Basics of Mechanical Engineering-1

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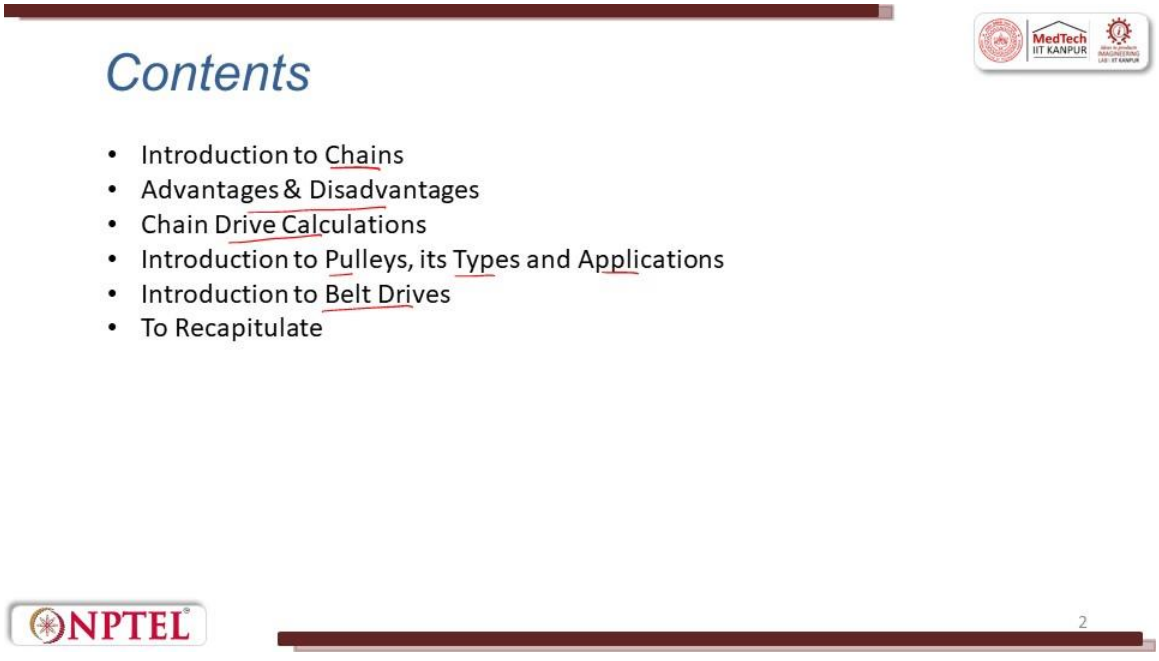
Week 11

Lecture 46

Chains, Pulleys and Belts

Welcome to the next lecture in the course Basics of Mechanical Engineering 1. I have discussed about couplings, shafts, keys, screws, fasteners in the last two lectures. This lecture would focus upon Chains, Pulleys and Belts which are again components or the parts of the machine development. We are talking about the theory of machines, we are talking about the design of the elements and we are now discussing about chains, pulleys and beds in this lecture.



I will go through the Introduction to Chains, its Advantages and Disadvantages over the other kinds of the power transmission systems and Chain Drive Calculations we will try to go through.

Then Introduction to Pulleys, its Types and Applications we will go through and also I will walk you through the belt drives and its types and we will recapitulate what we did in this week.

Introduction to Chains

Chains are flexible mechanical components used to transmit power and motion between sprockets in a system. Chains are widely employed in various applications due to their ability to handle high loads and operate over long distances.

Types of Chains:

1. **Roller Chains:** Composed of cylindrical rollers linked together by side plates. They are commonly used in conveyors, motorcycles, and bicycles.
2. **Silent Chains:** Designed with teeth that mesh smoothly with sprockets, silent chains reduce noise and vibration. They are often used in applications requiring quiet operation

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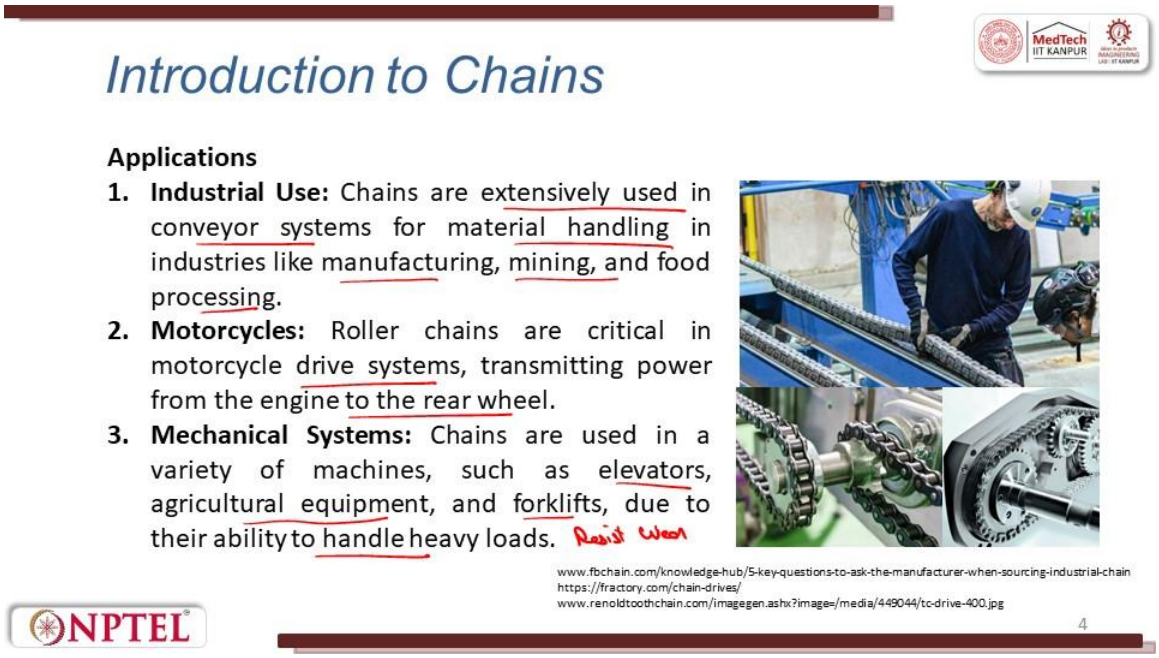
Introduction to Chains. Chains are flexible mechanical components used to transmit power and motion between sprockets. Now, make sure the point that is mentioned here is or the word that is mentioned here is between sprockets that is to run a chain, there needs to be a sprocket like you see a sprocket in your bicycle, machines which runs; chains are widely employed in various applications due to their ability to handle high loads and operate over long distances.

