Computer Aided Design and Manufacturing

By
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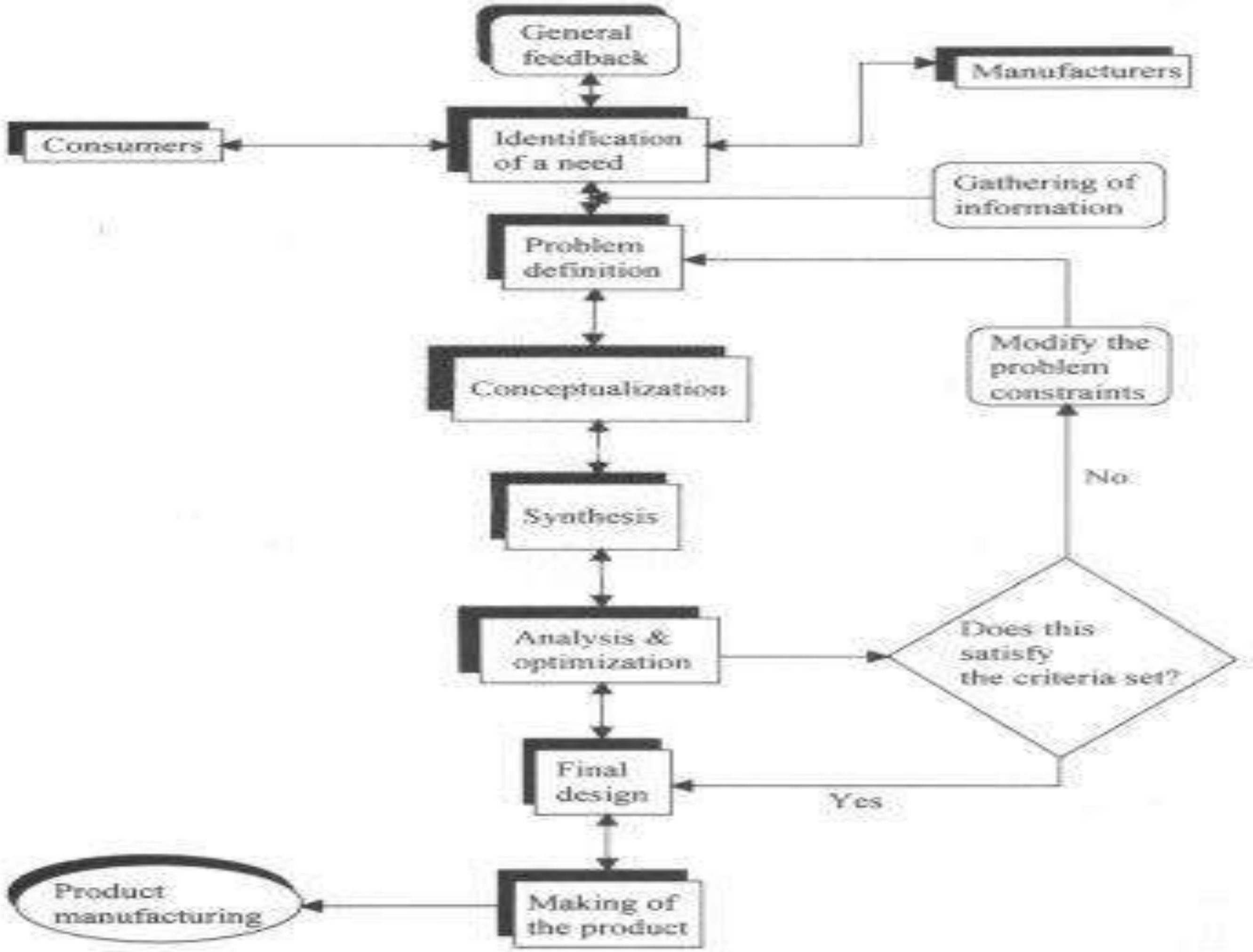
2.1 INTRODUCTION

2.2 CONVENTIONAL APPROACH TO DESIGN

2.3 DESCRIPTION OF THE DESIGN PROCESS

1. Problem definition
2. Conceptualization
3. Synthesis
4. Analysis
5. Manufacturing



The steps in design

2.3.1 Problem Definition

A well-defined problem is the key to a successful design solution. The design process involves many stages requiring careful thinking; the problem definition helps everyone focus on the objectives of the problem and the things that must be accomplished.

The problem definition should include the following:

(1) A statement of objectives and goals to be achieved

(2) A definition of constraints imposed on the design

(3) Criteria for evaluating the design

2.3.2 Conceptualization

Conceptualization is the process whereby a preliminary design satisfying the problem definition is formulated. This brings into play the engineer's knowledge, ingenuity, and experience.

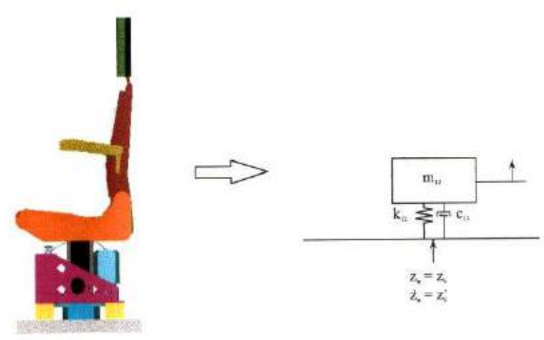
2.3.3 Synthesis

This is one of the most challenging tasks an engineer faces. At this stage, the information required for the proposed conceptualization is organized and a plan is devised for achieving that design. To achieve a viable synthesis decision, all the elements affecting the design, including product configuration, cost, and labor, must be considered.

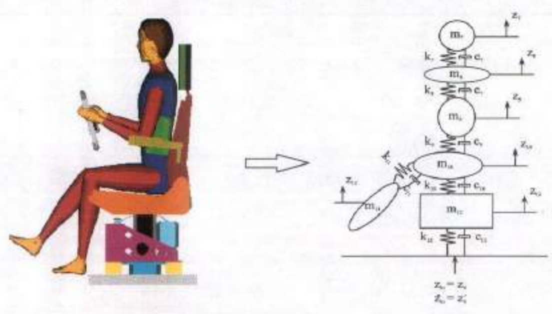
2.3.4 Analysis

Analysis is concerned with the mathematical or experimental testing of the design to make sure it meets the criteria set forth in the problem definition. The engineer must test all possible factors important to the design.

For instance, if we need to design the car suspension, we usually represent the body of the car by a mass, M, and the suspension by springs and dampers (linear or non-linear). A vibration analysis is then conducted for extraction of the spring and damper parameters that yield the most comfortable ride.



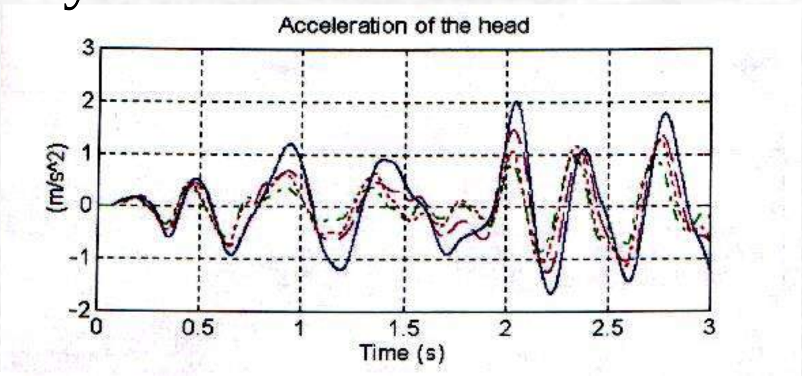
Vibration analysis of a car seat.

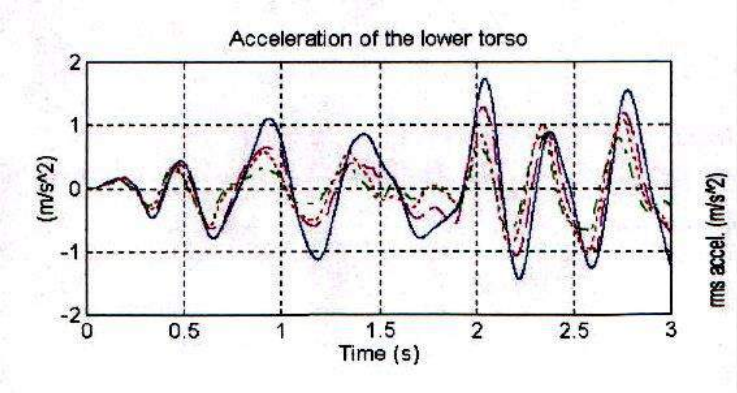


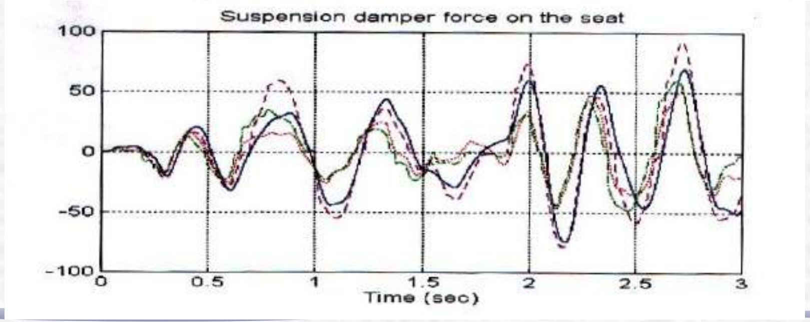
Vibration analysis of an occupied car seat

Experimentation in analysis is another critical step in design.

For instance, one might use a lumped mass model representing a car and analyze its behavior with different vibration stimulus or conduct a modal analysis experiment in which a real automobile is tested in the laboratory making use of shakers, transducers, and Fourier analyses.





