Basics of Mechanical Engineering-1

Prof. J. Ramkumar

Dr. Amandeep Singh

Department of Mechanical Engineering

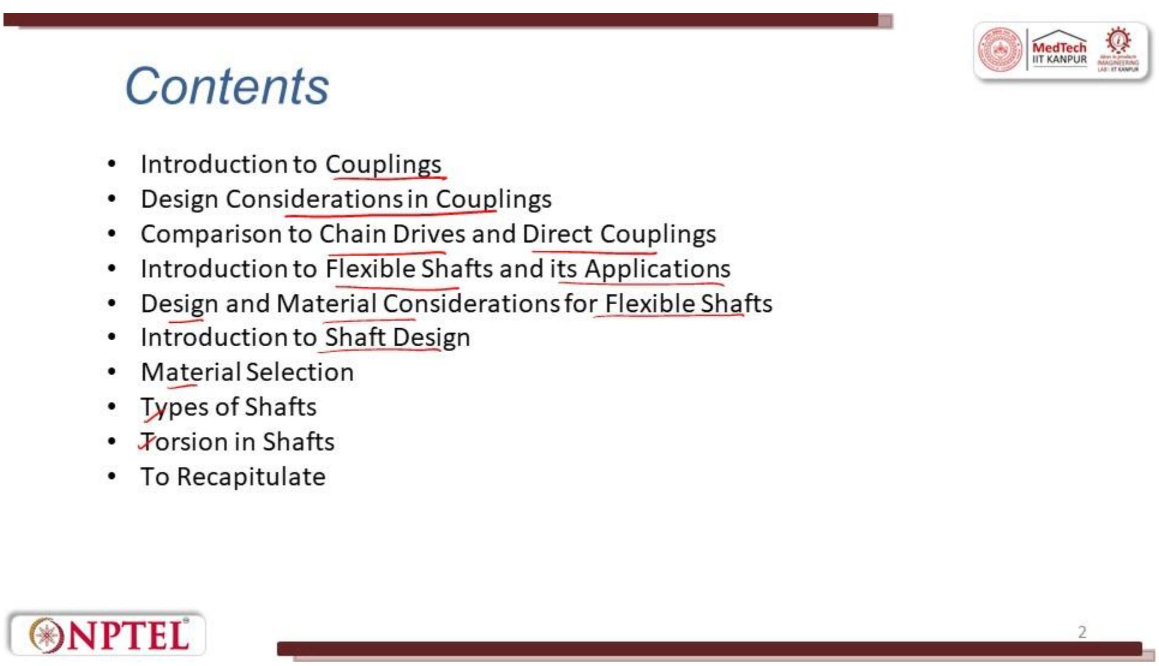
Indian Institute of Technology, Kanpur

Week 11

Lecture 44

Couplings and Shafts

Welcome to the next week in the course Basics of Mechanical Engineering 1. We are discussing the Components and Systems of the machines in this part of the week. For example, we will discuss Couplings and Shafts in this lecture. Further lectures in this week would include keys, belts, pulleys and different other components or the systems which are there in the machine development. So, Coupling and Shafts.

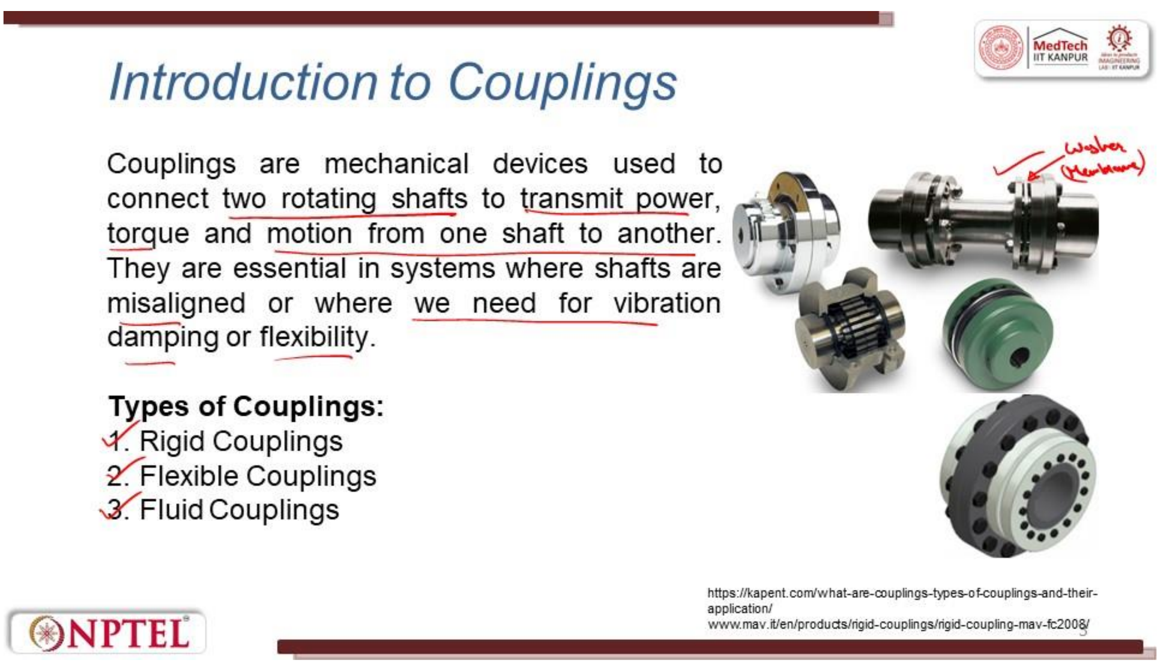


The contents in this lecture would flow like this. We will give you Introduction to the Couplings. What is the need of coupling? Couplings are generally used in machinery to connect shafts or to transmit power. It has several roles.

For example, two shafts are there which is a play between shafts. Coupling helps to cover that play. Then the coupling helps to have a flexibility between shafts. Couplings helps to curb the vibrations if those are there. Then they protect the components from the impact or torque overload etc.

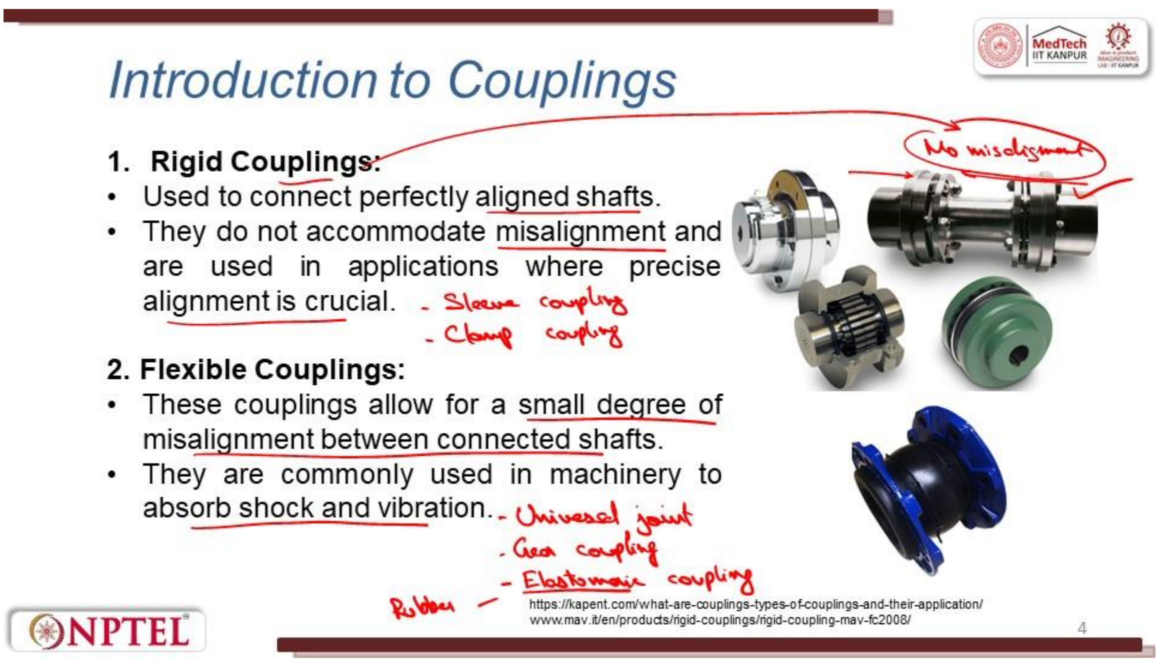
The equipment performance is also increased when you use couplings also. So, certain Design Considerations are there when we design couplings. We will also Compare couplings to the Chain Drives. Chain drives will be discussed in the coming lectures in this week. Then Flexible Shafts and its Applications will be discussed.

Design and Material Considerations for flexible shafts and introduction to Shaft Design would be covered. Material selection for the shaft would also be covered. Types of Shaft and Torsion in the Shaft we will see certain numerical problems here. Different kinds of couplings are there, flexible coupling, rigid coupling in those further itself the classification could have single joint coupling or we call them as one piece split clamp coupling or two piece split clamp coupling. It could be three piece, four piece multiple couplings could be there.



Let us have a brief introduction on what coupling is. Couplings as mentioned here are mechanical devices used to connect two rotating shafts to transmit power. It could be used to transmit power, to transmit torque and transmit motion from one shaft to another. They are essential in systems where shafts are misaligned or where we need for vibration damping or flexibility. There are multiple types of couplings.

There are a few couplings which are shown here. You can see this is a very Rigid Coupling here. There could be some flexibility with a washer put over here or maybe we could put a membrane which is little flexible. So, there are different kinds of sub-couplings are there. Types of couplings could be rigid coupling, flexible coupling and fluid couplings where completely automatic transmission is expected that it is Fluid Coupling.

