Shri Vaishnav Vidyapeeth Vishwavidyalaya, Indore

Think Excellence. Live Excellence.

Department of Mechanical and Automobile Engineering

ME-B & AU- 2 Year IV SEM

Term Exam - I, February -2018

Max.Marks:20 **Time Duration: 1:00 hrs**

Subject Name: **Machine Design I**	Subject code: **BTME 404**	Write name of CO mapping with your paper: CO1, CO2, CO3, CO4, and CO5.Analyze and select machine elements/components. Know the applications of the various elements, materials used to make them, and methods used.

Q.1.a: What is stress concentration? What are the causes of stress concentration?

Ans: Stress concentration and its causes:

A stress concentration in a solid is a place where there is a lot of stress, either because a force is applied in a particular area or there is a change in the cross-sectional area.

Notches, holes and variation in cross section throughout a part lead to stress concentrations where fatigue cracks start. The material is susceptible to fracture at points of stress concentration.

Methods of reducing stress concentration:

1. Provide a fillet radius so that the cross-section may change gradually.

2. Sometimes an elliptical fillet is also used.

3. If a notch is unavoidable it is better to provide a number of small notches rather than a long one. This reduces the stress concentration to a large extent.

4. If a projection is unavoidable from design considerations it is preferable to provide a narrow notch than a wide notch.

5. Stress relieving groove are sometimes provided.

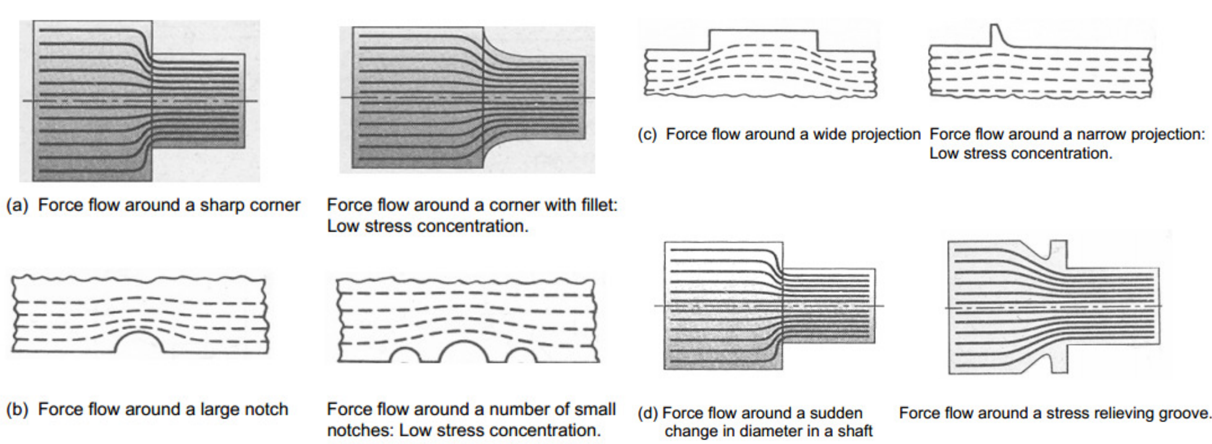

***Fig.1.1*:** Various methods to reduce stress concentration

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Q.1.b: What are the various design considerations?

Ans: Considerations in machine designing mean the important points to keep in mind while designing the components. There is no limit of considerations in designing of a machine and its components. In engineering, a machine design engineer has to keep various points for the successful design of his machine. So, here are the 10 important considerations of design:

1. Type of Load and Stresses caused by the Load:

The load on the Machine Component may act in several ways due to which the Internal Stresses are set up.

2. Motion of Parts:

The successful operation of any Machine depends largely upon the simplest arrangements of the Parts, which will give the required motion. Hence the Motion of the Part may be,

A) Rectilinear Motion, which includes Unidirectional and Reciprocating Motion

B) Curvilinear Motion, which includes Rotary, Oscillatory Simple Harmonic

C) Constant Velocity

D) Constant or Variable Acceleration

3. Selection of Material:

Every Machine Design Engineer should have a thorough knowledge of the Properties of Material and their behavior under working conditions.