So, when the distances are very close by and the strength required is high, gears are used. If the distances are far, the big gear hub is to be built very difficult. So, that is why the chains are used. So, chains are of various kinds, roller chains, silent chains. Roller chains are generally composed of cylindrical rollers linked together by side plates.

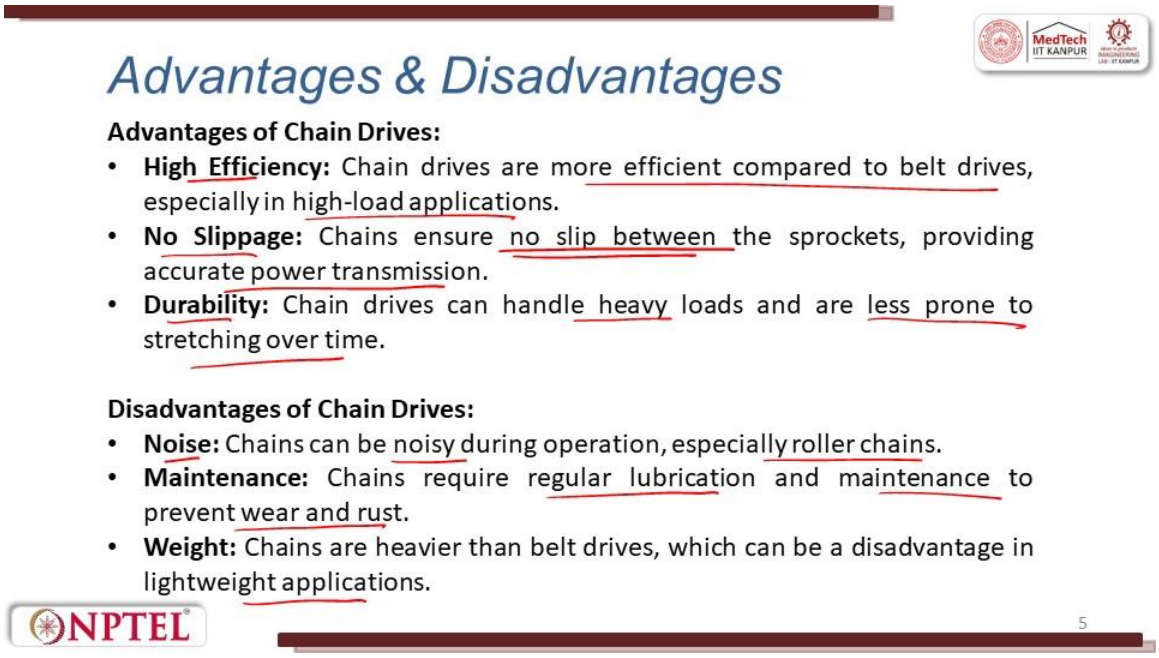
So, these are rollers and these are side plates. This is side plate and here inside we have a roller. They are commonly used in conveyors, motorcycles and bicycles. So, this is due to they have strength and durability. Silent chains.

These are designed with teeth that mesh smoothly with sprockets. Silent chains reduce the noise and vibration. These are often used in applications requiring quiet operation. For example, in your engines or your automotive timing chains I could put here. Automotive timing chains where the sound or the noise is to be reduced as far as possible.



A certain applications where change and use not only in automobile that you have seen there are industrial applications that you see in this figure. These are the chains which are there for a positive motion transformation. So, you can see chains are there to drive a conveyor belt here. So, industrial use is there that the chains are extensively used in conveyor systems for material handling in industries like manufacturing, mining, food processing, etc. Roller chains are critical in motorcycle drive systems, transmitting power from the engine to the rear wheel.

