Basics of Mechanical Engineering-1

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Week 11

Lecture 45

Keys, Nuts, Bolts, Screws and Fasteners

Welcome to the next lecture in the course Basics of Mechanical Engineering 1. I am Dr. Amandeep Singh along with me Professor Ramkumari is co-teaching this course. We have discussed about coupling and shafts in the previous lecture. I will talk about Keys, Nuts, Bolts, Screws and Fasteners in this lecture. Predominantly, what I am going to discuss here is the components or the small tools which are used to make joints.

These are generally temporary joints. Keys are small metal component or small it could be rectangular. We will see that kinds of the keys taper rectangular. So, it is a metal component connects the rotating shaft with a stationary shaft. So, that the stationary shafts also starts rotating.

So, nuts and bolts and screws are also there to fasten means to connect or join the two different components which are in mechanical functioning of a system or a machine.

Contents

So, we will talk about the keys and their function in shaft systems, forces acting upon some key we will try to talk about other keys we will just put it in the references you can discuss upon them. Poles of uniform strength we will discuss, fastening the types, we will try to talk about the screws and we will try to talk about tensile and shear stress analysis. A very broad introduction to this would be given in the last few slides.

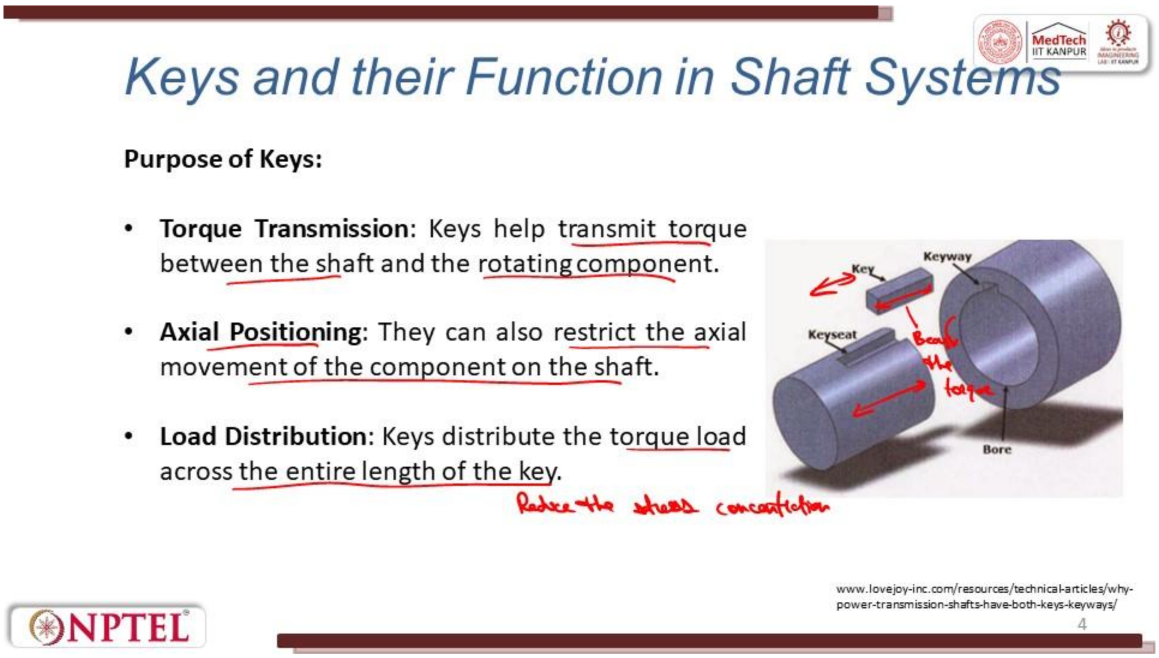
Keys and their Function in Shaft Systems

- A **key** is a mechanical component used to connect a rotating machine element to a shaft.
- The key fits into matching slots (called keyways) in both the shaft and the rotating part, such as gears, pulleys, or couplings.
- Its main purpose is to prevent relative rotation between the two parts.

(Keyed joint)

https://engineeringproductdesign.com/wp-content/uploads/Shaft-keys_keyway-examples.webp

Definition of keys. Keys and their function in shaft system. Key is a mechanical component used to connect rotating machine elements to shaft. This is a kind of a key. This is a rectangular key. The cross section is rectangular and the ends are circular here. So, this is a rest for key. This is known as keyrest with the keyrests.



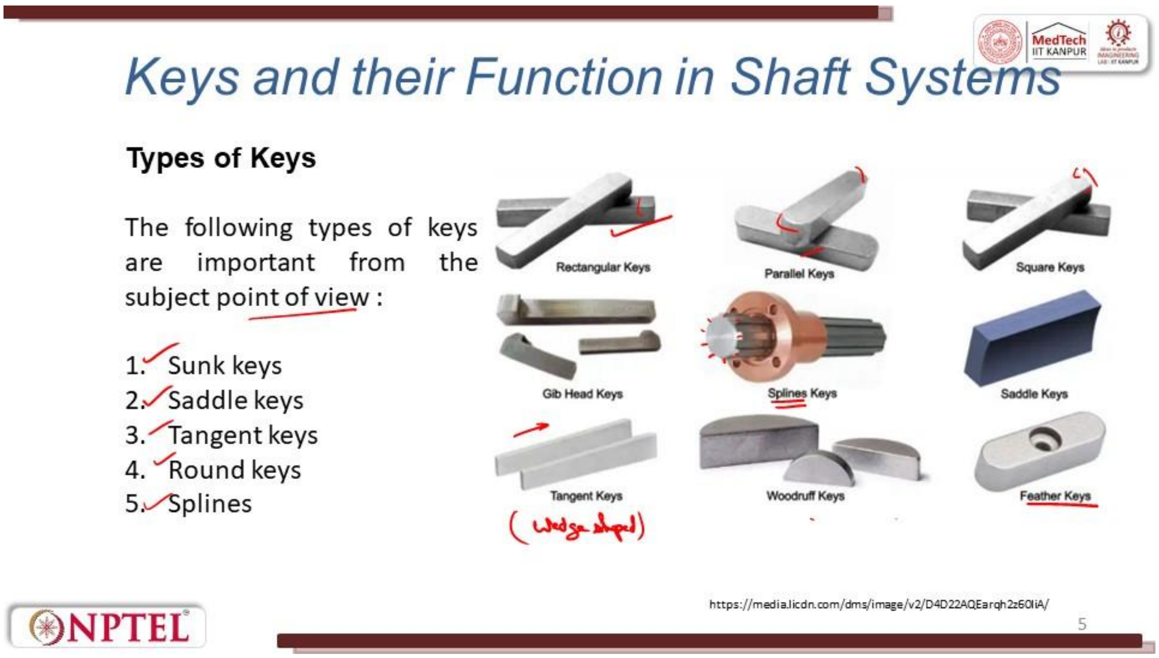
Key prevents the two parts from rotating relative to each other which allow the torque transmission. So, key fits into the machining slots which are called keyways. This is keyrest or this is also called keyway.

So, in both the shafts keyways are there that is the gears, pulleys, couplings are connected to the rotating shaft. Its main purpose is to prevent relative rotation between the two parts. That is what is the key made for. So, it is keyed joint when the joint is made out of key it is known as a keyed joint. This is a temporary joint.

When the key is removed, the joint could be removed. Purpose of keys. The purpose of key, as I mentioned, is majorly Torque Transmission. Keys helps to transmit torque between the shaft and the rotating component. Axial Positioning is also the other function that it performs.

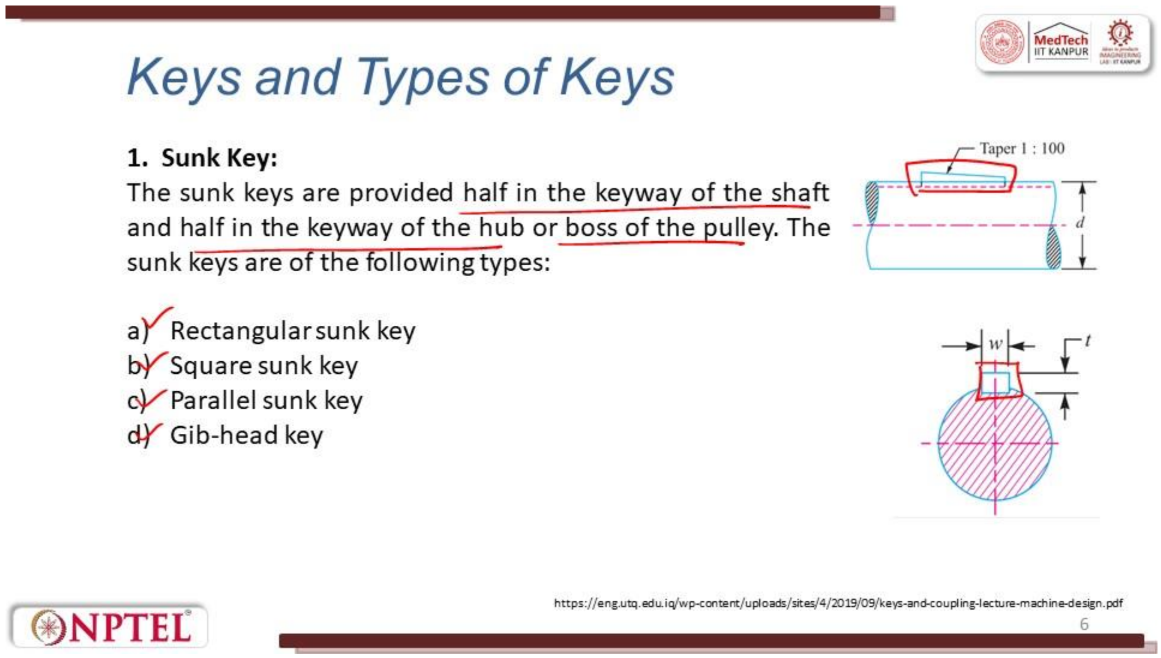
That is, they can restrict the axial movement of the component on the shaft. That is, along the axis, it would not move. That is, it would not rotate in this direction. However, in this direction, the components could move. That is, along the radius, they could move.