4. Form and Size of the Parts:

In order to Design any Machine Part for form and size, it is necessary to know the Forces which the Part must sustain. So, any suddenly applied or impact load must be taken into consideration, which may cause failure. The smallest Practicable Cross-Section may be used, but it may be checked that the Stresses induced in the Designed Cross-Section are reasonably safe

5. Frictional Resistance and Lubrication:

There is always a Loss of Power due to Frictional Resistance. Hence, Careful attention must be given to the matter of Lubrication of all surfaces which moves in contact with others.

6. Safety of Operator:

A Machine Designer should always provide a safety device for the safety of the operator. Also, The Safety Appliances should in no way interfere with the operation of the Machine.

7. Use of Standard Parts:

The uses of Standard Parts are closely related to the Cost of Machine. Because the Cost of Standard Parts is only a fraction of the cost of similar parts made to order.

8. Convenient and Economical Features:

The operating feature of the machine should be carefully studied. The Starting, Controlling and Stopping Levers should be located on the basis of convenient handling.

9. Workshop Facilities:

A Design Engineer should be familiar with the limitation of his Employer's Workshop. So, we can avoid the necessity of having work done in some other Workshop.

10. Assembling:

Every Machine must be assembled as a unit before it can function. The final Location of any Machine is important. Hence, The Design Engineer must anticipate the exact location and the local facilities for erection.

Q.1.c: Explain S-N Curve in detail.

Ans: A SN-Curve (sometimes written S-N Curve) is a plot of the magnitude of an alternating stress versus the number of cycles to failure for a given material. Typically both the stress and number of cycles are displayed on logarithmic scales.

SN-Curves were developed by the German scientist August Wöhler (Picture 1) during the resulting investigation of an 1842 train crash in Versailles, France. In this crash, the axle of the train locomotive failed under the repeated "low level" cyclic stress of everyday usage on the railroad.

For this first we have to understand Fatigue Failure:

Fatigue is the progressive, localized, permanent structural change that occurs in materials subjected to fluctuating stresses and strains that may result in cracks or fracture after a sufficient number of fluctuations. Fatigue fractures are caused by the simultaneous action of cyclic stress, tensile stress and plastic strain. If any one of these three is not present, fatigue cracking will not initiate and propagate. The cyclic stress starts the crack; the tensile stress produces crack growth.

A SN-Curve can contain several different areas: a plastic region, an elastic region and an infinite life region.

The graph mentioned below is an example of S-N curve. The lines are downward-sloping. We can see from this graph that the more the number of cycles becomes; the smaller stress even causes fatigue fracture. However, we can find one line that it won't fracture by getting a load on unlimitedly as long as the load is one constant repetitive stress. It is called Fatigue Limit.

The Fatigue or endurance limit of a material is defined as the maximum amplitude of completely reversed stress that the standard specimen can sustain for an unlimited number of cycles without fatigue failure. Since the fatigue test cannot be conducted for unlimited or infinite number of cycles, 10^6 cycles is considered as sufficient number of cycles to define the endurance limit.

Department of Mechanical and Automobile Engineering

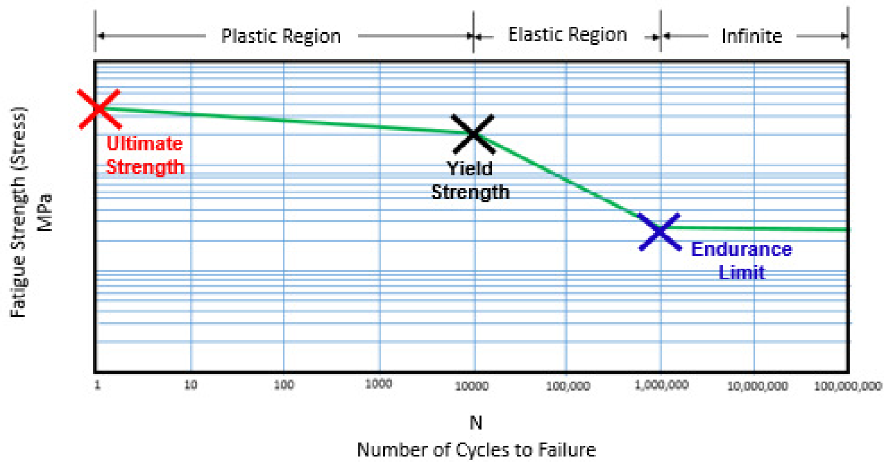

Fig.1.2: SN curve

OR

Explain the following mechanical properties:

i. Elasticity, ii. Hardness, iii. Malleability

iv. Creep v. Fatigue vi. Resilience.

