Introduction to Engineering Design

ME 310: Mechanical Design

Sappinandana Akamphon

Department of Mechanical Engineering, TSE

Who am I?

Sappinandana Akamphon
ENG 421/4
sup@engr.tu.ac.th

What are we covering?

- Design principles
- Power sources and transmission
- Joints
- Power transmission components

Expected Skills at the End

Analyze and design a simple mechanical power transmission system

Schedule

Week	Topics
1	Engineering Design Processes. Safety Factors.
2	Review of Mechanics of Materials. Stress Concentration.
3	Materials Selection.
4	Shafts and Shaft Components.
5	Mechanical Springs.
6	Welding, Bonding, Permanent Joints.
7	Screws, Fasteners, Nonpermanent Joints.
8	**Midterm**
9	Rolling-Contact Bearings.
10	Lubrication and Journal Bearings.
11	Spur and Helical Gears.
12	Bevel and Worm Gears.
13	Clutches, Brakes, and Couplings.
14	Belts, Chains, and Ropes.
15	Case Studies

Reading Materials

- Akamphon. S., 2020, ME 310: Mechanical Design I.
- Juvinall, R. C., and Marshek, K. M., 2006, Fundamentals of Machine Component Design. 4th Edition, Wiley.
- Hibbeler, R. C., 1997, Mechanics of Materials, 3rd Edition, Prentice Hall.
- Shigley, J. E. and C. R. Mischke, 2009, Mechanical Engineering Design. McGraw Hill.

Grading

Project I progress	10%
Project I	10%
Midterm	30%
Project II progress	10%
Project II	10%
Final	30%

Engineering Design

- Application of science and engineering
- Define structure of system in details
- Allow manufacturers to be able to make it

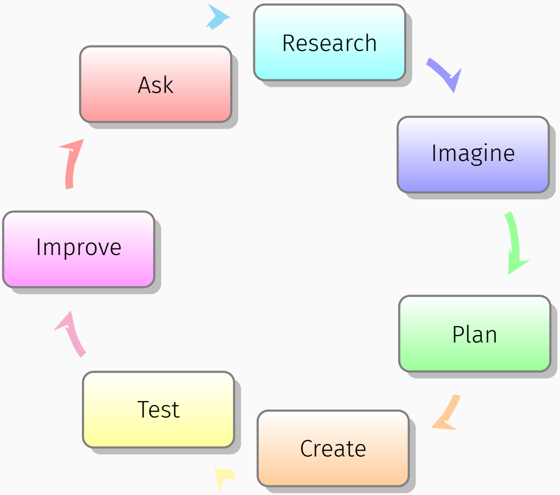
What about Mechanical Design?

Mechanical engineers need to define

- Materials
- Dimensions
- Shapes

So that the designed product can function properly

Engineering Design Processes



Ask: What seems to be the problem?

- What do you want to make?
- Why is it needed?
- What is the product supposed to do/not to do?

Research: More details on the problems and products

- Talk to customers to better understand problems and needs
- Conduct independent research get a clearer picture
- Look into previous works/products. What works? What doesn't?

Imagine: Come up with conceptual design

- Brainstorm ideas
- Exchange opinions on different solutions

Plan: How should we proceed?

- Check problems, needs, constrains
- Evaluate ideas and select the best one
- Plan how to move forward

Create: Make it happen

- Design the components
- Respect constraints and requirements developed earlier
- Build prototype and verify

Test: Does it work?

- Perform analysis and test on prototype
- Use in actual operating conditions
- Get feed back from customers
- Evaluate what needs improvement

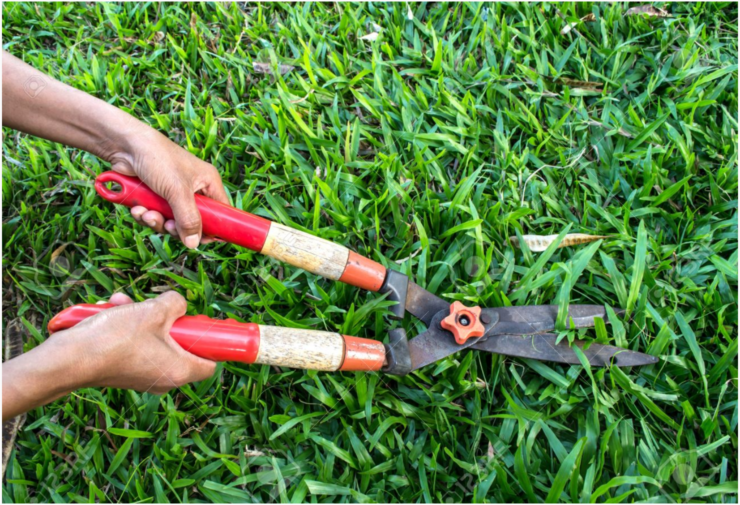
Improve: Make it better

- Redesign and improve based on feedback and tests

Application of Engineering Design: Lawn Mower

- So many lawn in Thammasat
- How do you keep them all nice and tidy?

Scisscors?

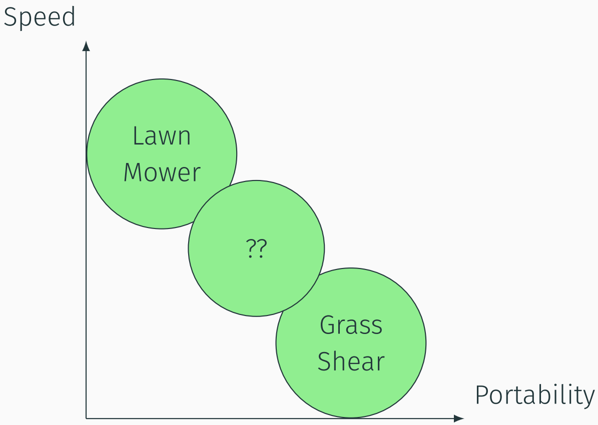


Machete?