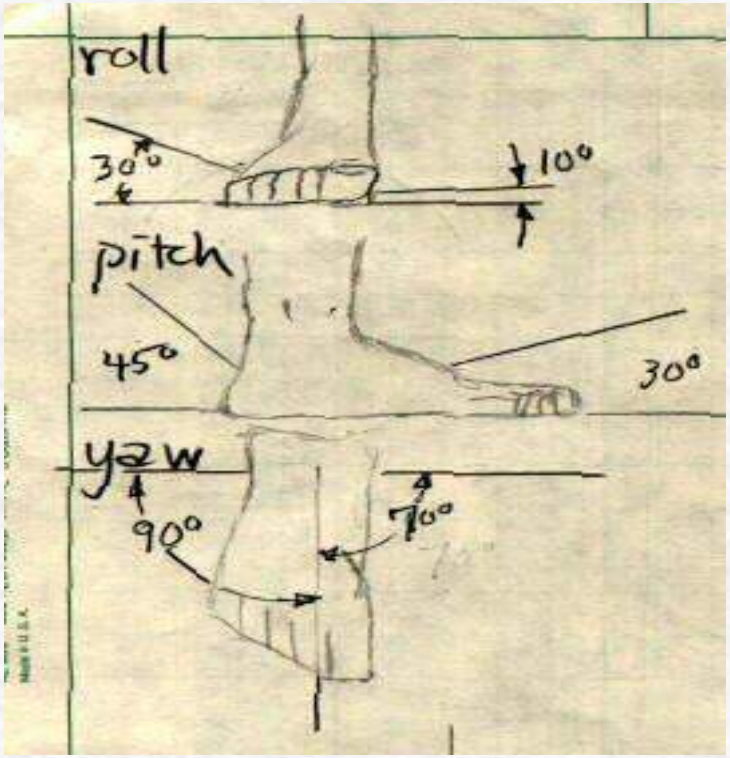


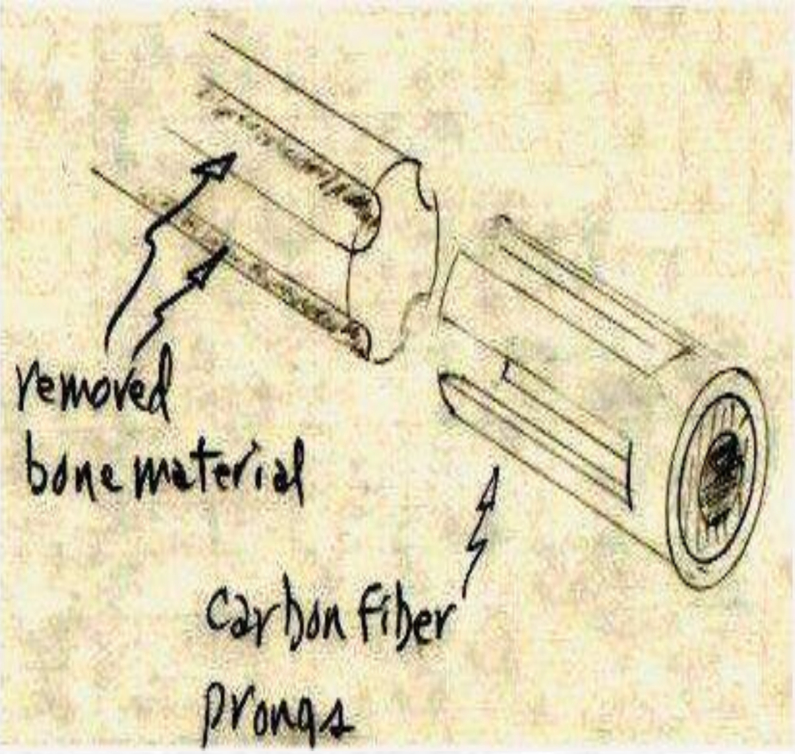
Examples of structural testing

Example: ENGINEERING DESIGN PROCESS

- ***2.3.1 Problem Definition***
- The assignments, to design a prosthetic leg or arm or an automatic sorting mechanism, serves as the "identification of a need." The purpose of the conveyer mechanism is to separate defective parts from those that meet the products' specs. In the case of the prosthetics, the goal of the examples given here is to achieve a design that would allow all the activities that would be possible with real limbs.

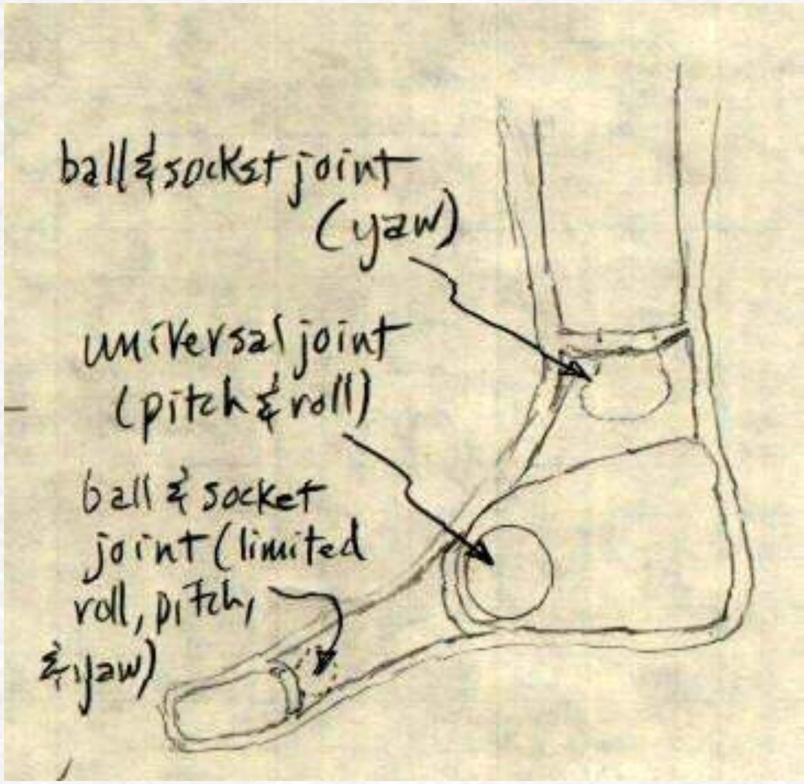
2.3.2 Conceptualization

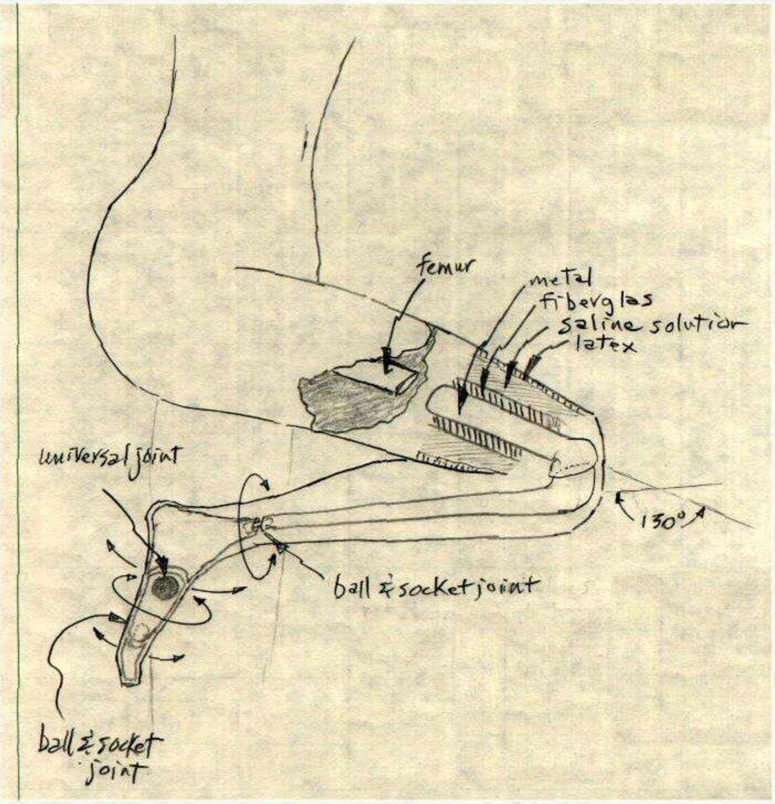




Defining the range of human motion aids the engineer in conceptualizing possible design

Configuration of the components and the choice of materials begins at this stage.

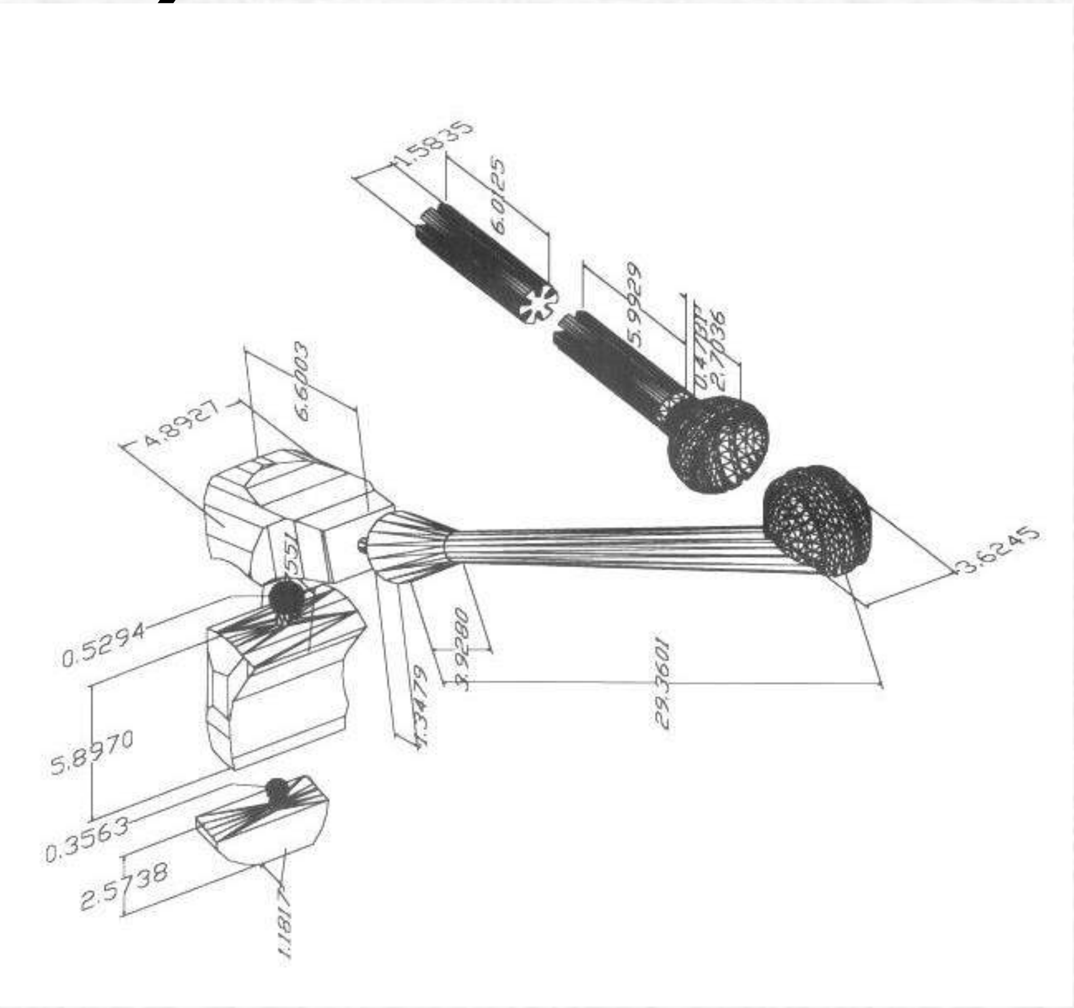




The complex movements of the foot are broken down into a group of simple movements

The mental model begins to take shape at the conceptualization stage.

