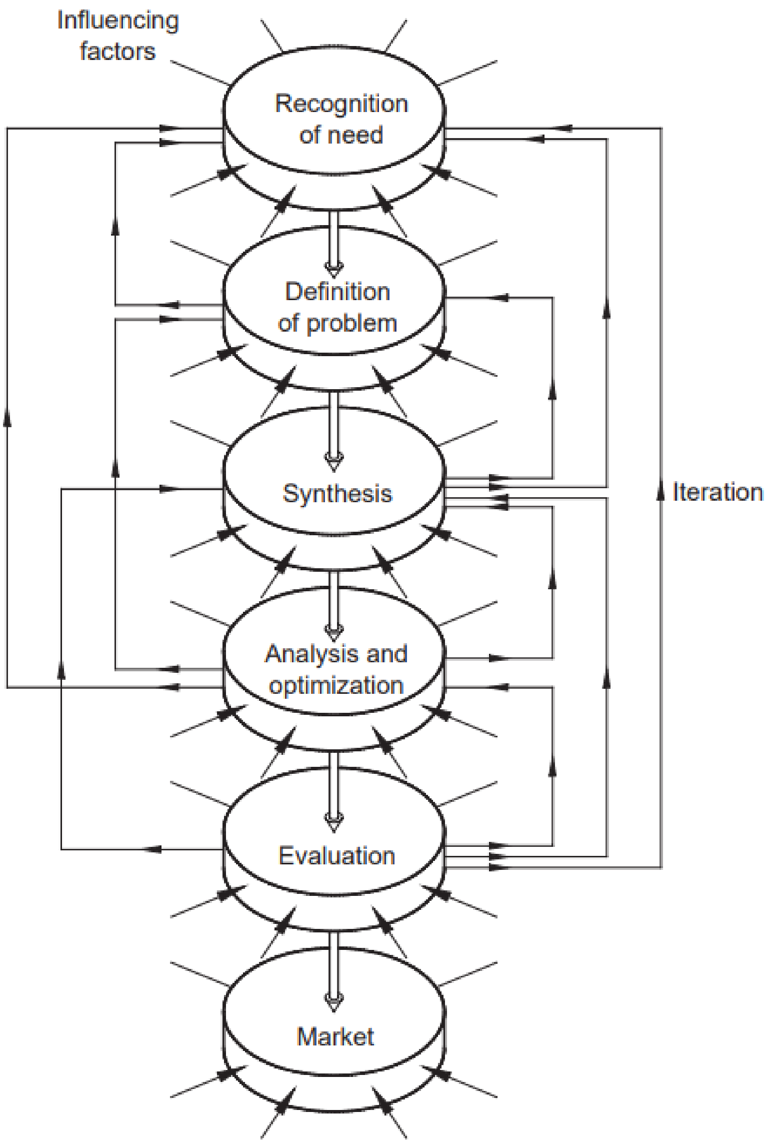
01 INTRODUCTION

The Design Process

The engineering design process is a common series of steps that engineers use in creating functional products and processes. Figure below shows a more formal description of the design process that might be associated with mechanical engineering.



Often design begins when an individual or company recognizes a need, or identifies a potential market, for a product, device or process. Definition of problem involves all the specifications of the product or process to be designed. Synthesis is the process of combining the ideas developed into a form or concept, which offers a potential solution to the design requirement.

Analysis involves the application of engineering science to examine the design to give quantitative information such as whether it is strong enough or will operate at an acceptable temperature.

Optimization is the process of repetitively refining a set of often-conflicting criteria

to achieve the best compromise.

Evaluation is the process of identifying whether the design satisfies the original requirements.

Reliability for Failure Prevention

Reliability is a matter of extreme importance in the engineering of a product, and this point is becoming increasingly recognized. On the other hand, it is important that components not be overdesigned to the point of making them unnecessarily costly, heavy, bulky, or wasteful of resources.

Reliability emphasizes the ability of equipment to function without failure. Reliability describes the ability of a system or component to function under stated conditions for a specified period of time.

Failure

Failure of a loaded member can be regarded as any behaviour that renders it unsuitable for its intended function. Failure of mechanical members can be by elastic deflection, general yielding or by fracture. The scope of this project is restricted to the design of components on the strength basis and specifically mechanical members subjected to static loading undergoing static failure.

Factor of Safety

While designing a component, it is necessary to provide sufficient reserve strength in case of an accident. This is achieved by taking a suitable factor of safety (FOS). FOS is defined as

$$\text{FOS} = \frac{\text{Failure Stress}}{\text{Allowable Stress}}$$

Failure Stress is the value of stress at which the member would fail and the allowable stress is the stress value, which is used in design to determine the dimensions of the component. It is considered as a stress, which the designer expects will not be exceeded under normal operating conditions.

Theories of Static Failure

Multiaxial stress state can be biaxial or triaxial. In practice, it is difficult to devise experiments to cover every possible combination of critical stresses because tests are expensive and a large number is required to obtain results with good confidence. Therefore, a theory is needed that compares the normal and shear stresses σ_x, σ_y, σ_z, τ_{xy}, τ_{yz}, and τ_{xz} with the uniaxial stress, for which experimental data are relatively easy to obtain. Therefore the "theory" behind the various classical failure theories is that whatever is responsible for failure in the standard tensile test will also be responsible for failure under all other conditions of static loading.

Unfortunately, there is no universal theory of failure for the general case of material properties and stress state. Instead, over the years several hypotheses have been formulated and tested, leading to today's accepted practices. Being accepted, we will characterize these "practices" as theories as most designers do.