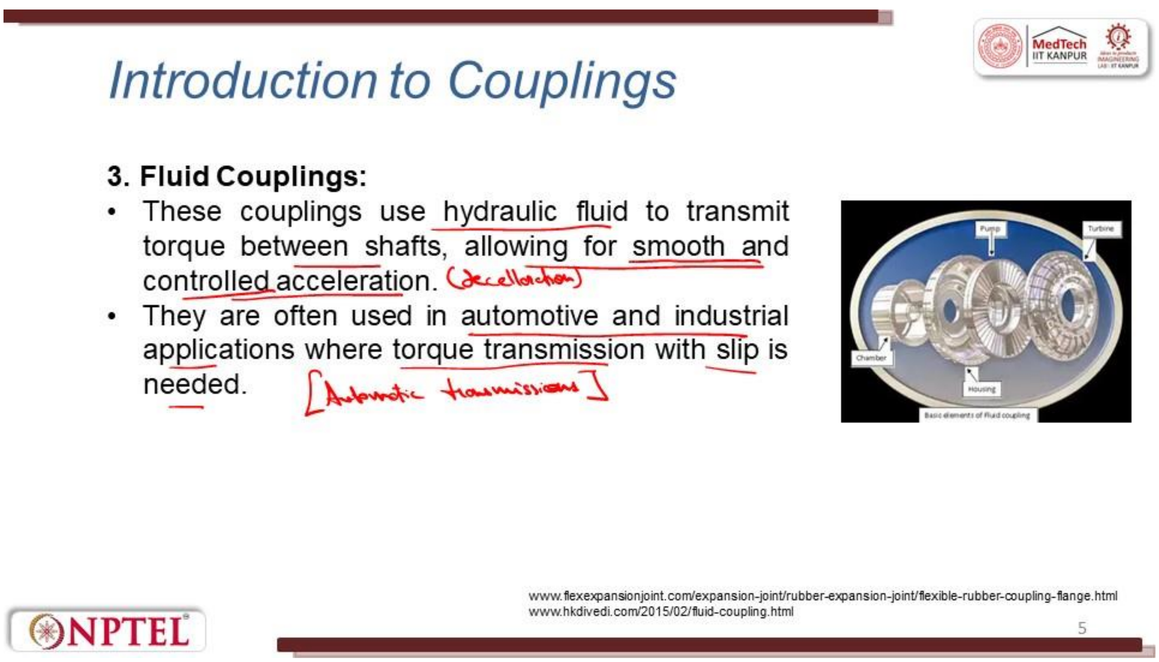


First is Rigid couplings. Rigid coupling is used to connect perfectly aligned shafts. When the shafts are perfectly aligned, that is there is no misalignment, then we use rigid couplings. When the axis of the two shafts are perfectly aligned to each other and those are exactly horizontal, then only rigid coupling could be used because there is no play that is allowed here. They do not accommodate misalignment and are used in applications where precise alignment is crucial.

Here, certain examples where these are used are sleeve couplings or it could be clamp couplings which in example given here. Then comes Flexible couplings. These couplings allow for a small degree of misalignment between connected shafts. They are commonly used in machinery to absorb shock and vibration. So, here because flexibility is now allowed to some degree.

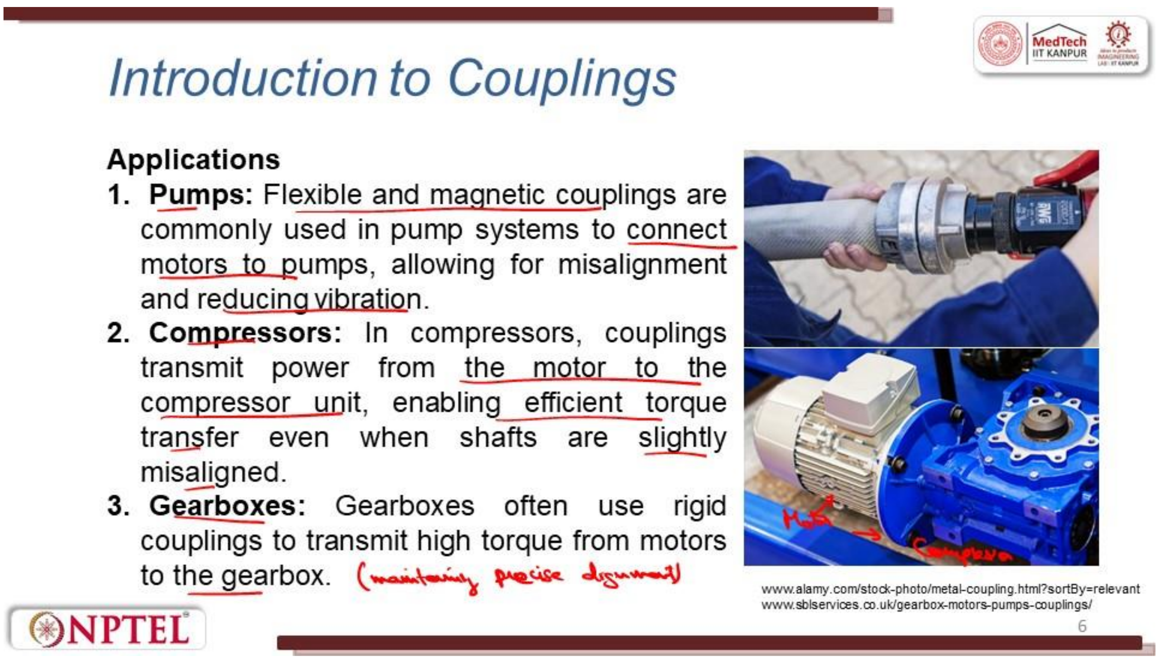
So, there could be certain coupling such as we have universal joint. Then we have gear coupling because vibrations in gears are there. So, those could be covered using this kind of a coupling. Also, we have Elastomeric couplings. When I say elastomers, they are materials or polymers such as rubber.

So rubber like material which has property that can be stretched when stressed even then it comes back to its original position for flexible couplings there that accommodates the misalignment between angle, between axis or so. Similarly, we have Fluid couplings.



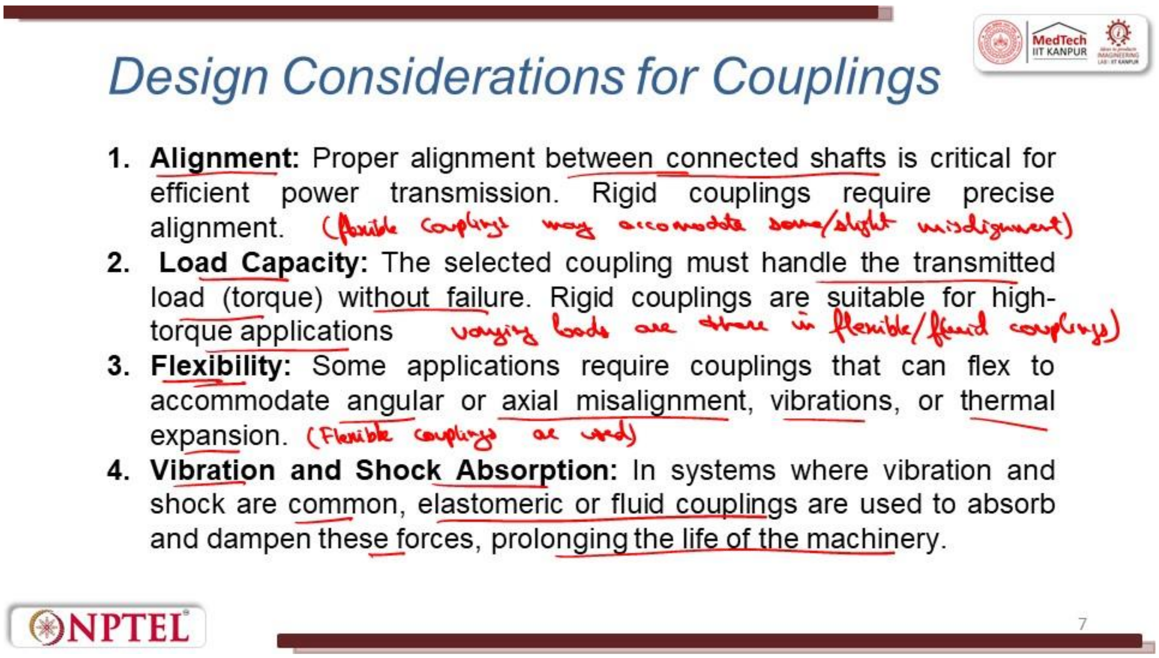
Fluid couplings are couplings that use hydraulic fluid to transmit torque between shafts, allowing for smooth and controlled acceleration. So smooth acceleration like nowadays we use hydraulic brakes in vehicles, in automobiles or so, where the smooth acceleration stopping of the car should be there or deceleration which is there in the car should be very smooth.

So hydraulic systems are there in the bikes itself, the bicycles use now hydraulic brakes where these kinds of couplings are there. The fluid helps to have a smooth and controlled acceleration or deceleration. They are often used in automotive and industrial applications where torque transmission with slip is needed. For example, in automatic transmissions. In automatic transmissions, because these are controlled by an automatic system, manual system is not there, so it is expected to be smooth so that a certain jerk doesn't happen.



Then, let us now see the certain applications of the couplings. Applications could be in pumps, in compressors, in gearboxes also. For example, in pumps, flexible and magnetic couplings are commonly used and these help to connect motors to pumps. This allows for misalignment and reduce the vibration. In compressors, couplings transmit power from the motor to compressor.

From the motor to compressor unit, the power is transmitted which enables efficient torque transfer even when shafts are slightly misaligned you can see from motor, this is the motor and this is our compressor unit the power is transmitted here then in gearboxes. Gearboxes often use rigid couplings to transmit high torque from motors to the gearbox. So, this maintains precise alignment.



Next comes Design Considerations in Couplings. First and foremost thing is Alignment. Proper alignment between connected shafts is critical for efficient power transmission. Rigid couplings require precise alignment, so while flexible couplings can accommodate some or slight misalignment. Flexible couplings may accommodate some or slight misalignment. Similarly, Load Capacity, selected coupling must be designed to handle the transmitted torque or transmitted load without failure. Rigid couplings are suitable for high torque applications because those are very rigid.