Then comes the Load Distribution. Load distribution, that is the key distributes the torque load across the entire length of the key. This complete length bears the torque. So, this reduce the stress concentration. So, lengthier the key is, more distributed is the stress here.



Let us try to talk about the types of keys. Keys are of various types. The following types of keys are important from the subject point of view that you are trying to learn here. That is Sunk keys, Saddle keys, Tangent keys, Round keys and Splines. These are rectangular keys.

The cross section is rectangular. These are parallel keys. The cross section is rectangular but the ends are parallel. These are square keys. Here the cross section is also square and the ends are also completely straight. These are Gib-Head keys.



I will try to talk about them when I talk about the sunk keys. Spline keys, these are the splines. You can see if the torque transmission is very heavy, single key might not be able to bear the load. That is, the stress concentration has to be distributed into multiple keys.

Then in place of keys, we use splines. These are spline keys. You can see 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10 splines are used here. Then we have saddle keys which are only to put the two components over each other. Tangent keys are also there which are wedge shaped.

These are sometimes put from the outer open surfaces. Woodruff keys are there. Then we have feather keys. Let us try to talk about the Sunk keys only. These are called as Sunk keys.

As the name suggests, these are submerged or put there inside the shaft completely. Half of the portion is there in the shaft and half of that is there inside. in the rotating element or that is it could be the gear or anything that you wish to rotate using the shaft. Here in sunk keys are provided half in the keyway of the shaft and half in the keyway of the hub or boss of the pulley whether it is pulley, it is gear whatever you wish to rotate using this.

Keys and Types of Keys

a) Rectangular sunk key. A rectangular sunk key is shown in Fig.

The usual proportions of this key are :

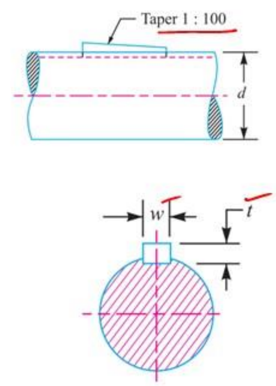
Width of key, w = d / 4 ; and

thickness of key, t = 2w / 3 = d / 6

where

d = Diameter of the hole in the hub.

The key has taper 1 in 100 on the top side only.

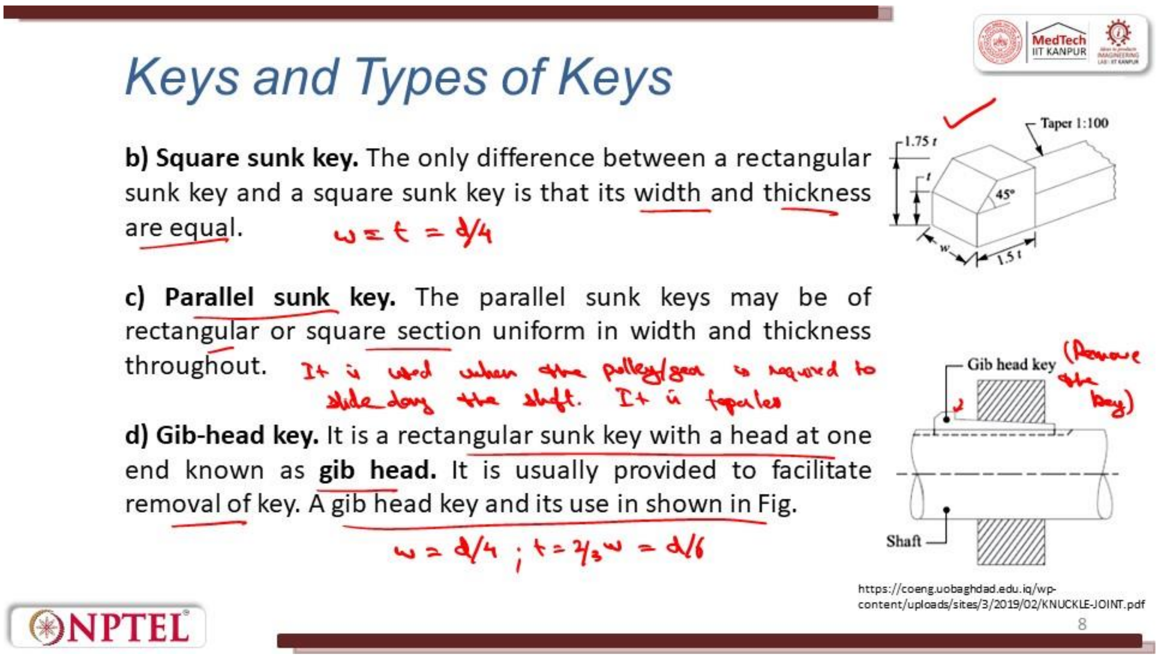


https://eng.utq.edu.iq/wp-content/uploads/sites/4/2019/09/keys-and-coupling-lecture-machine-design.pdf

The Sunk keys are of following types. It could be Rectangular Sunk key, it could be a Square Sunk key, it could be Parallel or it could be Gib-Head. This is a typical rectangular sunk key where width and thickness is given. Let us try to see each of the types of the sunk keys one by one. Rectangular Sunk key. Rectangular Sunk key is shown in this figure.

This is a rectangular sunk key where width and thickness is given. Here, width is generally d by 4, d is diameter of the shaft and thickness is 2w by 3. That is, it is d by 6. The width, whatever it is given, thickness is proportional to it. So, where diameter of the shaft is d the key has a taper in general 1 in 100 on the top side only.

So, this is 1 in 100 taper is also there. So, that the key is inserted easily here. So, this is a specific or typical rectangular key.



Similarly, we have Square sunk key. This is a square sunk key that is given here where The difference between Rectangular sunk key and Square sunk key is that width and thickness are equal in square sunk key. So, here width is equal to thickness = d/4. In the rectangular sunk key, the width was different than thickness where you can see thickness is d/6, width is d/4 or it could be some other proportion as well. But when we talk about a Square key, it is always the same that is width and thickness is same that is generally is equal to d/4. Then comes the Parallel sunk key.

Parallel sunk key may be of rectangular or square section uniform in width and thickness throughout. Parallel sunk key is taperless and is used where pulley, gear or other mating piece is required to slide along the shaft. So, I will put it here. It is used when the pulley or you put it gear that is the other mating piece is required to slide along the shaft. So, this is why it is taperless which means for example, two shafts are there, this is one shaft, this is the other shaft.

Generally, a key would be there that would be fixed and these would be rotating for example, this is rotating this is a pulley that is rotating using this shaft. When it is a parallel sunk key, this is allowed to move in this direction when it is allowed to move in this direction, taper could not be allowed, there is a taperless key would be put here for example, this button is a taperless key that is allowing the shaft to move in this direction along the axis. So, this is the purpose of using a parallel sunk key. Next comes the Gib-Head key.

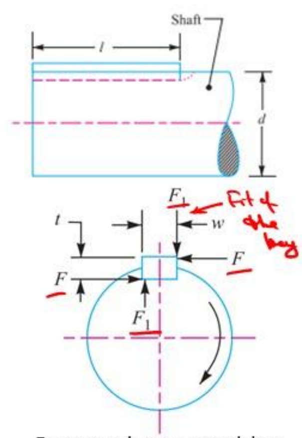
Gib-Head key it is a rectangular sunk key with head at one end that is known as Gib-Head. So, this is a Gib-Head key. It is usually provided to facilitate removal of the key a Gib-Head key it is used in this one, in this figure, this is a shaft is the Gib-Head key. This allows you to hit here and helps you to remove the key using the Gib-Head here generally width of the key is d/4 and thickness is equal to 2 by third times of the width, which is equal to d/6 as we discussed about the rectangular key. So, these are the general proportions of the Gib-Head key. So, this is gib-head.

Forces acting on a Sunk Key

When a key is used in transmitting torque from a shaft to a rotor or hub, the following two types of forces act on the key :

1. Forces (F_1) due to fit of the key in its keyway, as in a tight fitting straight key or in a tapered key driven in place. These forces produce compressive stresses in the key. Difficult to determine (F_1)

2. Forces (F) due to the torque transmitted by the shaft. These forces produce shearing and compressive (or crushing) stresses in the key.



