FACTOR OF SAFETY

Design is related to real field problem connected with different types of ~~uncertaintiel~~ uncertainties.

1. Degree of load uncertainty.
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3. Degree of uncertainty in stress calculation method.
4. Degree of uncertainty in the theory of failure.
5. Reliability requirement.
6. Manufactoring tolerance in geometry

Reliability requiremed is influenced by factors given below.

a) catastropic consquence of failure in term of life loss, damage or closer of production system,

b) cost of machine as well as it maintainance cost

c) Life of machine

The uncertainties are of various types. various types of uncertainties may be classified under five groups.

1. Uncertainty in material properties
2. Uncertainty in ~~str~~ calcuted stress
3. Uncertainty in the failure analysis
4. Uncertainty in manufacturing tolerance
5. Reliability requirement.

Because of various uncertainties in ~~rel~~ real-life problems. It is necessary to consider a margin of safety. There is variation in the definition of ~~the~~ margin of safety. Margin of safety may be defined as below.

$$\text{Margin of safety} = \text{Failure condition} - \text{Allowable condition}$$

$$= \text{Failure condition}\left(1 - \frac{\text{Allowable condition}}{\text{Failure condition}}\right)$$

$$= \text{Failure condition}\left(1 - \frac{1}{\dfrac{\text{Failure condition}}{\text{Allowable condition}}}\right)$$

$\dfrac{\text{Failure condition}}{\text{Allowable condition}}$ is a dimensionless quantity and is called factor of safety. Margin of safely is a dimensional quantity whereas factor of safety is dimensionless ~~quand~~ quantity. Margin of safety may also be defined Dimensionless form of margin of safety

$$\text{Margin of safety} = \text{Failure condition} - \text{Allowable condition}$$

$$\frac{\text{Margin of safety}}{\text{Allowable condition}} = \frac{\text{Failure condition}}{\text{Allowable condition}} - 1$$

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Concept of factor of safety - Page - 1

Margin of safety (Dimensionless) = Factor of safety − 1

If the condition be stress, failure condition and allowable condition are failure stress and allowable stress respectively.

Margin of safety = Failure stress − Allowable stress

$$\text{Factor of safety} = \frac{\text{Failure stress}}{\text{Allowable stress}}$$

If factor of safety be more than 1,

Failure stress > Allowable stress

Margin of stress = +ve and situation is safe from failure.

If factor of safety be 1,

Failure stress = Allowable stress

Margin of stress = 0 and situation is on the verge of failure.

If factor of safety be a fraction less than 1 and positive,

Failure stress < Allowable stress

Margin of stress = −ve and situation is a failure.

Now considering the various types of uncertainties as grouped earlier, factor of safety for stress can be more elaborated as below.

$$\text{Factor of safety (F.S.)} = F.S._{\text{material}} \times F.S._{\text{stress}} \times F.S._{\text{Failure analysis}} \times F.S._{\text{Manufacturing tolerance on geometry}} \times F.S._{\text{Reliability}}$$

If the following values be assumed

$F.S._{\text{material}} = 1{\cdot}2$; $F.S._{\text{stress}} = 1{\cdot}25$; $F.S._{\text{failure analysis}} = 1{\cdot}2$; $F.S._{\text{manufacturing tolerance on geometry}} = 1{\cdot}15$; $F.S._{\text{Reliability}} = 1{\cdot}4$

$$F.S. = 1{\cdot}2 \times 1{\cdot}25 \times 1{\cdot}2 \times 1{\cdot}15 \times 1{\cdot}4 = 2{\cdot}898$$

we take, F.S. = 3

Factor of safety is assumed to determine the value for allowable stress from failure stress. Allowable stress helps the designer to calculate dimensions of any component.

The failure stress of a material is a material property. The larger the value of the factor of safety, the smaller the value of the allowable stress. In machine design practice, a dimension of a component is calculated with a stress value that is equal to or less than allowable stress. If the value of the stress is very low, the calculed value of the dimension of component is very large and may acceptable as a practical solution. So ~~allowable stress~~ factor of safety is specified with a range of values. From this concept of factor of safety, ~~the~~ a maximum value of allowable stress and a minimum value of allowable stress are obtained. Any value of stress within ~~the~~ two extreme values are take as working value of stress for computation of dimension.

After the completion of the design, each dimension of a component is checked. Stresses in the component are evaluated to calculate the value of factor of safety. If the computed value of factor of safety lies within the range of values for factor of safety, which is specified for design, the design is assumed to safe from condition of stress.