In flexible and fluid couplings, loads are varying because flexibility is there, it is not completely rigid transmission, varying loads are there in flexible and fluid couplings. Then comes Flexibility, some applications require couplings that can flex to accommodate angular or axial misalignment vibrations or thermal expansion. Flexible couplings are ideal for this use. The word flexibility means here flexible couplings are only used. Then comes Vibration and Shock Absorption.

In systems where vibration and shock are common, elastomeric or fluid couplings are used to absorb and dampen these forces prolonging the life of the machinery.

Then brief comparison between Chain Drives and Direct Couplings. Efficiency: chain drives are more efficient as they do not slip unlike belt drives direct coupling is even more efficient but rigid with no flexibility for distance or alignment issue, so that means if I talk about slip maximum possible slip that is there is in bell drives. This is more than what is there in chain drives.

This is even more than some of the rigid couplings. This is about the slip. Then comes Durability. Chain drives last longer but require more maintenance, we'll talk about chain drives because the weight to the design ratio, the overall weight of the system increases when the chain drive is used, belts are lighter in weight, so belts are also quieter chains are little noisy but those wear out faster and in regular replacement. Belt drives are the most economical because we do not have to design any serrations or any accommodation of the coupling or the chain components there.

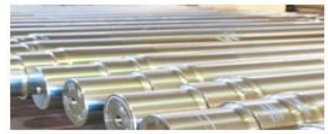
So, belts are most economical followed by chain drives and direct coupling is expensive, but efficient in specific application. So, if I say Cost, again I would put it as belt chain. So, this cost is lesser, belt is lesser than chain is lesser than the couplings. This is cost, this is slip that is being allowed here.

Introduction to Shafts

A shaft is a rotating machine element, usually circular in cross section, which is used to transmit power from one part to another or from a machine which produces power to a machine which absorbs power.

Role of Shafts in Power Transmission:

- Shafts are critical mechanical components used to transmit rotational motion and power in machinery.
- They connect various machine elements such as gears, pulleys and couplings, ensuring efficient power transfer from one component to another.



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www.driveshaftsoftulsa.com/blogs/news/the-different-drive-shaft-components

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Now comes the general Shafts introduction. A shaft is a rotating machine element usually circular in cross section which is used to transmit power from one part to another or from a machine which produces power to machine which absorbs power. A machine that produces power, I would say your engine in your automobile that produces power, from there the transmission torque is there that transmits the power to the wheels so that absorbs the power and the wheels are rotated and the automobile moves. So, role of shafts in power transmission, shafts are critical mechanical components used to transmit rotational motion and power in machinery. They connect various machine elements such as gears, pulleys, couplings, ensuring efficient power transfer from one component to another.

Introduction to Shafts

Primary Function:
Transmit torque and rotational motion between connected parts, allowing for the functioning of engines, machines and vehicles.

Common Uses:
Shafts are found in vehicles (drive shafts), industrial machinery, conveyor systems, and pumps. They must endure various stresses like torsion, bending and axial forces during operation.

https://content.app-sources.com/s/39721457513420822/uploads/Images/Shaft_Sinking-1658536.jpg?format=webp

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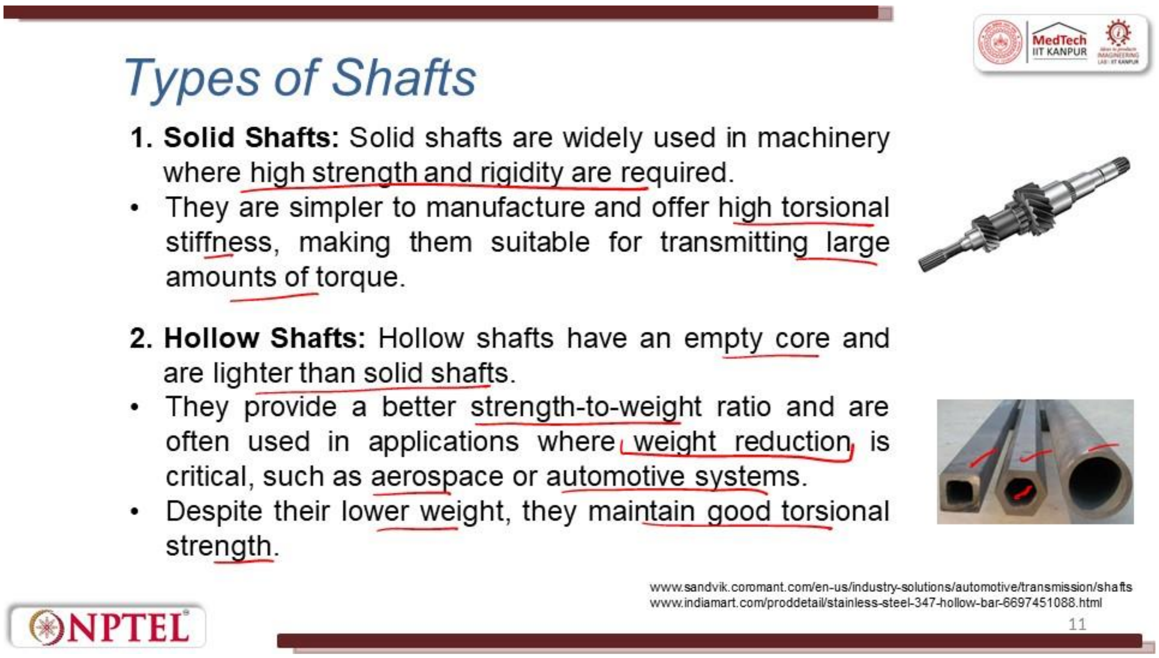
Their major functions that it does is transmit torque and rotational motion between connected parts allowing for functioning of engine, machines and vehicles.

Common uses of shafts are given here. These are found majorly in vehicles. For example, drive shafts and industrial machinery, conveyor systems and pumps. They must endure various stresses like torsion, bending, axial forces during operation. So, these all become the design consideration when we try to design a shaft.



Let us try to see the Types of Shafts. Shafts could be of multiple types, it could be solid, it could be hollow, fixed or rotating. So what are Solid Shafts? Solid Shafts are widely used in machinery where high strength and rigidity are required. Like we talked about the Rigid Coupling, Solid Shafts are used where high strength is required, they are simpler to manufacture and offer high torsional stiffness making them suitable for transmitting large amounts of torque because these shafts have no joints these do not have any angles between them in general. So these are straight rods which are divided for the rotational motion.

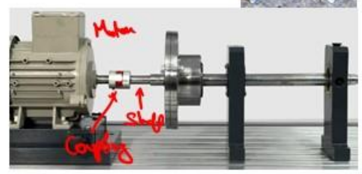
So they are solid and they can transmit power with high strength and rigidity. Then comes Hollow Shafts. We call them Hollow Shafts or Hollow Pipes are there. This could be used as shafts as well. Hollow shafts have an empty core and lighter than solid shaft.

The light weight or strength to weight advantage or strength to weight ratio is always better here and these are often used in applications where weight reduction is the requirement or weight reduction is critical. It is mentioned here such as in aerospace, in automotive systems or so where weight is to be reduced but strength is required equivalent so there the hollow shafts are used despite their lower weight they maintain good torsional strength. This is again law of physics, you understand when for the same material when the pipe is hollow or a shaft is hollow, it would have strength even higher than what is there in the solid shaft.

Types of Shafts

3. **Fixed Shafts:** Fixed shafts are stationary and serve as support for rotating components like pulleys or gears.
- These shafts do not rotate but carry the load of rotating elements.

4. **Rotating Shafts:** Rotating shafts are responsible for transmitting rotational motion and torque.
- They are subjected to torsional stress and bending loads due to their rotation and are often used in motors, gearboxes, and drives.



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Then comes Fixed shafts. Fixed shafts are stationary and serve as support for rotating components like pulleys or gas.

These shafts do not rotate but carry load of rotating elements. So, fixed shafts are there that only carry loads they do not rotate. Rotating shafts are there which are actually related. Rotating shafts are responsible for transmitting rotational motion and torque. For example, this is a rotating shaft from a motor.

We have a shaft here and this is a coupling. The motion is being transmitted here. They are subjected to torsional stress and bending loads due to their rotation and often used in motors, gearboxes and drives.

Shafts Material Selection

Criteria for Selecting Materials for Shafts:

1. **Strength:**
- The shaft material must be strong enough to withstand the applied torque and forces without failing.
- High tensile and shear strength are critical for reliable performance.

2. **Fatigue Resistance:**
- Shafts experience cyclic loading, which can lead to fatigue failure.
- Materials with high fatigue strength, such as alloy steels, are preferred for applications with repetitive loading.

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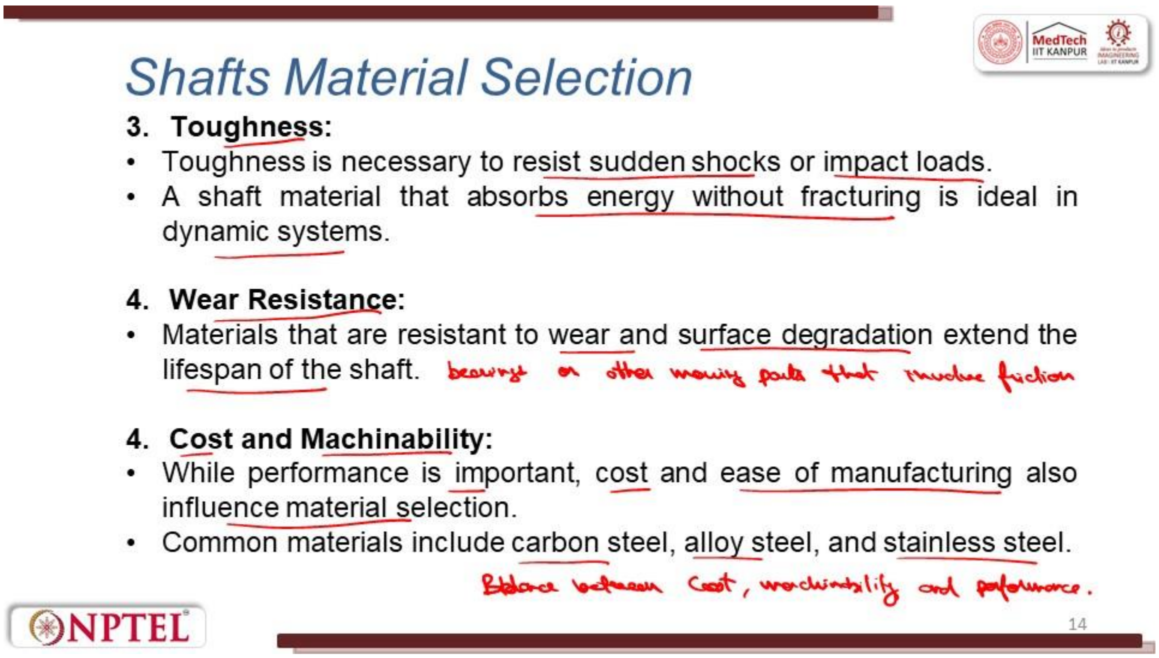
Let us try to now see the properties of the shaft material. That is the criteria for selecting materials for shafts.

