***The Elements of Mechanical Design*, James G. Skakoon, ASME Press, 2008**

Part I - Elementary Rules of Mechanical Design

1. Create designs that are explicitly simple, keep complexity intrinsic
    1.1. The less thought and knowledge a device requires, the simpler it is
    1.2. Applies to production, testing and use
    1.3. Simple - when everyone involved sees nothing that looks that looks complicated from his/her perspective
    1.4. When complexity is unavoidable, bury it and make it invisible
    1.5. Restrict complexity to its own hierarchical level in the design
    1.6. Purchase parts instead of making components
    1.7. Specify components by standards

Examples
    http://507movements.com/mm_247.html
    http://507movements.com/mm_251.html
    http://507movements.com/mm_278.html

2. Keep the functions of a design independent from each other
    2.1. Decompose the devise or system into basic functions, then keep them separate
    2.2. Often not completely possible, understand how and why compromised
    2.3. While keeping functional independence, take opportunity to combining functions within parts

Example
    http://507movements.com/mm_069.html

3. Use exact constraints when designing structures and mechanisms, never over constrain a design
    3.1. Exact constraints are statically determinate, over constrained designs are statically indeterminate
    3.2. Advantages:
        3.2.1. Reduced or no binding
        3.2.2. Reduced or no play
        3.2.3. Repeatable positioning
        3.2.4. No internal stress from assembly
        3.2.5. Loose-tolerance parts
        3.2.6. Easy assembly
        3.2.7. Robustness to wear and environment

4. Plan the load path in parts, structures and assemblies
    4.1. Load paths should be:
        4.1.1. Short
        4.1.2. Direct
        4.1.3. In a line, or at least in a plane
        4.1.4. Symmetric
        4.1.5. Non-redundant, or at least elastic
        4.1.6. Locally-closed
        4.1.7. Easily analyzed if necessary

5. Triangulate parts and structures to make them stiffer

5.1. Truss members
5.2. Shear webs
5.3. Stiffening flanges
5.4. Triangulating ribs

6. Avoid bending stresses, prefer tension and compression
   6.1. Bending and torsion are not efficient at lead-bearing due to stress distributions
   6.2. Tension and compression are far more efficient, design for uniform stress
   6.3. If beams cannot be avoided, use I-sections
   6.4. If torsion rods cannot be avoided, use tubes

7. Improve designs with self-help
   7.1. Use applied loads to improve performance:
      7.1.1. create new, useful forces
      7.1.2. transform or redirect forces
      7.1.3. balance forces with themselves or existing forces
      7.1.4. distribute forces

Examples

http://507movements.com/mm_174.html
http://507movements.com/mm_180.html
http://507movements.com/mm_278.html
http://507movements.com/mm_251.html
http://507movements.com/mm_247.html
http://507movements.com/mm_247.html
http://507movements.com/mm_381.html
http://507movements.com/mm_463.html
http://507movements.com/mm_493.html
http://507movements.com/mm_494.html

8. Manage friction in mechanisms
   8.1. avoid sliding friction
   8.2. maximize length of linearly-guided components
   8.3. prefer rotary motion over linear motion
   8.4. use rolling element bearings wherever possible
   8.5. use flexures to eliminate friction

Examples

http://507movements.com/mm_027.html
http://507movements.com/mm_250.html
http://507movements.com/mm_255.html
http://507movements.com/mm_256.html
http://507movements.com/mm_257.html
http://507movements.com/mm_258.html
http://507movements.com/mm_259.html
http://507movements.com/mm_270.html
http://507movements.com/mm_381.html
http://507movements.com/mm_493.html

Part II - Essentials of Thought and Procedure in Mechanical Design

1. Use 3-D solid model layouts to find the best arrangement of parts and assemblies
    1.1. As an aid to thinking
    1.2. For communicating design ideas
    1.3. Combine with sketching and 2-D modeling as necessary and appropriate

2. Invert geometry to reveal new solutions
    2.1. Mechanical design is all about geometry - organizing features and components in 3-D space
    2.2. To help search for better alternatives, "invert" the geometry whenever a roadblock is hit"
        2.2.1. inside -> outside
        2.2.2. right -> left
        2.2.3. above -> below
        2.2.4. symmetric -> asymmetric
        2.2.5. in-line -> offset
        2.2.6. smaller -> larger
        2.2.7. parallel -> normal
        2.2.8. pressure -> vacuum
        2.2.9. axial -> radial
        2.2.10. flat -> curved
        2.2.11. translating -> rotating

Examples

http://507movements.com/mm_247.html
http://507movements.com/mm_251.html
http://507movements.com/mm_278.html

