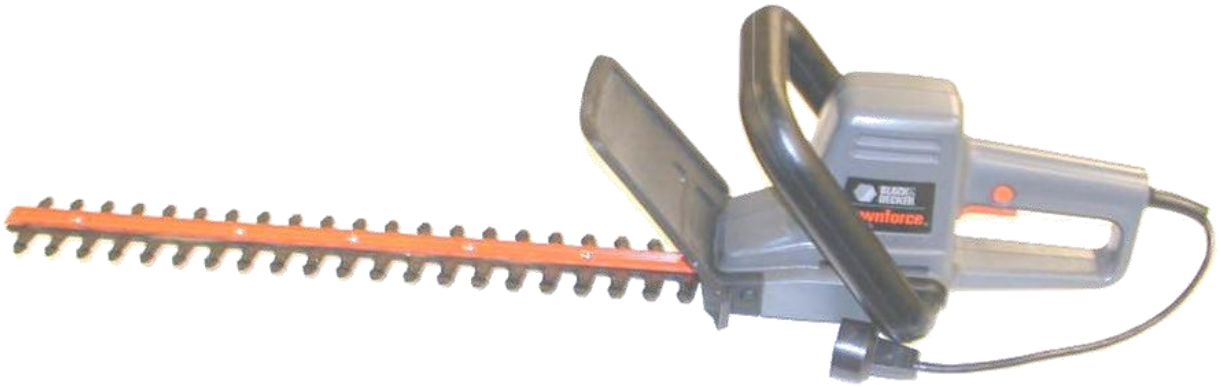
Reverse Engineering



Why Reverse Engineering?

Teaching Chances

- Good learnability of the product development by use of Working step sequence, with concrete images about a Product begin.
- The following considerations can be reflected to the available product.
- Compensation of the missing experience of the students in the product development by "understanding" the products
- Developing of concrete images of the possibilities of the product's Realization
- Understanding of the approaches of other developers promotes the understanding of own construction problems.

Why Reverse Engineering?

Chances for the Product development

In 1955 had BSA with the A 10 Road rocket the rocket epoch begun. specially desired counted "super Rocket and Rocket Gold star"

OLDTIMER MARKET, 05/2005

Reverse Engineering

"Examining competitive or similar or prior products in great detail by dissecting them or literally taking them apart."

- Dym & Little

"What does this do?"

"How does it do that?"

"Why would you want to do that?"

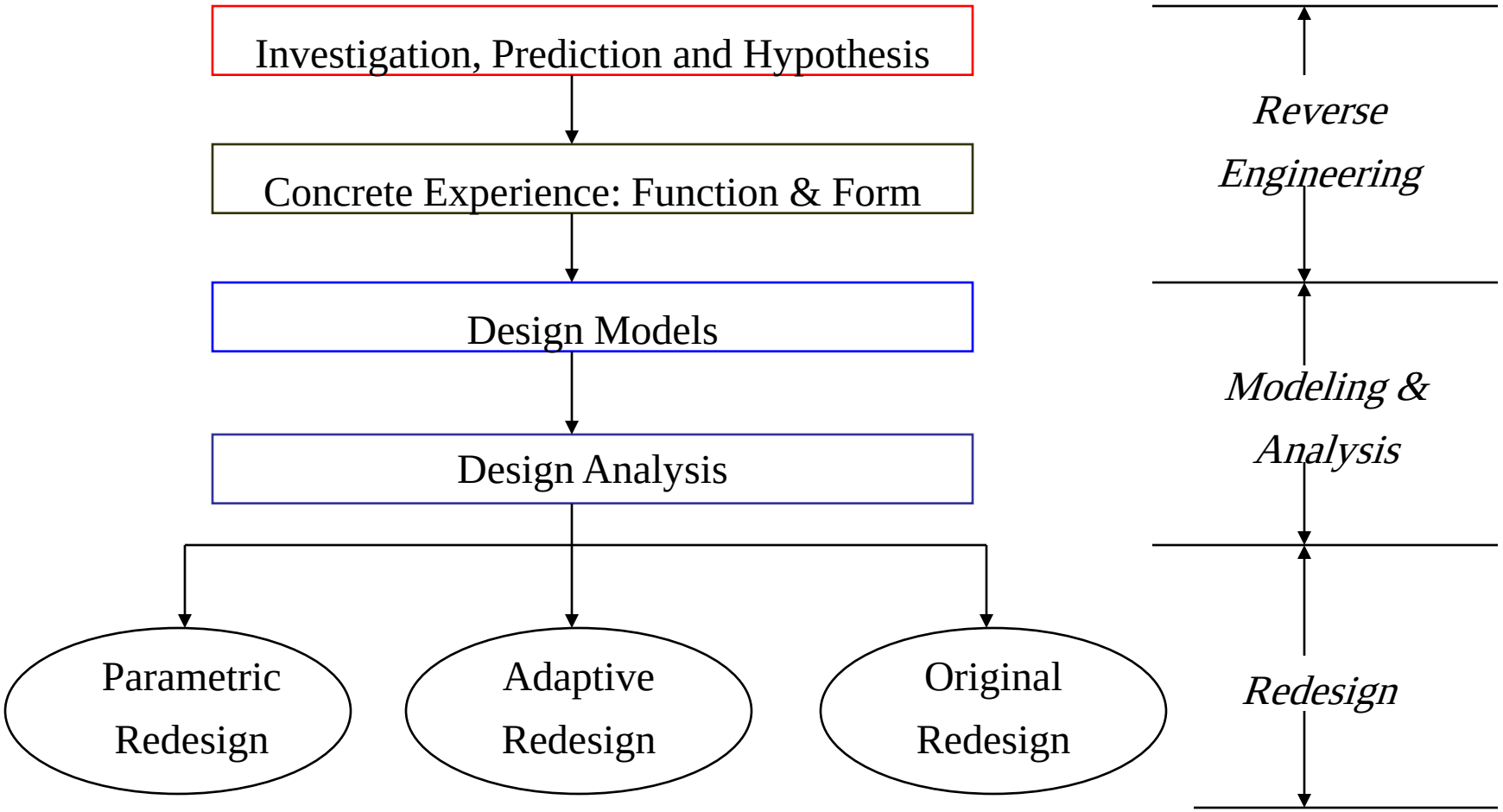
Reverse Engineering

Gain insight into our own design problem by looking at how other people have addressed the same issues.

Restrictions:

- Expensive designs
- Protected by patents
- May be the competitor's design
- Design may not work very well

Reverse Engineering Methodology



Adapted from Otto and Wood's "Reverse Engineering and Redesign Methodology" UT Austin

Reverse Engineering Methodology

1. Investigation, Prediction and Hypothesis
   - Develop black box model
   - Use / Experience product
   - List assumed working principles
   - Perform economic feasibility of redesign
   - State process description or activity diagram

Reverse Engineering Methodology

2. Concrete Experience: Function and Form

- Plan and execute product disassembly
- Group defined systems and components together
- Experiment with product components
- Develop free body diagrams
- Identify function sharing and compatibility
- Transform to engineering specs. and metrics

Reverse Engineering Methodology

3. Design Models

- Identify actual physical principles
- Constantly consider the customer
- Create engineering models and metric ranges
- Alternatively or concurrently build prototype to test parameters

Reverse Engineering Methodology

4. Design Analysis

- Calibrate model
- Create engineering analysis, simulation or optimization
- Create experiment and testing procedures
- Model Optimization

Reverse Engineering Methodology

5. Parametric Redesign
   - Optimize design parameters
   - Perform sensitivity analysis and tolerance design
   - Build and test prototype

Reverse Engineering Methodology

6. Adaptive Redesign
   - Recommend new subsystems
   - Search for inventive solutions
   - Analyze force flows and component combinations
   - Build and test prototype

Reverse Engineering Methodology

7. Original Redesign
   - Develop new functional structure
   - Choose alternatives
   - Verify design concepts
   - Build and test prototype

System Level Design

Reverse Engineering requires understanding the product or design as a system or set of systems that work and interact together.

This concept is known as **System Level Design**.

System = Components + Connections

Components

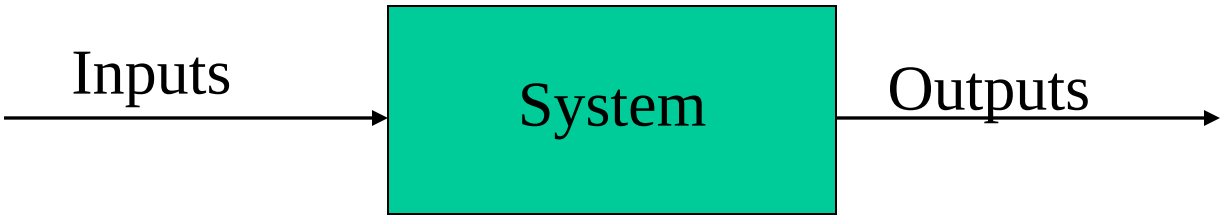
- Physical - pick-up, measure, draw on CAD
- Functional - flowcharts, difficult to define

Connections

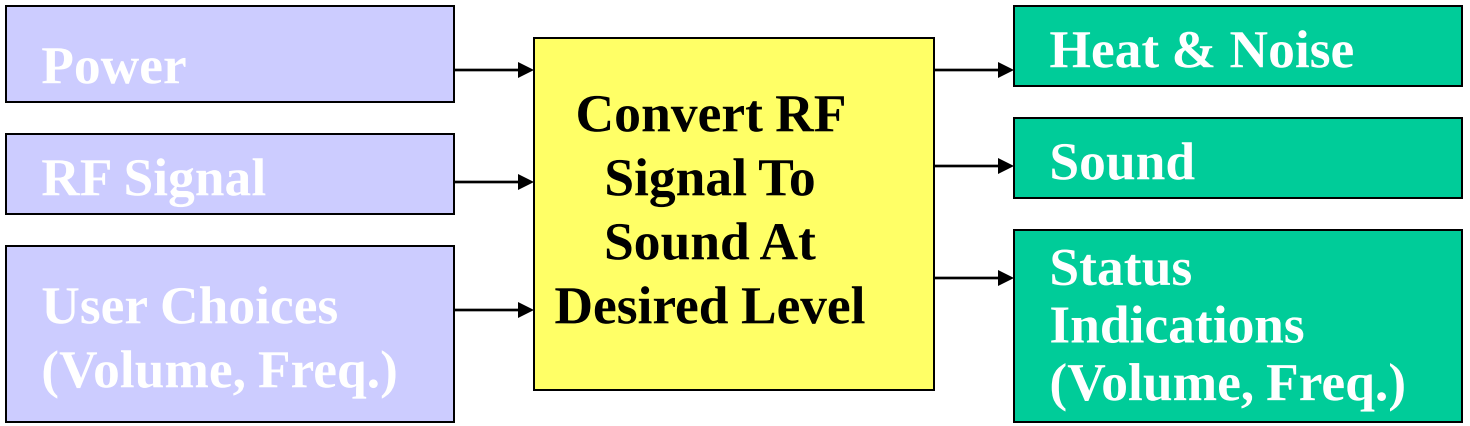
- Fundamental - intended design
- Incidental - created by physical proximity of components (vibration, heat transfer, etc.)

