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Mechanical Analysis and Design
ME 2104

Lecture 12

Detailed design

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Plan for today

- Lecture – Detail design (35 min)
- Team meeting (60 min)
  - » Function carriers
  - » 1st Layout
- Summary (5 min)

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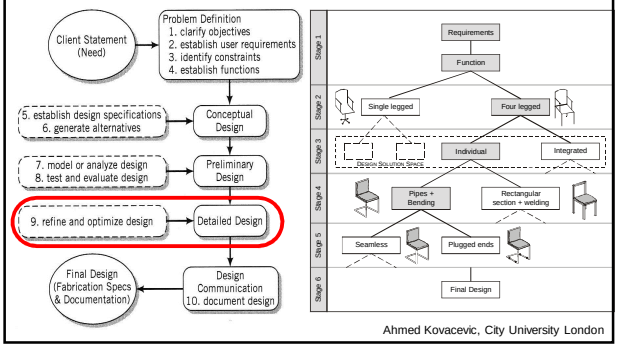
Engineering design process



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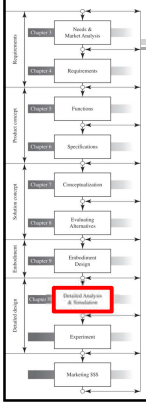

Derailed design

- Engineering Design Process 2nd Edition, Chapter 10
  - » Understand the detailed design stage
  - » Identify and select engineering materials that suit a product
  - » Construct a bill of materials
  - » Use techniques introduced in this chapter to evaluate and analyze design cost

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What is the detail design stage?

- Final step before prototyping
- Analysis and simulation
- Material selection
- Dimensions and tolerances
- 3D CAD model

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Steps in detailed design (analysis)

1. Check design safety -calculate forces on each component
2. Select materials – make a list of materials that satisfy stress requirements and using decision matrix select the best
3. 3D CAD model & manufacturing drawings (Solidworks)
4. Check manufacturability with available manufacturing methods – use rapid prototyping when possible
5. Cost analysis for a prototype and production unit
6. Aesthetics

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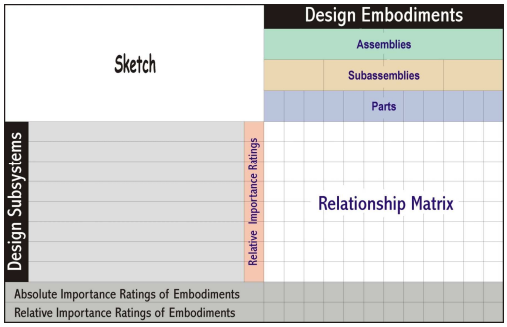
QFD 3 (Embodiments)



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Chair Example - Stage 3 Chart

	Relative Importance	Back Cushion: Cushion	Back Cushion: Board	Back Cushion: Cover	Seat Cushion: Cushion	Seat Cushion: Board	Seat Cushion: Cover	Hind Leg Assembly: Back rest frame	Hind Leg Assembly: Hind Seat Support	Hind Leg Assembly: Hind Legs	Left Seat Support	Right Seat Support	Front Leg Assembly: Left Front Leg	Front Leg Assembly: Right Front Leg	Front Leg Assembly: Front Seat Support	LeftAR Assy: Left Arm rest	LeftAR Assy: Left A.R. Support	RhtAR Assy: Right Arm rest	RhtAR Assy: Right A.R. Support
Seat Cushion Assy	9				9	9	9		9		9	9			9				
4Legs	7									9			9	9					
Back rest assy.	6	9	9	9															
Back rest frame	3							9		3									
Hand rest	4															9		9	
Hand rest support	9																9		9
Good Surface	1			9			9			9			9	9		9		9	
Target Information		LEFT VACCANT																	
Absolute Importance		54	54	63	81	81	90	27	81	81	81	81	72	72	81	45	81	45	81
Relative Importance		5	5	6	8	8	9	3	8	8	8	8	7	7	8	5	8	5	8

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- An essential characteristic of the finished design is its easiness and cost effectiveness for manufacture. Therefore materials and associated manufacturing process selection is an essential consideration that has to be undertaken before any decisions on the detail design can be taken.
- Material and Manufacturing process selection involves:
  - » The identification of design functions related to materials and manufacturing processes.
  - » The material and manufacturing related functions are translated into quantitative, actionable and measurable material and manufacturing process characteristics
  - » These form the basis to select the appropriate materials and manufacturing processes.