Forces acting on a sunk key

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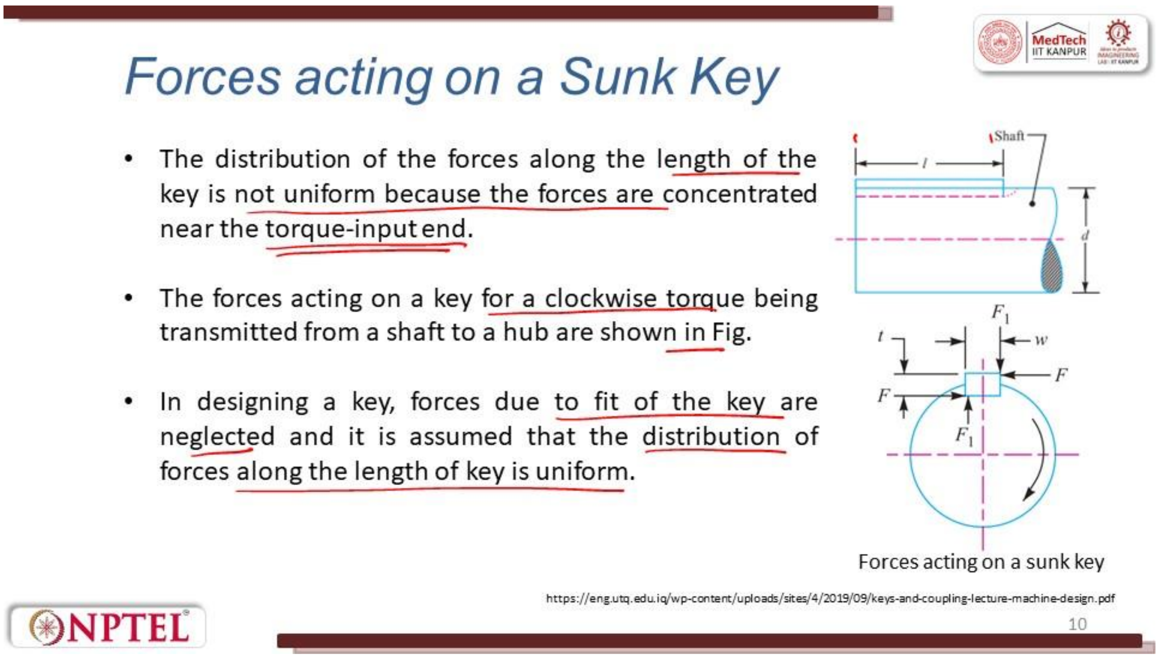
Now, let us try to see what are the forces which are acting on a key. Forces acting on a Sunk Key. When a key is used in transmitting torque from a shaft to a rotor or hub, the following two types of forces act on the key.

Forces F1 due to fit of the key in its key way. As in a tight fitting straight key or in a tapered key driven in place these forces produce compressive stresses in the key. So you can see this is a key that is fit and this is force F1 that is because of the fit of the key. Then other forces F that you can see which are there along the thickness, this is F1 you can see, along the width here, this is F1, this is F1, this is F and this is F. So, F is the force due to the torque transmitted by the shaft. This force is produced sharing and compressive or crushing stress in the key.

So, it is very difficult to determine the force F1. However, the force is F that is due to torque transmitted could be determined using experimentation or so that could be taken into account.

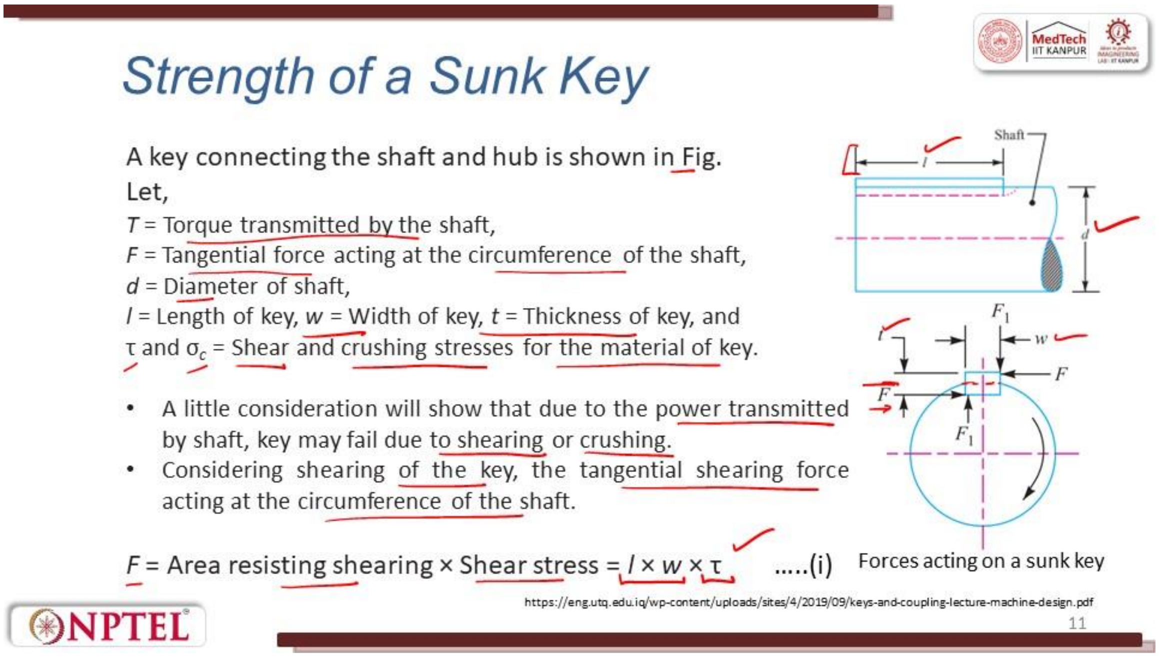


The distribution of forces along the length of the key is not uniform because the forces are concentrated near the torque input end. For example, this is rotating shaft. And here we have a key.

This is a long key here. The distribution of force would be different because this is a rotating end that is rotating. Here the torque would be more. Here the torque would be lesser. So, torque distribution is varying here.

That is what is mentioned here. The torque distribution or the torque is concentrated at the input end. That is what is mentioned here. The forces are more concentrated at the torque input end. The forces acting on a key for a clockwise torque being transmitted from a shaft to a hub are shown in figure here.

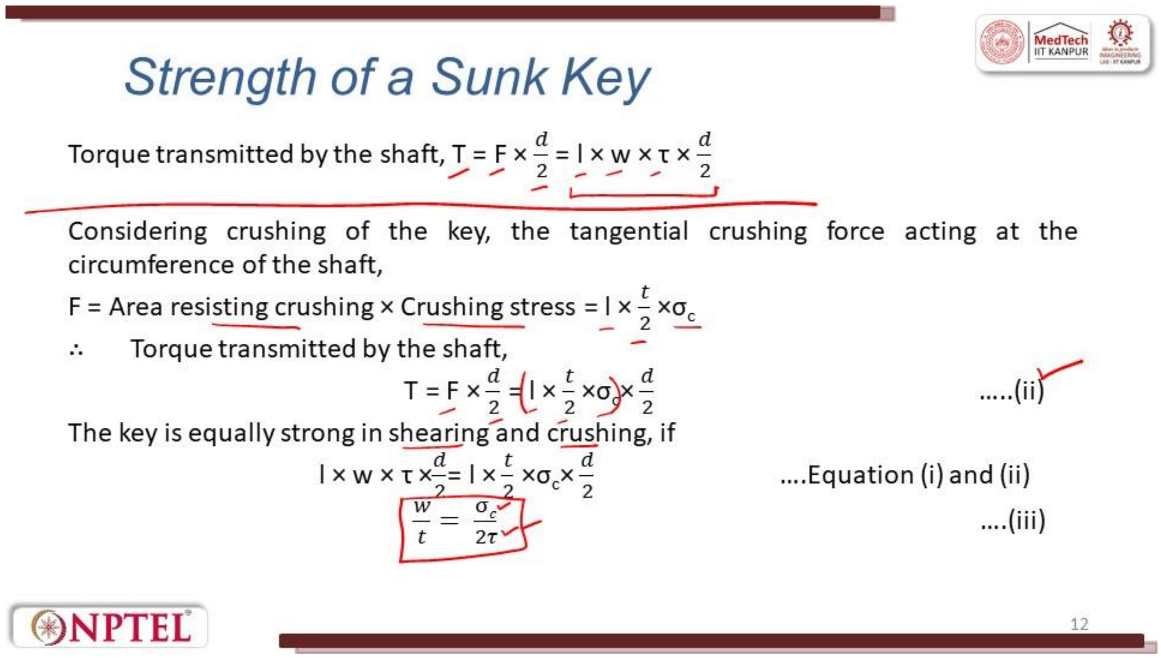
These are the again forces that we looked at. This is length of the key that is given and along the length as we said the forces concentration would be different along the torque input end. In designing a key, forces due to fit of the key are neglected because it could not be determined and these are also very less in magnitude than the forces which are there due to the torque transmission. So, it is assumed that the distribution of the forces along the length of the key is uniform.



So, as we can calculate or we can determine the strength of the key empirically and we try to take this assumption. Key connecting the shaft and hub is shown in figure. Let T is equal to torque transmitted by the shaft. F is tangential force acting at the circumference of the key. This is F tangential force that is acting. Diameter of the shaft is d, which is given here, diameter.