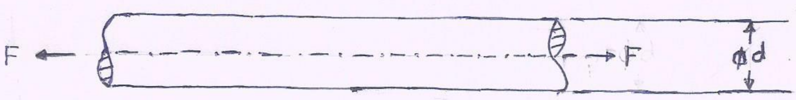
Example:

compute the diameter of a rod that will carry a tensile load of 25KN.

Solution:

Material selection = Fe E 200

Material type: Ductile, isotropic and Homogeneous



$F = 25KN = 25000N$ Failure stress $= \sigma_{yield} = 200 MPa$

Assume factor of safety $\equiv 3 - 4$

Allowable stress $\equiv 66.\dot{6} - 50$ MPa

we take, Allowable stress $= 65 MPa = [\sigma_t]$

cross-sectional area $= \frac{\pi}{4} d^2$

Equilibrium equation:

$$\frac{\pi}{4} d^2 [\sigma_t] = F \; ; \quad d = \sqrt{\frac{4F}{\pi [\sigma_t]}} = \sqrt{\frac{4 \times 25000}{\pi \times 65}} = 22.12933612 \text{ mm}$$

we take, $d = 24$ mm (Rounded)

Check: $$[\sigma_t] = \frac{4F}{\pi d^2} = \frac{4 \times 25000}{\pi \times 24^2} = 55.25213302 \text{ MPa}$$

$$F.S = \frac{200}{55.25213302} = 3.619114737$$

Computed ~~d~~ value for diameter d is acceptable.

~~So~~ Design Dimension for $d = 24$ mm (Recommended)

N.B. :

1. Factor of safety is specified as a range of values.

$$a \leq F.S. \leq b$$

where a and b are lower limit and upper limit respectively of factor of safety. The range of values for factor of safety yields a range of values for allowable stress.

$$A \geqslant \text{Allowable stress} \geqslant B$$

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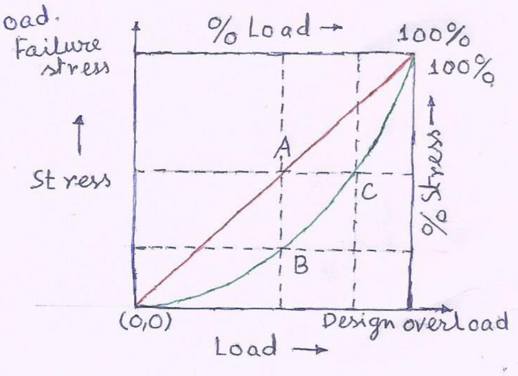
If only one value of factor of safety be speified or available, it implies the lower limit a for the range of values of factor of safety. The upper limit b for the range is as ∞ (infinity) and corresponding value of lower limit B for allowable stress is zero.

2. Factor of safety in terms of load:

$$\text{Factor of safety} = \frac{\text{Design overload}}{\text{Normal load}}$$

Normal load – Every component is designed under a system of ~~to~~ specified loads which the component is supposed to withstand without failure for a speified period of time called life of the component. This load is called normal load.

Design overload – The load at which the designed component will fail is called design overload.



Comparision of factor of safty based stress and factor of safety based on load is shown in figure. variation with load may be linear or non-linear.

Linear variation

Non-linear variation

3. More elaborate definition of factor of safety (F.S.):

$$F.S. = \frac{\text{Significant strength of the material}}{\text{corresponding significant stress due to normal load}}$$

Here word "Significant" refers to the theory of failure under consideration.

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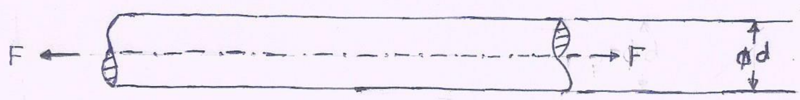

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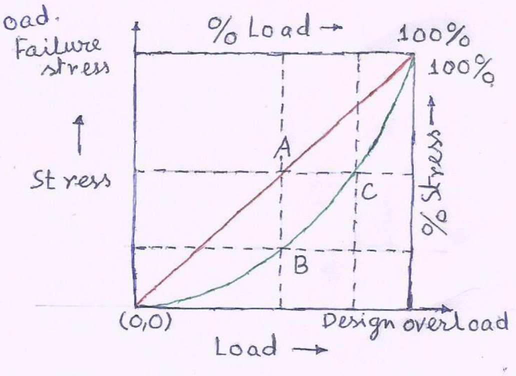

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