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- The Production Plans greatly depend on the Manufacturing facilities available and the quantity to be produced.
- For example, if every new motor car has to be supplied with a hydraulic jack (instead of the scissors jack), which consists of a cast body, then each major motor manufacturer should have a huge foundry to produce jacks. This is a typical case where the quantity to be produced dictates the design.

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TABLE 10.1 Material Properties

Material	Density Kg/m³	ν Poisson's ratio	E MPa	σ_y MPa	σ_{ult} MPa	Melting Temperature °C	Thermal Conductivity W/mK
Pure Metals							
Beryllium	1827		3.033	3.792	6.205	1282	218
Copper	8858	0.33	1.172	0.689	2.206	1082	400
Lead	11349	0.43	0.138	0.138	0.172	327	35
Nickel	8858		2.069	1.379	4.826	1440	91
Tungsten	19 376		3.447		20.68	3367	170
Aluminum	2768	0.33	0.689	0.241	0.758	649	235
Alloys							
Aluminum 2024-T4	2768	0.33	0.731	3.034	4.137	579	121
Brass	8581	0.35	1.034	4.136	5.102	932	109
Cast iron (25T)	7197	0.2	0.896	1.655	8.274	1177	55
Steel: 0.2% C Hot Rolled	7833	0.27	2.068	2.758	4.826	1516	89
Cold Rolled	7833	0.27	2.068	4.482	5.516	1516	89
Stainless Steel Type 302 C. R.	7916	0.3	1.999	6.895	9.653	1413	21
Ceramics							
Crystalline Glass	2491	0.25	0.862	1.379		1249	1.3
Fused Silica Glass	2214	0.17	0.724			1582	1.1
Plastics							
Cellulose Acetate	1301	0.4	0.017	0.345	1.379		0.17
Nylon	1135	0.4	0.028	0.552	0.896		0.25
Epoxy	1107		0.045	0.483	2.068		0.35

TABLE 10.2 Bill of Materials

Item	Part	Quantity	Name	Material	Source
1	G-9042-1	1	Governer body	Cast aluminum	Lowe's
2	G-9138-3	1	Governer flange	Cast aluminum	Lowe's
9	X-1784	4	Governer bolt	Plated steel	Fred's Fine Foundry

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Mechanical Vegetable Harvesting Machine Example

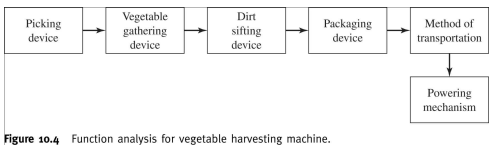

Figure 10.4 Function analysis for vegetable harvesting machine.

	Option 1	Option 2	Option 3	Option 4
Vegetable picking device		 Triangular plow	 Tubular grabber	 Mechanical picker
Vegetable placing device	 Conveyor belt	 Rake	 Rotating mover	 Force from vegetable accumulation
Dirt sifting device	 Square mesh	 Water from well	 Slits in plow or carrier	
Packaging device				
Method of transportation		 Track system	 Sled	
Power source	Hand pushed	Horse drawn	Wind blown	Pedal driven

Figure 10.5 Morphological chart for vegetable harvesting machine.

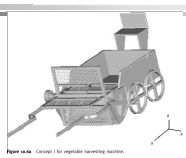

Figure 10.6a Concept I for vegetable harvesting machine.