Length of the key is given l. The width of the key is w. The thickness of the key is d. Tau and σc are shear and crushing stresses for the material of the key. A little consideration will show that due to power transmitted by the shaft, key may fail due to shearing or crushing. That is why we have taken tau and σc. Considering shearing of the key, the tangential shearing force acting at the circumference of the shaft is given like this.

$$F = Area\,resisting\;shearing \times Shear\;stress = l \times w \times \tau$$



Similarly,

Torque transmitted by the shaft, $T = F \times \frac{d}{2} = l \times w \times \tau \times \frac{d}{2}$

Considering crushing of the key, the tangential crushing force acting at the circumference of the shaft,

F = Area resisting crushing × Crushing stress = $l \times \frac{t}{2} \times \sigma_c$

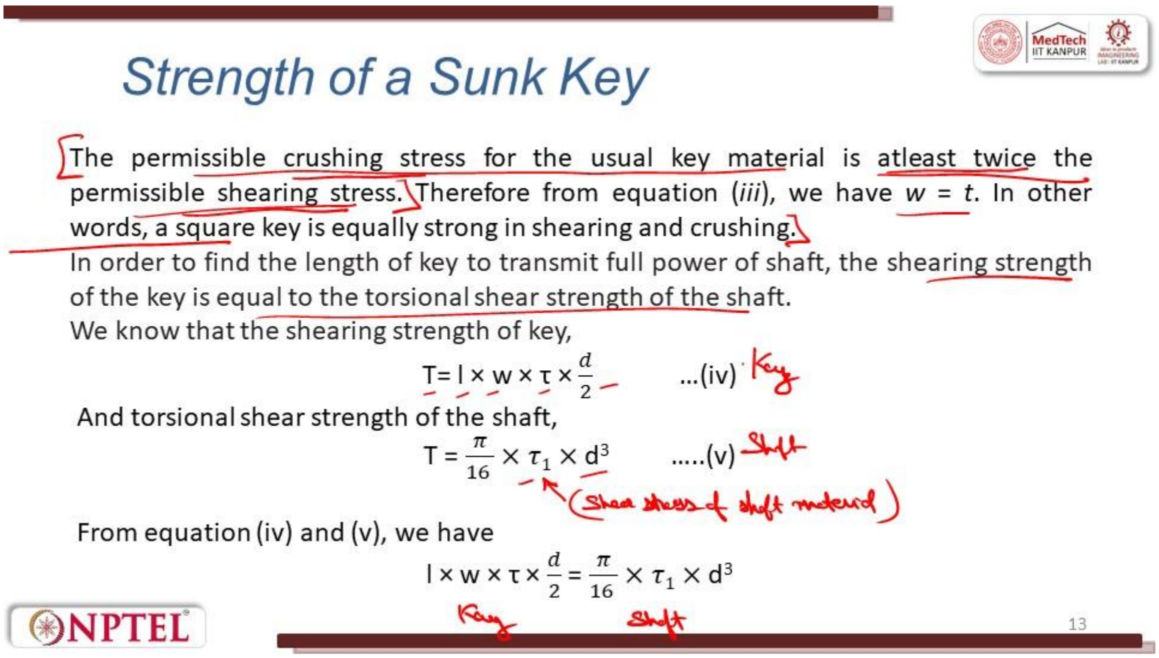
∴ Torque transmitted by the shaft,

$$T = F \times \frac{d}{2} = l \times \frac{t}{2} \times \sigma_c \times \frac{d}{2} \quad \text{.....(ii)}$$

The key is equally strong in shearing and crushing, if

$$l \times w \times \tau \times \frac{d}{2} = l \times \frac{t}{2} \times \sigma_c \times \frac{d}{2} \quad \text{....Equation (i) and (ii)}$$

$$\frac{w}{t} = \frac{\sigma c}{2\tau} \quad \text{....(iii)}$$



The permissible crushing stress for the usual key material is atleast twice the permissible shearing stress. Therefore from equation (*iii*), we have $w = t$. In other words, a square key is equally strong in shearing and crushing.

In order to find the length of key to transmit full power of shaft, the shearing strength of the key is equal to the torsional shear strength of the shaft.

We know that the shearing strength of key,

$T = l \times w \times \tau \times \frac{d}{2}$ …(iv)

And torsional shear strength of the shaft,

$T = \frac{\pi}{16} \times \tau 1 \times d^3$ …..(v)

From equation (iv) and (v), we have

$l \times w \times \tau \times \frac{d}{2} = \frac{\pi}{16} \times \tau 1 \times d^3$

Strength of a Sunk Key

$$l = \frac{\pi}{8} \times \frac{\tau_1 \times d^2}{w \times \tau} = \frac{\pi d}{2} \times \frac{\tau_1}{\tau_2} = 1.571\ d \times \frac{\tau_1}{\tau_2}$$ .....(Taking w = d/4) ....(vi)

When the key material is same as that of the shaft, then $\tau = \tau_1$.

$l = 1.571\ d$ [From equation ....(vi)]

$$l = \frac{\pi}{8} \times \frac{\tau 1 \times d^2}{w \times \tau} = \frac{\pi d}{2} \times \frac{\tau 1}{\tau 2} = 1.571\ d \times \frac{\tau 1}{\tau 2}$$ .....(Taking w = d/4) ....(vi)

When the key material is same as that of the shaft, then $\tau = \tau_1$.

$l = 1.571\ d$ [From equation ....(vi)]

Numerical Problem

Design the rectangular key for a shaft of 50 mm diameter. The shearing and crushing stresses for the key material are 42 MPa and 70 MPa.

Solution:

$\tau = 42$ MPa $= 42$ N/mm²
$\sigma_c = 70$ MPa $= 70$ N/mm²
$d = 50$ mm
Design tables: (50 mm shaft dia.)
$w = 16$ mm
$t = 10$ mm
$l =$ length of key $= ?$

Shearing: $T = l \times w \times \tau \times \frac{d}{2}$ (KEY)
$= l \times 16 \times 42 \times \frac{50}{2} = 16800 \times l$ N-mm —— (1)

Shaft: $T = \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times 42 \times (50)^3$ (SHAFT)
$= 1.03 \times 10^6$ N-mm —— (2)

Equating (1) and (2)
$l = 1.03 \times 10^6 / 16800 = 61.31$ mm

Crushing: $T = l \times \frac{t}{2} \times \sigma_c \times \frac{d}{2}$ (KEY)
$= l \times \frac{10}{2} \times 70 \times \frac{50}{2} = 8750 \times l$ N-mm —— (3)

Equating (2) and (3)
$l = 1.03 \times 10^6 / 8750$
$l = 117.7 \simeq 120$ mm

So, let us go through a quick problem statement to understand this. Design a rectangular key for a shaft of 50 millimeter diameter. The shearing and the crushing stresses are given here which are 42 MPa and 70 MPa respectively.

Solution. Given : $d = 50$ mm ; $\tau = 42$ MPa $= 42$ N/mm^2 ; $\sigma_c = 70$ MPa $= 70$ N/mm^2

The rectangular key is designed as discussed below:

From Table 13.1, we find that for a shaft of 50 mm diameter,

Width of key, $w = 16$ mm **Ans.**

and thickness of key, $t = 10$ mm **Ans.**

The length of key is obtained by considering the key in shearing and crushing.

Let l = Length of key.

Considering shearing of the key. We know that shearing strength (or torque transmitted) of the key,

$$T = l \times w \times \tau \times \frac{d}{2} = l \times 16 \times 42 \times \frac{50}{2} = 16\,800\, l \text{ N-mm} \quad ...(i)$$

and torsional shearing strength (or torque transmitted) of the shaft,

$$T = \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times 42\,(50)^3 = 1.03 \times 10^6 \text{ N-mm} \quad ...(ii)$$

From equations (*i*) and (*ii*), we have

$$l = 1.03 \times 10^6 / 16\,800 = 61.31 \text{ mm}$$

Now considering crushing of the key. We know that shearing strength (or torque transmitted) of the key,

$$T = l \times \frac{t}{2} \times \sigma_c \times \frac{d}{2} = l \times \frac{10}{2} \times 70 \times \frac{50}{2} = 8750\, l \text{ N-mm} \quad ...(iii)$$

From equations (*ii*) and (*iii*), we have

$$l = 1.03 \times 10^6 / 8750 = 117.7 \text{ mm}$$

Taking larger of the two values, we have length of key,

$$l = 117.7 \text{ say } 120 \text{ mm } \textbf{Ans.}$$

Nuts and Bolts: Basics

Nuts and bolts are a type of **threaded fasteners** used for holding components together in mechanical structures. The bolt provides the tensile force, while the nut serves to create a clamping action. Together, they form a strong, reliable connection, which can be easily disassembled when needed.

- **Bolt**: A cylindrical rod with a head on one end and threads on the other. Bolts typically pass through a hole in one or more components and are secured with a nut.
- **Nut**: A hexagonal or other-shaped piece with an internal thread that pairs with the bolt to hold parts together.

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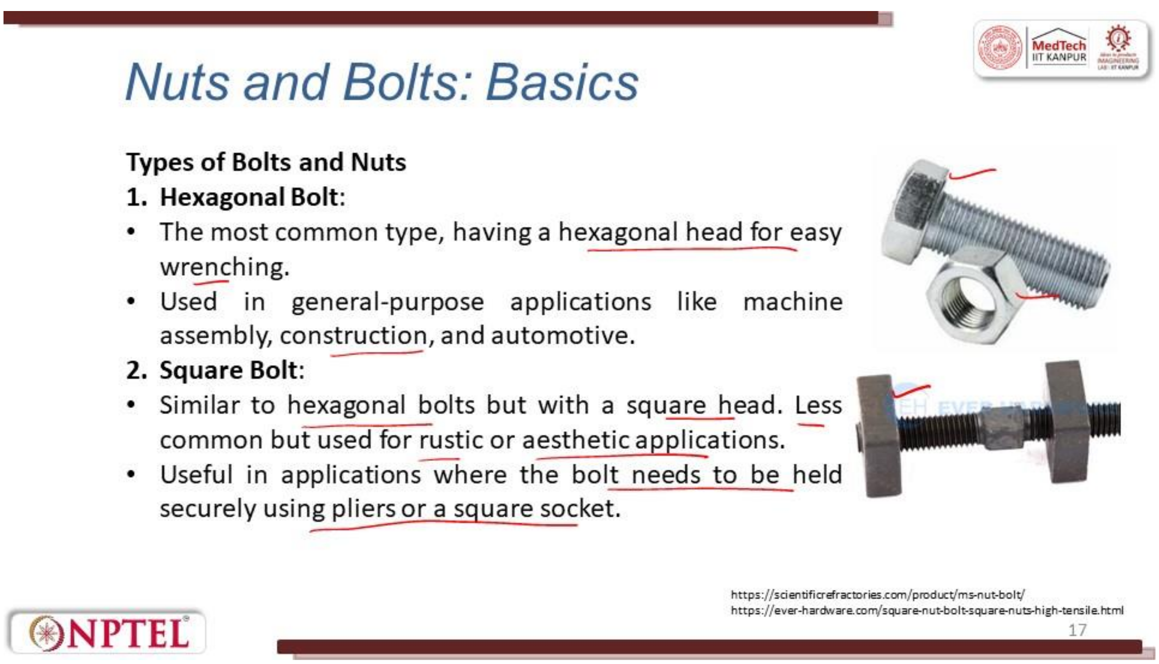
Let us now talk about the nuts and bolts. Nuts and Bolts are type of threaded fasteners used for holding components together in mechanical structures. The bolt provides the tensile force while the nut serves to create a clamping action. So, bolt is for tensile force and nut is for clamping action.