2.3.3 Synthesis

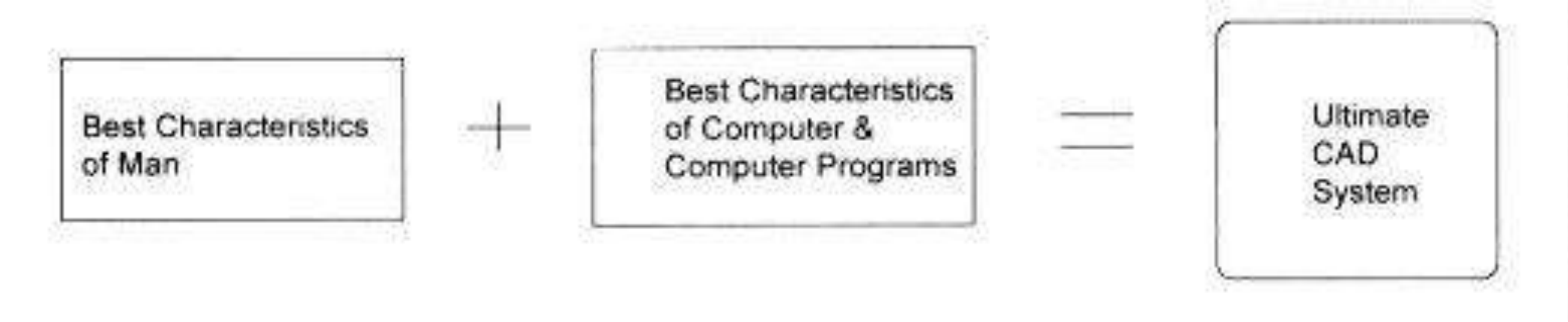


Assemble view

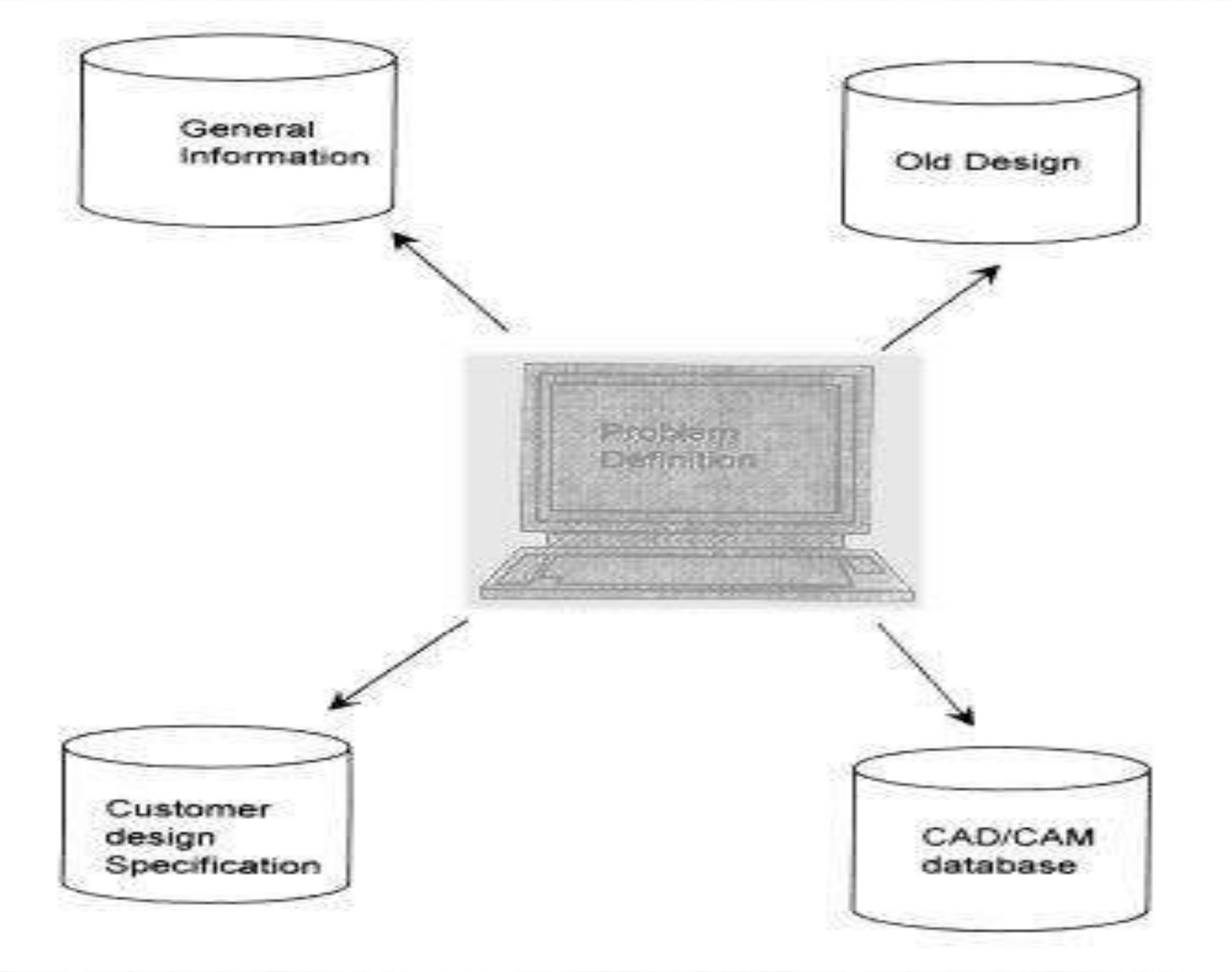
2.3.4 Analysis

The engineer would determine (either mathematically or through testing) whether the goals set forth in the problem definition step had been reached. If they had, the project would proceed toward a final design and manufacture. If those goals were not reached satisfactorily the engineer would return to the early stages of the process either to modify the problem definition or fine-tune the conceptualization facet of the design process.

2.4 COMPUTER-AIDED DESIGN

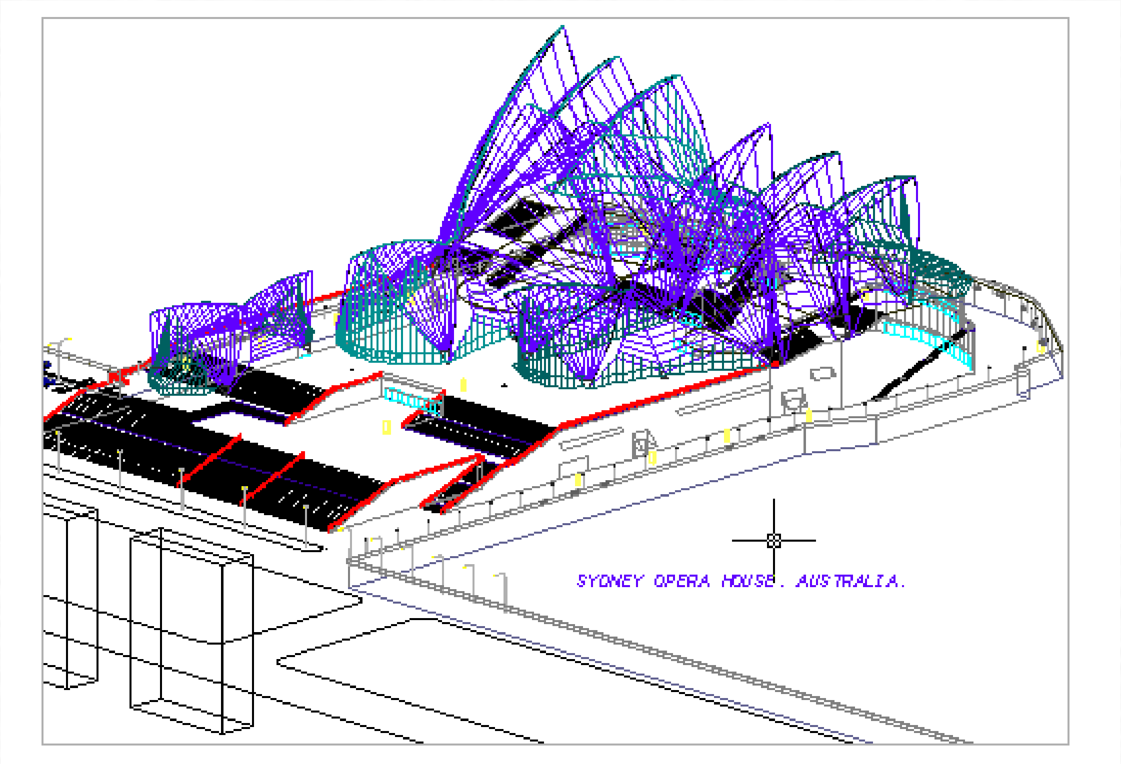


Characteristics of CAD



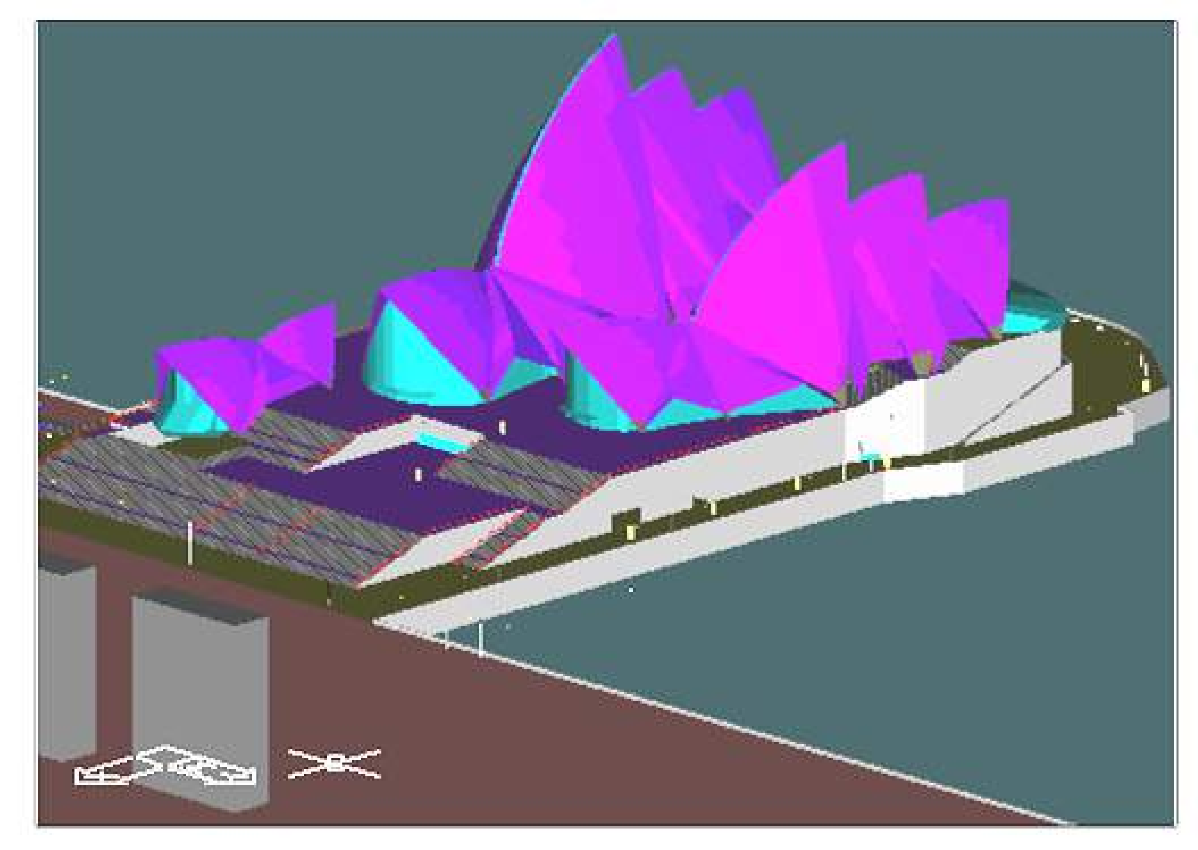
Interaction with various sources of information

- ***2.4.1 Drafting and Design***
- ***2.4.2 Wireframe Modeling***



A Wireframe model.