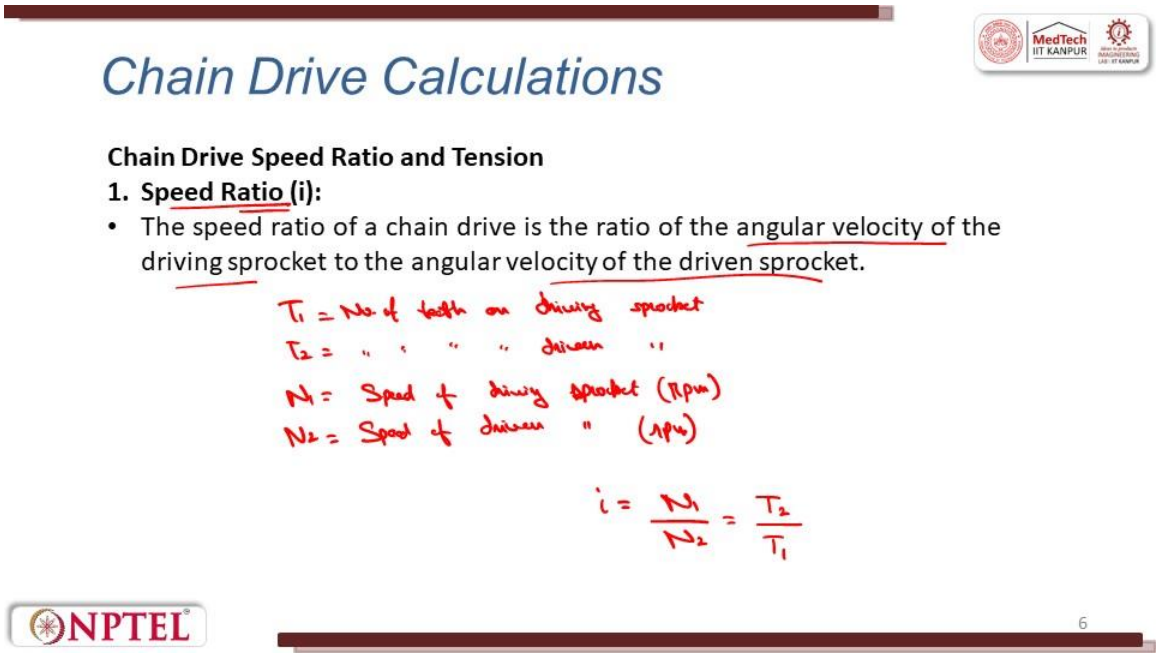
Mechanical systems chains are used in variety of machines such as elevators, agricultural equipment, forklifts due to their ability to handle heavy loads and they also are very useful when we have to resist wear.



When we try to talk about the pros and cons of the chain drives, the advantages could be put here as high efficiency, no slippage and durability. Because they run over this sprocket, slippage is not there. High Efficiency means chain drives are more efficient compared to belt drives, especially in high load applications, but they are also heavy. That would come as a disadvantage.

No Slippage, chains ensure no slip between the sprockets. That is the positive motion transmission without slippage. This provides accurate power transmission. Durability, chain drives can handle heavy loads and are less prone to stretching over time because those are all mechanical components. The rollers, the side plates are all made out of metal.

So, stretching is not there which is there in the case of belts. Disadvantages could be Noise because these again mechanical components, mechanical components made out of metal would produce noise. Your chains could be noisy during operation especially the roller chains. Maintenance, chains require regular lubrication and maintenance to prevent wear and rust. Weight, chains are heavier than belt drives which can be disadvantage in lightweight applications.



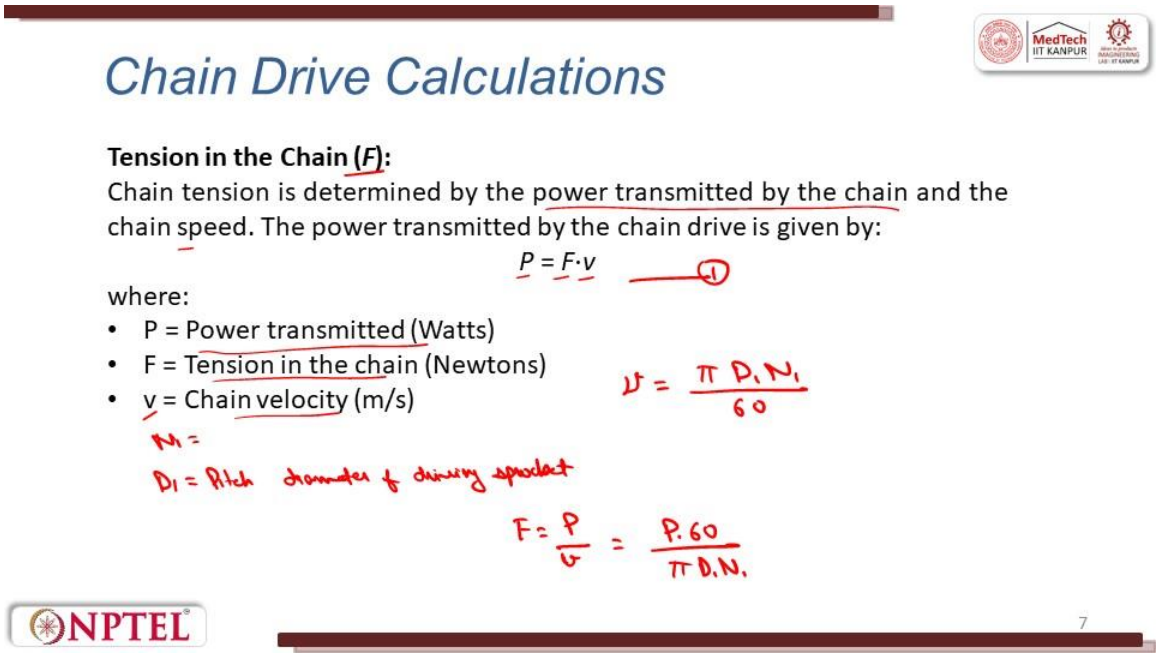
To calculate or to design a chain drive, we need to find its speed ratio. Speed ratio of a chain drive is the ratio of the angular velocity of the driving sprocket to the angular velocity of the driven sprocket.