First thing is Strength. The shaft material must be strong enough to withstand the applied torque and forces without failing. That is high tensile and shear strength are critical for reliable performance. Fatigue resistance like we took the example that we took the test for the strength of the components in like tensile test, compression test, those were for the shafts, bending test were also for the shafts, what is the bending strength there. So, those were all for the components such as shafts.

Fatigue strength is there where cyclic loading that is continuous vibrational loading is there that is tested on a component where shafts experience cyclic loading. So fatigue resistance which can lead to fatigue failure that is tested here. Materials with high fatigue strength such as alloy steels are preferred for applications with repetitive loading. So this is fatigue resistance. Also certain other criteria such as toughness, wear resistance, Cost or machinability those are there.



Let us see those toughness is necessary to resist sudden shocks or impact loads like the impact load that we had a experiment demonstrated in the previous weeks. A shaft material that absorbs energy without fracturing is ideal in dynamic systems. Without fracturing means for the specific load for which is designed. Then Wear Resistance, materials that are resistant to wear and surface degradation extend the lifespan of the shaft because the surface of the shaft is prone to corrosion, is prone to rust also. So, Wear Resistance and surface degradation should be the property that is required.

Then comes Cost and Machinability. We could use shafts made of alloy steel or beware. But that shaft would be very expensive. Machinability of those shafts would be very tough to be taken off. So then cost becomes a factor.

While performance is important, cost and ease of manufacturing also influence the material selection. Here common materials include carbon steel, alloy steel, stainless steel or so. For example, carbon steel would be very expensive that can be used at the places where even stainless steel will be used but this is cost inefficient if you do it. So, wear resistance if I say, this is more critical when we talk about bearings which involves friction or other moving parts involve friction. Similarly, we talked about Cost and Machinability. So, there should be a balance between Cost, Machinability and Performance.

Introduction to Flexible Shafts

- Flexible shafts are mechanical components designed to transmit torque and rotational motion between two points, even when the shafts are bent or misaligned.
- These shafts consist of wound steel wire or other flexible materials that allow for bending without losing the ability to transfer power.

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www.goodway.com/accessories/tube-cleaner-shafts-brushes-machine-accessories/flexible-shaft-dry-tube-cleaning-super

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Then comes Flexible shafts these are the shafts which are flexible you could see. Flexible shafts are mechanical components designed to transmit torque and rotational motion between two points even when the shafts are bent or misaligned these are completely bent or flexible shafts here this is a flexible shaft here. These shafts consist of wound steel wire or other flexible materials that allow for bending without losing the ability to transfer power allow for bending is that critical or the keyword here.

Introduction to Flexible Shafts

Importance in Torque Transmission:

- Flexible shafts enable power transmission in systems where direct alignment of the driving and driven shafts is not possible, offering flexibility. Reduces the need of precise alignment.
- They accommodate angular, axial, and even offset misalignments, making them versatile for applications in tight spaces or systems that require rotational motion in multiple directions.

So, importance of the flexible shaft in torque transmission, flexible shafts enable power transmission in systems where direct alignment of driving and driven shaft is not possible offering flexibility to this reduce the need of precise alignment.

They accommodate angular, axial and even offset misalignments which make them versatile for applications and tight spaces or systems that require rotational motion in multiple directions. So these are flexible shafts.

Applications of Flexible Shafts

1. **Automotive Systems:** Flexible shafts are used in speedometers, throttle linkages, and transmission systems where direct drive connections are difficult or impractical.
2. **Remote Power Transmission:** Flexible shafts are employed in applications where power needs to be transmitted over a distance, such as in conveyor systems or automated manufacturing lines.
3. **Hand Tools for Drilling:** In hand tools like flexible drills and grinders, flexible shafts allow the user to reach tight or awkward spaces, providing greater maneuverability.

Acceleration cable/shaft

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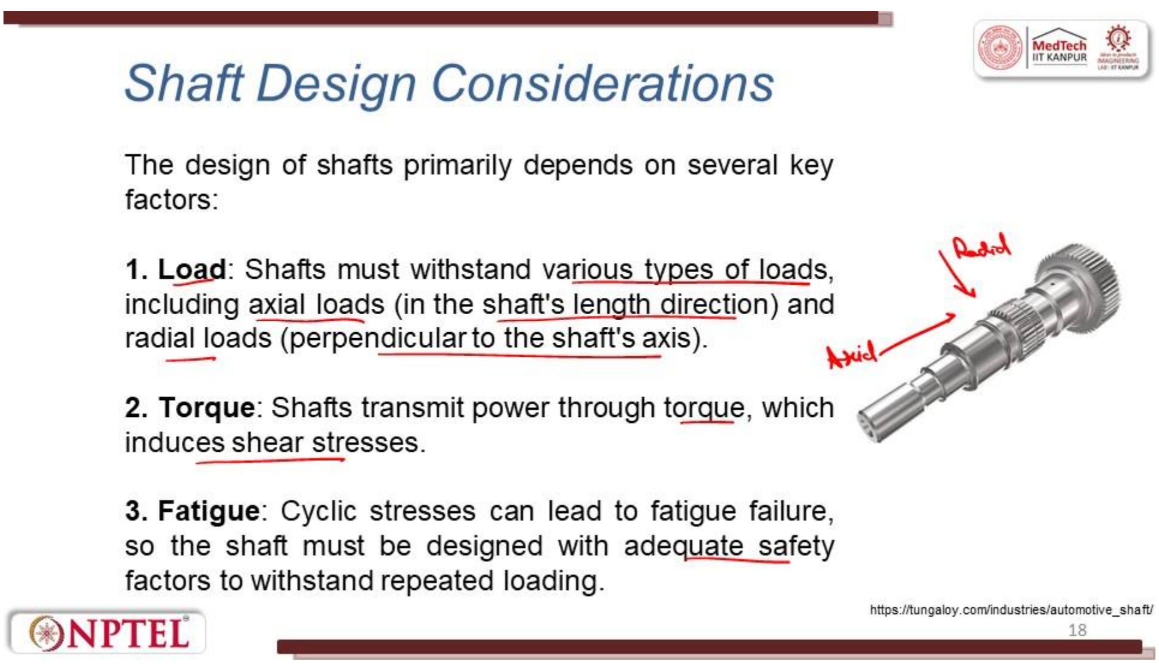
These are used in multiple places such as in automotive systems, in remote power transmission, in hand tools for drilling or so. Flexible shafts are used in speedometers in automated systems, in throttle linkages and transmission systems where direct drive connections are difficult or impractical. For example, this is you can see an accelerator, you call it a wire or you call it shaft in automobile systems, in speedometers that is here.

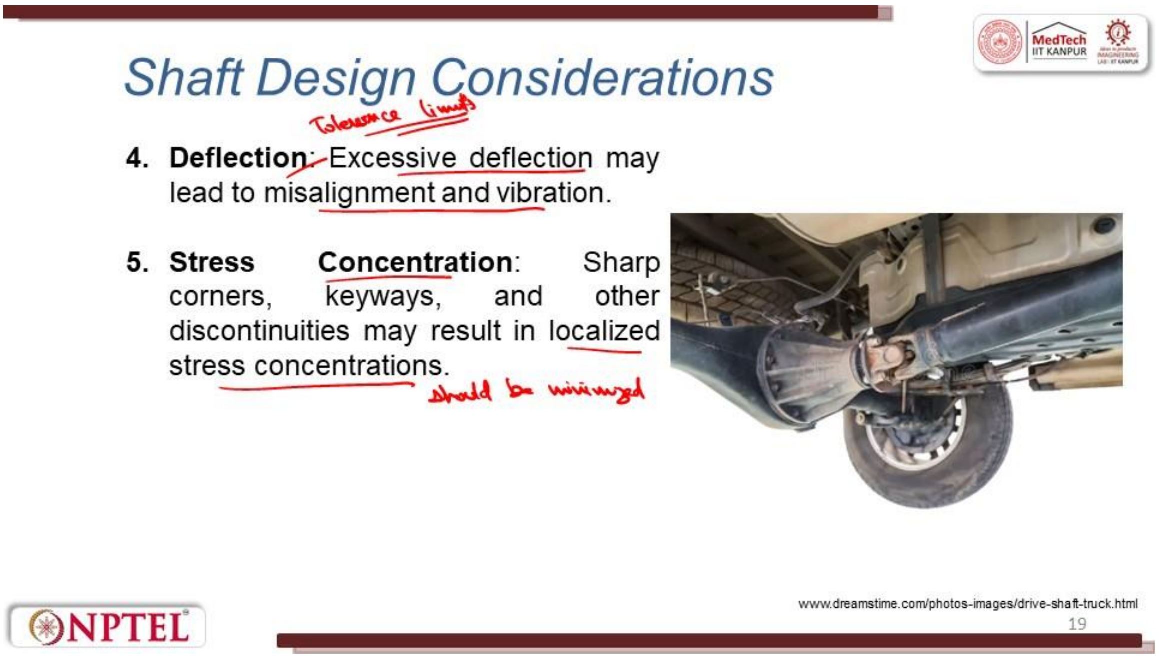
Then Remote Power Transmission flexible: shafts are employed in applications where power needs to be transmitted over a distance such as in conveyor systems or in automated manufacturing lines or so. Hand tools for Drilling in hand tools like flexible drills and grinders. Flexible shafts allow the user to reach tight or awkward spaces that is intricate or difficult to reach spaces which are there. In those cases, flexible shafts provide greater maneuverability. Let us see design considerations in shaft.