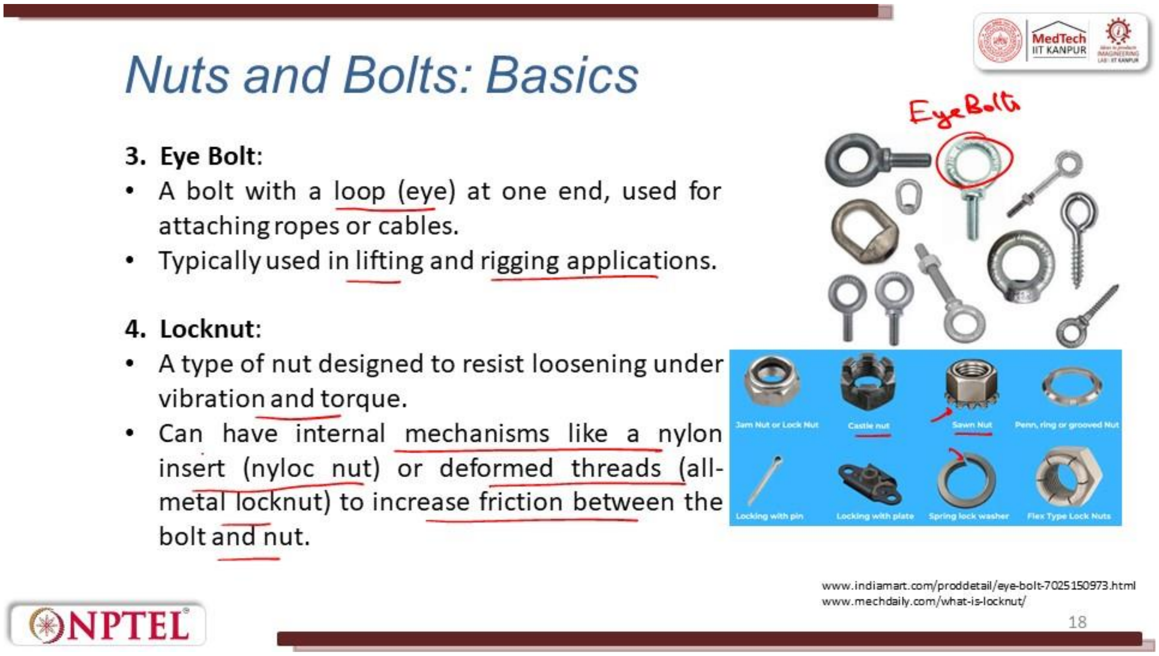
Together they form a strong reliable connection which can be easily disassembled when needed. Bolt, as a definition it is a cylindrical rod with head on one end and threads on the other. Bolts typically pass through a hole in one or more components and are secured with a nut.

Nut, by definition it is a hexagonal or other shaped piece with an internal threads that pairs with the bolt to hold parts together so simply putting the definitions of nuts and bolts there are types of nuts and hexagonal bolt, hexagonal nut that you might have heard multiple times, you might have used multiple times you have seen it multiple times, you have designed that in your engineering drawing or so similar we will discuss here hexagonal bolt or square bolt eye bolt knock nut or so so let us see the types of bolts and nuts.



Hexagonal bolt, the most common type having a hexagonal head for easy wrenching. This is a hexagonal bolt and this is a hexagonal nut. This is used in general purpose applications like machine assembly, construction and automotive. A Square bolt is similar to hexagonal bolt but with a square head.

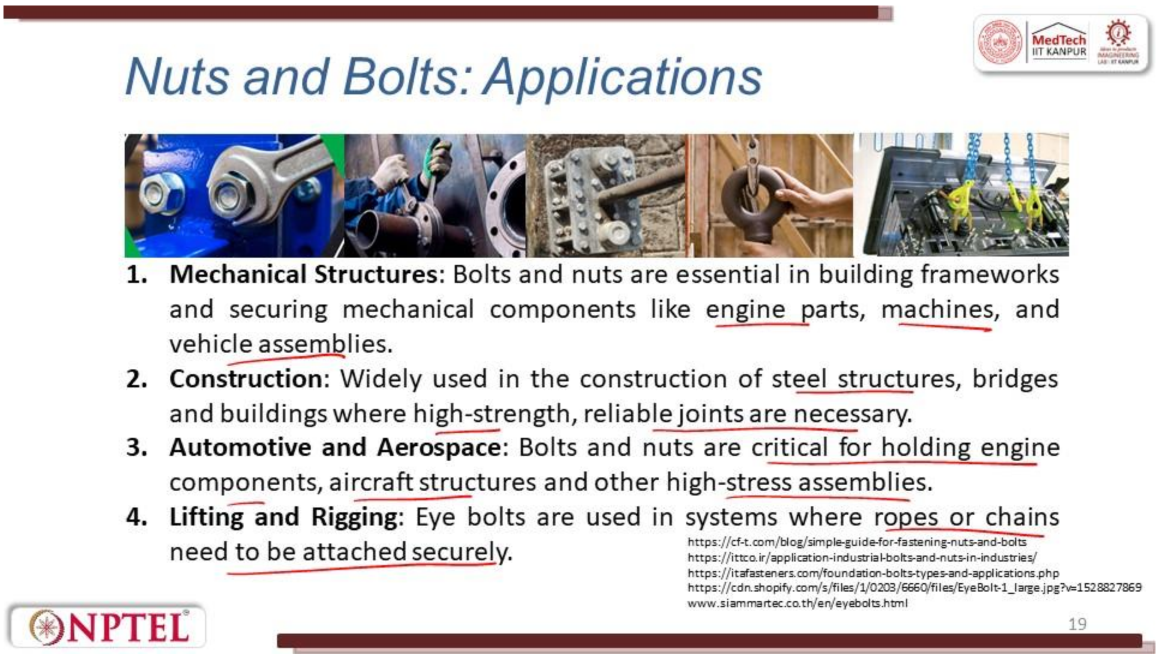
This is a square head that is here. It is less common but used for rustic or aesthetic applications. These are useful in applications where bolt needs to be held securely using pliers or a secure socket. So, these are major two designs which are used.



Other than that, multiple places are there where Eye bolt is used. A bolt with a loop or eye at one end is used to attach ropes or cables. These are all eye bolts here. So, you can see a loop here. This is to attach a rope or be using a rod or so we try to lock it or unlock it. Typically used in lifting and rigging applications eye bolts are used.

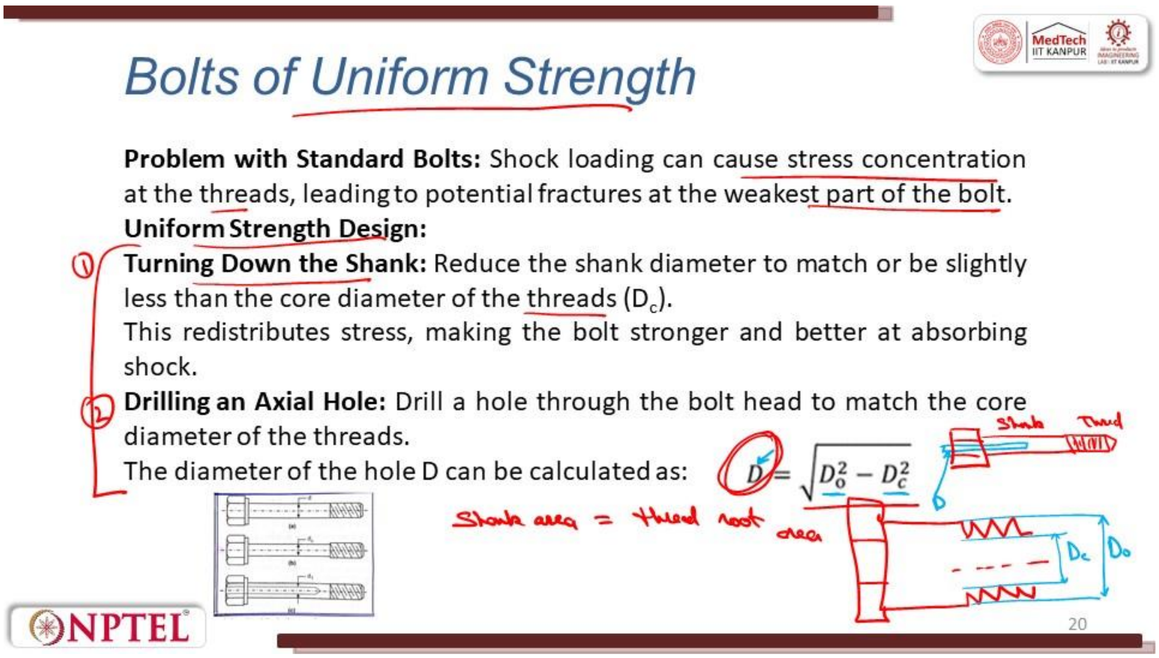
Similarly, we have a Locknut. A type of a nut designed to resist loosening under vibration and torque. It does not get loose under vibration. That is why we try to provide a sawn nut or a castor nut. That is a kind of a locknut.