- It can be expressed in terms of the number of teeth on the driving sprocket (T_1) and driven sprocket (T_2):

$$i = \frac{N_1}{N_2} = \frac{T_2}{T_1}$$

where:

- N_1 = Speed of the driving sprocket (RPM)
- N_2 = Speed of the driven sprocket (RPM)
- T_1 = Number of teeth on the driving sprocket
- T_2 = Number of teeth on the driven sprocket



This could help us to also calculate the tension in the chain, the tension in the chain F. It is determined by power transmitted by the chain and the chain speed, the power transmitted by the chain drive is given by:

$$P = F \cdot v$$

where:

- P = Power transmitted (Watts)
- F = Tension in the chain (Newtons)
- v = Chain velocity (m/s)

Chain velocity v is related to the speed of the driving sprocket and the pitch diameter D_1:

$$v = \frac{\pi D_1 N_1}{60}$$

Substituting v in the power equation, chain tension can be calculated as:

$$F = \frac{P}{v} = \frac{P \cdot 60}{\pi D_1 N_1}$$

Numerical Problem

A chain drive transmits 15 kW of power from a driving sprocket with a diameter of 0.25 m, rotating at 300 RPM, to a driven sprocket. Calculate:

1. The speed ratio
2. The chain tension

Solution:

$i = ?$; $F = ?$

$P = 15\ kW = 15 \times 10^3\ W$

$T_1 = 20$; $T_2 = 40$; $D_1 = 0.25\ m$

$N_1 = 300\ rpm$

$$i = \frac{T_2}{T_1} = \frac{40}{20} = 2$$

$$v = \frac{\pi D_1 N_1}{60} = \frac{\pi \times 0.25 \times 300}{60} = 3.927\ m/s$$

Chain Tension, F:

$$F = \frac{P \cdot 60}{\pi D_1 N_1} \quad \text{or} \quad F = \frac{P}{v}$$

$$F = \frac{15 \times 10^3 \times 60}{\pi \times 0.25 \times 300}$$

$$F = 3820\ N$$

So, based upon this relation let us try to go through a problem statement where they have given that a chain drive transmits 15 kilowatt of power from a driving sprocket with a diameter of 0.2 meters rotating at 300 rpm to the driven sprocket. Calculate the speed ratio, the chain tension.

Solution:

Speed Ratio (i):

- Given the number of teeth on the driving sprocket T_1=20 and on the driven sprocket T_2=40, the speed ratio is:

$$i = \frac{T_2}{T_1} = \frac{40}{20} = 2$$

This means the driven sprocket rotates at half the speed of the driving sprocket.

Chain Tension (F):

- Given:
  - Power P=15 kW=15,000 W
  - Diameter of driving sprocket D_1=0.25 m
  - Speed of driving sprocket N_1=300 RPM

First, calculate the chain velocity v:

$$v = \frac{\pi D_1 N_1}{60} = \frac{\pi \times 0.25 \times 300}{60} = 3.927\ \text{m/s}$$

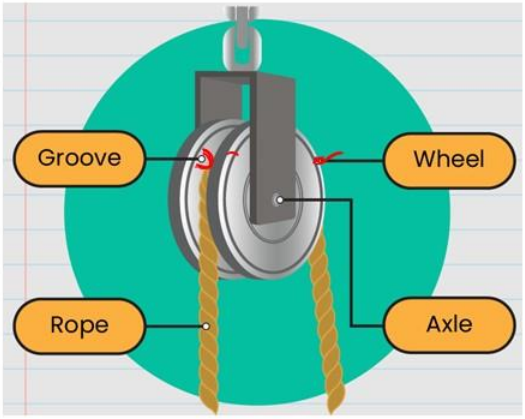
Now, calculate the chain tension F:

$$F = \frac{P \cdot 60}{\pi D_1 N_1} = \frac{15,000 \cdot 60}{\pi \times 0.25 \times 300} = 3,820\ \text{N}$$

Therefore, the chain tension is 3,820 N.

Introduction to Pulleys

- A pulley is a simple machine consisting of a wheel with a groove around its circumference, over which a rope or belt can run to transmit force and motion.
- Pulleys are used to lift loads, change the direction of force, and transmit power in various mechanical systems.



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Let me try to now talk about Pulleys. A pulley is a simple machine consisting of a wheel with a groove around its circumference. This is a wheel that has a groove around its circumference here.

So, this groove is to accommodate the belt or rope here. So, the groove that is there on its circumference over which a rope or belt can run to transmit force and motion. Pulleys are used to lift loads, change the direction of force and transmit power in various mechanical systems.

There are multiple types of pulley again, Fixed pulley, Movable pulley, Compound pulley, Belt and Pulley system. They are used for industrial lifting system, crane mechanisms, elevators, pump transmission or so.

There are again pros and cons. These we will discuss and we will also discuss about mechanical advantage that we take from a pulley and rope system.