2.4.3 Geometric Modeling

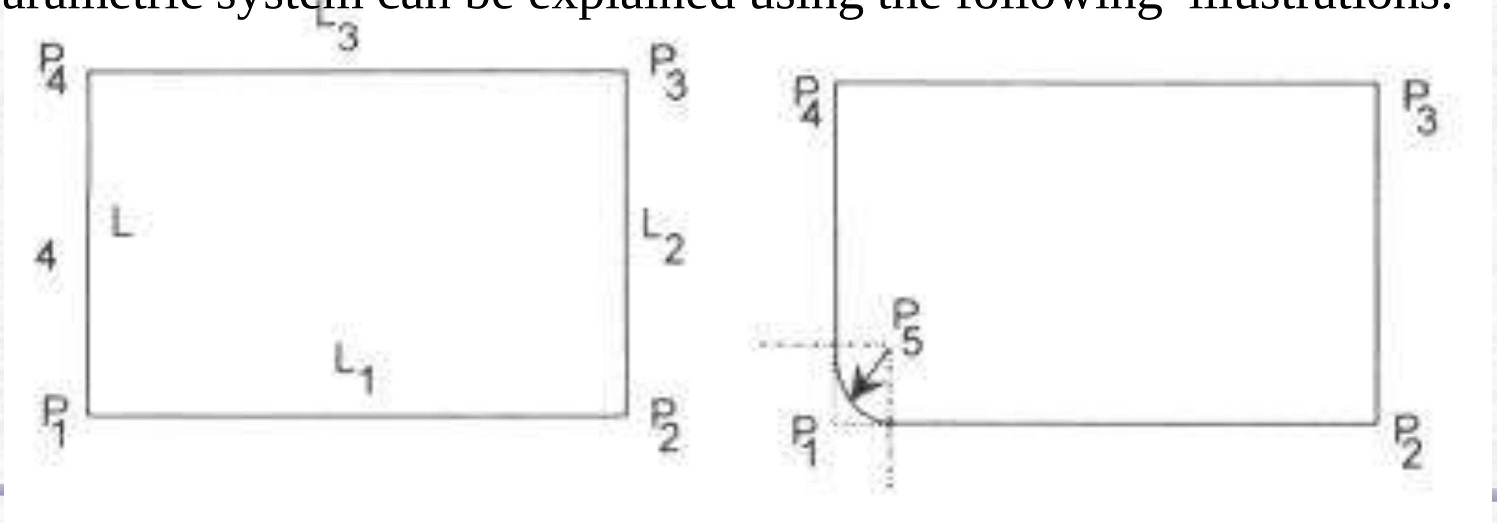


An example of solid modeling

2.5 PARAMETRIC AND VARIATIONAL DESIGNS

2.5.1 Parametric Design Systems

In a parametric design, the engineer selects a set of geometric constraints that can be applied for creating the geometry of the component. The geometric elements include lines, arcs, circles, and splines. A set of engineering equations can also be used to define the dimensions of the component. This simple concept of a parametric system can be explained using the following illustrations.



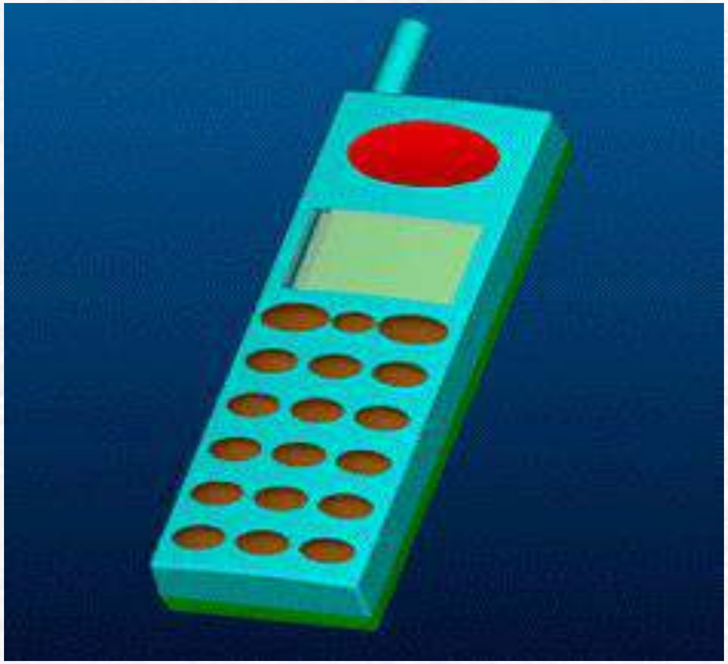
Parametric design of a block

Geometric Constraints

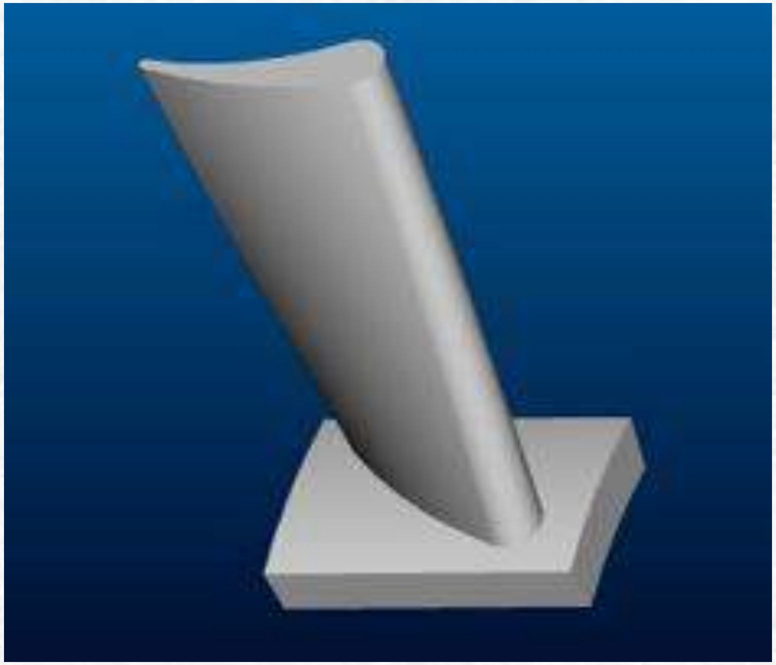
1. Solve P_1 (origin)
2. Solve L_1 (horizontal line from origin)
3. Solve P_2 (known distance on line from P_1)
4. Solve L_2 (vertical line at 90º from P_2)
5. Solve P_2 (known distance on line)
6. Solve L_3 (horizontal line at -90º from P_3)
7. Solve P_4 (known distance on line from P_3)
8. Solve L_4 (vertical line from P_4 at -90º)
9. Solve P_5 (point at distance from P_1 at 45º)
10. Solve arc (known radius, start, and endpoint)

