Aspects of Mechanical Design

There is a lot of information on mechanical design floating around. The student is encouraged to look into this body of information and apply it to their design projects. Here I present just a few basic “pointers” commonly used in Engineering Design.

Mechanical design problems usually start with some sort of problem statement. What are we trying to do or improve? Why? Generally it will be “blurry” at first, i.e., something like: “Improve fuel consumption of the Campro Engine”, or “Decrease cost of the torchlight”. We must help define the problem by focusing on the constraints, e.g., “Improve Fuel consumption, but do not reduce power, cost can not increase by more than 2%, Emissions …”

Economics will always be an important factor. Any potential solutions should include economic analysis as well as a time line, as time in money. Manufacturability is another important factor. For example you can design an engine modification to save energy (say replacing your current engine with a more “high-tech” engine), but if the energy required to make the modification (i.e., Manufacture the new engine) is more than the expected savings of energy from the modification, then it is a waist of time. Energy is another important factor Efficiency may or may not be an important factor. In a power plant efficiency is crucial: It will be worth it to improve the efficiency of the plant by 2% even if it costs 1,000,000 RM to do so, if the plant burns 50,000,000 RM of natural gas per year. In this case the “pay back period” of the modification is only one year, and large plants typically have life times of >20 years, meaning you just saved 19,000,000 RM over the life of the plant! With a wind turbine the efficiency is not important, as the wind is free, but the installed cost and cost of maintenance is. This is related with efficiency (less efficient turbines require larger rotors, and heavier towers), but a less efficient, less expensive system might work out to be the best choice.

Impedance matching is a concept often overlooked in initial designs. Loads need to be matched to the source of power running the load for efficient operation, this is impedance matching. It does not make sense to buy a 5 kW generator for 2,500 RM to run your walkman which requires only 1.5 W. Instead buy a small solar panel for 80 RM and never need batteries again!

Always it makes sense to learn as much as possible when facing a new problem, so do a literature search. It is probably that someone else has already faced this problem before, and there is no need to reinvent the wheel if it has already been done.

Take Data! There is almost always a number of different ways of getting data pertaining to your problem. For example if you are to design an improved conveyer system in a factory you can: (1) Measure the weight and quantity of the items to be moved, (2) Calculate the energy required based on the kinetic energy of the system of moving objects, plus potential energy (3) Examine the current systems power requirements, (4) Visit manufacturer websites and get power/torque/speed data for their systems, (5) measure the power consumption of a conveyer system unloaded and loaded to get an idea of efficiency…

You are an engineer! Once you have data you need to start calculating the other important parameters. Make simple models first, then get more sophisticated as your data and techniques improve. Be sure to check your work with common sense: if you calculate that it will take 14.652 A to run your walkman, you have a serious problem! Often you can “test” various hypothesis or options in the model much easier then you can in actual hardware for example how long will it take a window crank motor to open the steel door?

In situations where a component failure can cause damage to people, property or the environment it is important to do a Failure Mode and Effect Analysis. This aids in assessing the potential risk of various failure modes, and may point the way to improving design toward “fail safe” modes: In nuclear power plants the control rods (which stop the nuclear reaction by absorbing neutrons) are withdrawn from the “pile” or nuclear core by an electrical mechanism similar to a solenoid. In case of a power failure the rods automatically drop back into the core and shut it down, preventing a melt down. If it were designed such that the control rods had to be “pulled into the core”, a power glitch would drop the rods out of the core, resulting in an uncontrollable reaction and Chernyobal all over again.

Solutions must be tested! There are always unknown or overlooked aspects in any large project, and verification is an important step in any solution. Testing should start with the collection of data: make small changes in the existing system and measure their effects. Intermediate components can be tested as soon as they are produced. Assemblies should be tested as much as possible before implementing them “on line”. This will often reveal deficiencies in the design which require modification before implementation can occur. Try to find these deficiencies as early as possible, as it is harder to fix them later on in the process.

Finally, your job is not finished when the new system is commissioned. You need to take the relevant data proving that what you designed is functioning properly and meets the problem requirements. You should take pride in your work: Document the whole process carefully including your final data verifying the performance of your design to communicate with others and show off!

BASIC STEPS IN MECHANICAL DESIGN PROCESS

1) Problem Definition
    - Constraints
    - Who’s the Customer?
    - Data gathering: What is known, what is not.
2) Literature Search: What are possible solutions?
3) Analysis
    - Modeling
4) Develop ideas for a solution
    - Solution Evaluation
    - FMEA: Failure Mode Effect Analysis
    - Optimization
    - Design for Manufacturability
5) Prototype Fabrication
6) Testing
    - Modification
7) Volume Production
8) Continuous verification and Testing
    - Customer Feedback
9) Take data to verify your gains or improvements
    - Add this to your resume!

Additional Information taken from various sources:

Mechanical engineering design is a part of the overall domain of mechanical engineering. The advent of mechanical engineering and the intrusion of equipment have largely redefined human lifestyles. Mechanized equipment, from tractors and cultivators to a wide variety of industrial machinery, had effected an explosion in agricultural productivity during the early 20th century. In the process, this promoted a massive shift from rural to urban life, resulting in the development of newer equipment for the urban economy. Hence mechanical engineering evolved at an ever accelerating rate over the century.