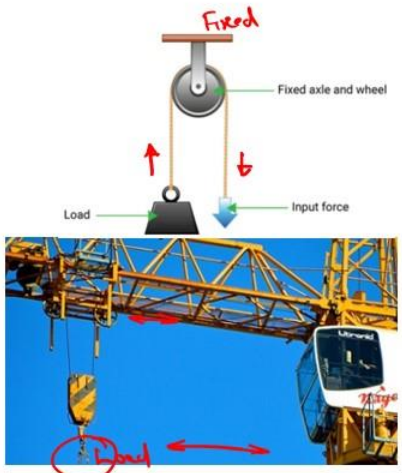
Types of Pulleys

1. **Fixed Pulley:**
   - A pulley that is fixed in place and rotates around a stationary axis.
   - It changes the direction of the force applied but does not provide a mechanical advantage.

   Used in Flagpoles or window blinds

2. **Movable Pulley:**
   - A pulley that moves with the load.
   - It provides a mechanical advantage by reducing the amount of input force needed to lift the load.

   Used in cranes and lifting systems



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https://study.com/academy/lesson/movable-pulley-definition-lesson-for-kids.html

Fixed pulley. So, regarding the types of pulleys, first type is Fixed pulley a pulley that is fixed in place and rotates around a stationary axis is a Fixed pulley. This is fixed here that means it is called as a Fixed Pulley.

So fixed axle and wheel is there only this wheel rotates it is a fixed pulley this is a load there is an input force that is there it changes direction of force applied but does not provide a mechanical advantage action of force means when the force is applied in this direction, this load is lifted up. It is change in direction only, but mechanical advantage is not there. That is whatever load you applied here, equivalent load will be pulled up. Movable pulley.

The pulley that moves with load, it provides a mechanical advantage by reducing the amount of input force needed to lift the load. So, this pulley is here, which is also movable along with this crane in the left or right direction here horizontal movement. So, instance a load could be held here if some load is here this load could be moved in this direction or in the other direction. So, that means it also provides a mechanical advantage along with taking the load up. So, this is how the pulley works here.

So, these kinds of movable pulleys are often used in cranes and lifting systems. And a general fixed pulley is commonly used in flag poles or may be for your window blinds where mechanical advantage is not required.

Types of Pulleys

3. Compound Pulley (Block and Tackle):

- A system of fixed and movable pulleys used together to create a mechanical advantage.
- This system significantly reduces the input force required to lift heavy objects.

Used in hoisting equipment

4. Belt and Pulley System:

- Used in power transmission, where belts loop around pulleys to transmit rotational motion between two shafts.
- These systems are common in machinery like engines and conveyor belts.

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https://fractory.com/belt-drives/

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Then comes another type that is compound pulley for block and tackle. A system of fixed and movable pulleys used together to create a mechanical advantage is known as a compound pulley where fixed pulleys are also there and the movable pulleys are also there. So, blocking and tackling both the things are there this system significantly reduces the input force required to lift heavy objects.

So there could be multiple pulleys, you can say multiple pulleys are there to hold a load and they can help us to hoist a system which is generally used in hoisting equipment. Then comes belt l pulley system. This is a pulley along with this we have a belt. So, this belt is rotating over a pulley. These are used majorly in power transmission where belts loop around the pulleys to transmit rotational motion between two shafts. These systems are common in machinery like engines and conveyor belts or so.

Applications of Pulleys

1. **Industrial Lifting Systems:**
   - In factories and civil sites, pulley systems are widely used in cranes and hoists.
   - A compound pulley system (block and tackle) enables workers to lift very heavy objects e.g. beams, blocks, machinery etc. by applying a fraction of force.

2. **Crane Mechanisms:**
   - Cranes use pulley systems to lift loads with significantly reduced effort.
   - The use of multiple pulleys allows a crane to lift heavy loads like building materials, shipping containers, or equipment with controlled and smooth operation.

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What are applications of using a pulley? Industrial lifting systems. In factories and civil sites, pulley systems are widely used in cranes and oil hoists. A compound pulley system that is block and tackle enables workers to lift very heavy objects, for example, beams, blocks, machinery, etc., by applying a fraction of force.

Crane Mechanisms. Cranes use pulley systems to lift loads with significantly reduced effort. The use of multiple pulleys allows a crane to lift heavy loads like building material, shipping container, equipment with control and smooth operation or so. You can see this is a pulley system where multiple pulleys are being used and these helps to drive. So these are drives, belt drives which are there which are driven through a pulley and a conveyor belt is there that helps to take the load.

Applications of Pulleys

3. Elevators:

- Elevators use pulley systems to lift or lower cabin using counterweights and cables, ensuring smooth vertical movement.

4. Power Transmission:

- Pulleys are used in engines and industrial machinery to transmit power between rotating shafts using belts or ropes. e.g. car engines, bicycles and industrial conveyor systems.

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Now next is it has Applications in Elevators. Elevators use pulley system to lift or lower cabin using counter weights and cables ensuring smooth vertical movement. So, there also pulley systems are there in Power Transmission pulleys are used in engines and industrial machinery to transmit power between rotating shafts using belts and ropes. So, those that is also one of the applications like in car engines, in bicycles, in industrial queer systems also. So, what are the advantages?