Like we talked about the strength, the load that shaft could withstand is a consideration. Shafts must withstand various types of Load. For example, axial loads in the shaft's length direction and radial loads in perpendicular to the shaft axis. So, in this direction, it is axial. In this direction,



It is radial. Torque. Shaft transmit power through torque which induces shear stresses. Fatigue. Cyclic stresses can lead to fatigue failure to the shaft.

This must be designed with adequate safety. This is discussed when we talked about the shaft. So regarding the flexible shafts when we try to talk about the proper design ensures shaft can carry torque without failure.

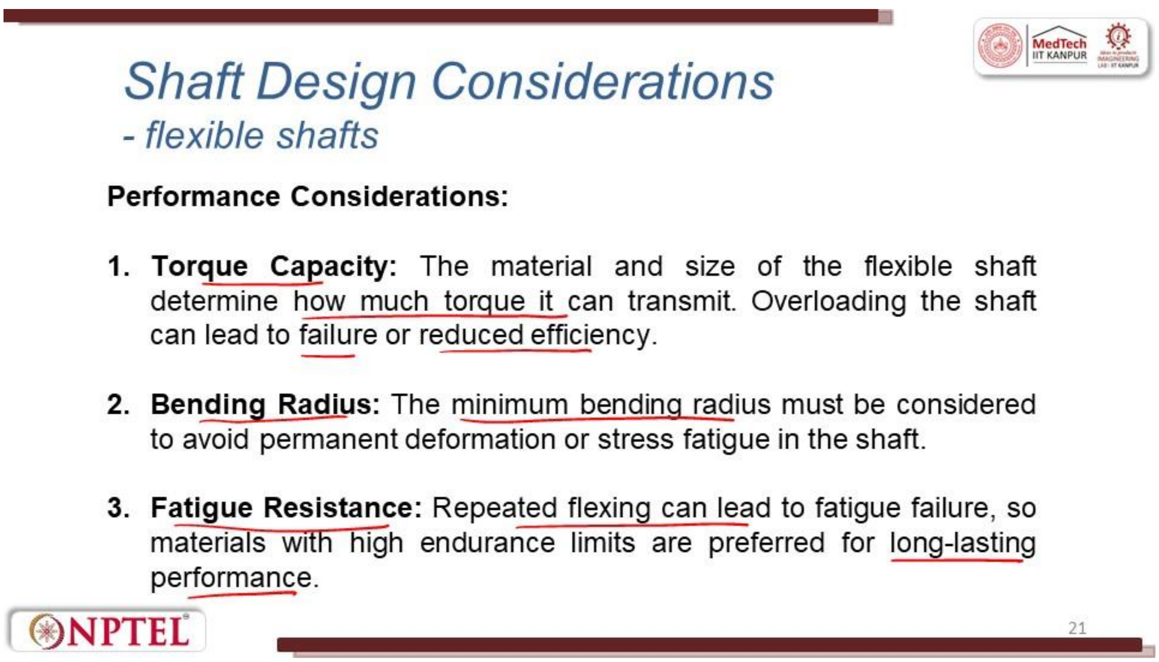


So deflection in the shaft that what is the allowed deflection that is there, excessive deflection should not be there, whatever tolerance limits are there for deflection those are only taken. There are tolerances or tolerance limits between which the flexibility is allowed or deflection is allowed.

Stress Concentration, sharp corners, keyways and other discontinuities may result in localized stress concentrations. So, these should be avoided when we talk about the shaft design. If not avoided, the stress concentration areas should be minimized.

Then, regarding the flexible shafts, when we talk about the design consideration, flexible shaft geometry, the diameter of the flexible shaft directly imparts the torque capacity. Larger diameters can handle high torques, while smaller diameters are more flexible, but with lower torque limits.

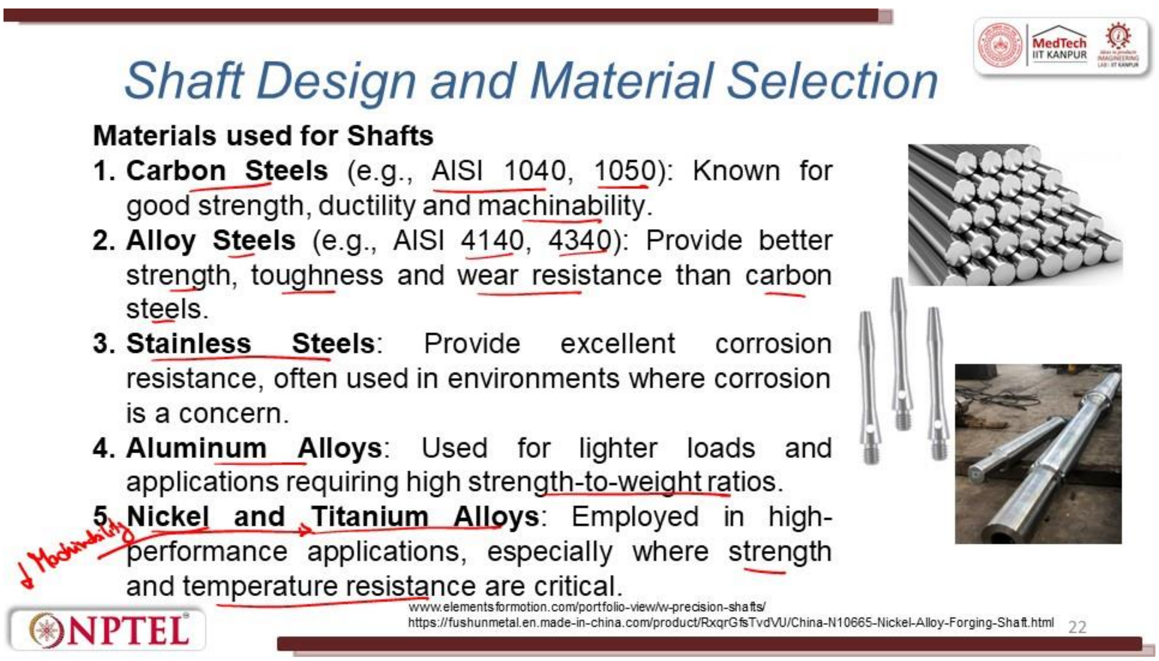
Then winding pattern of the wire, that is, it could be spiral or helical. This affects the shaft's flexibility and the smoothness of power transmission. That is, what is a Geometry, whether it is wide, whether it is thin, that is modern diameter, whether it is spiral, whether it is helical. So, these determine the strength of the shaft.



Other than those, the regular criteria that we saw in the previous design for flexible shafts as well, the performance considerations such as the Torque Capacity, the Bending Radius, the Fatigue Resistance are taken.

In the Torque Capacity, the material and size of the flexible shaft determine how much torque it can transmit. Overloading the shaft can lead to failure or reduced efficiency. Then comes Bending Radius. The minimum bending radius must be considered to avoid permanent deformation or stress fatigue in the shaft. Fatigue Resistance, this is again repeated flexing can lead to fatigue and failure.

Shafts, those are rotating and vibration is there. Fatigue failure is very prominent there. So that is why fatigue is coming time and again when we talk about the regular shaft design, when we talk about couplings, when we talk about the flexible shafts. So fatigue testing for the shafts becomes a critical characteristic to prefer a long-lasting performance in the shaft.



Materials used for shafts could be Carbon Steels, for example, AISI 1040 or 1050. This is known for good strength, ductility and machinability. Alloy steels, for example, AISI 4140 and 4340. These provide better strength, toughness and wear resistance than carbon steels. Then comes Stainless Steel. These provide excellent corrosion resistance often used in environments where corrosion is a concern.

So stainless steel is used where the resistance to corrosion is required more. Then comes Aluminium Alloys. These are used for lighter loads and applications requiring high strength to weight ratios. Aluminium because it is lighter in weight than the steel components. So when the strength to weight ratio is the concern aluminium oil is used to design a shaft or to take it as a material for the shaft.

Then comes Nickel or Titanium. Titanium again it is used when strength to weight ratio is required but machinability is an issue. I will put it here. Machinability that is difficult. I will put an arrow down side.

When we talk about titanium alloys, these are employed in high performance applications, especially where strength and temperature resistance are critical because high temperature strength or strength at red hot temperatures, that is also high for titanium alloys.

Then when we talk about materials for flexible shafts, steel and stainless steel are generally used. These are most common materials for flexible shafts due to their high strength, durability and ability to resist wear and fatigue. Then comes Composite materials. Composite materials are lightweight.

So lightweight composites and polymers are used for applications requiring corrosion resistance and lower weight. Then comes Flexible Steel Wire. The core of many flexible shafts consist of a tightly wound steel wire which provides the ability to flex while maintaining the required torque transmission properties.