Develop black box model avoiding bias in the analysis.

Graphic representation of the system or object being designed, with inputs shown entering on the left and outputs leaving on the right.



Example: Radio

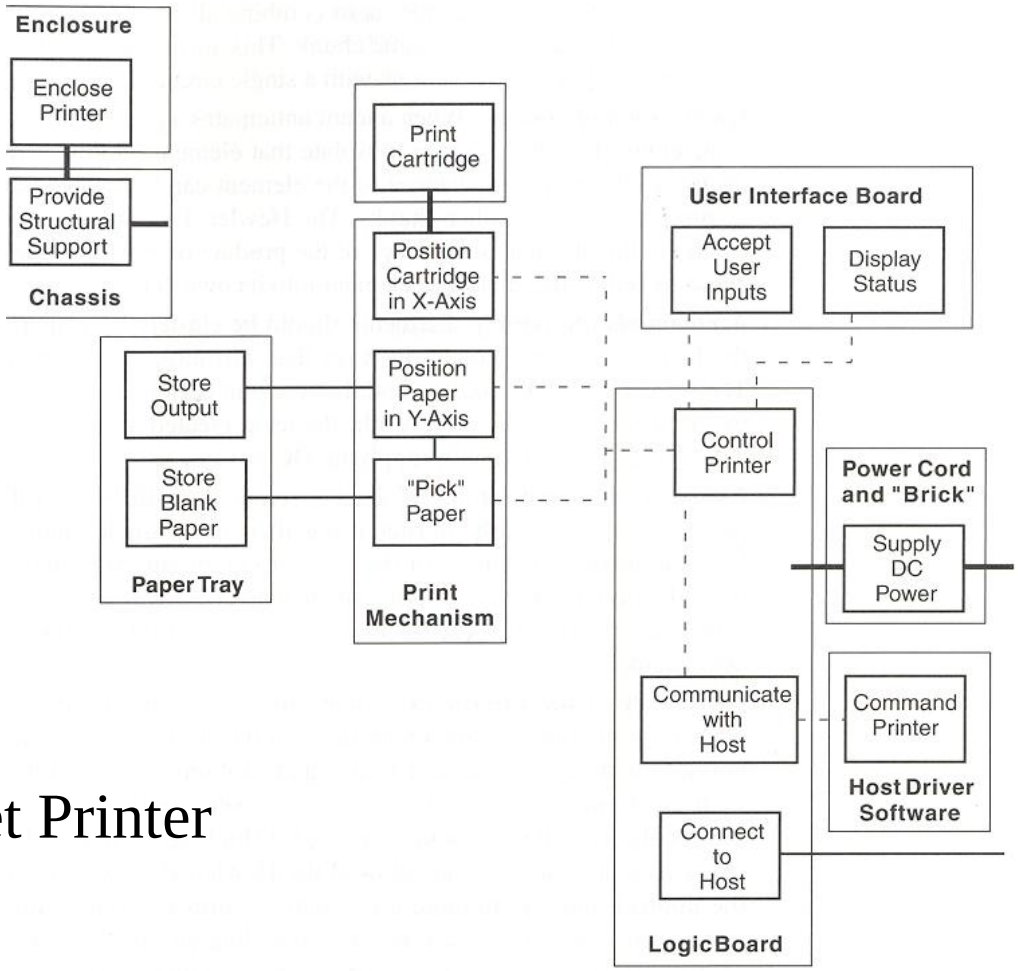


RF=radio frequency

Continue with the glass box approach.

- Identify sub-systems
  - Electrical
  - Mechanical
  - Task oriented
- Define interactions and flow of forces
  - Intentional
  - Unintentional
  - Wires, signals, material, data, etc.

'Glass Box' Example



Ink Jet Printer

Final Breakdown

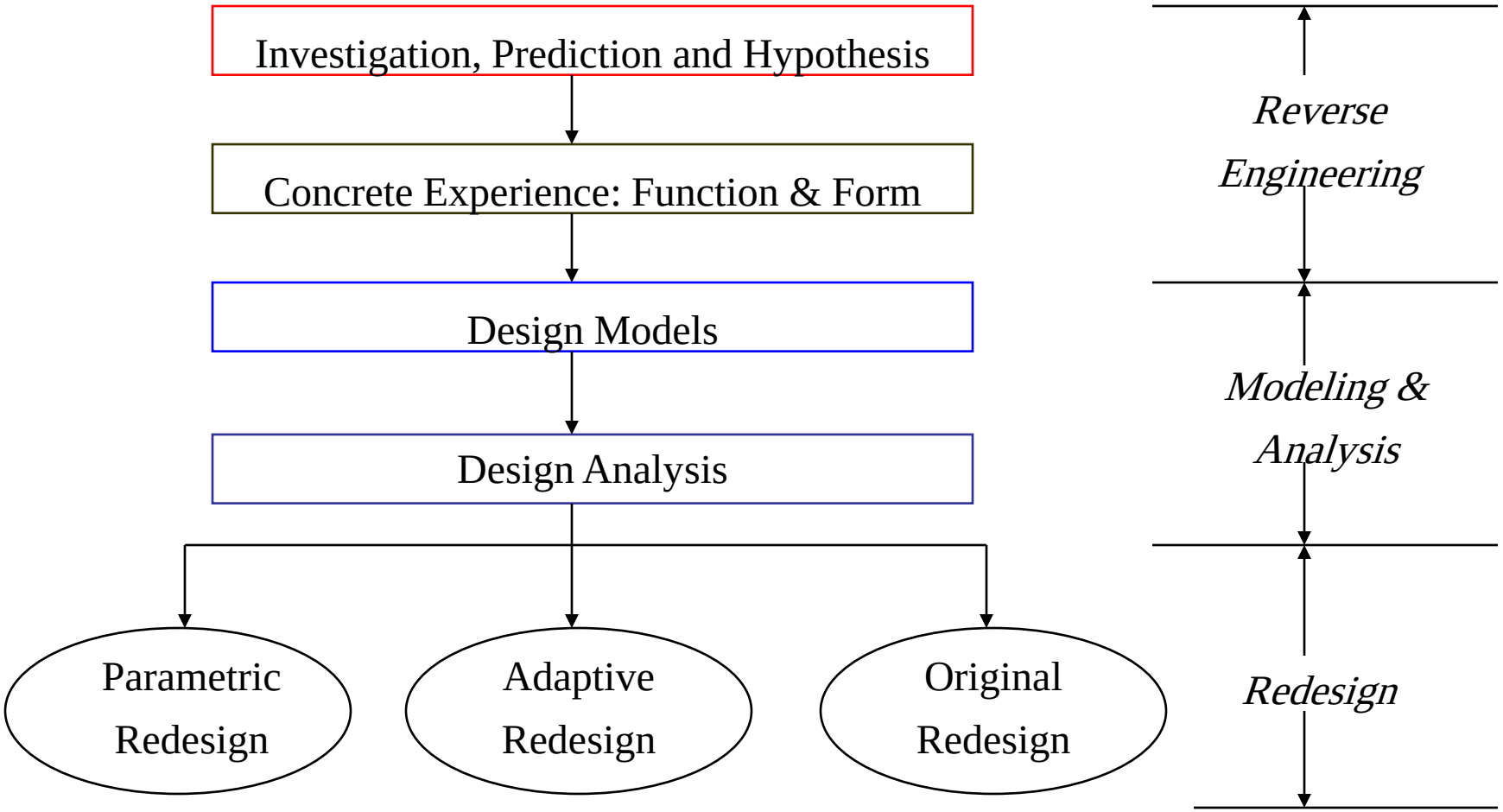
For every piece or component of interest, discuss:

1) How was it made
2) Why it was made this way
3) Design issues
4) The material it is made out of
5) Complexity and cost
6) Ergonomic issues
7) Interaction with other components

Example Project

Black and Decker Hedge Trimmer

Reverse Engineering Methodology



Adapted from Otto and Wood's "Reverse Engineering and Redesign Methodology" UT Austin

Reverse Engineering Example Project

1. Investigation, Prediction and Hypothesis

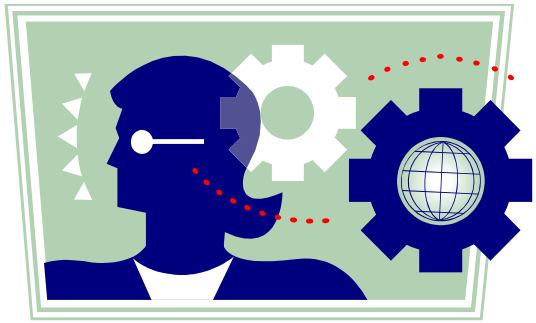
Develop Black Box Model

- Assemble product and conduct a test
- What goes in? What comes out? (i.e. power, noise, heat, vibration)

Reverse Engineering Example Project

Conduct a single test of the performance of the product:

- Record product performance attributes
  - Shearing speed
    - 3300 strokes/min
    - 5:1 Gear reduction = 16,500 RPM for the motor



Reverse Engineering Example Project

What is the market for this product?