Introduction to Pulleys

Advantages of Pulleys:

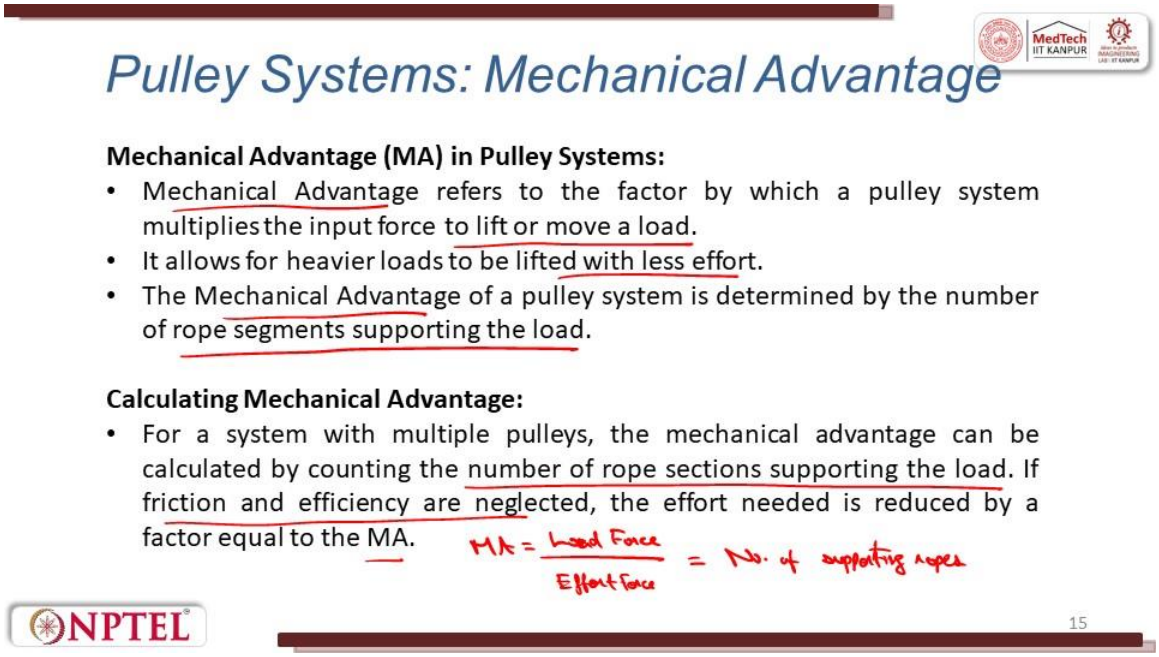
- **Mechanical Advantage:** Movable and compound pulleys reduce the input force needed to lift heavy loads.
- **Versatility:** Pulleys are adaptable to various applications, from simple load lifting to complex power transmission systems.

Disadvantages of Pulleys:

- **Friction:** In belt and pulley systems, friction can reduce efficiency, especially over long distances.
- **Space Requirements:** Some pulley systems, like block and tackle, require significant space to operate effectively. Slip (compound systems)

Major advantage is the mechanical advantage that is movable and compound pulleys reduce the input force needed to lift heavy loads. Versatility pulleys are adaptable to various applications from simple load lifting to complex power transmission systems. There are certain disadvantages because we are talking about pulleys not chains friction is there. In belt and pulley system friction can reduce efficiency especially over long distances. Then space requirements are there some pulley systems like block and tackle require significant space to operate efficiently and also there could even be a slip.

When the pulley systems are used and sprockets are not there chains are not there in some of the systems slip could also be there. Specifically, when we are talking about the compound systems.

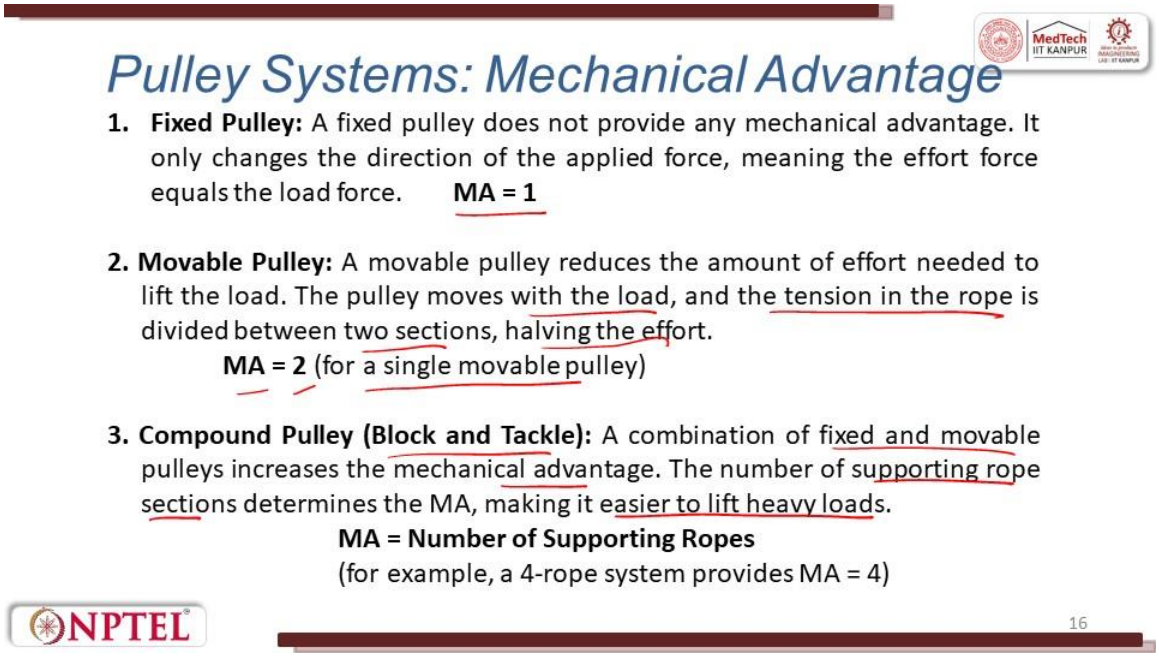


So, what is Mechanical Advantage in Pulleys? Mechanical advantage refers to the factor by which a pulley system multiplies the input force to lift or move a load. It allows for heavier loads to be lifted with less effort.