3. Build prototypes of everything, but not all at once
    3.1. Different prototypes simulate 1) function, 2) size (or form) and/or 3) process, not always within the same prototype
    3.2. Virtual prototypes and analytical models
    3.3. Machining, rapid prototyping
    3.4. Do not overlook paper, tape, cardboard, foam core, pins, glue as prototype materials

4. Separate strength from stiffness, and stiffness from strength
    4.1. Strength - how much load causes yielding or breaking without considering deflection
    4.2. Stiffness - how much something deforms, without considering yielding or breaking
    4.3. Often track together, but not always
    4.4. Once a material (plastic, steel, aluminum, etc) has been chosen, the most effective way to improve strength or stiffness is through geometry
    4.5. Even if something doesn't yield or break, do not assume it is stiff enough for its purpose
    4.6. Stiffening something may cause failures where none existed before

5. Never overlook buckling phenomena in parts and structures
    5.1. Buckling - geometric instability of (usually) slender structures or walls, not strongly related to material properties
    5.2. Always investigate, improve through changes in geometry

6. Analyze and test for trends and relationships

6.1. Analytical models are most useful for general trends and relationships
6.2. A single problem solution or FEA analysis is of limited use
6.3. Families of solutions and what-if analyses, along with experimental data, are required for understanding

7. Identify contingency plans to minimize risks in design
   7.1. Are these 3 bolts aren't enough can I use larger ones? Can I use 4 bolts? What needs to be done to accommodate these changes?
   7.2. If this linear slide doesn't work, what needs to be done to accommodate rolling contact bearings?
   7.3. Can I add ribs to this part if it isn't stiff enough?
   7.4. If this plating doesn't hold up, can the part be made in stainless steel?
   7.5. What would happen if the vendor supplies parts that are slightly out of specification?
   7.6. Can the system be easily serviced if it proves unreliable?

Part III - Some Practical Advice

1. Avoid press fits
   1.1. Press fits are always over constrained, hard to assemble, often impossible to disassemble
   1.2. Look instead to elastic fits, snap tits, tapered fits

2. Use closed sections or 3-D bracing for torsional stiffness

3. When designing springs, use low spring rate and high initial deflection
   3.1. Usually require fairly constant force over wide range of deflection
   3.2. Easier to accomplish with lower spring rate and larger deflection
   3.3. Decrease spring rate - increase number of coils, decrease wire size, increase coil diameter
   3.4. Decrease stress - decrease wire diameter, increase coil diameter, increase number of coils
   3.5. Increase load - increase wire diameter, decrease number of coils, decrease coil diameter
   3.6. Maximum force applied limited to amount of spring material

4. Minimize and localize tolerance path in parts and assemblies

5. Use mechanical amplification to reduce failures
   5.1. Use load-bearing parts and structures to bear load
   5.2. Use latches, fasteners and adhesives to keep those components in place

6. Include lead-in in assembled designs
   6.1. Chamfers and fillets
   6.2. Start mating parts together
   6.3. Align mating part to the desired final position
   6.4. Direct applied forces

7. Design assemblies to be self-locating, self-fixturing, self-securing, self-aligning, self-adjusting
   7.1. Design location, adjustment, fastening and alignment features as intrinsic characteristics
   7.2. More reliable and inexpensive than separate components, users or fixtures

8. Use self-assembling symmetry to create a whole from two halves

Design for Assembly

1. Reduce part count and part types
2. Eliminate adjustments
3. Design for self-alignment and self-location
4. Ensure visual and physical access
5. Ensure ease of handling bulk parts
6. Minimize reorientation during assembly
7. Design to prevent improper assembly
8. Design for symmetry or obvious asymmetry

With Experience Comes Wisdom

- Have a backup. Ask yourself where the risk areas are
- Start with the simplest principle and add complexity as needed
- Really creative people can take unrelated things and put them together in novel ways
- Modeling something full-scale is enlightening. When that model is handed to a client, it is often a revelation - either good or bad
- Prototyping is essential to communicate with non-technical clients
- The number of iterations is directly related to the quality of the final design
- Stiffening a part by intuition often results in failure
- In machine design, parts are more often designed for stiffness than for strength
- Predicting the effects of friction is always a gamble
- Mechanical design typically consists of transmitting of converting motion, or devising joints to hold it all together
- Linear motion is more difficult to accomplish successfully than rotary motion
- Mechanical design is far more about common sense and cleverness than the need for analysis to provide the solution
- Always sidestep the need for a detailed analysis
- When presented with a difficult requirement, try to design around it
- When a problem is identified, fix the cause, not the effect
- Resist the tendency to become too detailed too quickly
- Nurture a few competing ideas from the beginning - you'll be more impartial and more likely to change your mind when necessary
- It is very common to make things far more complicated than they need be
- The design isn't finished when you can't add more; the design is finished when you can't take anything else away