Lawn Mower?

Case Study: Grass Cutting Solution

- Lawn Mowers $\rightarrow$ fast, but cumbersome
- Shears/Machete $\rightarrow$ slow, portable



Can we do any better? Something in between?

- Make one yourself

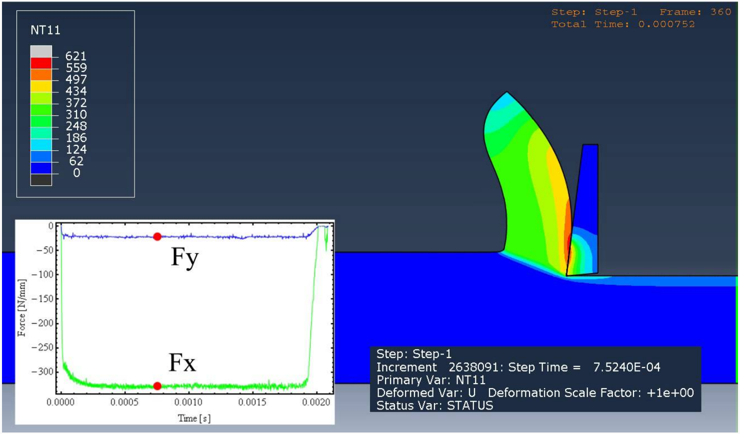
Defining Key Component

- What is the most important component in a grass cutting device?
- A component that completes the main function
- For a grass-cutter device $\rightarrow$ the cutting mechanism

The cutting mechanism... obviously

- blade, shear, ...

Key Analysis: Shearing Force



Same problem, different approach

- blade $\rightarrow$ hard, sharp, but moving slowly
- can something softer, but moving fast does the same job?

Fast spinning wires?

Problem $\rightarrow$ Component

- Define what needs to be done
- Be specific
- Most design problems already have partial solutions

Defining constraints

- Deadline?
- Budget?
- Load requirements?

Finding best solution

- Systematic method
- Validate & evaluate possible solutions

FRDPARRC Chart

- **FR** Functional Requirements $\rightarrow$ what job does it have?
- **DP** Design Parameters $\rightarrow$ what dimensions/shapes/materials does the job?
- **A** Analysis $\rightarrow$ how would you determine that proper DP?
- **R** References $\rightarrow$ where do you get that method(s) from?
- **R** Risks $\rightarrow$ is there any potential problems from your design?
- **C** Countermeasures $\rightarrow$ how do you solve that potential problem?

Case Study: Coconut Milk Production

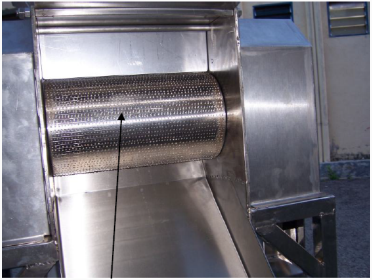
Current solution: coconut rabbit!?

Develop idea through FRDPARRC chart

- Goal: obtain scraped/minced coconut meat for squeezing into coconut milk

FR	Scrape meat	Pulverize meat + shell
DP	Scraper	Grinder
A	Strength of meat Beam bending	Strength of shell + meat Grinding teeth strength
R	Mechanics of Materials Statics	Mechanics of Materials Statics
R	Scraper teeth broken	Stuck grinder
C	Additional focus on teeth strength	Check clearance

Final Products



Major Design Considerations

- Strength
- Deformation
- Uncertainty

Strength vs Stress

$$\textit{strength} < \textit{stress} \rightarrow \textit{failure}$$

Deformation

How sure are you about ...

- your design calculation(s)?
- your supplier specifications?
- your customer knowledge?

Safety Factor!

What is that?

Safety Factor

Component should be stronger than the required stress

- The stronger, the safer it is

$$N_s = \frac{\text{Strength}}{\text{Stress}}$$

- "Strength" and "Stress" depend on material and criterion in consideration

The Safer, The Better …right?

The bigger safety factor, the safer your component is

So why don't we design everything with a N_s = 100000

Too Much of a Good Thing

Is there a cost for *excessive* safety factor?

Total Safety Factor

- A choice of safety factor is a combination of mainly two considerations
    - design and usage conditions: how well something should be design and manufactured and how badly it will be treated.
    - economic and safety factors: how bad it is going to be when it fails.

$$N_s = N_{s,cond} N_{s,econ}$$

Design and Condition Safety Factors, $N_{s,cond}$

Reliable materials, controllable conditions + loading	1.25 - 1.5
Well-known materials, reasonable conditions + loading	1.5 - 2
Average materials, ordinary conditions + loading	2 - 2.5
Lesser-known materials, average conditions + loading	2.5 - 3
Untried materials + average conditions Average materials + unknown conditions	3 - 4
Repeated loading	use S_e
Impact forces	Include impact factor
Brittle material (based on S_{ut})	Double N_s

Economic and Safety Safety Factors, $N_{s,econ}$

Characteristics		Danger to Personnel		
		mild	moderate	severe
Economic Impact	mild	1.0	1.2	1.4
	moderate	1.0	1.3	1.5
	severe	1.2	1.4	1.6

Exercise: Design of a Swing Set

- Components: chains, seats, stand structures
- Draw a conceptual design
- Fill a FRDPARRC sheet for each component
- Give a safety factor + reasoning