- "Suitable for small shrubbery" – Black & Decker Product Catalog
- Homeowners with small yards and limited budget
- For use only 3-4 times a year

What are the costs associated with this product?

- Design - Manufacturing - Assembly – Packaging - Resale ($40.00)

Reverse Engineering Example Project

How long will this product last?

- Assumed durability of each component (outdoor use, dirt)
- Availability of replacement parts and service shops

What features does this product have that are important?

- Molded-in cord retainer
- Lock off switch prevents accidental start-up
- Lock on switch for continuous running
- Lightweight design for less fatigue (4.5 lbs.)

Additional Comments and Remarks -1

by: jenni796 (Fri Apr 7 '00)
Pros: light weight, very durable
Cons: none

•Trimming the bushes is my only contribution to our 2 acre yard.

•I bought my first Black & Decker hedge trimmer at Wal*Mart because it was very inexpensive compared to most other trimmers

•Black & Decker has an excellent reputation.

•The 13" seemed a little too small… The 18" seemed heavier

•I also wanted electric rather than gas because being a busy woman, I had no time to learn about mixing gas.

Durability: Excellent Noise Level: Average Purchase Price: $25.00

Additional Comments and Remarks -2

by: dadof6 (Fri Apr 7 '00)
Pros: Easy to handle and lite too!
Cons: Electric and water never mix!

•While it may be a good trimmer it also has it's downside!

•The first problem with it being electric is that you need a drop cord.

•The second problem is that since it is electric and you use it outside, you run the risk of being electrocuted! Remember most people doing lawn work are also running sprinklers to water the lawn. *I have had good friends killed simply by using these trimmers on wet grass.*

•Over all this tool does a great job of trimming but the hazards to your personal safety far out weigh the pros of this tool.

Durability: Good Noise Level: Average Purchase Price: $39.95

Additional Comments and Remarks -3

by: lpmiller (Tue Jun 27 '00)
Pros: Cheap, powerful, lightweight
Cons: Weak manual, requires an outlet.

•just about the cheapest thing you'll find on the market

•as usual the fine folks at B & D come through.

•As long as the cord reaches, I have the power I need.

•safety lock located at the top of the trimmer; release the trigger, the safety clicks on

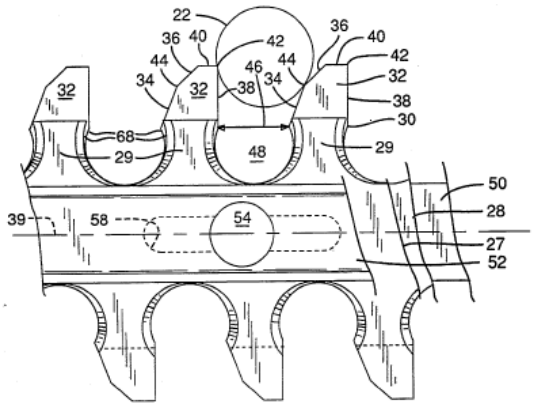
•One of the safety tips that really amused me was, “Do not use in rain.” On the one hand, I’m just not that stupid, on the other hand...well, we all know someone, don’t we? Folks, it is an electric trimmer. Do Not Use In Rain. Or the bathtub. Really.

Durability: Excellent Noise Level: Average Purchase Price: $29.99

Patent Search on Hedge Trimmers

After completing a search on the U.S. Patent and Trademark website:

http://www.uspto.gov



Patent # 5,778,649 (1998)

Power Driven Hedge Trimmer

Patent # 5,581,891 (1996)

Hedge Trimmer with Combination Shearing and Sawing Blade Assembly

US005412873A

United States Patent [19]
Gibson

[11] **Patent Number: 5,412,873**
[45] **Date of Patent: May 9, 1995**

[54] **RECIPROCATING HEDGE TRIMMER TOOL HAVING CUTTING TEETH WITH ASYMMETRICAL GUARD PORTIONS**

[75] Inventor: **Duane M. Gibson**, Milwaukie, Oreg.
[73] Assignee: **Blount, Inc.**, Portland, Oreg.
[21] Appl. No.: **95,600**
[22] Filed: **Jul. 21, 1993**

[51] **Int. Cl.**[6] **B26B 9/02**
[52] **U.S. Cl.** 30/355; 56/DIG. 17; 56/DIG. 20; 56/297; 56/158; 30/196; 30/216
[58] **Field of Search** 56/158, 232–236, 56/255, 257, 264, 297, 296, 295; 30/216–220, 225, 228, 196, 355; 83/855, 854

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Primary Examiner—Michael Powell Buiz
Assistant Examiner—Pamela O'Connor
Attorney, Agent, or Firm—Robert L. Harrington

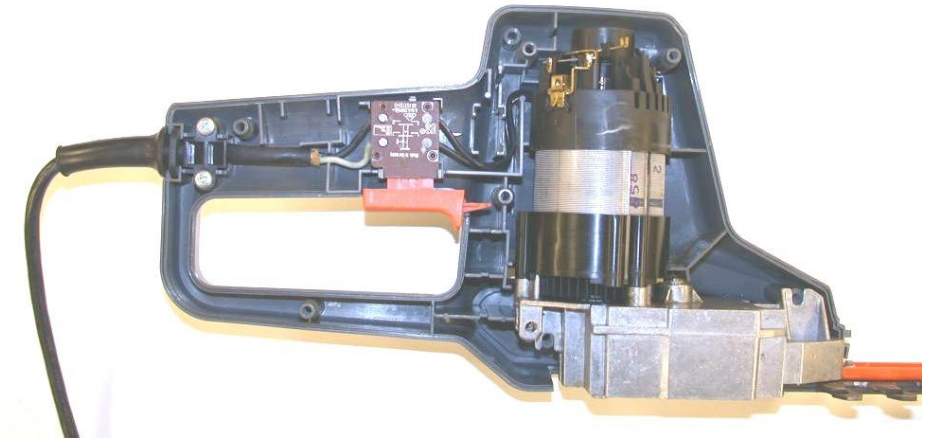
[57] **ABSTRACT**

A hedge trimmer blade assembly preferably a double acting assembly having upper and lower reciprocating blades. Superimposed cutting teeth extend laterally from the sides of the assembly from each of the blades. Guard portions extend from the teeth of the upper blade only on one side and from the teeth of the lower blade only on the other side. The guard portions are asymmetrical with a straight side and a tapered side, the taper preferably including a shallow bevel near the base and a sharper bevel near the tip of the guard portion. The cutting teeth of both upper and lower blades on both sides form oval shaped cutting chambers with cooperative hook configurations at the entry to the cutting chambers. The upper and lower blades are preferably identical in configuration but inverted one relative to the other in the assembly. The straight sides of the guard portions are all faced toward the power head of the trimmer to produce a hooking action as the user sweeps the trimmer during operation.

6 Claims, 3 Drawing Sheets

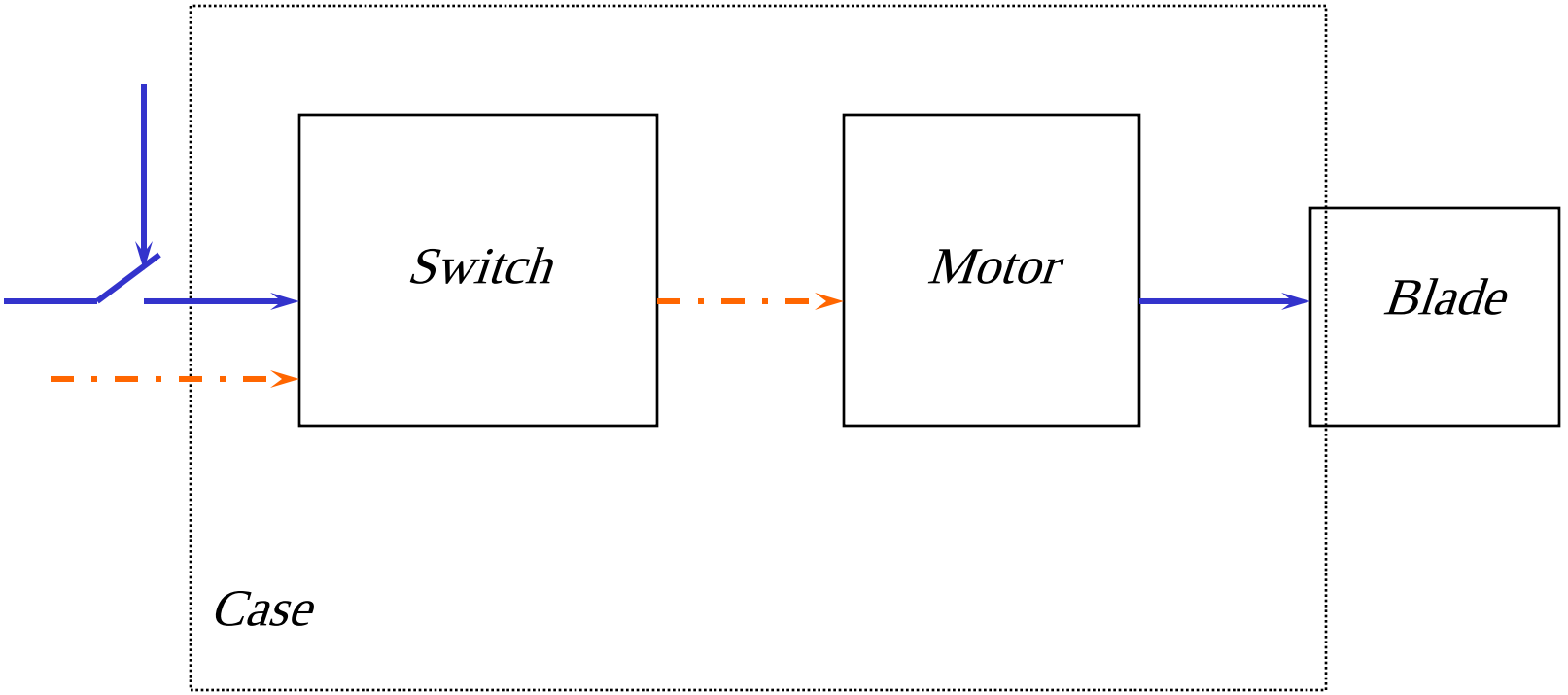
2. Concrete Experience: Function and Form

- Carefully begin Disassembly
- Document steps and components with photographs, sketches or video



Hedge Trimmer Sub-Systems and Interactions

- Group defined systems and subsystems together.