Ans:

i. *Elasticity:* This is the ability of a material to deform under load and return to its original size and shape when the load is removed. Such a material would be required to make the spring as shown.

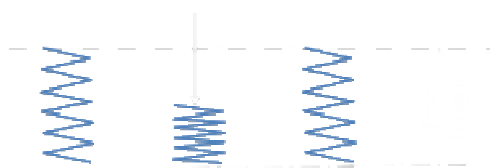

Fig.1.3: Spring elasticity

ii. ***Hardness:*** This is the ability of a material to withstand scratching (abrasion) or indentation by another hadrd body. It is an indication of the wear resistance of a material.

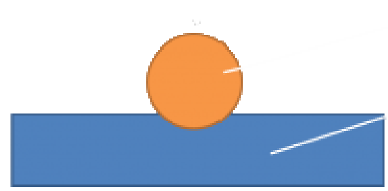

Fig.1.4: Hardness

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iii. ***Malleability:*** This is a term used when plastic deformation occurs as the result of applying a compressive load. A malleable material combines the properties of plasticity and compressibility, so that it can be squeezed to shape by such processes as forging, rolling and rivet heading.

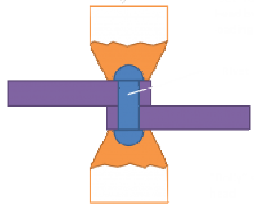

Fig.1.5: Malleability

iv. ***Creep:*** It is a time- dependent deformation under a certain applied load. Generally occurs at high temperature (thermal creep), but can also happen at room temperature in certain materials (e.g. lead or glass), albeit much slower. As a result, the material undergoes a time dependent increase in length, which could be dangerous while in service. The rate of deformation is called the creep rate. It is the slope of the line in a Creep Strain vs. Time curve.

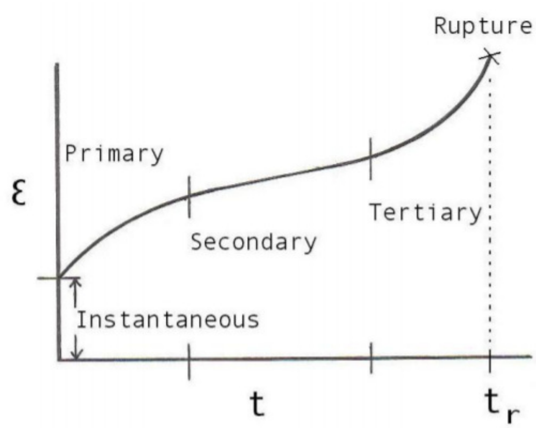

Fig.1.6: Creep

V. ***Fatigue***: Fatigue is the progressive, localized, permanent structural change that occurs in materials subjected to fluctuating stresses and strains that may result in cracks or fracture after a sufficient number of fluctuations. Fatigue fractures are caused by the simultaneous action of cyclic stress, tensile stress and plastic strain. If any one of these three is not present, fatigue cracking will not initiate and propagate. The cyclic stress starts the crack; the tensile stress produces crack growth.

vi. ***Resilience:*** In physics and engineering, resilience is defined as the capacity of a material to absorb energy when it is deformed elastically and then, upon unloading to have this energy recovered. In other words, it is the maximum energy per volume that can be elastically stored.

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Q.2.a: What is the mean by BIS explain any one with example.

Ans: Engineering materials has various compositions, types, Applications, properties. Every material have its own different mechanical properties, Bureau of Indian Standards (BIS) have standardized the designation method for steel and other material. These standards are mainly followed by Indian industries, other countries may be using ASME standard.

Designation of Steels

Steels are designated by a group of letters or numbers indicating any one of the following three properties.

1. Tensile strength;

2. Carbon content; and

3. Composition of alloying elements.

Steel, which are standardized on the basis of their tensile strength without detailed chemical composition, are specified by two ways- a symbol Fe followed by the minimum tensile strength in N/mm^2. Another method is FeE steel followed by the yield strength in N/mm^2. Example:

Fe350 – This indicates steel with tensile strength of 250 N/mm^2

FeE 250- yeild strength of 250 N/mm^2

Designation of Plain Carbon Steels: This consists following three quantities:

1. figure and indicating 100 times the average percentage of carbon.

2. a letter C

3. a figure indicating 10 times the average percentage of manganese.