Design Considerations for Flexible Shafts

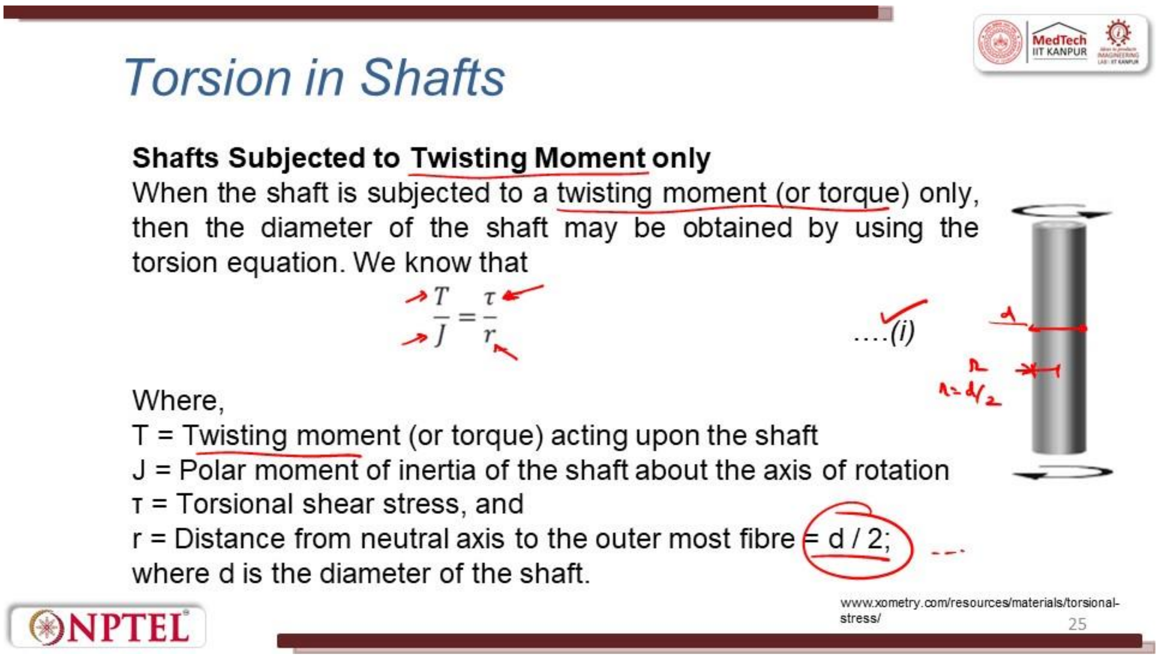
Applications

1. **Precision Instruments:**
   - Flexible shafts are used in devices such as optical systems and robotic arms, where precise control and motion in multiple planes are required.
2. **Medical Devices:**
   - In endoscopic instruments, flexible shafts enable the transmission of torque to tools inside the body, allowing surgeons to perform minimally invasive procedures with high precision.

https://veteriankey.com/endoscopic-instrumentation-and-documentation-for-flexible-and-rigid-endoscopy/

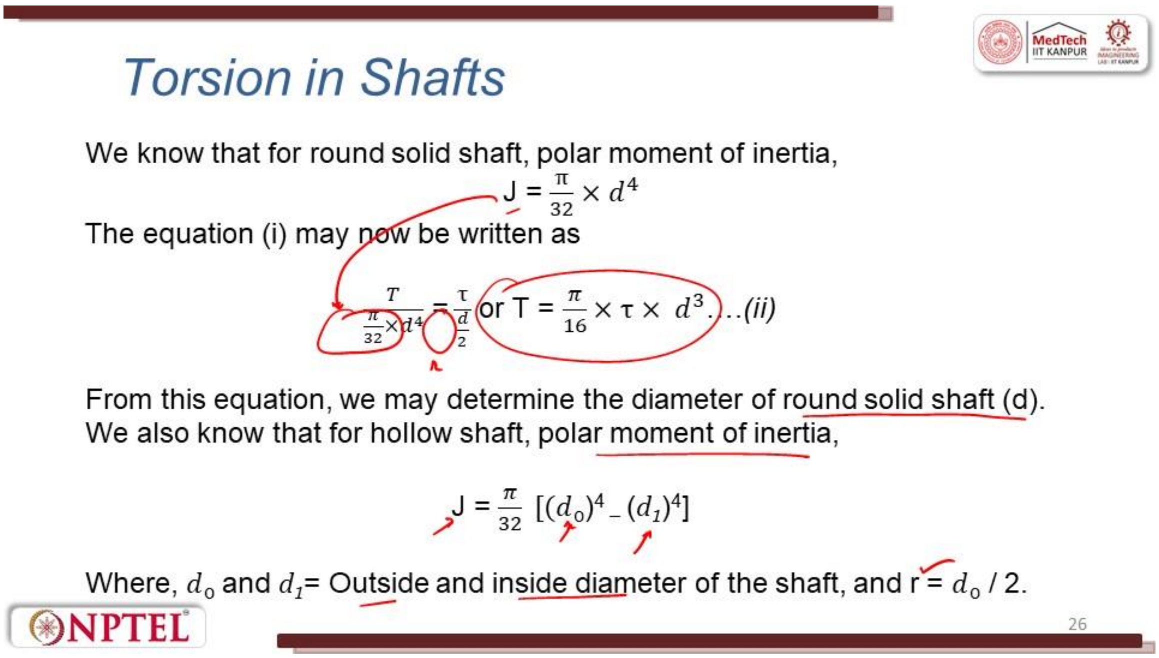
Design Considerations for Flexible Shafts. Let us talk to talk about the applications of flexible shafts. Flexible shafts are used in devices such as optical systems and robotic arms where precise control and motion in multiple planes are required. In medical devices, these are also used where in endoscopic instruments.

When the shaft goes inside the body through the anus or maybe sometimes through the mouth, flexible shafts enable the transmission of the torque to tools inside the body, allowing surgeons or for the diagnostic to perform minimally invasive procedures with high precision. So without cutting the body parts, shafts allow us to go inside and record the images. These are certain applications or the major applications for the flexible shafts.



Now, let us try to talk about the Torsion in Shafts. So, I will emotionally focus this on the twisting movement only, shafts which are subjected to twisting movement. When the shaft is subjected to a twisting movement or torque only, then diameter of the shaft may be obtained by using torsion equation, which we know $\frac{T}{J} = \frac{\tau}{r}$ where T is twisting moment that we mentioned here or torque acting upon the shaft, J is polar moment of inertia of the shaft about the axis of rotation, tau is the torsional shear stress. And r is the distance from the neutral axis to the outermost fiber.

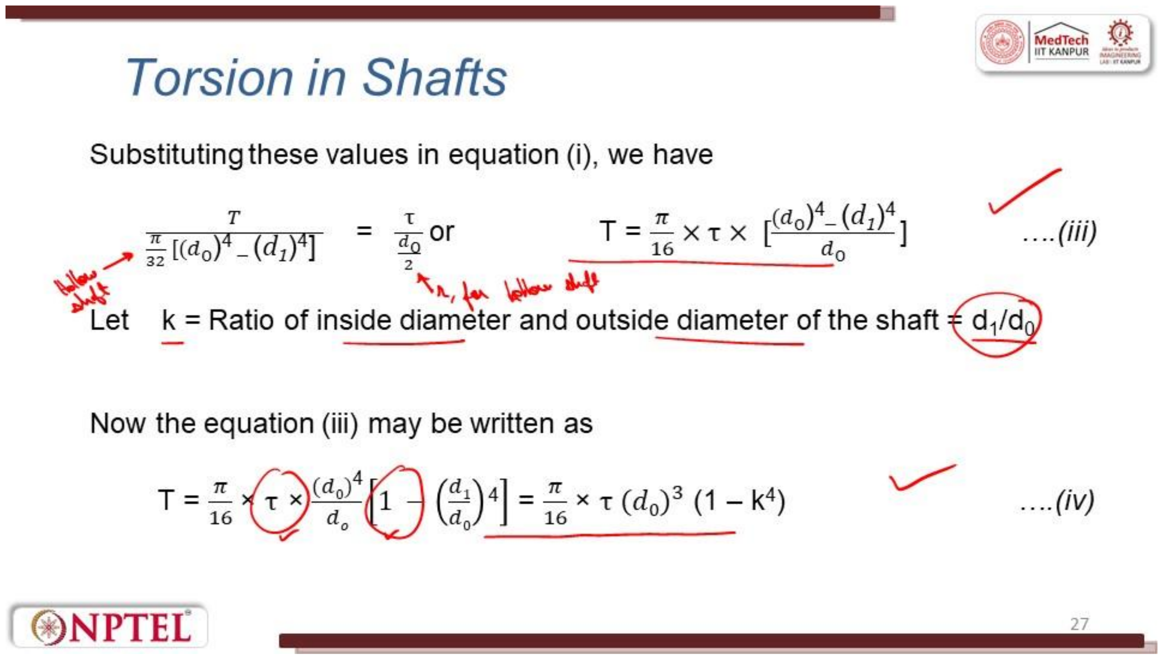
So, if I see this diagram, this r is here. This is my r, which is d/2, that is half of the diameter. This is d. So, r = d/2, which is given here, where d is diameter of the shaft.



Checking this, we know that for solid shaft, the polar moment of inertia $J = \frac{\pi}{32} \times d^4$. So, now equation 1 which is there, so this is equation 1 that could be rewritten here as

$$\frac{T}{\frac{\pi}{32}\times d^4} = \frac{\tau}{\frac{d}{2}} \text{ or } T = \frac{\pi}{16} \times \tau \times d^3$$

We also know that for hollow shaft, polar moment of inertia is this because when we talk about the hollow shaft, in hollow shaft, there are two diameters, that is the outside and inside d or we call it do or d_1. d_o is the outside diameter and d_1 is the inside diameter. So, it becomes the J. So, $J = \frac{\pi}{32} [(d_o)^4 - (d_1)^4]$. Here again r that is radius is equal to $d_o/2$.