Motor

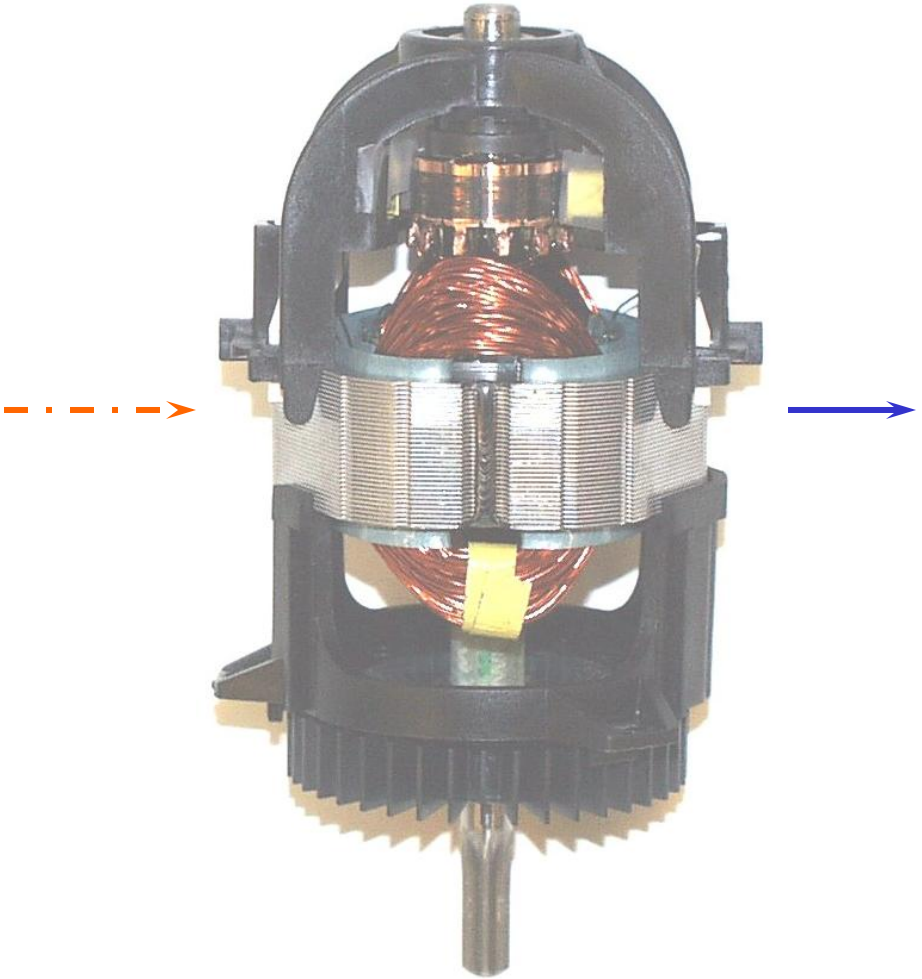
120 V - 8 Amp Motor

350 RPM

Why not batteries?

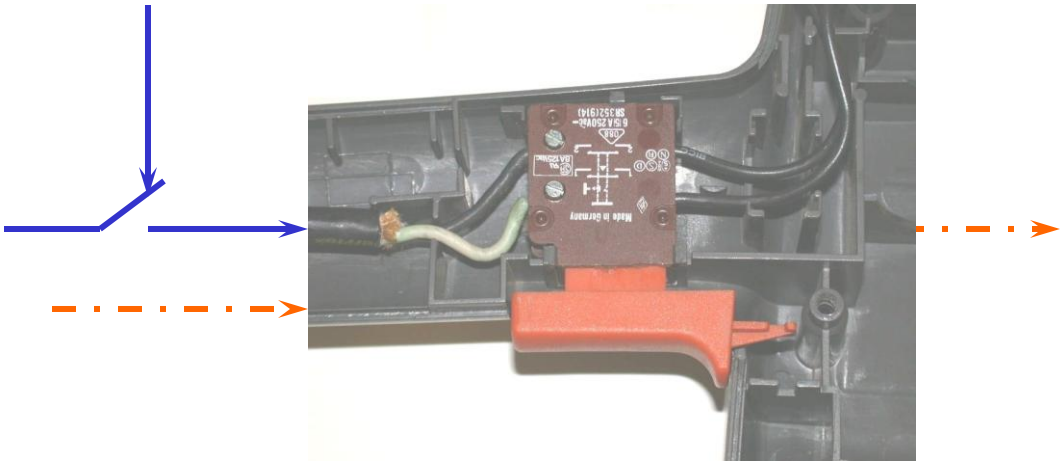
How important is size, speed?

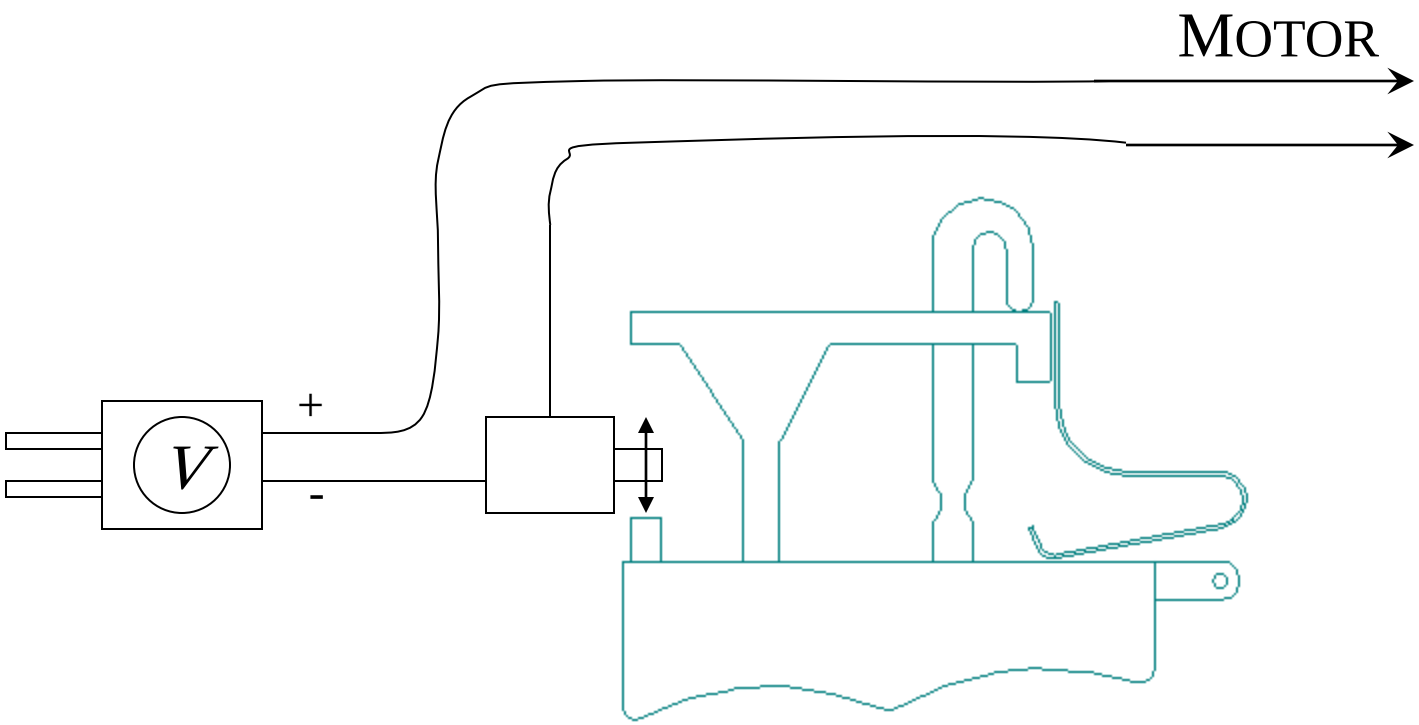
Was weight a consideration?



Switch

- Safety lock allows trigger action.
- Is this a regulatory requirement?
- Ergonomic issues of size and lever force
- What type of spring mechanism is used?