Structural metal behaviour is typically classified as being ductile or brittle, although under special situations, a material normally considered ductile can fail in a brittle manner. Ductile materials are normally classified such that $\varepsilon_f \geq 0.05$ and have an identifiable yield strength that is often the same in compression as in tension ($S_{yt} = S_{yc} = S_y$). Brittle materials, $\varepsilon_f < 0.05$, do not exhibit an identifiable yield strength, and are typically classified by ultimate tensile and compressive strengths, S_{ut} and S_{uc}, respectively (where S_{uc} is given as a positive quantity).

The generally accepted

Theories for ductile and brittle materials are as follows:

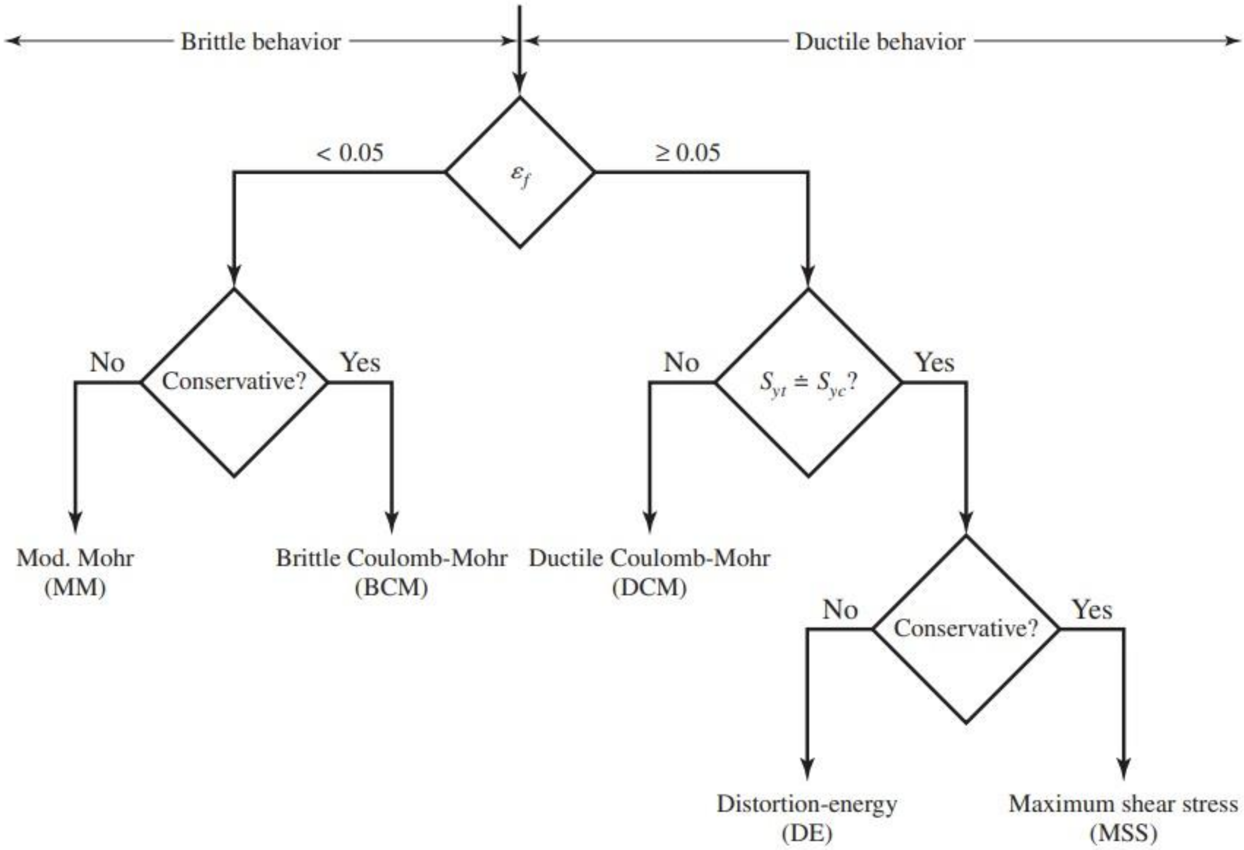
<u>Ductile materials (yield criteria)</u>

- Maximum shear stress (MSS)
- Distortion energy (DE)
- Ductile Coulomb-Mohr (DCM)

<u>Brittle materials (fracture criteria)</u>

- Maximum normal stress (MNS)
- Brittle Coulomb-Mohr (BCM)
- Modified Mohr (MM)

Rationale for Selection of Failure Theory



Recommended Values for a Safety Factor

1. FOS = 1.25 to 1.5 for exceptionally reliable materials used under controllable conditions and subjected to loads and stresses that can be determined with certainty—used almost invariably where low weight is a particularly important consideration.
2. FOS = 1.5 to 2 for well-known materials, under reasonably constant environmental conditions, subjected to loads and stresses that can be determined readily.
3. FOS = 2 to 2.5 for average materials operated in ordinary environments and subjected to loads and stresses that can be determined.
4. FOS = 2.5 to 3 for less tried materials or for brittle materials under average conditions of environment, load, and stress.
5. FOS = 3 to 4 for untried materials used under average conditions of environment, load, and stress.
6. FOS = 3 to 4 should also be used with better known materials that are to be used in uncertain environments or subjected to uncertain stresses.

7. Repeated loads: The factors established in items 1 to 6 are acceptable but must be applied to the endurance limit rather than to the yield strength of the material.
8. Impact forces: The factors given in items 3 to 6 are acceptable, but an impact factor should be included.
9. Brittle materials: Where the ultimate strength is used as the theoretical maximum, the factors presented in items 1 to 6 should be approximately doubled.
10. Where higher factors might appear desirable, a more thorough analysis of the problem should be undertaken before deciding on their use.