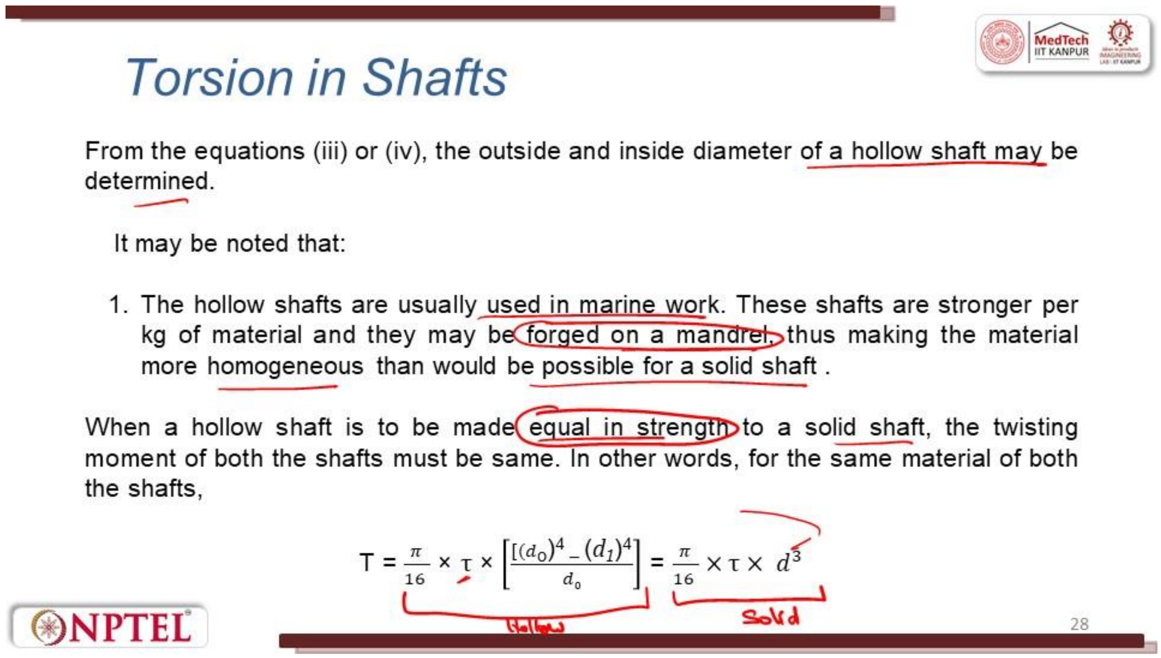
Now, I put the value for the hollow shaft here where

$$\frac{T}{\frac{\pi}{32}[(d_o)^4 - (d_I)^4]} = \frac{\tau}{\frac{d_o}{2}} \text{ or } \qquad T = \frac{\pi}{16} \times \tau \times \left[\frac{(d_o)^4 - (d_I)^4}{d_o}\right] \qquad \text{…..(iii)}$$

Let k = Ratio of inside diameter and outside diameter of the shaft = d_1/d_0

Now the equation (iii) may be written as

$$T = \frac{\pi}{16} \times \tau \times \frac{(d0)^4}{do}\left[1 - \left(\frac{d1}{d0}\right)^4\right] = \frac{\pi}{16} \times \tau\,(d0)^3\,(1 - k^4) \qquad \text{…..(iv)}$$

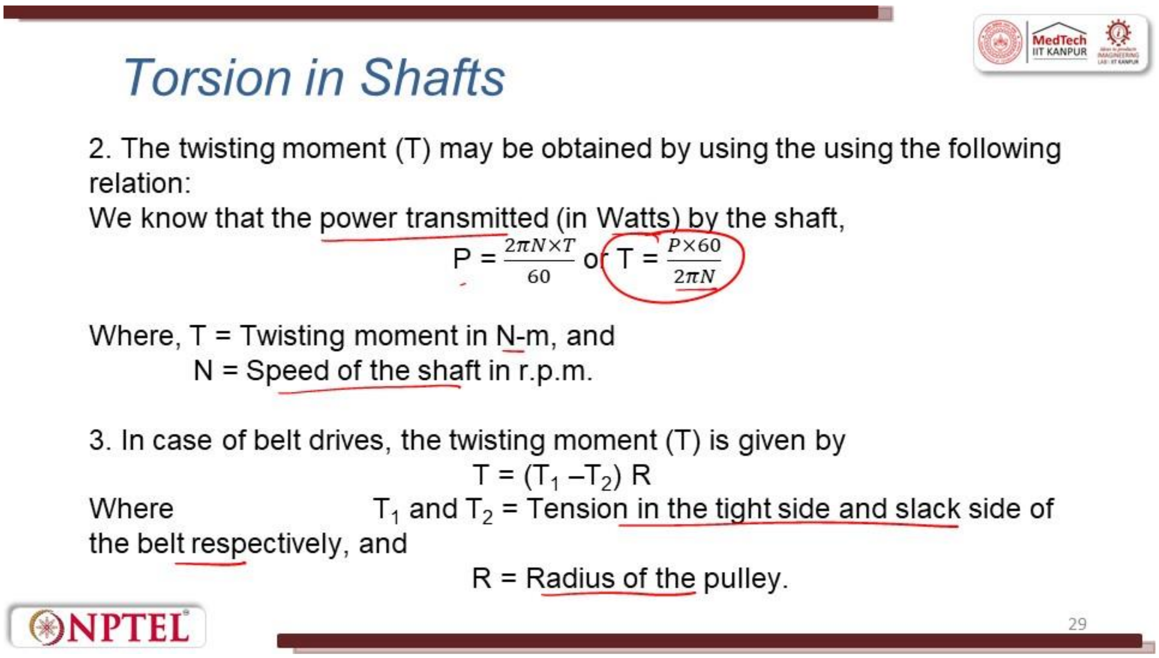


The outside and inside diameter of a hollow shaft may be determined. It may be noted that the hollow shafts are usually used in marine work. These shafts are stronger per kg of material than the solid shafts and they may be forged on a mandrel because those are hollow. So, when the shafts are hollow, for example, this is a shaft, this is a mandrel, this could be mounted on a mandrel.

So, these shafts are rotated and there is a mandrel that could be stationary that could even rotate with the shaft. So, thus making the material more homogeneous than would be possible for a solid shaft. So, this is a major application of the hollow shaft that could be forged on a mandrel. When a hollow shaft is to be made equal in strength to a solid shaft, the twisting moment of both the shafts must be same. In other words, for the same material of both the shafts, we are equating for the hollow shaft and for the solid shaft.

So, this is what I have for the hollow shaft and this is what I have for the solid shaft. So, to design them for equal strength, So, for the material to be of equal strength these are equated which is

$$T = \frac{\pi}{16} \times \tau \times \left[\frac{[(d_o)^4 - (d_I)^4]}{d0}\right] = \frac{\pi}{16} \times \tau \times d^3$$



Next is twisting moment may be obtained by using the following relation. Here we know that the power transmitted in watts by the shaft is V.

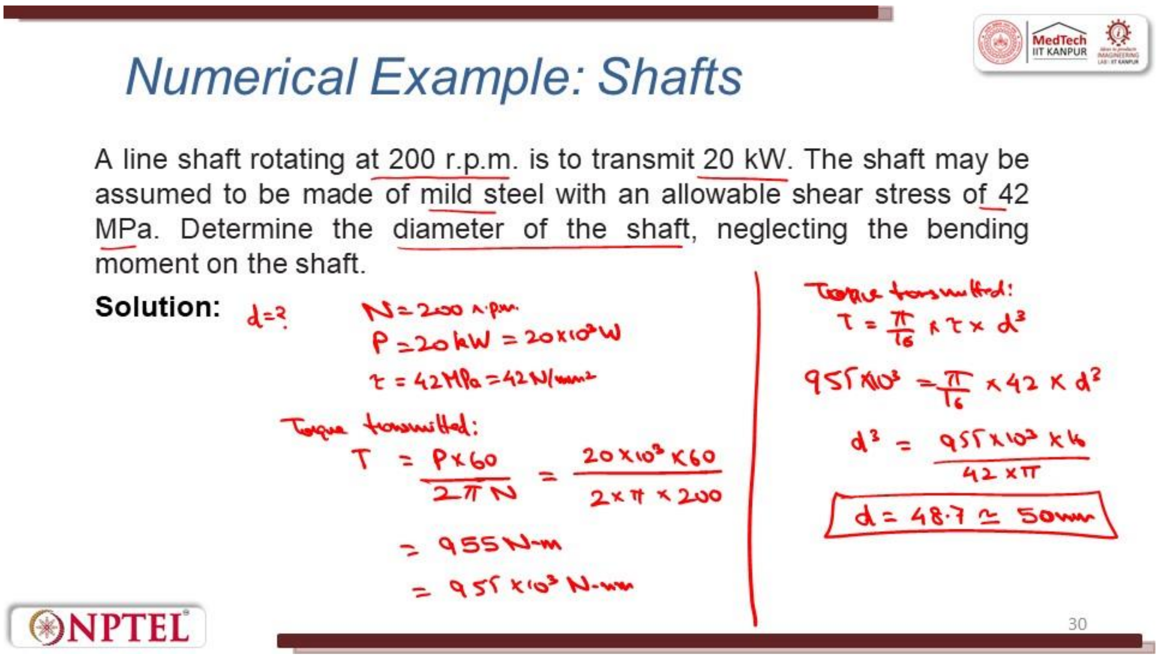
$$P = \frac{2\pi N \times T}{60} \text{ or } T = \frac{P \times 60}{2\pi N}$$

T is a twisting moment in Newton meter.

In case of belt drives, the twisting moment could be written as

$T = (T_1 - T_2) R$

Where, T_1 and T_2 = Tension in the tight side and slack side of the belt respectively and R = Radius of the pulley.



Let us try to solve a few numerical statements to understand the twisting moment and the torque that we have just understood in the previous slides. This is a problem statement that is given. A line shaft rotating at 200 rotations per minute is to transmit 20 kilowatts of the power. The shaft may be assumed to be made of mild steel with an allowable shear stress of 42 MPa. Determine the diameter of the shaft neglecting the bending movement of the shaft.

Solution:

N= 2000 rpm   P=20kW=20 X 10^2 σ=42 MPa=42N/mm^2 d=?