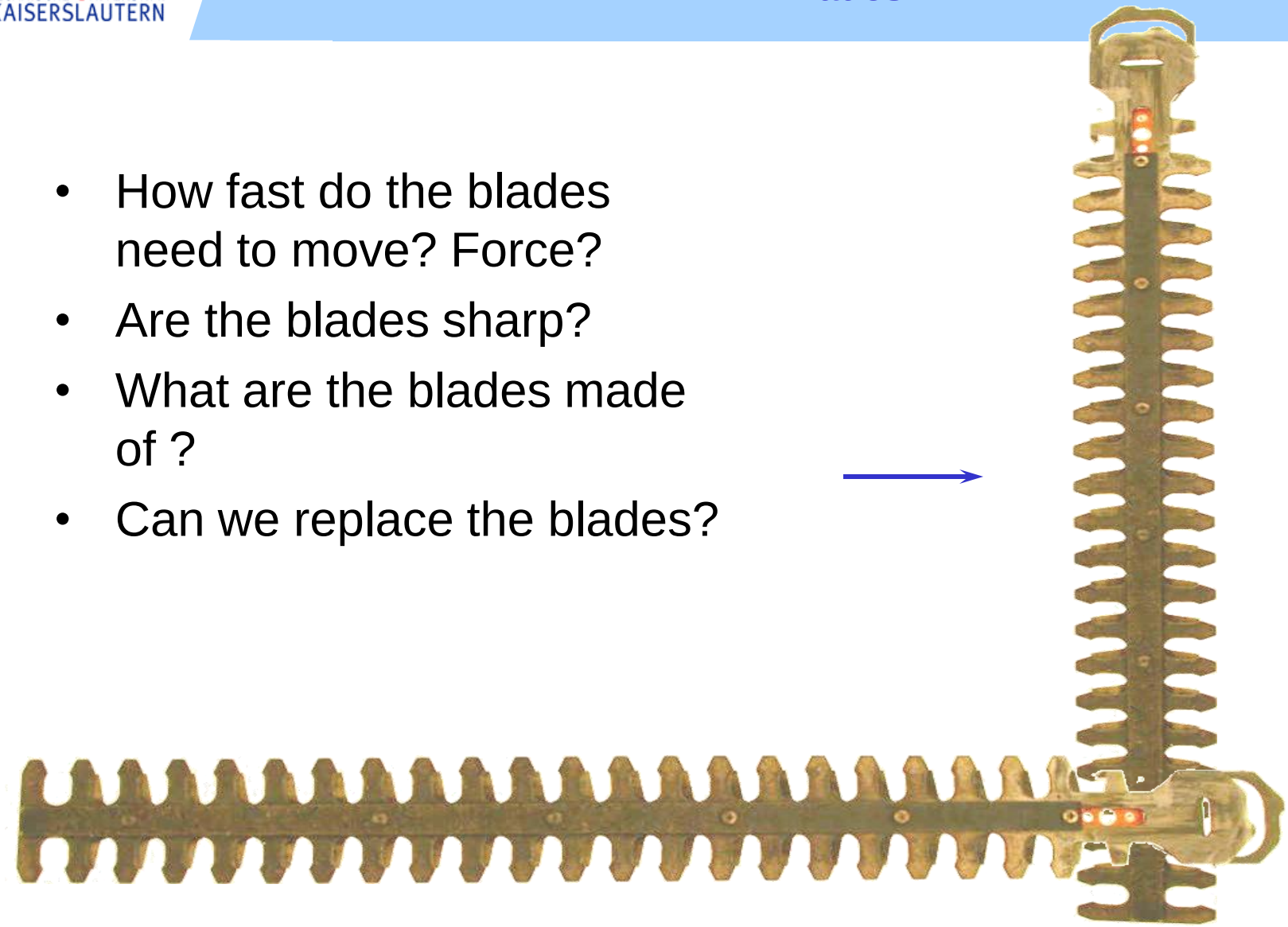




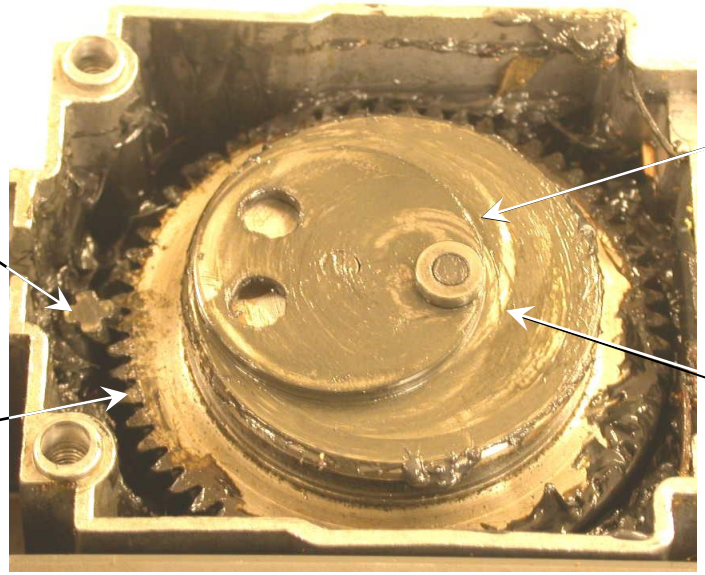
Sketch of Switch

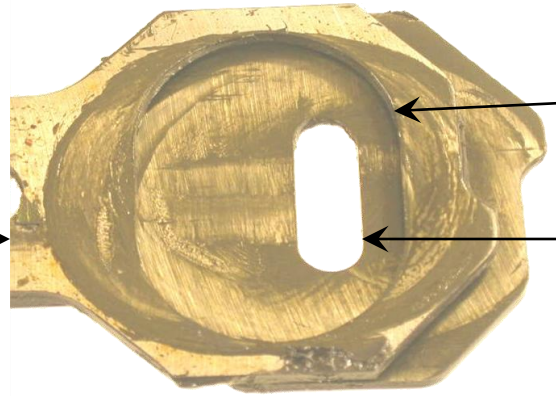
Blades

- How fast do the blades need to move? Force?
- Are the blades sharp?
- What are the blades made of ?
- Can we replace the blades?



two helical gears have a gear ratio of 1:15





Case

- How was the case made?
- Was the case designed to be esthetically pleasing?
- Why isn't the case made out of metal?
- What sort of costs are involved in the manufacturing of this case?

Feature List

- Switch - Plastic Injection Molded
- Gear – Die Cast Steel
- Case – Plastic Injection Molded
- Handle – Plastic Injection Molded
- Guard – Plastic Injection Molded

Reassemble Product

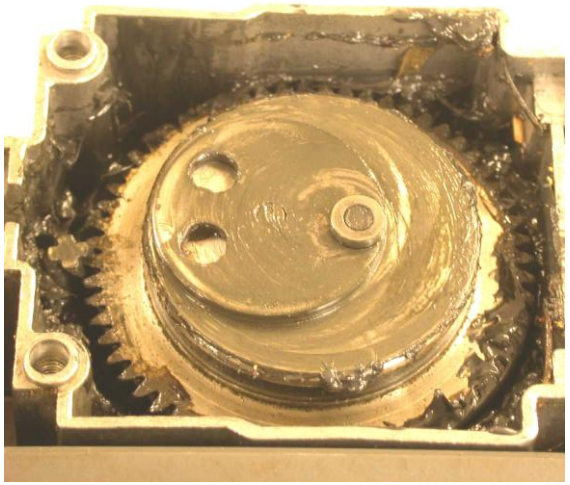
Transforming to engineering specifications

Example - Motor-Blade Kinematics

Helical gears

Number of teeth: input = 4

output = 60



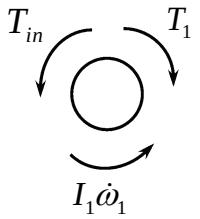
Motor speed = 22800 rpm

Output speed $= \frac{4}{60}\omega_{in} = \frac{1}{15}(22800\text{rpm})$

$= 1520$ rpm $= 159$ rad/s

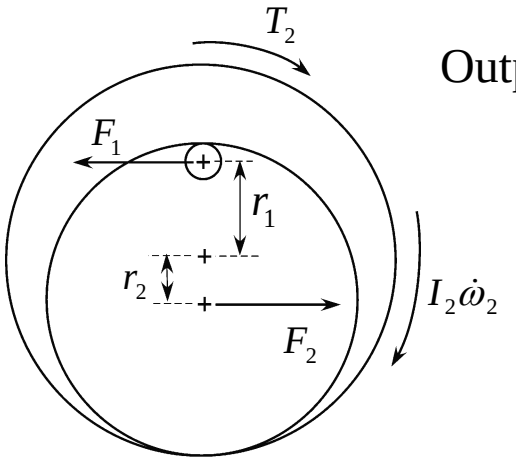
Maximum blade speed = 1 m/s

Transforming to engineering specifications



Input gear from motor

$$T_{in} - T_1 = I_1\dot{\omega}_1 \qquad T_1 = F_t\frac{d_1}{2} \qquad T_2 = F_t\frac{d_2}{2}$$



Output gear to blades

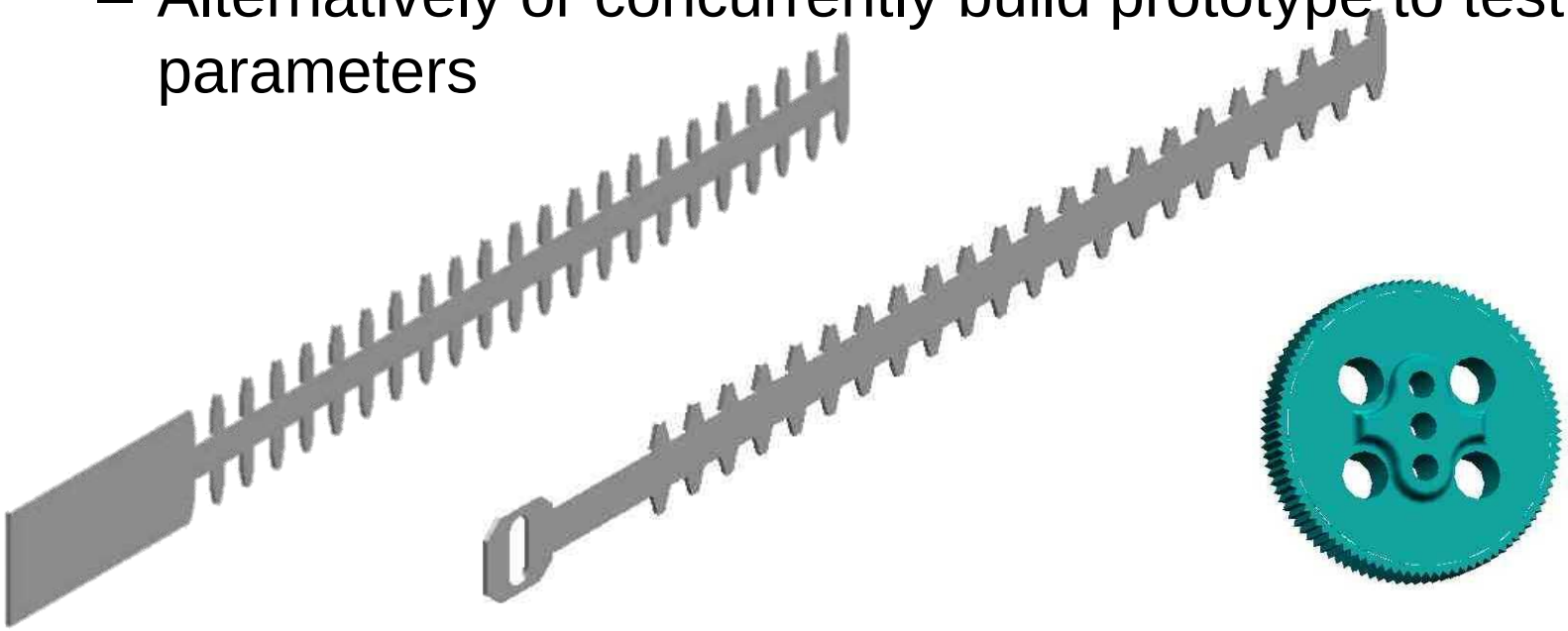
$$T_2 - F_1 r_1 - F_2 r_2 = I_2\dot{\omega}_2$$