Example: **55C4 indicates a plain carbon steel with 0.55% carbon and 0.4 % manganese.**

Designation of unalloyed free cutting steels.

This consists following quantities.

1. a figure indicating 100 times the average percentage of carbon.

2. a letter C

3. a figure indicating 10 times the average percentage of manganese.

4. a symbol S, Se, Te or Pb depending upon the element that is present and which makes the steel free cutting.

5. a figure indicating 100 times the average percentage of the above elements that makes the steel free cutting.

Example: **25C12S14 indicates free cutting steel with 0.25 % carbon ,1.2 % manganese and 0.14 % sulphur.**

Designation of high alloy steel

The designation of high alloy steels consist of following quantities

1. a letter 'X'

2. a figure indicating hundred times the average percentage of carbon

3. chemical symbol for allowing elements each followed by the figure for its average percentage content rounded off to the nearest integer.

4. chemical symbol to indicate especially at that added element to attain desired properties ,if any.

Example: **X15Cr25Ni12 is a high alloy steel with your own 15 % carbon, 25 % chromium and 12 % nickel**

Q.2.b: Write Short note on:

i. Soderberg Line ii. Goodman Line and iii. Gerber Line

Ans: A purely reversing or cyclic stress means when the stress alternates between equal positive and negative peak stresses sinusoidal during each cycle of operation. This kind of cyclic stress is developed in many rotating machine parts that are carrying a constant bending load. When a part is subjected cyclic stress, also known as range or reversing stress (Amplitude) (σ_a), it has been observed that the failure of the part occurs after a number of stress reversals (N) even if the magnitude of σ_a is below the material's yield strength. Generally, higher the value of σ_a, lesser N is needed for failure.

Unlike a pure reversing stress (σ_a) discussed above, a machine part may be subjected to a combined steady (mean) and reversing stress. Following design procedure handles such combined stress situation. A generalized stress condition, can be defined as combine purely reversing stress (σ_a) superimposed on a steady stress (σ_m). The following stress-time graph shows this combined reversing and steady stress condition. If the stress is varying between σ_{max} & σ_{min}, then the

Study/Mean /Avg. Stress $\sigma_m = \frac{1}{2}(\sigma_{max} + \sigma_{min})$

Reversing/Amplitude/range stress $\sigma_a = \frac{1}{2}(\sigma_{max} - \sigma_{min})$

When $\sigma_a = 0$ Load is purely Static and Criteria of failure is σ_{ut} or σ_{yt}. These limits are on Abscissa.

When $\sigma_m = 0$ the stress is completely reversing and criteria of failure is Endurance limit i.e. σ_e that is on ordinate.

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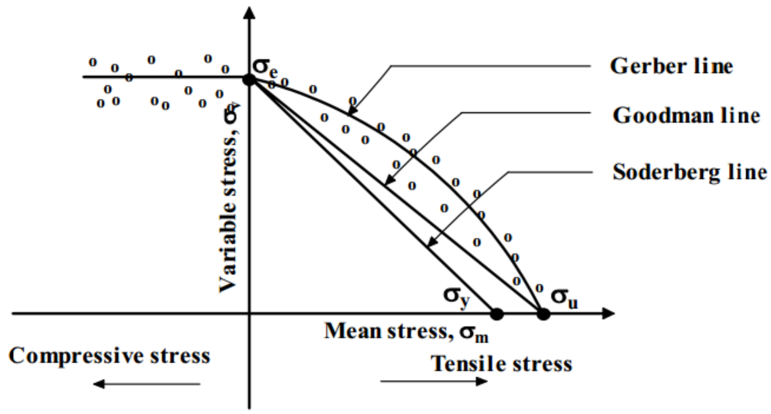

Fig.1.7: Soderberg line, Goodman line and Gerber line

SODERBERG'S LINE:

If we plot steady/mean stress (σ_m) along x axis and the range/variable stress (σ_a) along y axis, then the two extreme stress conditions, constitute two point on x and y axis. Soderberg Line is obtained by joining these two points. When in a machine part, both types of stress are present simultaneously, if the stress combination (σ_m & σ_a) is contained in the area defined by the Soderberg line, then the part should be safe. Any stress combination falling above the Soderberg's line would be unsafe.

$$\left(\frac{\sigma_m}{\sigma_y}\right)+\left(\frac{\sigma_v}{\sigma_e}\right)=1 \quad \text{Soderberg line}$$