Torque transmitted:

$T = \frac{P\times60}{2\pi N} = \frac{20\times10^3\times60}{2\times\pi\times200}$ = 955 Nm = 955 X 10^3 Nm

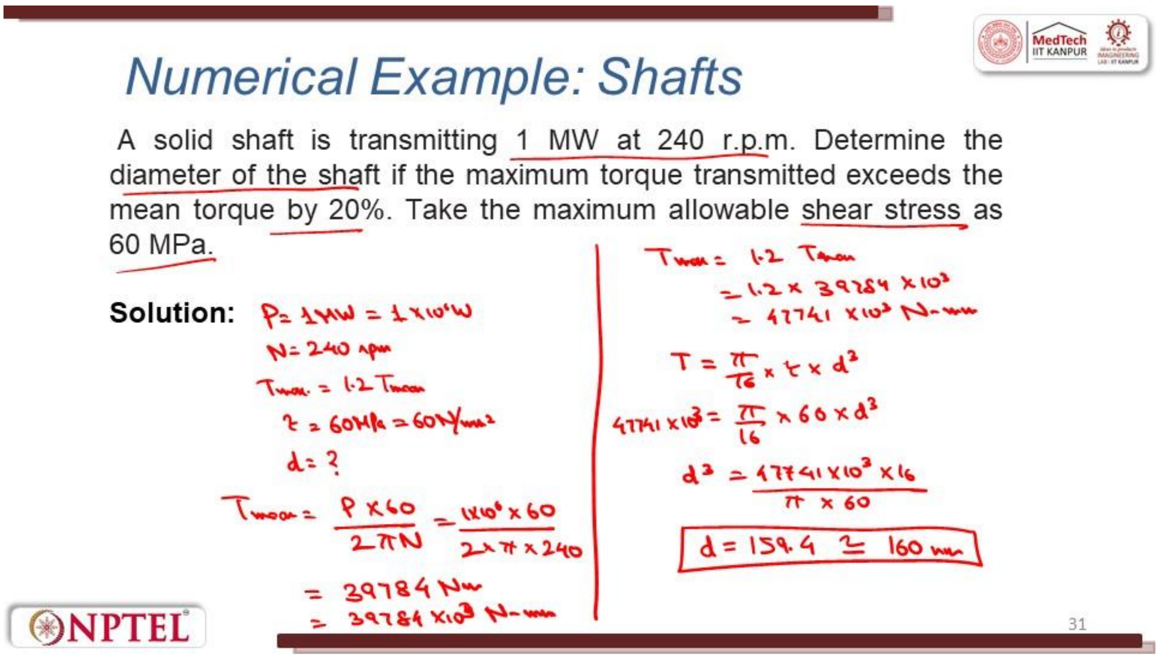
Torque Transmitted:

T = $\frac{\pi}{16} \times \sigma \times d^3$

955 X 10^3 = $\frac{\pi}{16} \times 42 \times d^3$

d^3 = $\frac{955\times10^3\times16}{42\times\pi}$

d = 48.7 ≈ 50 mm



Let us see another problem statement where it is given a solid shaft is transmitting 1 megawatt at 240 rpm. Determine the diameter of the shaft if the maximum torque transmitted exceeds the mean torque by 20 percent.

Solution: P = 1 MW = 1 X 10^6 W N = 240 rpm T_{max} = 1.2 T_{max} σ = 60MPa = 60 N/mm^2 d = ?

$T_{max} = \frac{P \times 60}{2\pi N} = \frac{1 \times 10^6 \times 60}{2 \times \pi \times 240}$ = 39784 Nm = 39784 × 10^3 N-mm

T_{max} = 1.2 T_{max}

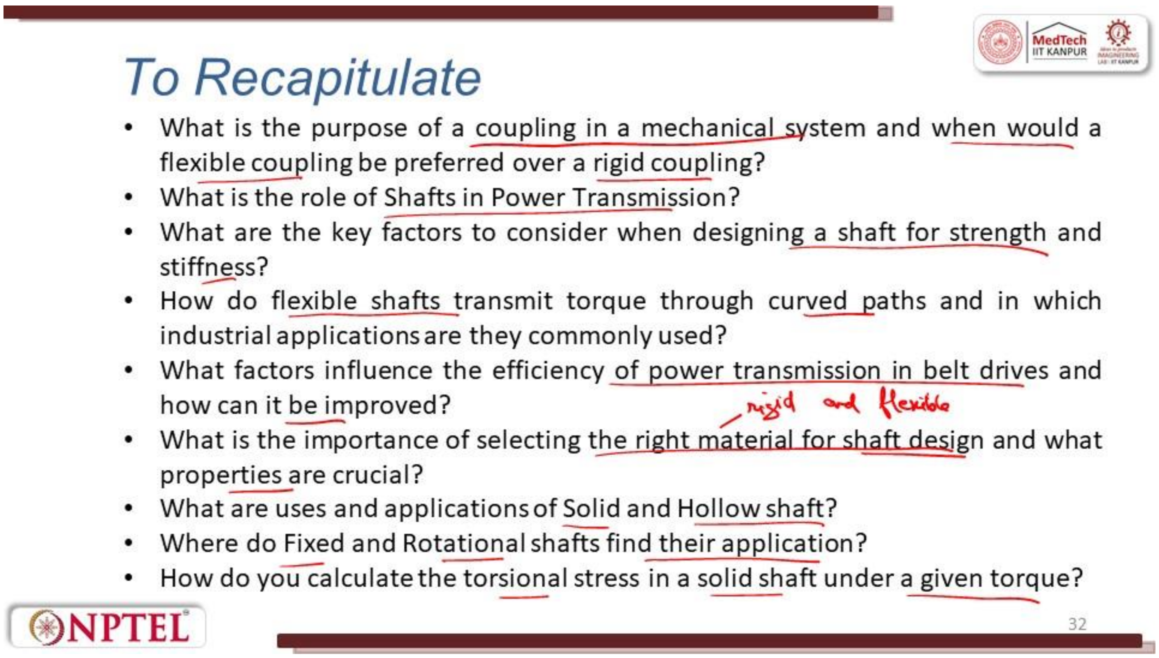
= 1.2 × 39784 × 10^3 = 47741 × 10^3 N-mm

$T = \frac{\pi}{16} \times \sigma \times d^2$

$47741 \times 10^3 = \frac{\pi}{16} \times 60 \times d^3$

$d^3 = \frac{47741 \times 10^3 \times 16}{\pi \times 60}$

d = 159.4 ≈ 160 mm



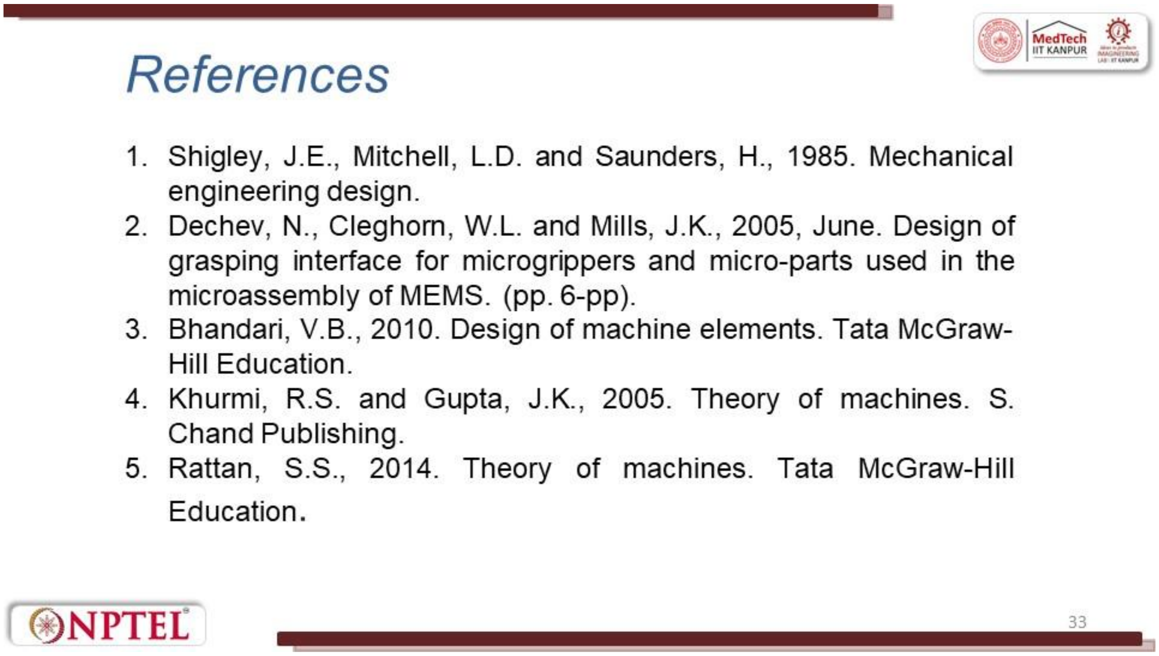
So, let us try to just recapitulate what we discussed in this lecture. The questions that you could ask yourself or try to introduce yourself to solve while going through this lecture and also going through the reference material.

First is what is the purpose of coupling in a mechanical system and when would a coupling that is flexible coupling preferred over a rigid coupling? What is the role of shafts in power transmission? What are the key factors to consider when designing a shaft for strength and stiffness? How do flexible shafts transmit torque through curved paths? And in which industrial applications they are commonly used?

Curved paths could be as I talked about the industrial application, talk about applications in automobile or so. You can answer those applications specifically where those are used. What factors influence the efficiency of power transmission in belt drives and how it can be improved? What is the importance of selecting right material for shaft design and what properties are crucial? When I say right material, we talked about both rigid and flexible.

So, all the characteristics or the design criteria which were there, try to list them down. So what are the uses and applications of solid and hollow shaft? The strength to weight ratio you can mention. Where do fixed and rotational shaft find their application? How do you calculate the torsional stress in solid shaft under a given torque?

And these are a few reference books which are taken for this PPT presentation and also certain other references were taken from the internet.



All the references of the sources are given. Beyond the figures which are presented in the different slides here. With this I am closing this lecture. I will meet in the next lecture where I will talk to talk about the keys and other components in the shaft systems as well which are used.

Thank you.