The following are parametric models used in the design of different products

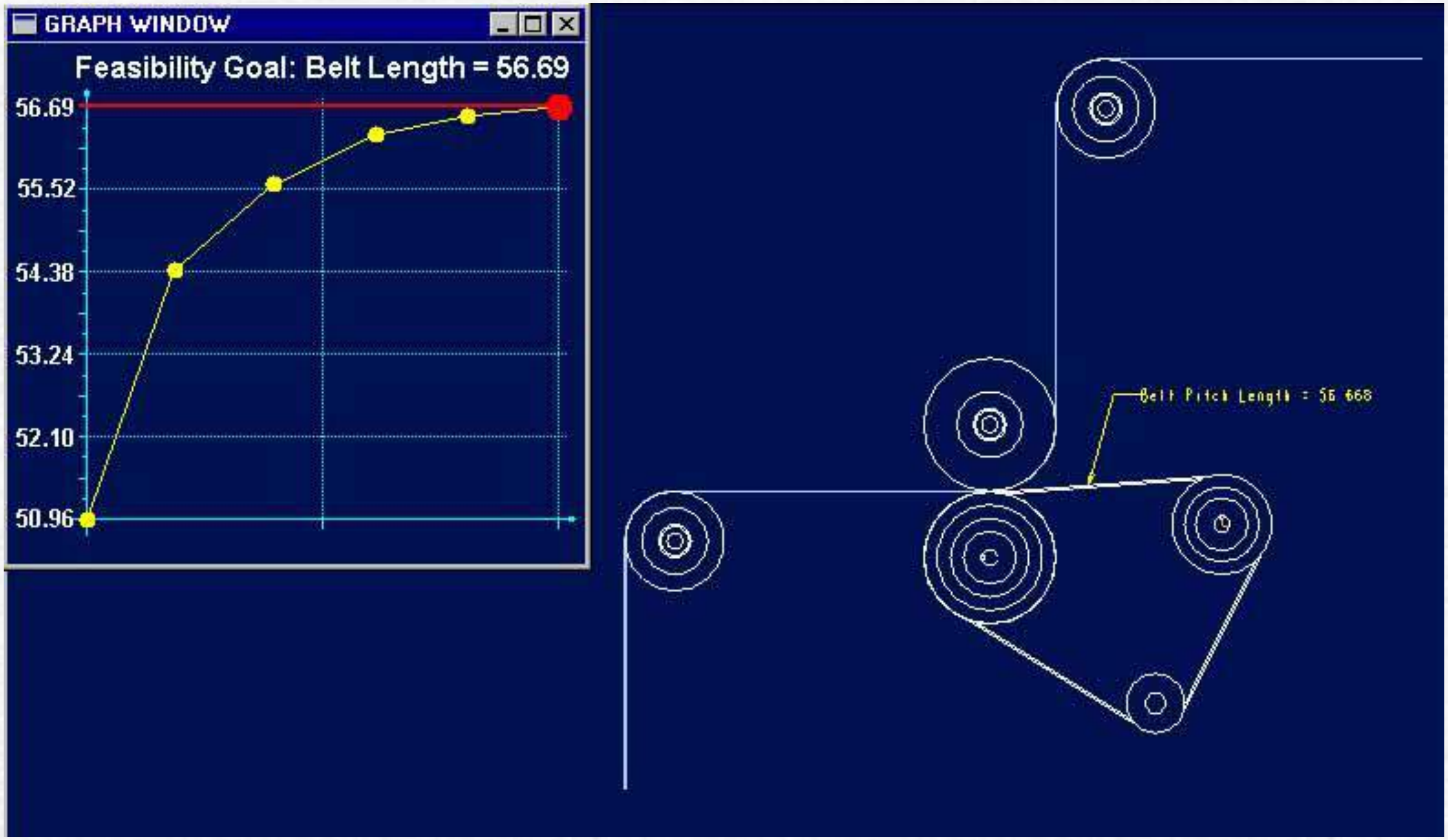
Keypad Design



Turbine Blade



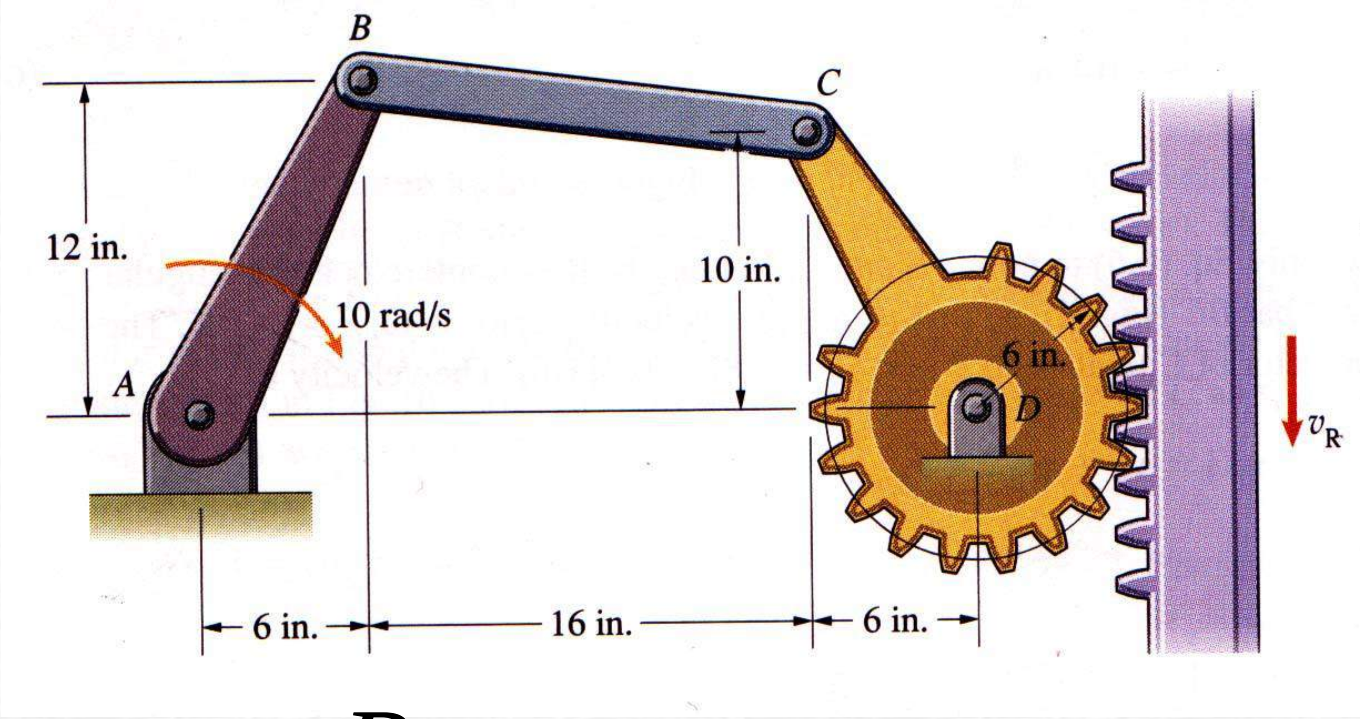
Belt Drive Design



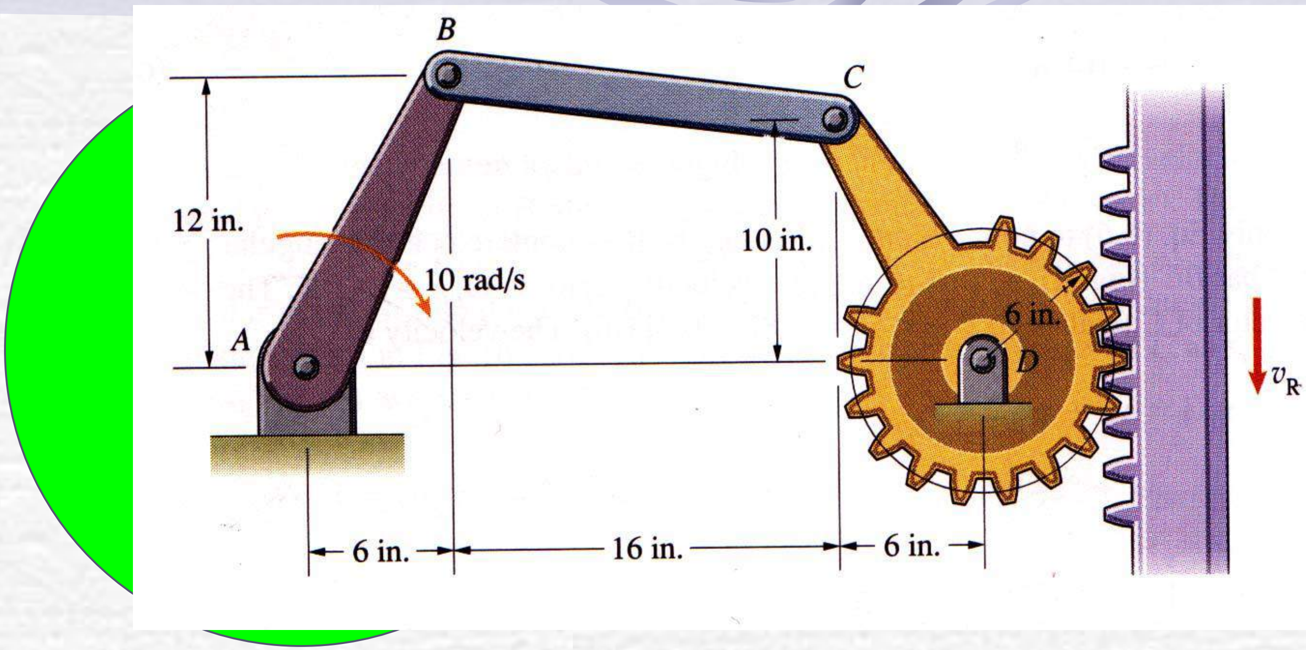
2.5.2 Variational Design Systems

Unlike the parametric approach, a variational system is able to determine the positions of geometric elements and constraints. In addition, it is structured to handle the coupling between parameters in the geometric constraints and the engineering equations. The variational design concept helps the engineer evaluate the design of a component in depth instead of considering only the geometric aspects to satisfy the design relationships.

Parametric design



$$R_{gear} \cdot \omega_{CD} = v_R$$



$$|AB|^2 = y_B{}^2 + x_B{}^2 \qquad |DC|^2 = y_{DC}{}^2 + x_{DC}{}^2 \qquad x_B + x_{BC} + x_{CD} = |AD|$$

$$|BC|^2 = y_{BC}{}^2 + x_{BC}{}^2 \qquad y_B + y_{BC} + y_{CD} = 0$$

The velocity of point B is: $v_B = v_A + \omega_{AB} \times r_{AB}$

The velocity of the point C is: $v_C = v_D + \omega_{CD} \times r_{DC}$

the velocity is expressed in terms of the velocity of B

$$v_C = v_B + \omega_{BC} \times r_{BC}$$

$$y_{DC}\omega_{CD} i - x_{DC}\omega_{CD} j = y_B\omega_{AB} i - x_B\omega_{AB} j - y_{BC}\omega_{BC} i + x_{BC}\omega_{BC} j$$

$$f(\omega_{CD}, \omega_{AB}, \omega_{BC}, y_{DC}, y_B, y_{BC}) = 0$$

$$g(\omega_{CD}, \omega_{AB}, \omega_{BC}, x_{DC}, x_B, x_{BC}) = 0$$

Given that

$$|AB|^2 = y_B{}^2 + x_B{}^2 \qquad y_B + y_{BC} + y_{CD} = 0$$

$$|BC|^2 = y_{BC}{}^2 + x_{BC}{}^2 \qquad x_B + x_{BC} + x_{CD} = |AD|$$

$$|DC|^2 = y_{DC}{}^2 + x_{DC}{}^2$$

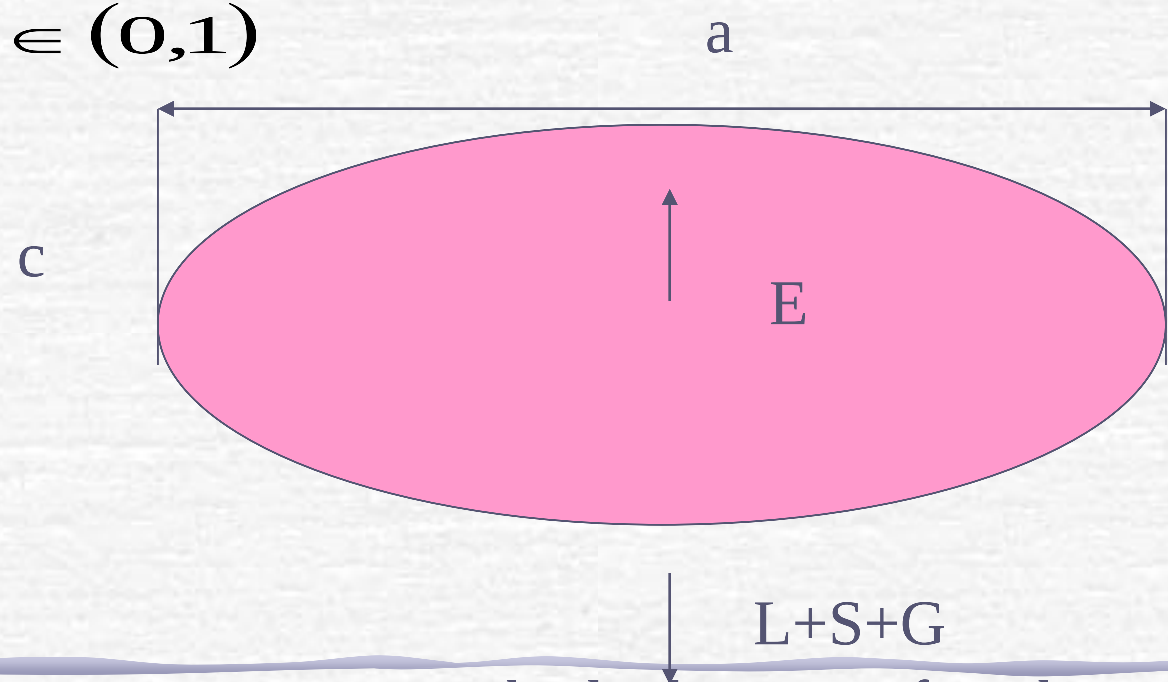
Airship Design

$$V = \frac{4}{3} \cdot \pi \cdot a^2 c$$

$$A = 2\pi a^2 + \frac{2\pi a c^2}{\sqrt{c^2 - a^2}} \sin^{-1}\left(\frac{\sqrt{c^2 - a^2}}{c}\right)$$

$$c = q \cdot a$$

$$q \in (0,1)$$



Free body diagram of airship.