This allows any loosening due to vibration. They can have internal mechanisms like a 9L insert or 9L nut or deformed threads all metal lock nut to increase friction between the bolt and nut. So, as you can see this is a deformed nut that is all metal which does not allow it to rotate very easily or it could have a spring washer in between. So, these are the kind of a lock nut.



In certain applications where nuts are used in mechanical structures that is bolts and nuts are essential in building frameworks and securing mechanical components like engine parts, machines vehicle assemblies or so, these are widely used in construction for steel structures bridges and buildings where high strength reliable joints are necessary automotive and aerospace applications. Bowls and nuts are critical for holding engine components in aircraft structures or other high stress assemblies or so. Lifting and Rigging Eye bolts are used in systems where ropes or chains need to be attached securely.

For instance, in automotive system, for example, for the screw jack in automotive systems also, when you use a screw jack, it is a nut and bolt assembly which helps to lift your car up or bring it down. It is nut and bolt assembly only. So, multiple applications where nuts and bolts are used for temporary joining and sometimes for the almost permanent joining.

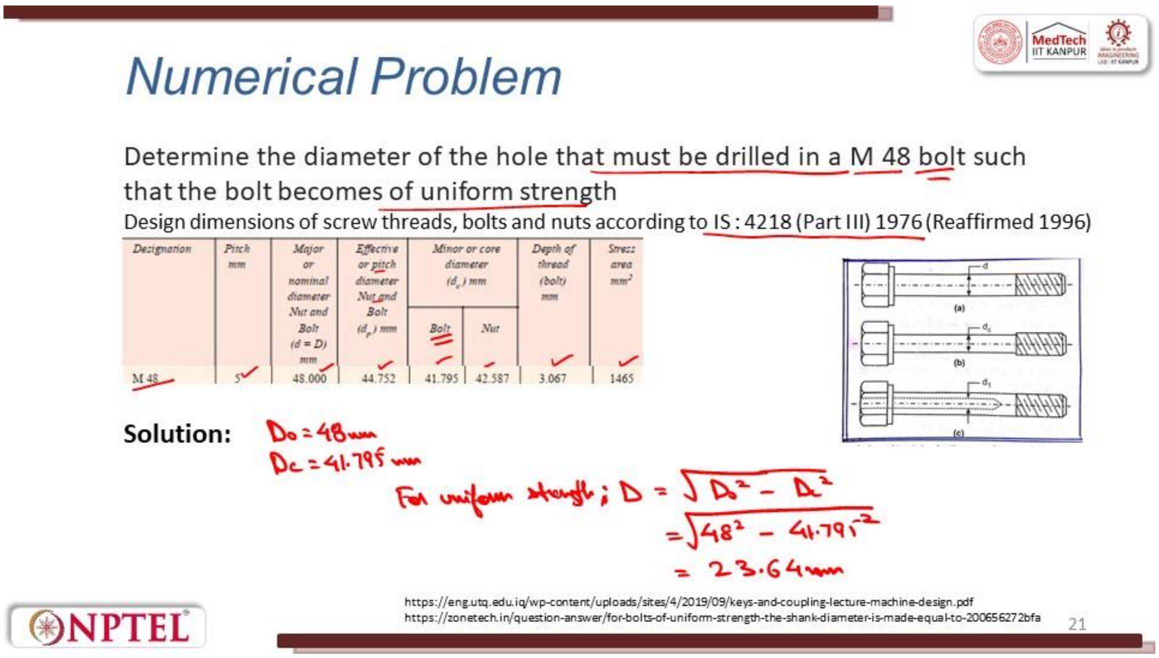


Next is Bolts of Uniform Strength. Problem with standard bolts. Shock loading can cause stress concentration at threads leading to potential fractures at the weakest part of the world. The Uniform Strength Design is important that is turning down the shank. Reduce the Shank diameter to match or to be slightly less than the core diameter of the threads. That is Dc. This redistributes stress making the bolt stronger and better at absorbing shock.

Drilling an Axial hole is another way to have the uniform strength that is we drill a hole through the bolt head to match the core of diameter of the threads. The diameter of the hole DE can be calculated as $D = \sqrt{D_O^2 - D_c^2}$. So, this will say that uniform strength is there that is the shank area equal to the thread root area. So, here to put it in more detail, for example, this is a hexagonal bolt and this is a shank and this is the threaded portion here. Here only the threads are there.

This is our shank and this is thread. Here what will we have? When we talk about the thread here or you say this is axis, this other part here, this is an outside diameter that is nominal diameter. This diameter is our outside diameter do which is nominal diameter and this smaller diameter that is the minimum diameter of the internal of the thread is Tc that is core diameter. So, the hole diameter that is there if we drill a hole here there could be hole that could be drilled here.

So, here diameter of this hole is D. This hole diameter is equal to square root of the the differences of the scales of the nominal diameter and the core diameter of a bolt. So, this is a bolt here that is a thread if I try to put in that color once again. For example, there could be shank here for the bolt and this could be bolt head here. So, this is how this is designed to make it more clear.



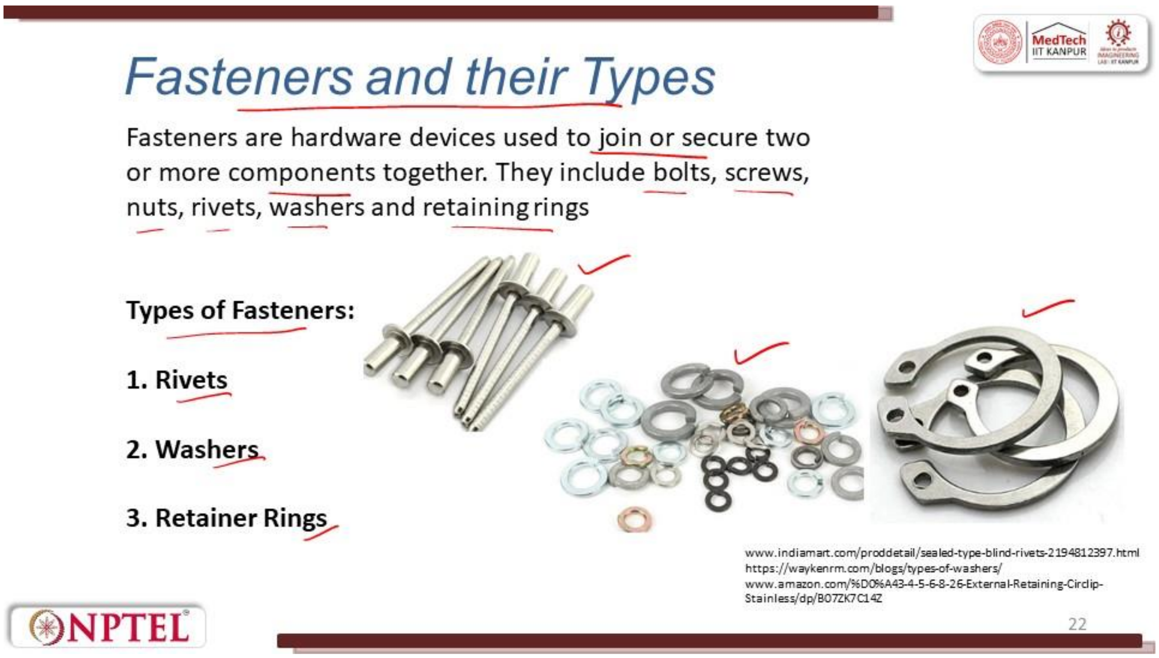
Let me show you a numerical where this is taken from a handbook from a M 48 bolt designs M is the diameter 48 that is M is notation.

Solution. Given : $D_o = 48$ mm

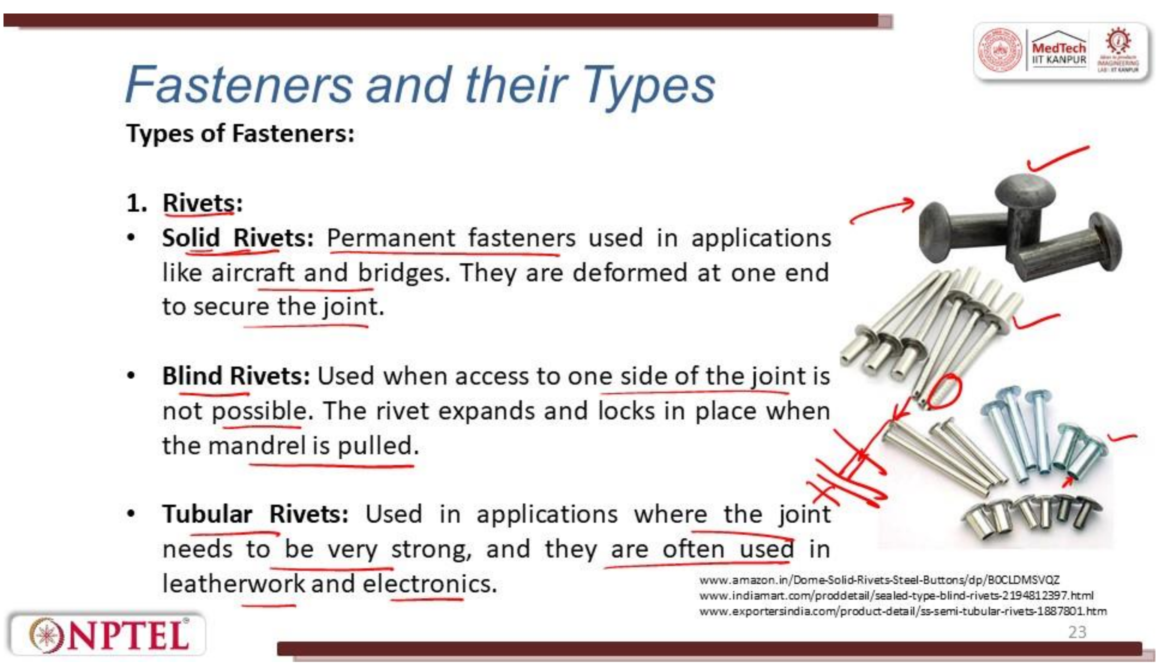
From Table 11.1 (coarse series), we find that the core diameter of the thread (corresponding to $D_o = 48$ mm) is $D_c = 41.795$ mm.