$$F_1 = m_1\left(r_1\dot{\omega}_2\sin\phi - r_1\omega_2^2\cos\phi\right)$$

$$F_2 = m_2\left(-r_2\dot{\omega}_2\sin\phi + r_2\omega_2^2\cos\phi\right)$$

3. Design Models

- Identify actual physical principles
- Create engineering models and metric ranges
- Alternatively or concurrently build prototype to test parameters



4. Design Analysis

- Calibrate model
- Create engineering analysis, simulation or optimization
- Create experiment and testing procedures

5. Parametric Redesign

- Optimize design parameters
- Perform sensitivity analysis and tolerance design
- Build and test prototype

6. Adaptive Redesign

- Recommends new subsystems
- Searches for inventive solutions
- Analyzes force flows and component combinations
- Builds and tests prototype

Example Project

Black and Decker Cordless Screwdriver

SKIP

1. Investigation, Prediction and Hypothesis

Develop Black Box Model

- Assemble product and conduct a test
- What goes in? What comes out? (i.e. power, noise, heat)

Conduct a single test of the performance of the product:

- Record product performance attributes
  - –No load Rotational speed: 150 rpm (claimed)

    142 rpm (measured)
  - –81:1 Gear reduction = 12,200 RPM for the motor
  - –Drove in 94 #6, ¾” self tapping screws into dry pine (not predrilled)

Product Market

What is the market for this product?

- “Great for Everyday Use” – Black & Decker Manual
- Homeowners with need for occasional use

What are the costs associated with this product?

- Design - Manufacturing - Assembly – Packaging - Resale ($20.00)

Product Features

How long will this product last?

- 2 year full warranty provided

What features does this product have that are important?

- Cordless, rechargeable battery
- Reversible direction
- Power/manual switch
- Relatively high torque
- Relatively long battery life

Additional Comments and Remarks -1

by Staceys1 (Nov 03 '00)
Pros: Durable and easy to use
Cons: none
Recommended: Yes

- Owned for about 5 years and is still going strong.
- Easy to use: position the screwdriver on the screw and press a button.
- It has a switch that reverses the way the head spins depending on whether you are trying to remove or put in a screw.
- The tip is easily taken out to switch between a Phillips head and a flathead screwdriver.
- Very durable. It's been dropped on concrete, and other than a few scratches, it still works fine.

Amount Paid (US$): 20 (on sale)

Additional Comments and Remarks -2

By: YYvonne (Jan 19 '01)
Pros: Makes tougher jobs a breeze for me
Cons: none
The Bottom Line: Makes screwing around a breeze! (Couldn't resist!)
Recommended: Yes

- Not really designed for heavy duty jobs
- Saves me a lot of strain in my wrists
- Lightweight and easily held
- I like the directional buttons on the screw driver
- I've never had the rechargeable battery die on me in the middle of a job.
- The batteries recharge quickly

Amount Paid (US$): 25

Additional Comments and Remarks -3

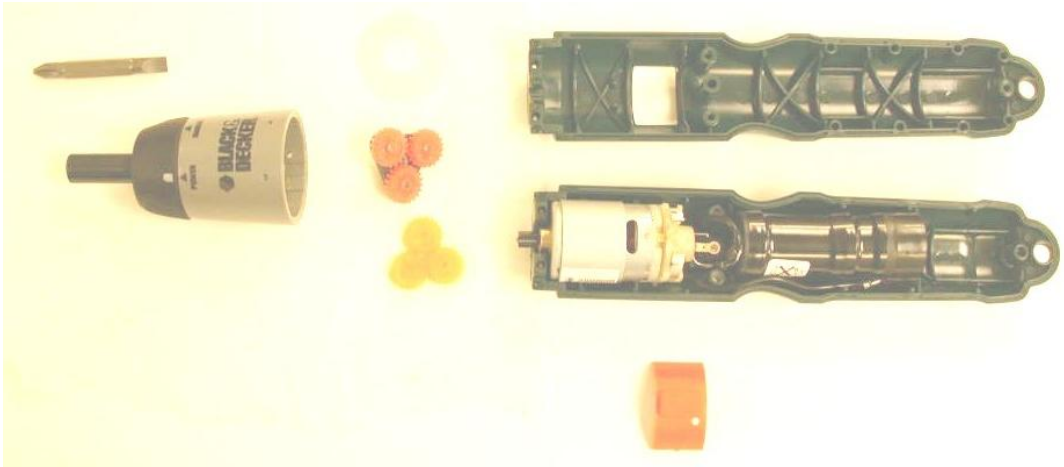
By: Seeker1 (dec09’00)
Pros: Easy to use, reversible heads, rechargeable
Cons: none known
Recommended: yes

- Best gift I ever bought my husband for myself!!!
- This is a tool we use constantly, for any household project, big or small
- Practically anyone could use, my daughter and myself included!!
- Has a battery pack which is rechargeable. When it loses it's charge, you simply plug it in, let it recharge and you're ready to go again.
- Has interchangeable bits, one on either end (phillips head and a slotted head).
- The feature that I really like is that it's reversible. You can either drive a screw in or back it out.
- Wonderful lifesaver of a tool.

Amount Paid (US$): 19.95

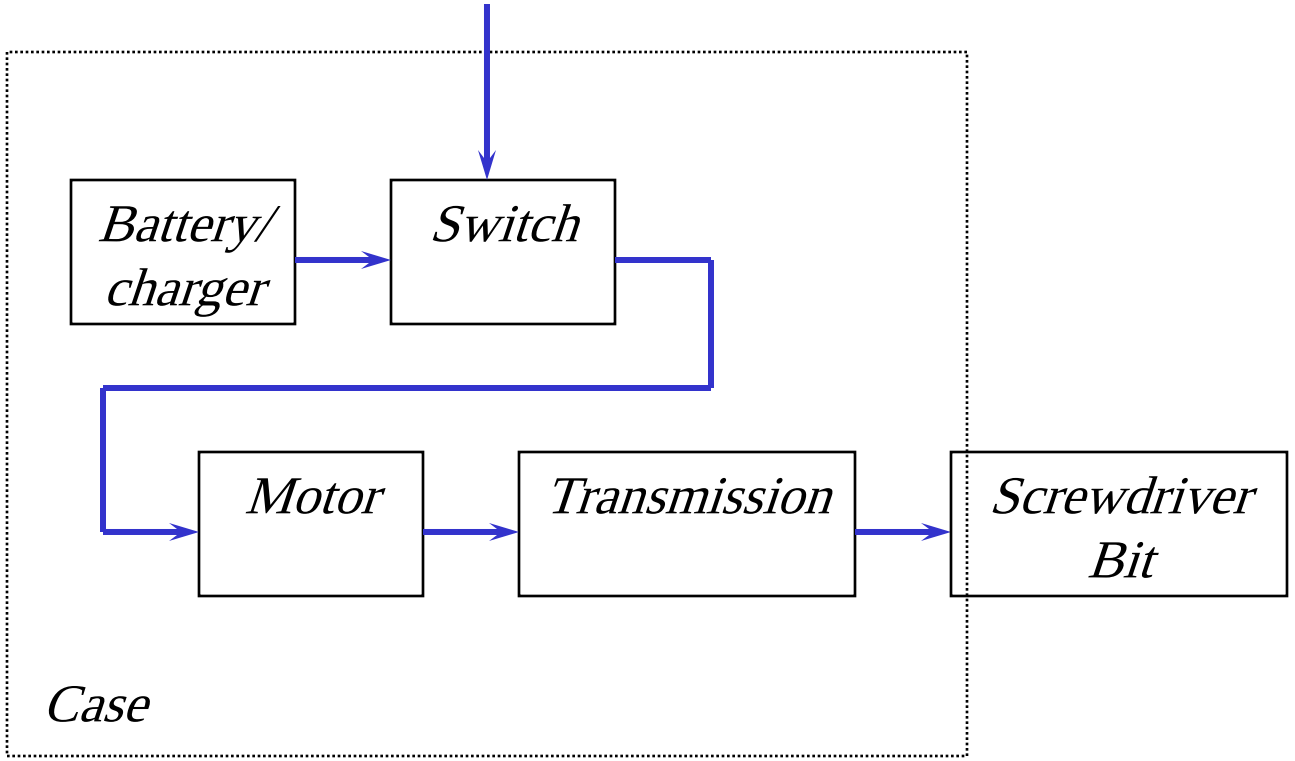
2. Concrete Experience: Function and Form

- Carefully begin Disassembly
- Document steps and components with photographs, sketches or video