The MA or Mechanical Advantage of a pulley system is determined by the number of rope segments supporting the load. Calculating mechanical advantage for a system with multiple pulleys, the mechanical advantage can be calculated by counting the number of rope sections supporting the load. If friction and efficiency are neglected, the effort needed is reduced by a factor equal to MA that is

$$\text{MA} = \frac{\text{Load Force}}{\text{Effort Force}} = \text{Number of Supporting Ropes}$$

For example, if there is a load of 500 kg and there are 10 people who could pull 50 kg only, 10 ropes could be applied. Each person pulling 50 into 10, 500 kg load could be pulled up. So, load force by effort force is equal to number of supporting ropes that are applied to pull. That is Mechanical Advantage.



So, how do we calculate Mechanical Advantage? For a Fixed pulley, does not provide any mechanical advantage in general. It can only change direction of the applied force meaning the effort force equal to the load force here MA = 1. For a Movable pulley a movable pulley reduces the amount of effort needed to lift the load. The pulley moves with load and the tension in the rope is divided between two sections halving the effort that is mechanical advantage is 2 because the pulley moves for a single movable pulley only. Compound pulley that is block and tackle a combination of fixed and movable pulleys increases the mechanical advantage.

The number of supporting rope sections determines the mechanical advantage making it easier to lift heavy loads where mechanical advantage is equal to number of supporting ropes. For example, four rope system provides a mechanical advantage = 4.

Numerical Problem

In a crane with a block and tackle system having 5 supporting ropes, the mechanical advantage is MA=5. If the load is 1000 N, calculate the effort force required.

Solution:

$$MA = \frac{\text{Load Force}}{\text{Effort Force}}$$

$$5 = \frac{1000\ N}{\text{Effort Force}(?)}$$

$$\text{Effort force} = \frac{1000}{5}\ N = 200\ N$$

So, to have a simple calculation it is given a crane with a block and tackle system having 5 supporting ropes and mechanical advantage is 5, the load is 1000 Newton.

Mechanical advantage, here it is given, is 5. Load force is 1000 Newtons and effort force is what is asked. This is what is to be determined with this gives me effort force is equal to 1000 by 5 Newton which is equal to 200 Newtons. So, which means with only 200 Newton of effort 1000 Newton of load could be lifted with a mechanical advantage of 5.

Introduction to Belt Drives

Belt Drives:

- Belt drives are mechanical systems that use flexible belts to transmit power between rotating shafts.
- They are commonly used in machines and vehicles for power transmission over long distances.

Types of Belts:

1. Flat Belts
2. V-Belts
3. Timing Belts

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So, with a brief introduction to pulleys let me now move to Belt Drives. Belt drives are mechanical systems that use flexible belts to transmit power between rotating shafts. So, this is a belt drive here that transmit power between the rotating shafts. They are commonly used in machines and vehicles for power transmission over long distances. Types of Belts could be Flat belts, V-belt or Timing belts.

Introduction to Belt Drives

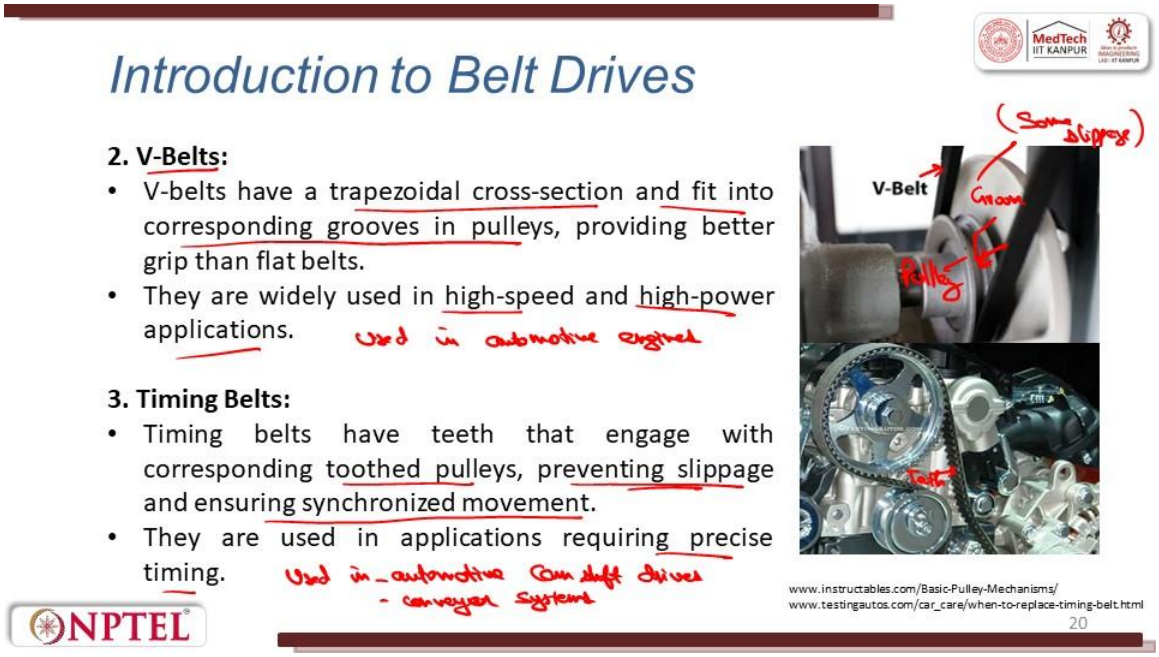
Types of Belts:

1. Flat Belts:

- Flat belts are simple and efficient, used for low-to-medium speed applications.
- They are made of flexible materials like leather, rubber, or synthetic fibers and are suitable for long-distance power transmission.

https://fractory.com/belt-drives/
www.shutterstock.com/search/airport-conveyer-belt

Flat belts are simple and efficient. These are used for low to medium speed applications. They are made of flexible materials like leather, rubber, synthetic fiber and suitable for long distance power transmission.