We know that for bolts of uniform strength, the diameter of the hole,

$$D = \sqrt{(D_o)^2 - (D_c)^2} = \sqrt{(48)^2 - (41.795)^2} = 23.64 \text{ mm } \textbf{Ans.}$$



Let us try to go through Fasteners and their types. Fasteners are hardware devices used to join or secure two or more components together. These are again joining devices. These include bolts, screws, nuts, rivets, washers, retaining rings and so on. About bolts, screws, nuts, we will keep discussing.

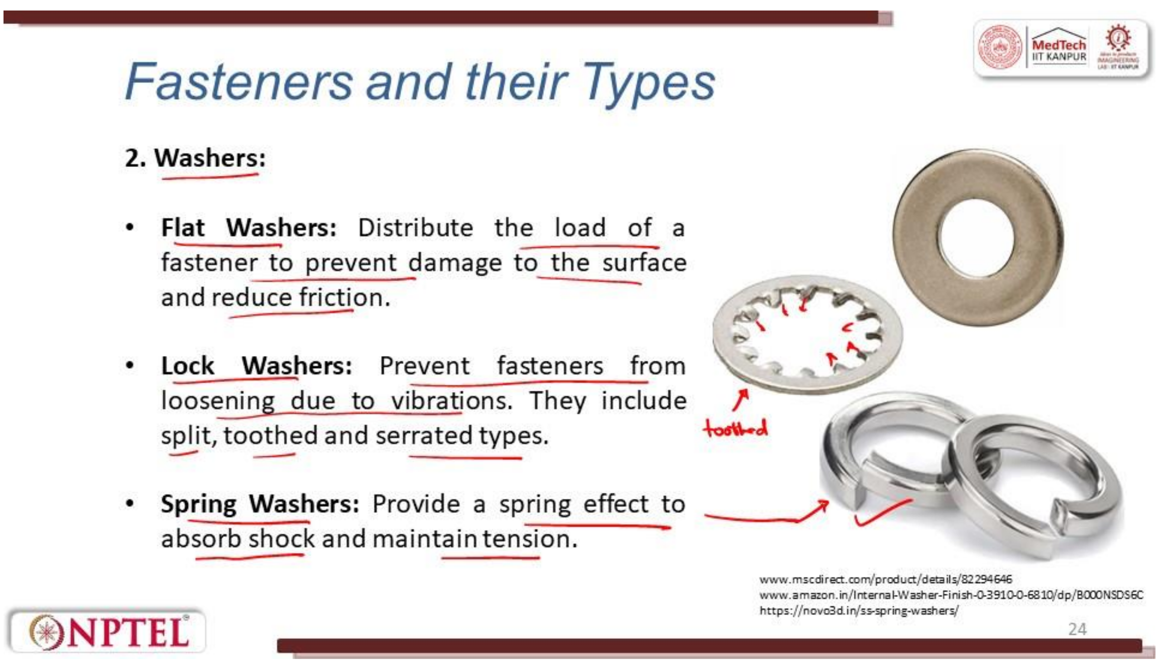


Types of fasteners are rivets, washers and retainer rings. These are rivets which are there you can see. These are washers that helps you to lock two bolts or nuts and these are retainer rings so that the things or the bolts or nuts that you put in a machine component that those are retained there. Types of fasteners. First is Rivets- Solid rivets. Solid rivets, because the name itself tells solid, these are permanent fasteners which are used in applications like aircraft and bridges.

They are deformed at one end to secure the joint. So, this is a permanent rivet that is there. It is deformed at one end. So, it is a kind of a permanent. It cannot be removed easily once it is put in any two mating surfaces.

Then we have Blind rivets. These are used when access to one side of the joint is not possible through only one side only, this rivet is put inside and the joint is made wherever joint is to be made, this rivet gets inside right two mating surfaces could be there on the other side access is not available. The rivet expands and locks in place when mandrel is pulled it mandrel is used to lock in these rivets which are blind rivets and when mandrel is pulled the rivet expands the other side of rivet this side also expands and it locks in place.

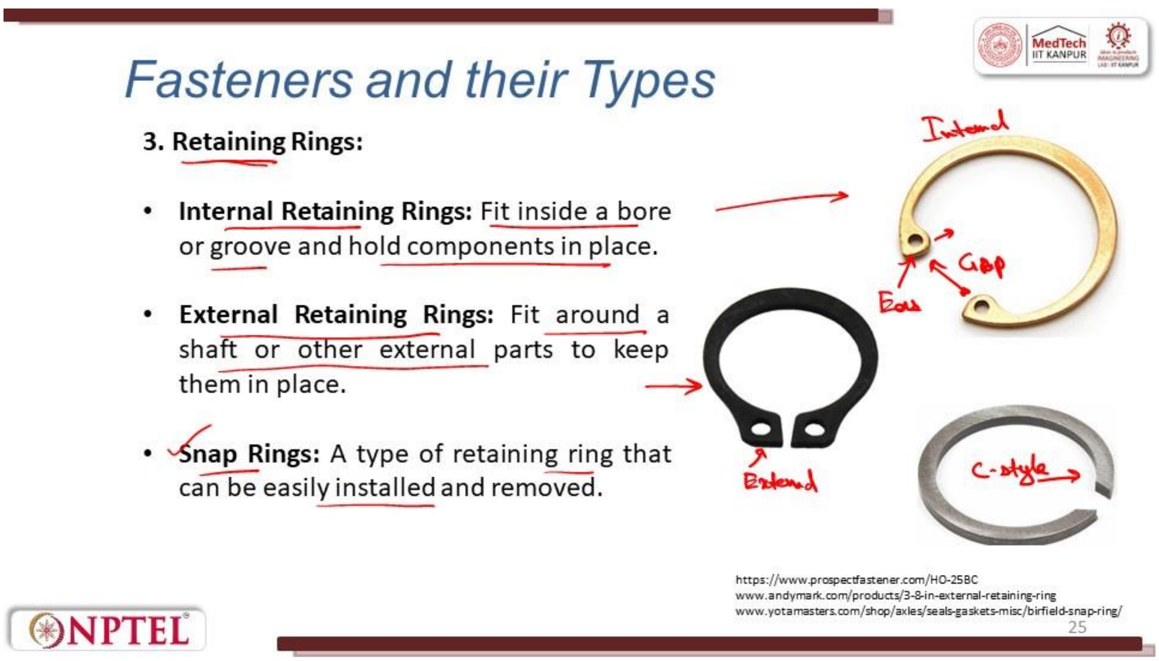
So, that the river is tightened. Then is tubular rivets. So, these are tubular rivets the kind of a tube which are hollow from inside these are where the joint needs to be very strong and they often are used in leather work and electronics. So, these are tubular rivets which are there.



Next come Washers. Washers are there to secure the spacing between nuts and bolts, between screws, I mean before the rivets also washers could be put. So, there are multiple kinds of washers, Flat washers, Lock washers, Spring washers. Flat washers distribute the load of a fastener to prevent damage to the surface and reduce friction. Lock washer is there as I have mentioned in the previous slides as well.

These are serrations here so that the load is distributed here. And these prevent fasteners from loosening due to vibrations. They include split tooth and serrated types. So these are tooth washers. It could be serrations, it could be split washers also.

Spring washers, this is a spring washer that provides a spring effect to the connection to the nut on the bolt to absorb shock and maintain tension. So, these are spring washers which are mentioned here.

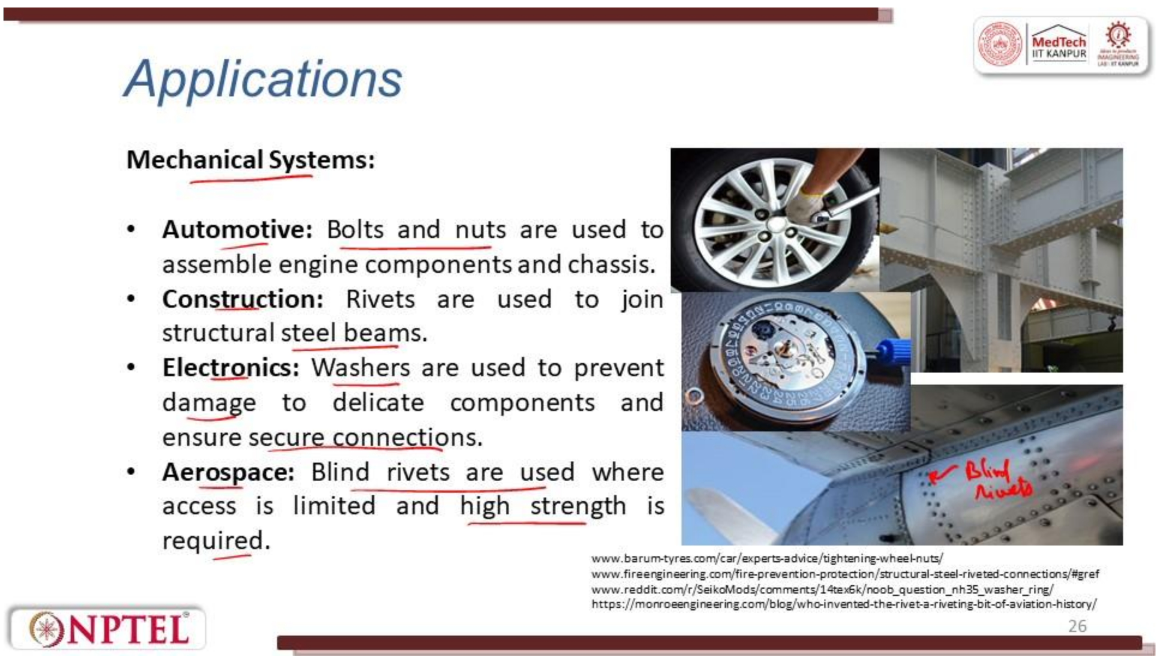


Then comes Retaining Rings. The word retaining itself tells that these are the rings which are used to fasten parts such as bearings to prevent them from coming off. So, these are put in place and the part does not come off.