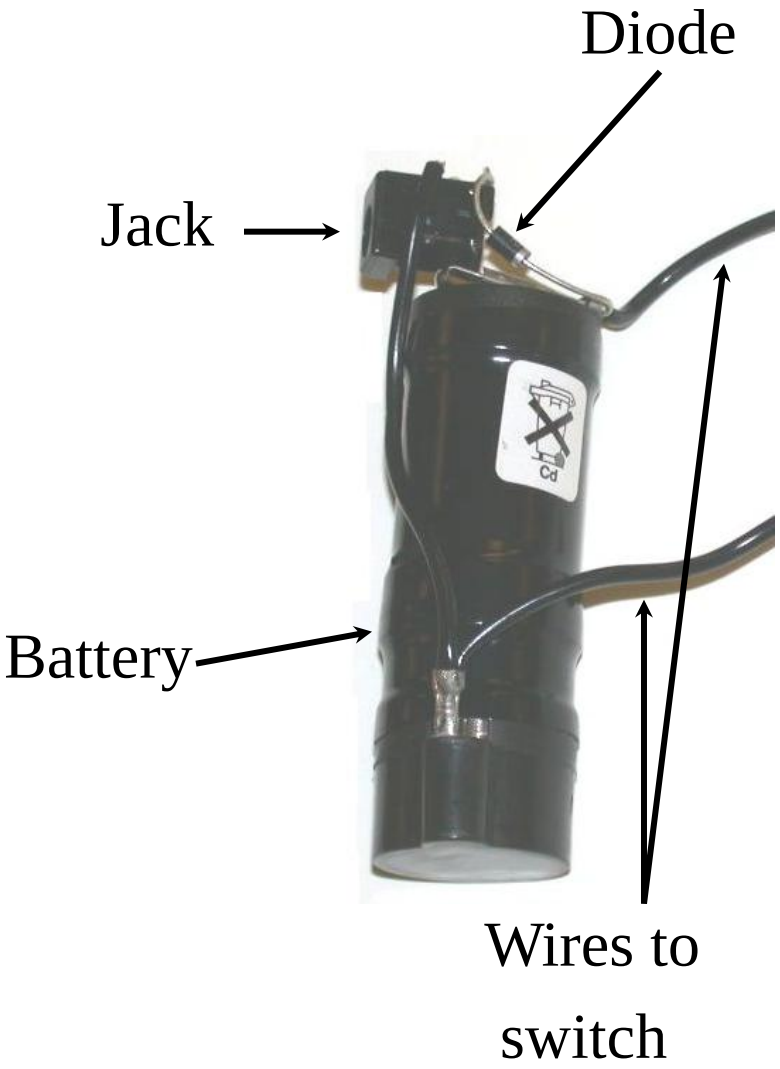
Cordless Screwdriver Sub-Systems and Interactions

- Group defined systems and subsystems together.



Battery/Charger

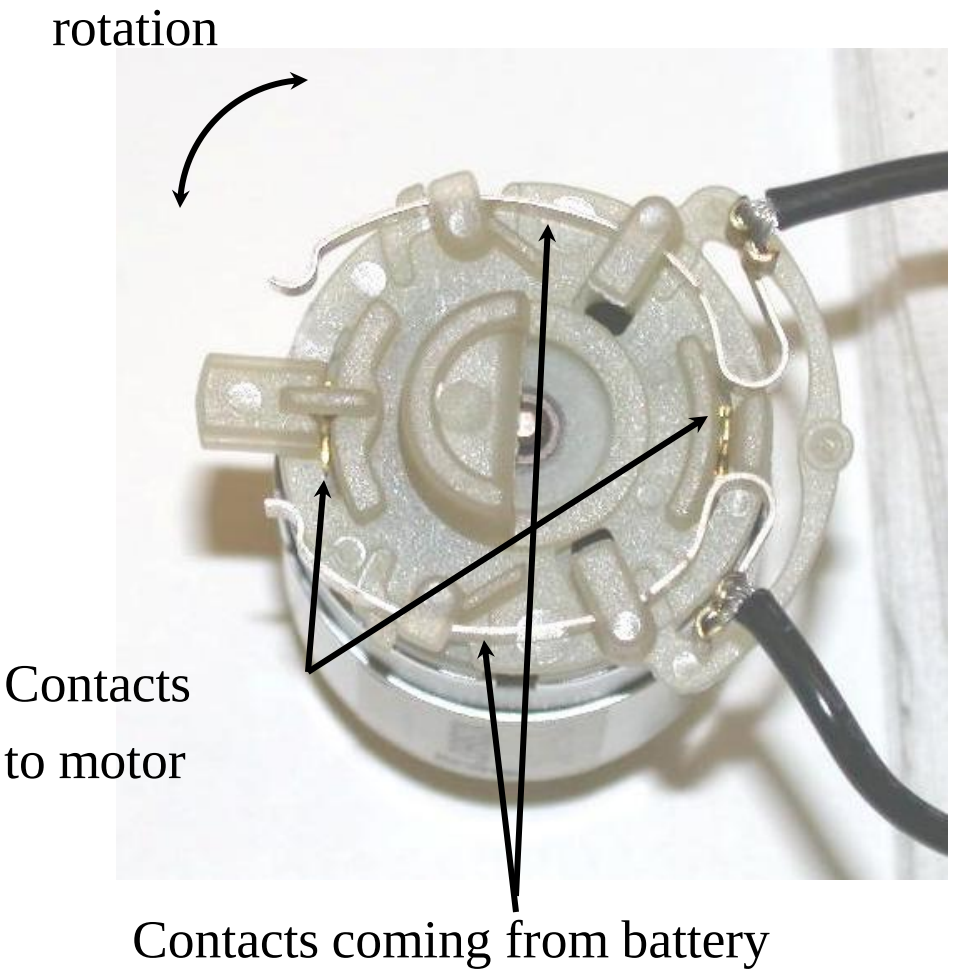
- Nickel Cadmium battery
- Jack for connection to AC transformer
- Diode to half-wave rectify the AC signal (charging)

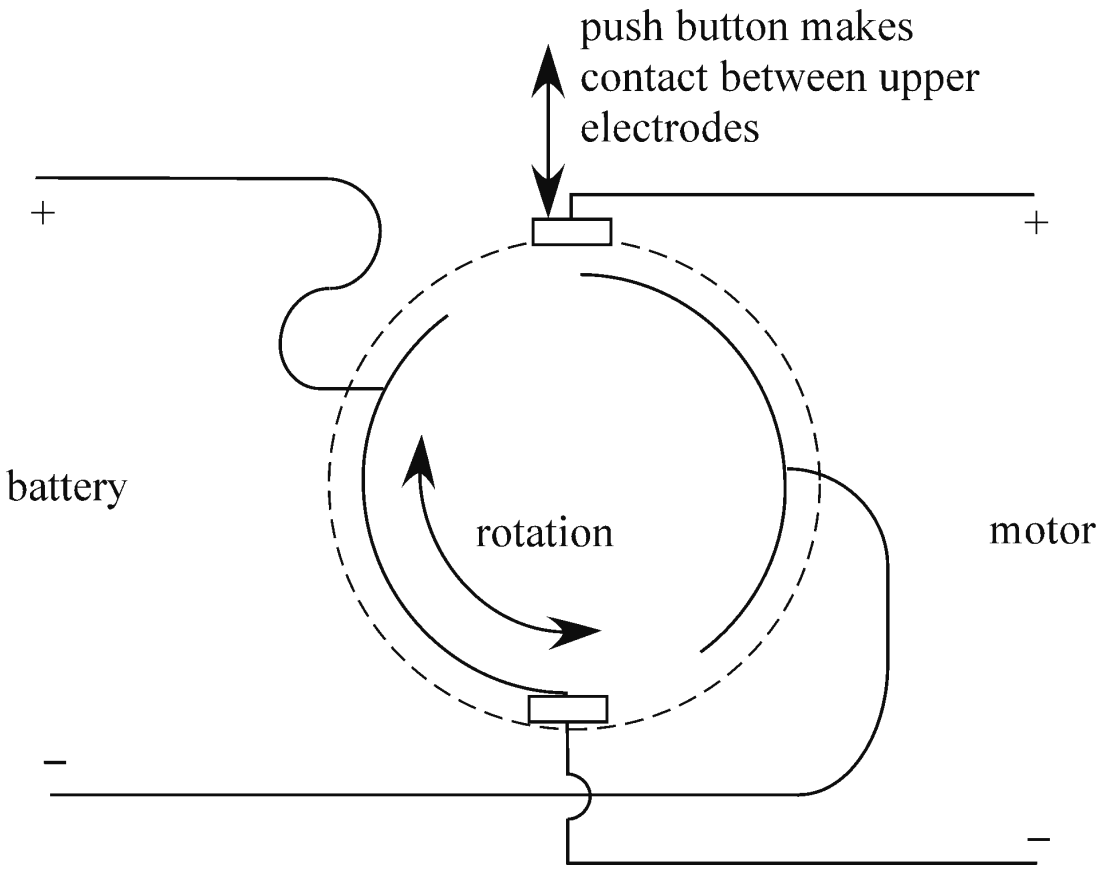


Switch

- Rotation of switching device lines up the contacts for either forward or reverse directions
- Pushing the switching device creates contact between the upper contacts

- How important is size, speed?
- Was weight a consideration?