From the equilibrium conditions we have

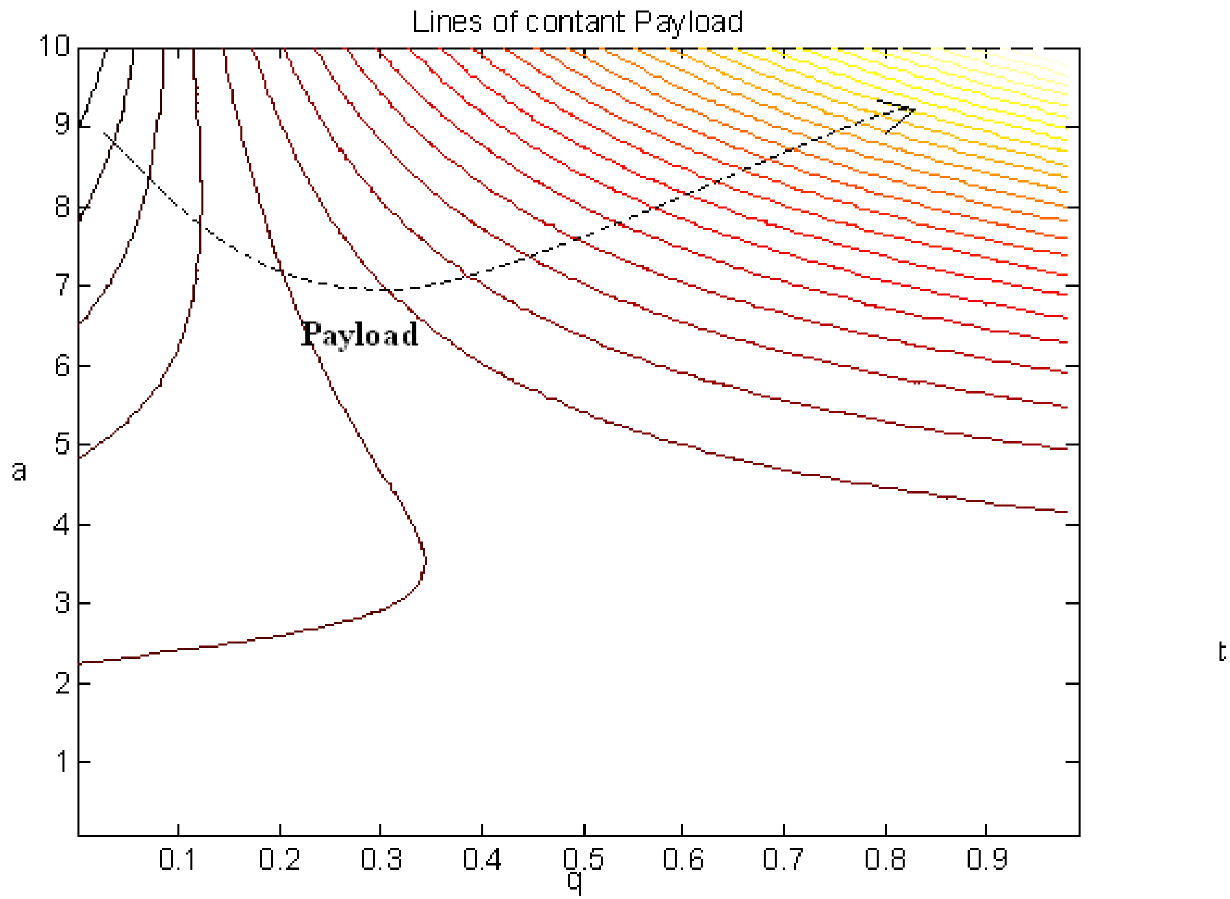
$$\sum F = 0$$
$$\downarrow$$
$$E = L + S + G$$

The density of the airship gas ρ_g the density of the atmosphere ρ_a the area density of the shell confining the dirigible gas σ. Therefore we define the corresponding forces:

$$E = V \cdot \rho_a g$$
$$S = \sigma \cdot A$$
$$G = V \cdot \rho_g g$$

$$V(a,q) \cdot \rho_g = L + A(a,q) \cdot \sigma + V(a,q) \cdot \rho_a$$

$$f(a,q,L) = 0$$



Load necessary for the airship.

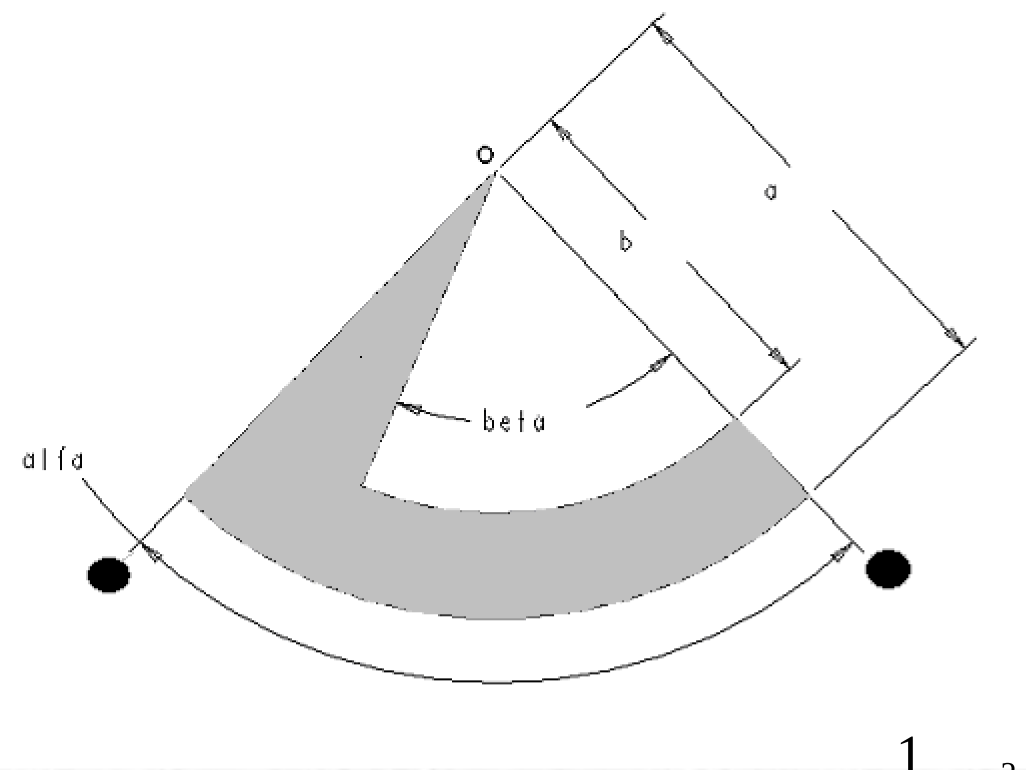
Pendulum

Pendulum Design:

$$I\ddot{\theta} + Mgl \cdot \sin(\theta) = 0$$

$$I\ddot{\theta} + Mgl\theta = 0$$

$$\omega^2 = \frac{Mgl}{I}$$



Movement of Pendulum

$$M = \frac{1}{2}\alpha a^2 e\rho - \frac{1}{2}\beta b^2 e\rho$$

$$I = \frac{a^4\alpha}{4}e\rho - \frac{b^4\beta}{4}e\rho$$

$$X=\frac{\frac{2}{3}a^3\cos\left(\frac{\alpha}{2}\right)\sin\left(\frac{\alpha}{2}\right)+\frac{2}{3}b^3\cos\left(\frac{\beta}{2}\right)\sin\left(\frac{\beta}{2}\right)}{\frac{1}{2}\alpha a^2+\frac{1}{2}\alpha b^2}$$

$$Y=\frac{\frac{2}{3}a^3\sin^2\left(\frac{\alpha}{2}\right)+\frac{2}{3}b^3\sin^2\left(\frac{\beta}{2}\right)}{\frac{1}{2}\alpha a^2+\frac{1}{2}\alpha b^2}$$