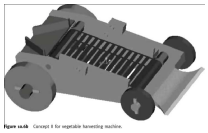

Figure 10.6b Concept II for vegetable harvesting machine.

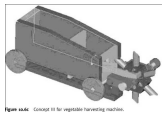

Figure 10.6c Concept III for vegetable harvesting machine.

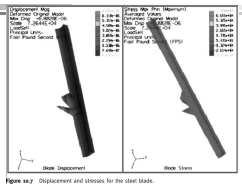

Figure 10.7 Displacement and stresses for the steel blade.

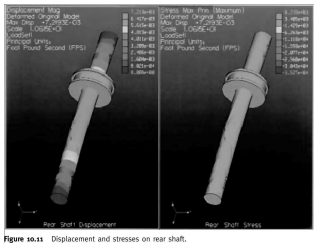

Figure 10.11 Displacement and stresses on rear shaft.

Figure 10.10 Loading on the rear shaft.

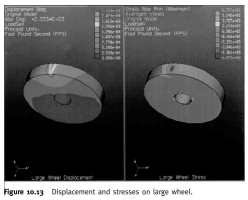

Figure 10.13 Displacement and stresses on large wheel.

Cost Analysis

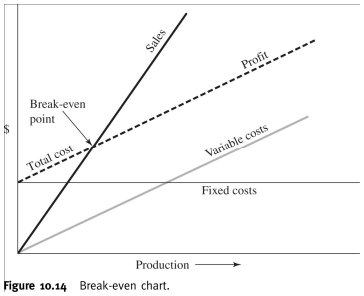

Figure 10.14 Break-even chart.

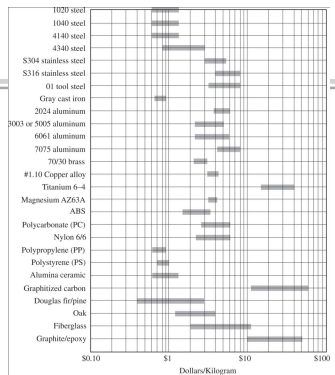

Figure 10.17 Material cost. Range of costs for common engineering materials. Price ranges shown correspond to various grades and forms of each material, purchased in bulk quantities (1994 prices). (Adapted from David G. Ullman, *The Mechanical Design Process*, McGraw-Hill, New York, 1992.)

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TABLE 10.3 The Make–Buy Decision

Reason to Make	Reason to Buy
Cheaper to make	Cheaper to buy
Company has experience making it	Production facilities are unavailable
Idle production capacity available	Avoid fluctuating or seasonal demand
Compatible and fits in production line	Inexperience with making process
Part is proprietary	Existence and availability of suppliers
Wish to avoid dependency on supplier	Maintain existing supplier
Part fragility requiring high packing	Higher reliability and quality
Transportation costs are high	

TABLE 10.4 Sample Production/Operation Cost Table of a Simple Fitting from a Steel Forging

Operations	Material	Labor	Overhead	Total
Steel forging	37.00			37.00
Set-up on milling machine		0.2	0.8	1.00
Mill edges		0.65	2.6	3.25
Set-up on drill press		0.35	1.56	1.91
Drill 8 holes		0.9	4.05	4.95
Clean and paint		0.3	0.9	1.2
Total	37.00	2.40	9.91	49.31

TABLE 10.5 Stapler Models

	Manual	Automatic
Selling price	31.25	12.5
Profit	$2	$5
Constraints		power supply 200 per day
Labor	18 person-minutes	54 person-minutes
Adjustment	3 person-minutes	5.4 person-minutes
Inspection	1 person-minute	1.5 person-minutes

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Conclusion

- This chapter discussed Detailed Design
- Described QFD Stages 1 to 5 and their related charts through a simple case study
- Explored Cost Analysis as related to product design

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Q & A

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Tasks for this week

- Finalise function carrier analysis
- 3rd QFD
- 3D SW models
- Meeting on Thursday…