Sketch of Switch

Motor

2.4 V Motor

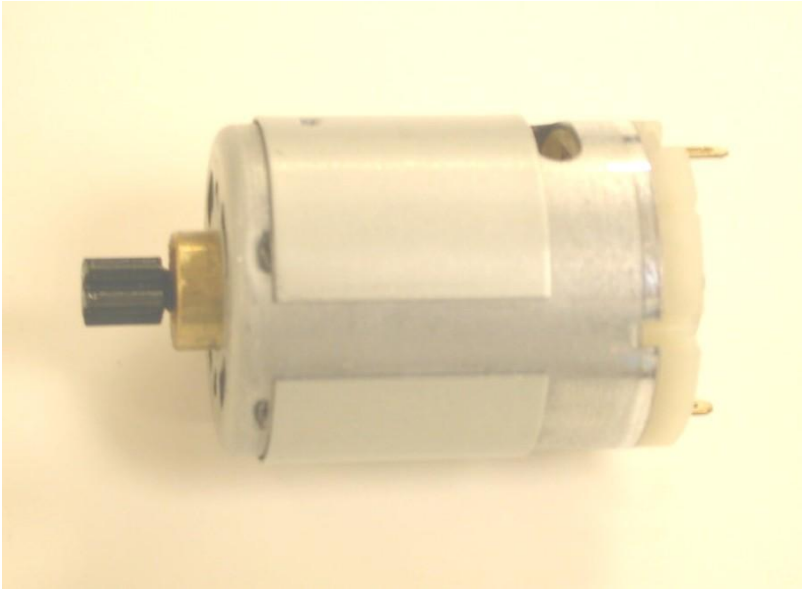
12200 RPM (no load)

3.567 Amps (no load)

Torque = .056 Nm (at stall)

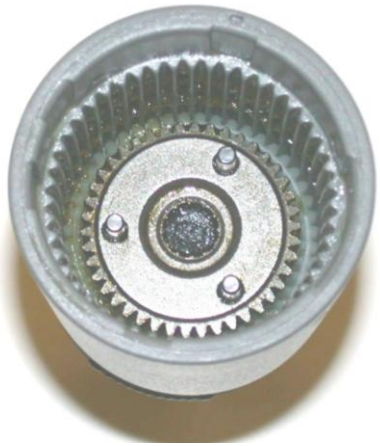
How important is size, speed?

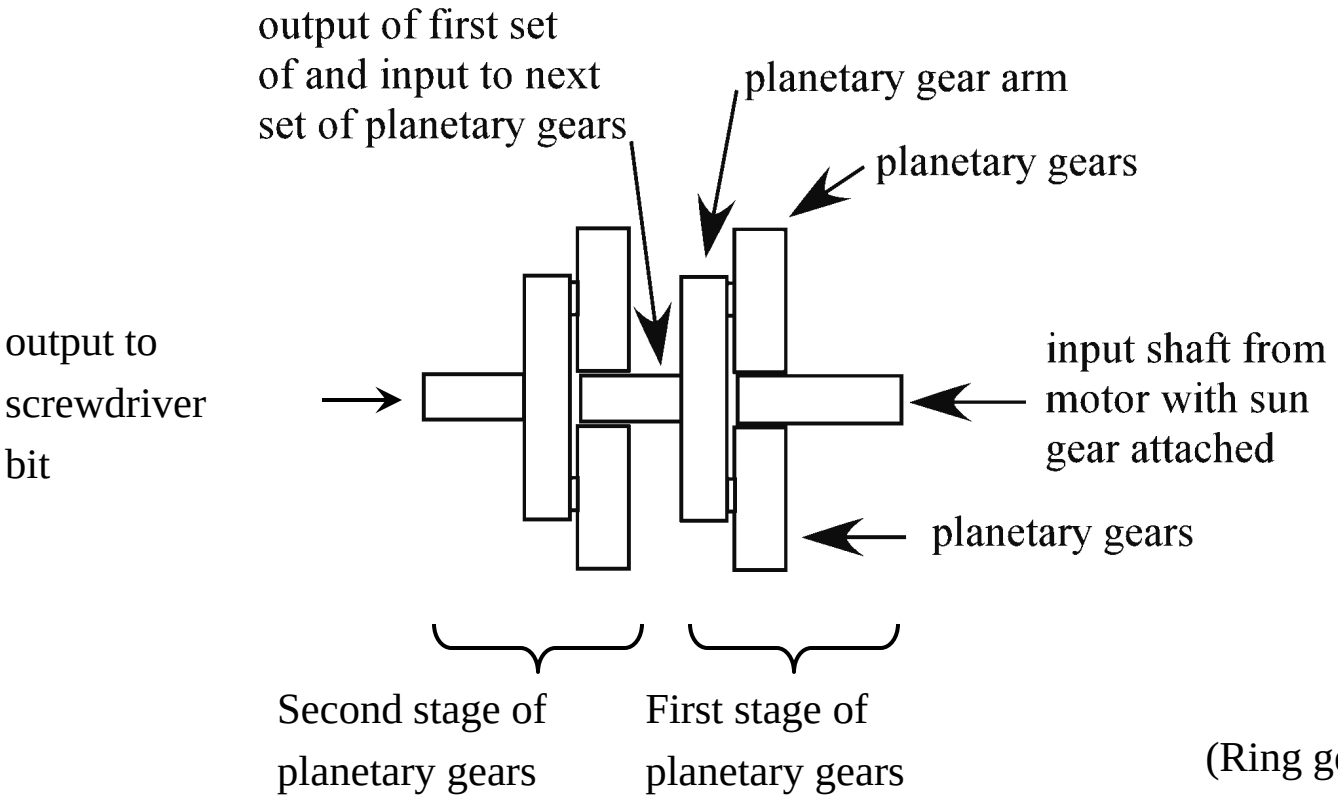
Was weight a consideration?



Transmission

- Sun gear: 6 teeth
- Planetary gear: 19 teeth
- Ring gear: 48 teeth
- Gear ratio = 81:1





(Ring gear not shown)

Screwdriver Bit

- How fast does the bit need to turn? Torque?
- What is the bit made of ?

Case

- How was the case made?
- Was the case designed to be esthetically pleasing?
- Why isn't the case made out of metal?
- What sort of costs are involved in the manufacturing of this case?

Feature List

- metal leads – extruded and bent
- plastic switch – injection molded
- plastic switching mechanism – injection molded
- plastic gears – injection molded
- casing – injection molding
- metal bit – extruded

Reassemble Product

Transforming to engineering specifications

Example - transmission Kinematics

1. Calculate gear ratio if carrier was fixed

$$r^* = -\frac{N_S}{N_R} = -\frac{6}{48} = -\frac{1}{8}$$

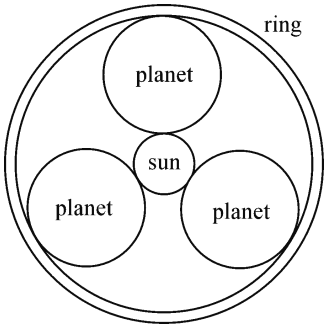
2. Calculate carrier speed out of first set of planetary gears

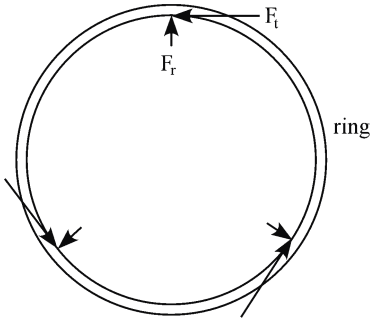
$$n_C = \frac{r^* n_S}{r^* - 1} = \frac{-1/8}{-9/8} n_S = \frac{1}{9} n_S = \frac{1}{9} 12200\,\text{rpm} = 1356\,\text{rpm}$$

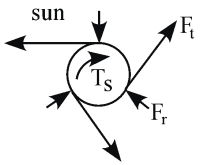
3. Calculate carrier speed out of second set of planetary gears

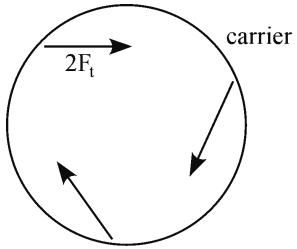
$$n_C = \frac{1}{9} n_S = \frac{1}{9} 1356\,\text{rpm} = 151\,\text{rpm}$$

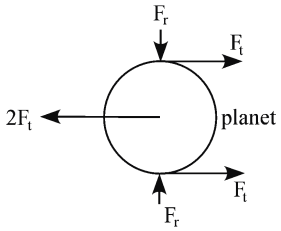
Transforming to engineering specifications











$r_{ps} = 2\,\text{mm}$ $\quad r_{pp} = 6.33\,\text{mm}$

$r_{pr} = 16\,\text{mm}$ $\quad r_{ps} = 8.33\,\text{mm}$

$$F_{t1} = \frac{T_{S1}}{3r_s} = \frac{.056Nm}{3(.002m)} = 9.33N$$

$$T_{c1} = 3F_{t1}r_c = 3(9.33N)(.00833m) = 0.233Nm$$

$$T_{s2} = T_{c1} = 0.233Nm$$

$$F_{t2} = \frac{T_{s2}}{3r_s} = \frac{0.233Nm}{3(.002m)} = 0.039N$$

$$T_{c2} = 3F_{t2}r_c = 3(0.039N)(.00833m) = 0.971Nm = 8.6inlbf$$

3. Design Models

- Identify actual physical principles
- Create engineering models and metric ranges
- Alternatively or concurrently build prototype to test parameters

4. Design Analysis

- Calibrate model
- Create engineering analysis, simulation or optimization
- Create experiment and testing procedures

5. Parametric Redesign

- Optimize design parameters
- Perform sensitivity analysis and tolerance design
- Build and test prototype

6. Adaptive Redesign

- Recommends new subsystems
- Searches for inventive solutions
- Analyzes force flows and component combinations
- Builds and tests prototype

To determine the environmental impact of the existing design evaluate each step of the *Product Life Cycle*

- Pre-production
- Manufacturing Process
- Product Life
- The After Life

Pre-production

- Replaceability of natural resources
- Availability of an alternative resource
- Energy required to obtain
- Energy to process
- Amount of waste created during processing
- Waste disposal method

- Energy to produce
- Waste created during production
- Type of waste- solvents, emissions?
- Reuse of in-process material waste?
- Material yield

Product Life

- Energy consumption
- Waste production
- Length of product life

The After Life

- Reuse
- Recycle- design for disassembly?
- Neither- harmful pollutants?

Discussion: Reuse vs. Recycle

Summary

Reverse engineering

- Tool to understand current design solutions and technology
- Use dissection, experimentation and analysis
- Save time and gain insight on current design challenges and solutions

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