So, that is why we put it there. So, these are ears of the rings and this is gap. These rings helps to lock the two mating parts, I would call mating parts into the parts which are to be joined this could be internal, this could be external depending upon the where do you put the rings. If these rings are here, this could be called as external. When the ears are outside, when the ears are inside, this is Internal Retaining rings.

This is a kind of a C style ring. So, internal retaining rings are there which fit inside a bore or groove and hold components in place. This is an Internal ring. External rings are there which fit outside or around a shaft or other external parts to keep them in place. These are external rings.

Snap rings are there, types of retaining ring that can be easily installed and removed. Simply snapping is putting in, taking out. Easy installation in and taking out, then it is known as snap ring. So, these are there, retaining rings.



Applications of the Fasteners. Fasteners have multiple applications in automotive, construction, electronics and aerospace industries. In Automotive industry, bolts and nuts are used to assemble engine components and chassis. Rivets are used to join structural steel beams in Construction. In Electronics, washers are used to prevent damage to delicate components and to sometimes provide spring action to ensure secure connections. In Aerospace Industry, blind rivets are used where access is limited and high strength is required when access is there from the one direction or one side only.

For example, these are blind rivets where access to the other side of the surface is not possible. So, blind rivets are used here.

Screws

Theory

Stress Concentration in Screws:

- Screws experience stress concentrations, particularly at the root of the threads, due to the reduced cross-sectional area. This can lead to higher local stresses compared to the rest of the screw.

Load Distribution in Threads:

- The load applied to a screw is distributed along the threads, where it creates both tensile and shear stresses. The distribution is not uniform and can vary depending on the screw's design and the load applied.

https://engineeringlearn.com/types-of-screws-and-their-uses-with-pictures/

Next comes Screws. Stress Concentration in Screws. Screws experience stress concentrations particularly at the root of the thread due to the reduced cross sectional area.

This can lead to higher local stresses compared to the rest of the screw. So, as I mentioned in the bolts as well. So, this is crest and trough this could be axis. So, here at the internal surface area the stress concentration is high. Load Distribution in Threads, load distribution when we talk about the load applied to a screw is distributed along the threads.

Where it creates both tensile and shear stresses, the distribution is not uniform and can vary depending on the screw's design and the load applied. It depends what kind of load is applied. It also depends what kind of screw are we using and what kind of the thread configuration are we using, what pitch are we using. Depending upon the load, the size, the diameter, the pitch, the kind of the screw, the kind of the thread, everything is decided accordingly. This is machine design.

Tensile and Shear Stress Analysis

1.Tensile Stress (σ_t)

- The tensile stress in a screw is calculated by dividing the applied load by the cross-sectional area of the screw:

$$\sigma_t = F/A$$

where:

- F = Applied load
- A = Cross-sectional area of the screw

For a screw with a diameter d and assuming it is solid, the area A is:

$$A = \frac{\pi\, d^2}{4}$$

Then again, let us recall the Tensile stress that is σ_t that we have discussed in the previous lectures. Tensile stress in a screw is calculated by dividing the applied load by the cross section area of the screw. Tensile stress is simply force per unit area or load per unit area where F is applied load. It is F/A where F is applied load and A is cross section area of the screw. Here cross section area $A = \frac{\pi d^2}{4}$ where d is diameter of the screw.

Tensile and Shear Stress Analysis

2.Shear Stress (τ)

1.The shear stress in a screw is calculated based on the applied shear force and the shear area:

$$\tau = \frac{F_{Shear}}{A_{Shear}}$$

where:

- F_{Shear} = Shear force
- A_{Shear} = Shear area

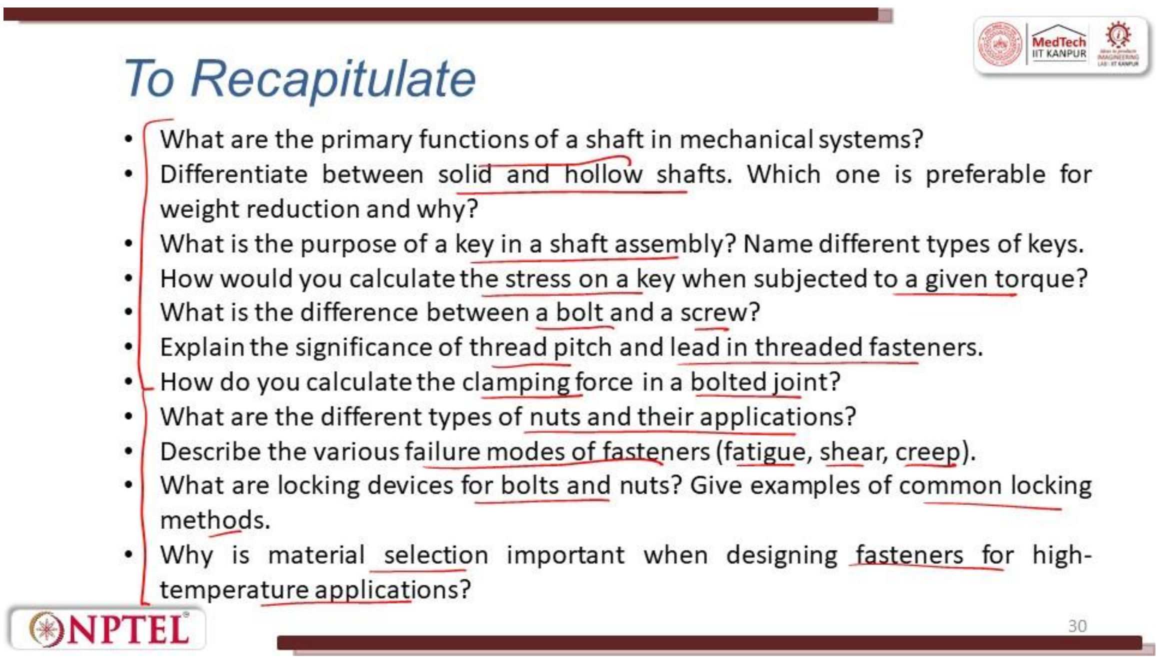
For a screw with a diameter d, the shear area is approximately:

$$A_{Shear} = \frac{\pi d^2}{4}$$

This approximation assumes the shear force is uniformly distributed over the screw's cross-section.

Shear stress could also be calculated. It is shear force per unit shear area. The shear stress in a screw is calculated based upon the applied shear force and shear area. $\tau = \frac{F_{shear}}{A_{shear}}$. F shear is shear force, A shear is shear area.

For a screw with diameter d, the area of shear could be calculated again as $A_{shear} = \frac{\pi d^2}{4}$. This approximation assumes that the shear force is uniformly distributed over the screws cross section. So, with this lecture, I am resting.



I will just recapitulate the things that I have covered. Let us try to see the question that could help you to ponder over the topics that were discussed in this lecture.

First question is what are the primary functions of a shaft in a mechanical system? Differentiate between solid and hollow shafts. Which one is preferable for weight reduction and why? What is the purpose of a key in a shaft and assembly? How would you calculate the stress on a key when subjected to a given torque?

What is difference between a bolt and a screw? Explain the significance of thread pitch and lead in threaded fasteners. How do you calculate clamping force in a bolted joint? What are the different types of nuts and their applications? Describe various failure modes of fasteners.

That is fatigue failure, shear failure, grip failure. This you can discuss and try to understand that. What are locking devices for bolts and nuts? Give examples of common locking devices. So, common locking methods that I have discussed.

Certain fasteners could be used to lock as well. Why is material selection important when designing fasteners for high temperature applications? There are certain questions which have repeated from the previous lecture as well, but you can go through them and try to understand the concept of keys, nuts, bolts, screws, fasteners in detail and we will keep discussing about different components and the systems in the machine design in the coming lectures.

References

1. Shigley, J.E., Mitchell, L.D. and Saunders, H., 1985. Mechanical engineering design.
2. Dechev, N., Cleghorn, W.L. and Mills, J.K., 2005, June. Design of grasping interface for microgrippers and micro-parts used in the microassembly of MEMS. (pp. 6-pp).
3. Bhandari, V.B., 2010. Design of machine elements. Tata McGraw-Hill Education.
4. Khurmi, R.S. and Gupta, J.K., 2005. Theory of machines. S. Chand Publishing.
5. Rattan, S.S., 2014. Theory of machines. Tata McGraw-Hill Education.

Thank you.