GOODMAN'S LINE:

Because of brittle nature of failure, Goodman proposed the safe design stress for steady stress should be extended to σ_u instead of σ_y in Soderberg's equation. This resulted in the safe design space as shown and the resulted in Goodman Design equation. Goodman Equation can be obtained from Soderberg equation by replacing σ_y by Su. However, in the safe area defined by Goodman line, when the magnitude of steady stress σ_m becomes more than σ_y, the part may fail from yielding from plastic deformation. The area is shown as unsafe region.

$$\left(\frac{\sigma_m}{\sigma_u}\right)+\left(\frac{\sigma_v}{\sigma_e}\right)=1 \quad \text{Goodman line}$$

GERBER LINE:

Gerber parabola refers to the parabolic line joining two points in x axis (σ_u) and y axis (σ_e). The x-axis is stress amplitude and y axis is mean stress.

$$\left(\frac{\sigma_m}{\sigma_u}\right)^2+\left(\frac{\sigma_v}{\sigma_e}\right)=1 \quad \text{Gerber line}$$

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Q.2.c: Define the following:

1. Endurance strength **2. Endurance limit**

3. Notch Sensitivity **4. Theoretical stress concentration factor**

Ans:

1. Endurance strength:

The maximum completely reversing cyclic stress that a material can withstand for indefinite (or infinite) number of stress reversals is known as the fatigue strength or endurance strength (Se) of the part material.

2. Endurance limit:

The highest stress that a material can withstand for an infinite number of cycles without breaking called also endurance limit.

3. Notch Sensitivity:

The notch sensitivity of a material is a measure of how sensitive a material is to notches or geometric discontinuities.

$$q = \frac{K_f - 1}{K_t - 1} \qquad 0 \le q \le 1$$

$$K_f = 1 + q(K_t - 1) \qquad 1 \le K_f \le K_t$$

q - Notch Sensitivity Factor

K_f - Theoritical Stress Concentration Factor for Axial or Bending Loading.

K_t - Theoritical Stress Concentration Factor for Torsional or Shear Loading.

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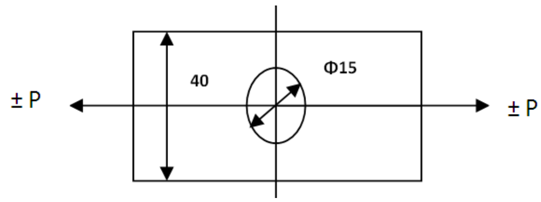
A Plate made of plain carbon steel 30C8 (S_{ut} = 450 N/mm^{2}) in hot rolled condition as shown in figure (all dimensions are in mm). The Thickness of plate is 35 mm. The theoretical stress concentration factor is 2.51 and notch sensitivity is 0.8. The surface finish factor and size factor are 0.67 and 0.85 respectively. For reliability of 90 % the reliability factor is 0.897. If the factor of safety is 1.5, determine the maximum completely reversed axial force the plate can take for the infinite life.



Solution:

Given Data:

σ_{ut}	= 450 N/mm^2	t	= 35 mm	K_t	= 2.51
q	= 0.8	Ka	= 0.67	Kb	= 0.85
Kc	= 0.897	FS	= 1.5	Fa	= ?

σ'_e	= 0.5 x σ_{ut}	= 0.5 x 450
σ'_e	= 225 N/mm^2	
Kf	= q x (Kt-1) + 1	= 0.8 * (2.51-1)+1
Kf	= 2.208	
Kd	= 1/Kf	= 1/2.208
Kd	= 0.4528	
σ_e	= Ka x Kb x Kc x Kd x σ'_e	= 0.67 x 0.85 x 0.897 x 0.4528 x 225
σ_e	= 52.0445 N/mm^2	
$(\sigma_e)_a$	= 0.8 x σ_e	= 0.8 x 52.0445
$(\sigma_e)_a$	= 41.636 N/mm^2	
$(\sigma_e)_a$	= Fa/A	
41.636	= Fa/ (40-15) x 35	
Fa	= 41.636 x 875	
Fa	= 36431.5 N/mm^2	
Ans: Fa	**= 36.4315 N/mm^2**	

For Solution of MST-I Paper Visit Website: ***www.pipleyasunil.wordpress.com*** ***(After MST Exam)***