$$l=\sqrt{X^2+Y^2}$$

$$b<a$$

$$\beta<\alpha$$

$$\beta=p\cdot\alpha$$

$$b=q\cdot a$$

$$p\in(0,1)$$

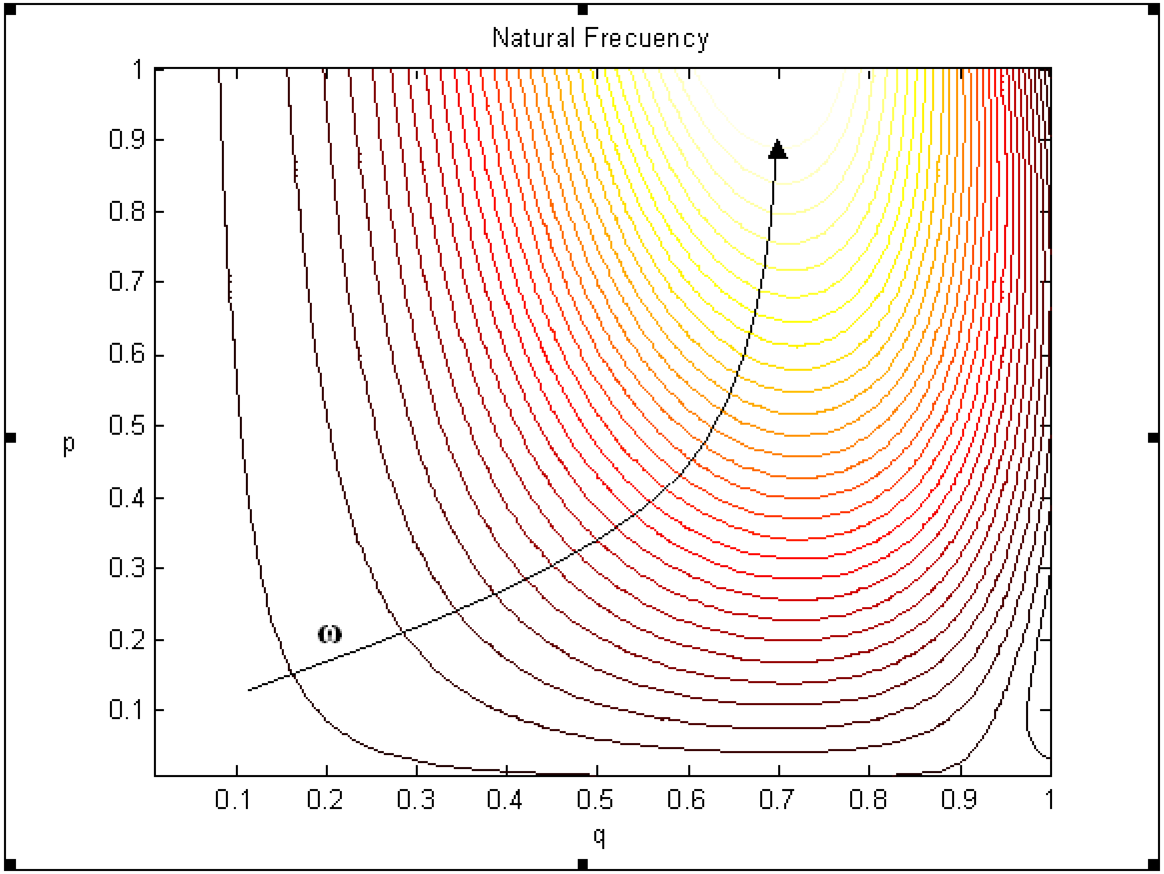
$$q\in(0,1)$$

$$\omega=\frac{Mgl}{I}=f(a,\alpha,p,q)$$

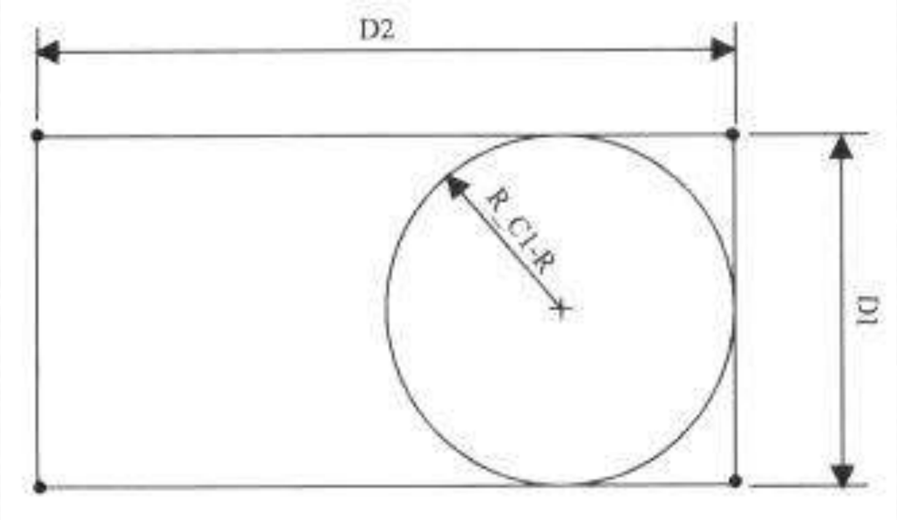
$$a=1$$

$$\alpha=1Rad=57.2958^0$$

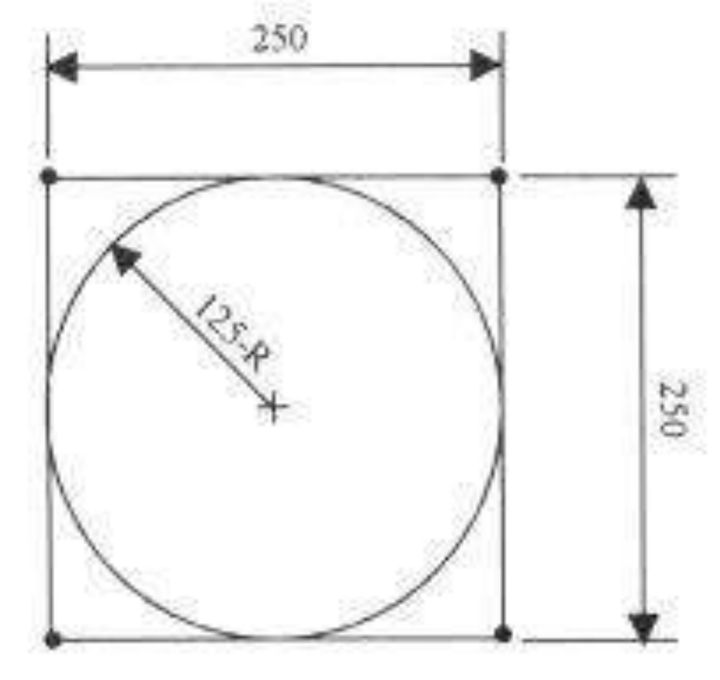
$$\omega=\frac{Mgl}{I}=f(p,q)$$



Plot of the Natural frequency equation

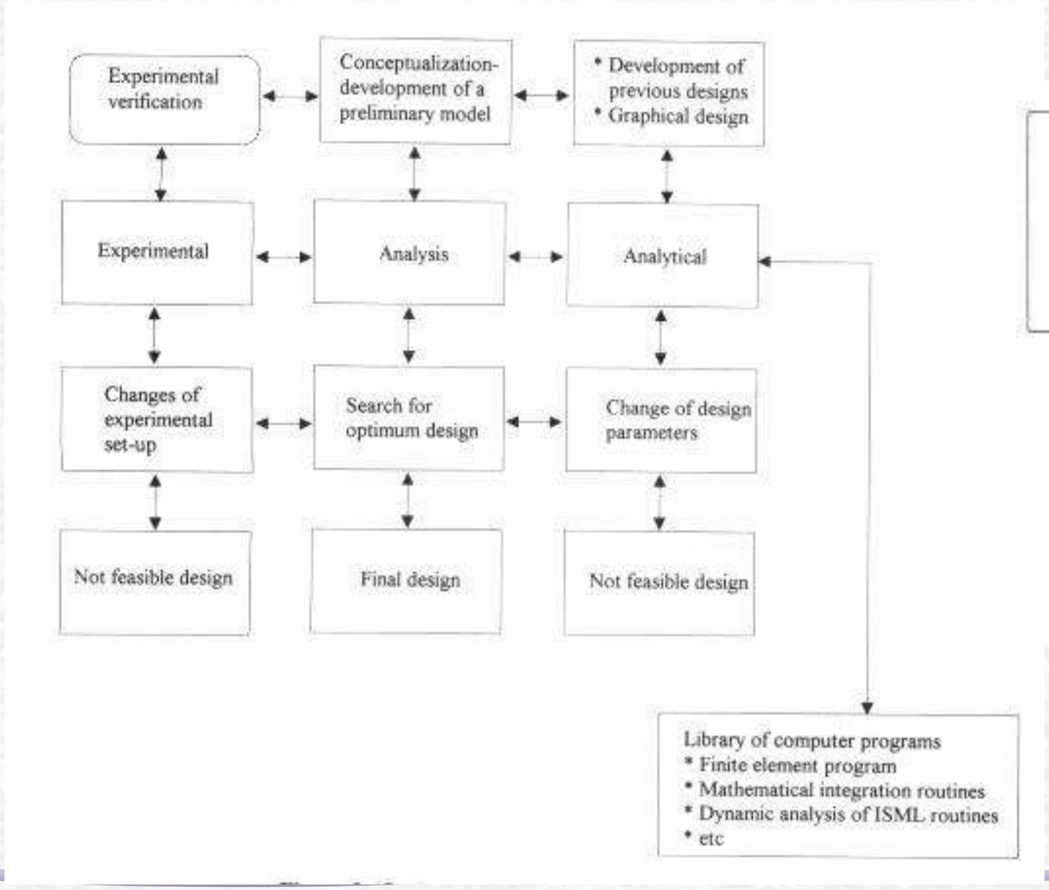


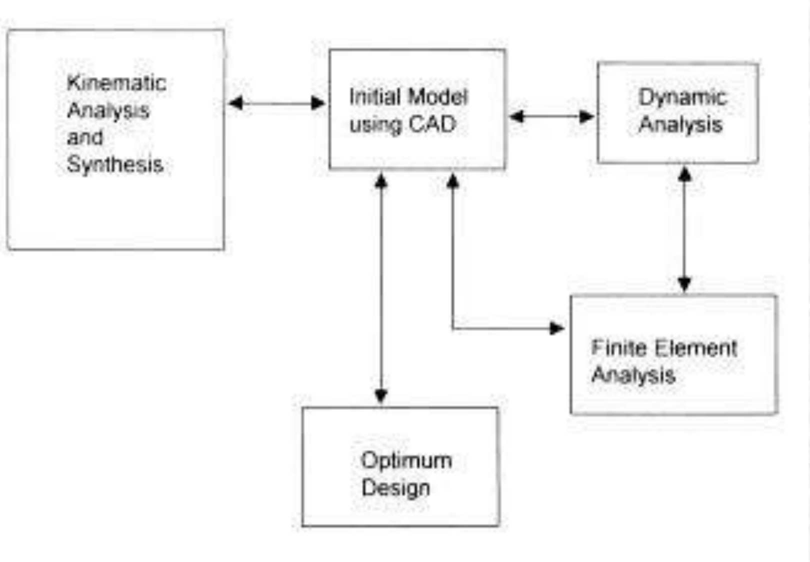
Design model to be optimized



Optimized design

2.6 ENGINEERING ANALYSIS AND CAD





Interfacing analysis functions with CAD

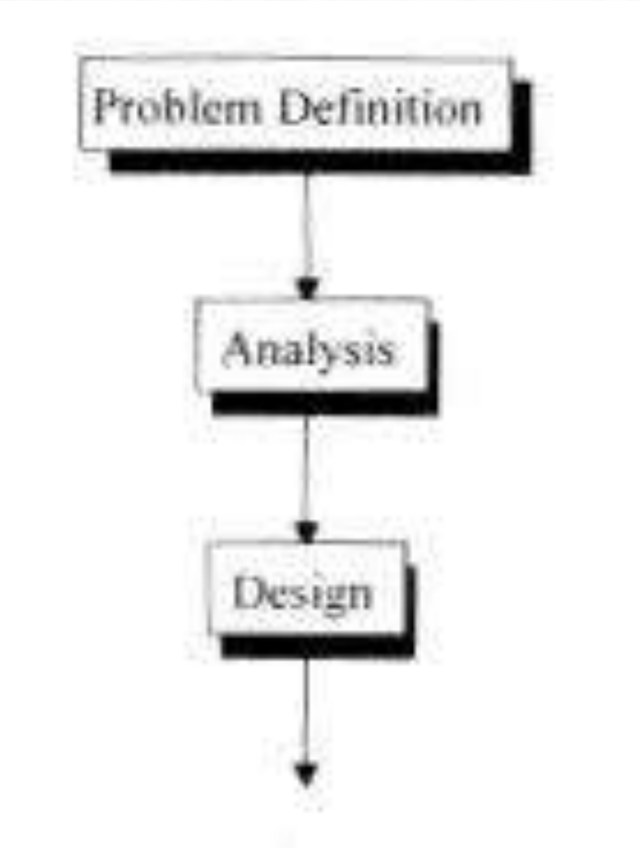
Process of engineering analysis in design

2.6.1 Analytical Methods

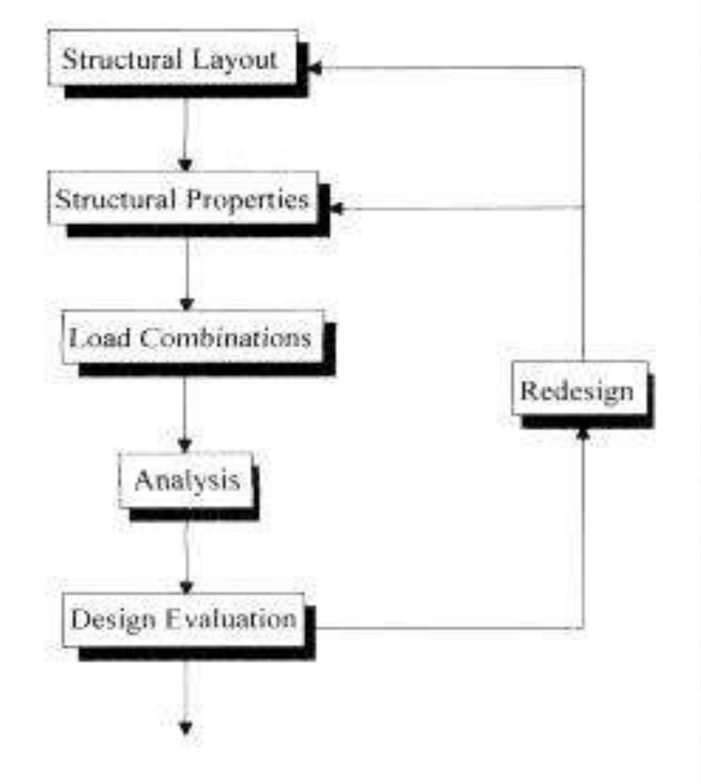
- *Finite-Element Analysis.*
- *Kinematics and Synthesis*
- *Static Analysis and Dynamic Analysis.*

