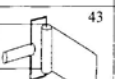
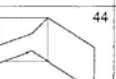
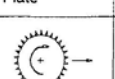
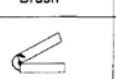

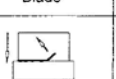

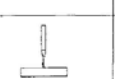

- (1) Shock resistant
 - (a) 8 ft drop test
- (2) Vibration resistant
 - (a) 4 to 33 Hz at 0.06 in amplitude
- (3) Weather resistant
 - (a) Temperature and humidity
- (4) Cardboard box packaging, stackable to 8 ft high, no special handling

vii. Disposal and Recycling

- (1) No environmentally hazardous materials

- (2) Easily disassembled for component recovery
 - viii. Political, Social, Legal
 - (1) OSHA standards (see www.osha.gov)
 - (2) Inoffensive product names (race, creed, gender)
 - (3) No patent infringement (see <http://patft.uspto.gov>, search for Wall Board, Wallboard, Joint Compound, Drywall)
 - ix. Product environment
 - (1) Temperature from 40°F to 120°F
 - (2) Pressure from sea level to 7000 ft
 - (3) Dust particles to 500 μm
 - x. Safety
 - (1) No sharps (except smoothing component)
 - (2) Shield electrical, hot, moving
 - xi. Documentation
 - (1) User's guide
 - (2) Maintenance manual
 - (3) Test reports
 - (4) Customer questionnaire (success in meeting needs)
 - xii. Life
 - (1) 5 yr
 - (2) 10,000 tape separations
 - (3) Modular to allow component upgrade
 - xiii. Materials
 - (1) Non-corrosive
 - xiv. Ergonomics
 - (1) Single operator, two hands
 - (2) Good balance
 - (3) Extended use (full shift)
 - xv. Aesthetics
 - (1) Product will convey ruggedness
 - (2) Durable finish
 - (3) Company colors
 - xvi. Weight
 - (1) 5 lb max (empty)
 - (2) 20 lb max (loaded with tape and joint compound)
 - xvii. Maintenance
 - (1) Standard fasteners
 - (2) Wear surfaces replaceable with standard tools
 - (3) Modular design for repair and cleaning
 - (4) No or very few lubrication points
 - (5) Facilitate removal of joint compound after day's use
2. Reduction to essential problem statement
- Simple, light, rugged, reliable commercial tool for continuous and simultaneous application of joint compound and drywall tape to drywall seams

3. Going straight to Working Principles for the DP's (only a subset of the complete morphological chart!):

Design parameter	Concept						
Means to dispense tape [(DP) ₃₁]	11 	12 	13 	14 			
Means to move joint compound [(DP) ₃₂]	21 	22 	23 	24 	25 	26 	
Means to dispense joint compound [(DP) ₃₃]	31 	32 	33 	34 			
Means to apply tape and joint compound to wall [(DP) ₃₄]	41 	42 	43 	44 			
Means to sever tape from roll [(DP) ₃₅]	51 	52 	53 	54 	55 	56 	57 

Lagniappe:

Several means for converting rotational motion into linear motion