In mechanical engineering, the development of any product involves some broad steps as mentioned below. Mechanical engineering design is an integral part of this process and shapes the utility of the product developed to a large extent.

Step 1 - Identify the Idea and Concept

Step 2 – Define the Requirements for realizing the concept.

Step 3 – Gather relevant Information on similar products.

Step 4 – The Design Phase.

Step 5 – Prototypes.

Step 6 – Production.

The mechanical engineering design phase is perhaps the most significant and challenging. There are two main steps to a true design, as explained below. Design is a judicious mix of science and art, of analysis and synthesis.

1. Macro level design (conceptual design):

Here the fundamental and very basic ideas are evaluated. Various possibilities of reaching a goal or serving a specific purpose are evaluated through brainstorming sessions and a detailed but reasonable list of requirements, at this stage. Viability and feasibility of the overall effort in compliance with the goal of the enterprise need to be understood. As ideas are evaluated, several things should be considered. A clear examination of the impact on time and cost goals for each concept is also done at this stage. In many cases technical innovation is required to accomplish a task. These are areas of technical stretch or PoP's (Proof of Principle).

2. Micro level design (principal design or characterization):

This is where the details of the design are worked out and are composed. This is the stage of hard-core design. Most of the technical resources and assets of the enterprise are best utilized in this stage so that the fundamental engineering is done in best form. This stage looks into -

- Adherence to requirements.
- Resolution of conflicts and issues
- Review for manufacturing feasibility.
- Progress Review

This stage also encompasses design optimization where every step of iteration of the design is tried out to reach the best outcome.

One aspect that remains of high significance throughout the process of mechanical engineering design is ‘Quality’. It is very important to have set processes that check quality of the product from a perspective that can be most alien to the overall product development atmosphere. A complete unbiased and customer focused effort to identify quality standards is essential in any engineering design.

A Bit on Decision Making in Engineering Design:

http://www.memagazine.org/desmar05/deciding/deciding.html

Engineering is the application of physical principles to the solution of problems and requires the skills of numeracy, creativity, ingenuity and practicality.

Innovation and Engineering Design - this degree takes an holistic view of the design process allowing consideration of all aspects of design from initial concept to manufacture and marketing. It highlights the inter-relationships between different aspects of engineering science and their application in the creation of products, processes and systems.

Design methodology, CAD/CAE philosophy, optimization, product liability, probability/statistical principles, ASME codes, safety, human factors, material selection, legal aspects of design, professional ethics. Design project to be completed in EGME 419, feasibility study, preliminary design, assembly drawings, interim project report. Oral presentation.

Construction of prototype, model or components. Testing of the proposed design, and preparation of a final design report. Teamwork and communications skills are emphasized. Oral presentation is required.

Design and application of machine components such as brakes, clutches, gears, springs, fasteners, lubrication of machine elements, bearings, gaskets, seals, "O" rings, methods for study of impact, dynamic loading and fatigue; comprehensive treatment of failure, safety and reliability.

Modeling, assembly and design documentation using Pro/ENGINEER. Design of mechanical components and assemblies using Advanced Pro/ENGINEER features such as blends, drafts, user defined features, relations, family tables and assembly management. Collaborative design project, utilizing online resources.

Application of analytical and computer optimization techniques to engineering design problems. Presentation of design as an optimization task. One dimensional minimization. Unconstrained and constrained nonlinear programming. Approximation concepts. Duality. Computer applications to design problems using a general purpose optimization program.

Advanced modern mechanisms. Analysis and synthesis of mechanisms. Advanced topics in computer-aided design of mechanical, thermal and fluid systems. Methodology of modern design. Optimization in design.

Grading Ideas:

10 points **First Progress Report:** comprehensive problem definition. Use the format described in Chapter 7 of CED to consider at least 26 design parameters, to quantify these parameters and to determine their relative importance . Points-distribution for grading: technical aspects ~ 5 points / presentational aspects ~ 5 points / creative engineering aspects ~ 0 points.

15 points **Second Progress Report:** conceptual designs, their evaluation by decision matrices and the selection of the best concept through appropriate analysis. Use the methodologies presented in Chapters 8 & 9 for creativity and Ch10 CED for the evaluation of the concepts. Points-distribution for grading: technical aspects ~ 1 point / presentational aspects ~ 7 points / creative engineering aspects ~ 7 points.

25 points **Final Report:** a comprehensive document detailing all aspects of the project. This report will include the First Progress Report and the Second Progress Report in the early sections. It will build upon these elements to formally stipulate the product realization process. Points-distribution for grading: technical aspects ~ 12 points / presentational aspects ~ 12 points / creative engineering aspects ~ 1 point.

10 points **Attend the designated ME481 Sessions** at the Student Design Conference in the Union Building to evaluate the presentations of the other ME481 teams. Final oral presentation and poster presentation.