2.6.2 Experimental Testing

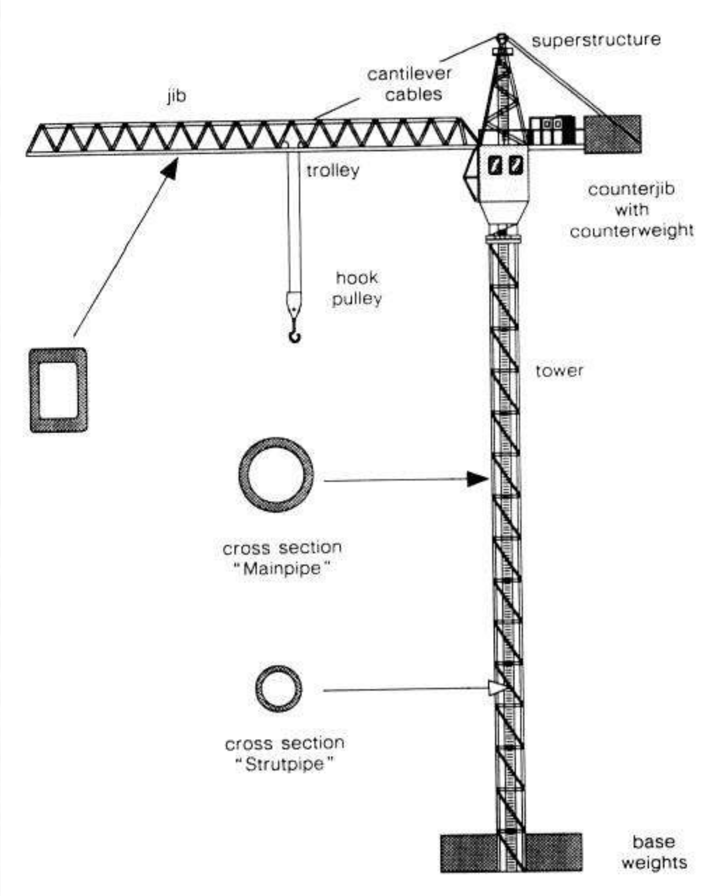
- EXAMPLE : USING CAD IN STEEL FRAME DESIGN



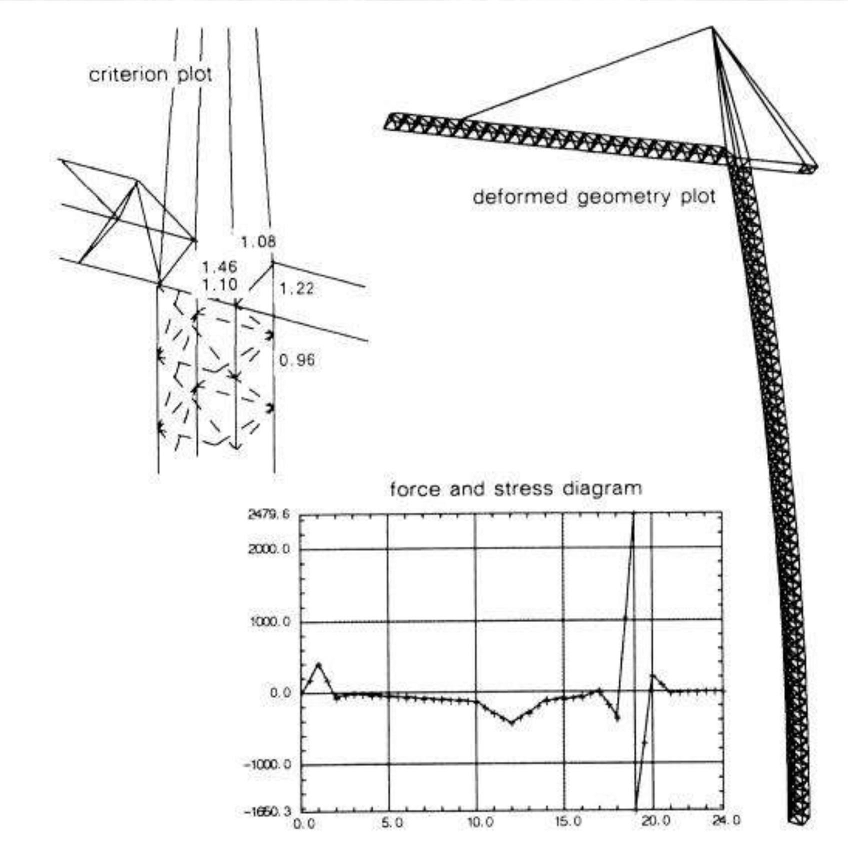
Steps followed in the design process



A CAD flowchart

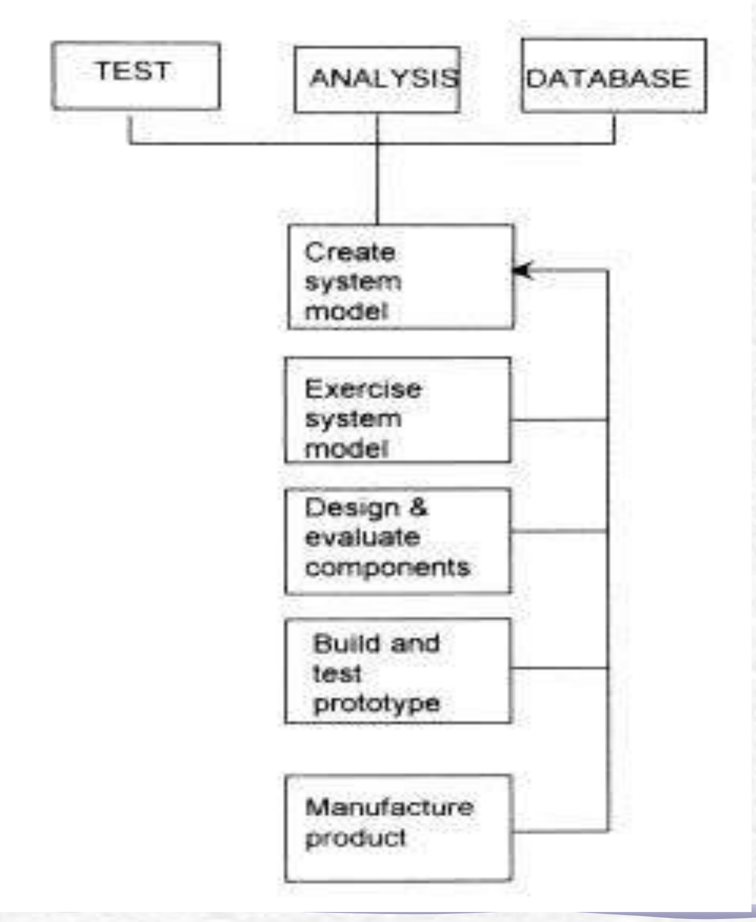


Terms used in crane construction (courtesy SDRC, Milford, Ohio)



Force and stress diagrams, deformation plot (courtesy SDRC, Milford, Ohio)

2.7 COMPUTER-AIDED ENGINEERING (CAE)

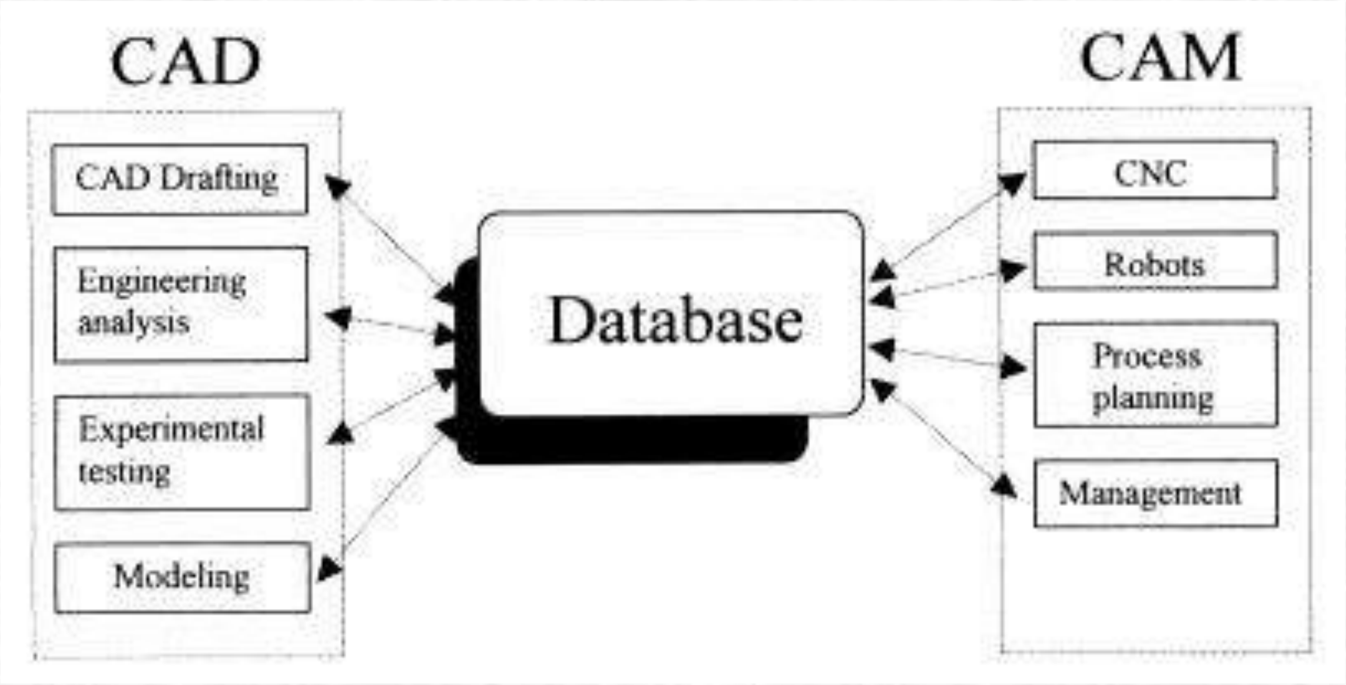


CAE structure as described in reference

The new CAE approach attempts to integrate and automate various engineering functions in the entire product development process:

1. Design
2. Analysis
3. Testing
4. Drafting
5. Documentation
6. Project Management
7. Data Management
8. Process Planning
9. Tool Design
10. Numerical control
11. Quality assurance

2.8 INTEGRATED DATABASE MANAGEMENT SYSTEMS IN CAE

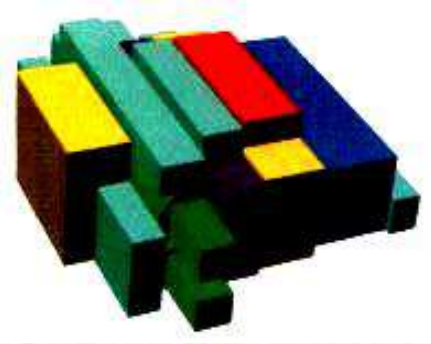


Database management system as described in reference

2.9 CAE PRODUCT DEVELOPMENT

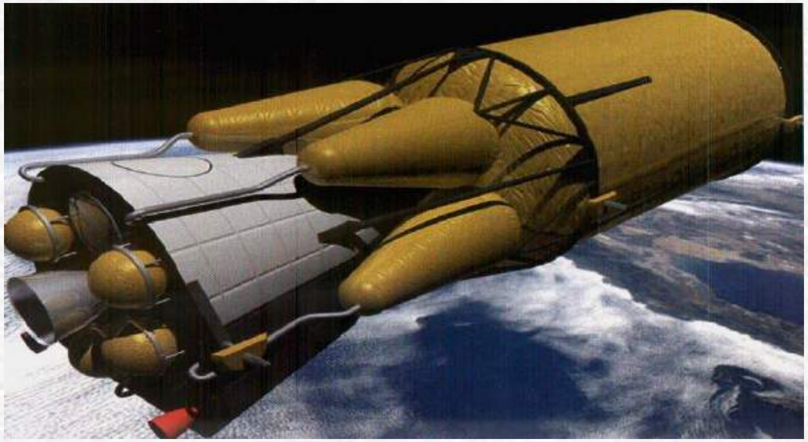
2.10 CAE IMPLEMENTATION

2.11 Simulation-Based Design and Beyond



Trunk design of the 1998 Dodge Intrepid

ISE allowed coordination of as many as 238 design & build teams working on the Boeing 777 simultaneously.



ISE facilitates simulation of entire space missions

With ISE, engineering teams will enjoy unprecedented freedom at every stage of a system's design.