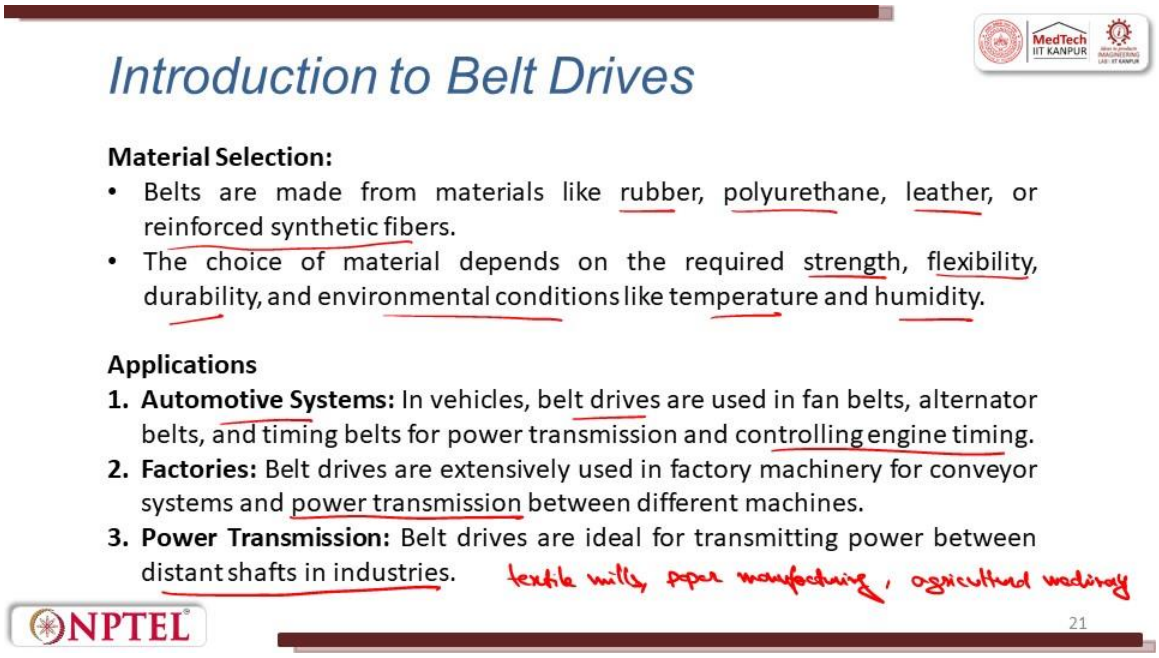


On the other hand, V-belts are there which have a trapezoidal cross section and fit into corresponding grooves in pulleys. So, this is a groove. So, this is our pulley that has groove.

And this is our V-belt that is given. They are widely used in high speed and high power applications. On the other hand, we have timing belts. Timing belts have teeth that engage with corresponding tooth pulleys, preventing slippage and ensuring synchronized movement. So, as I mentioned, there could be some slippage here.

Some slippage is there in pulley and belt system. To completely avoid it, we provide here the teeth. For example, in Timing belt. Now, these work equivalent to the chain drives. Only the pointer is this is not a chain, this is a belt that are having teeth here and this prevent the slippage.

They are used in applications requiring precise timing, for example, in automotive camshaft drives or they are also used in conveyor systems. These are Timing belts. On the other hand, V-belts are used in automotive engines.



Next is Material Selection. As I mentioned previously as well, belts are made from materials like rubber, polyurethane, leather or reinforced synthetic fibers.

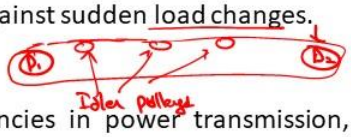
The choice of material depends upon the required strength, flexibility, durability, environmental conditions like temperature or humidity. Applications could be multiple like I mentioned in the previous slides, automatic systems in vehicles, belt drives are often used in fan belts, in alternate belts and timing belts for power transmission and controlling engine timing.

Factories: belt drives are extensively used in factory machinery for conveyor systems and power transmission between different machines. Power transmission: belt riser ideal for power transmitting or that is transmitting power between the stand shafts in industries. So, these industries could be textile mills, these could be paper manufacturing or in agriculture machinery, the multiple applications.

Advantages & Disadvantages

Advantages of Belt Drives:

- **Cost-Effective:** Belt drives are cheaper than chain drives and gear systems.
- **Noise Reduction:** Belts operate more quietly than chains or gears.
- **Flexibility:** Belts can transmit power over long distances and around obstacles using idler pulleys.
- **Shock Absorption:** Belts provide cushioning against sudden load changes.



Disadvantages of Belt Drives:

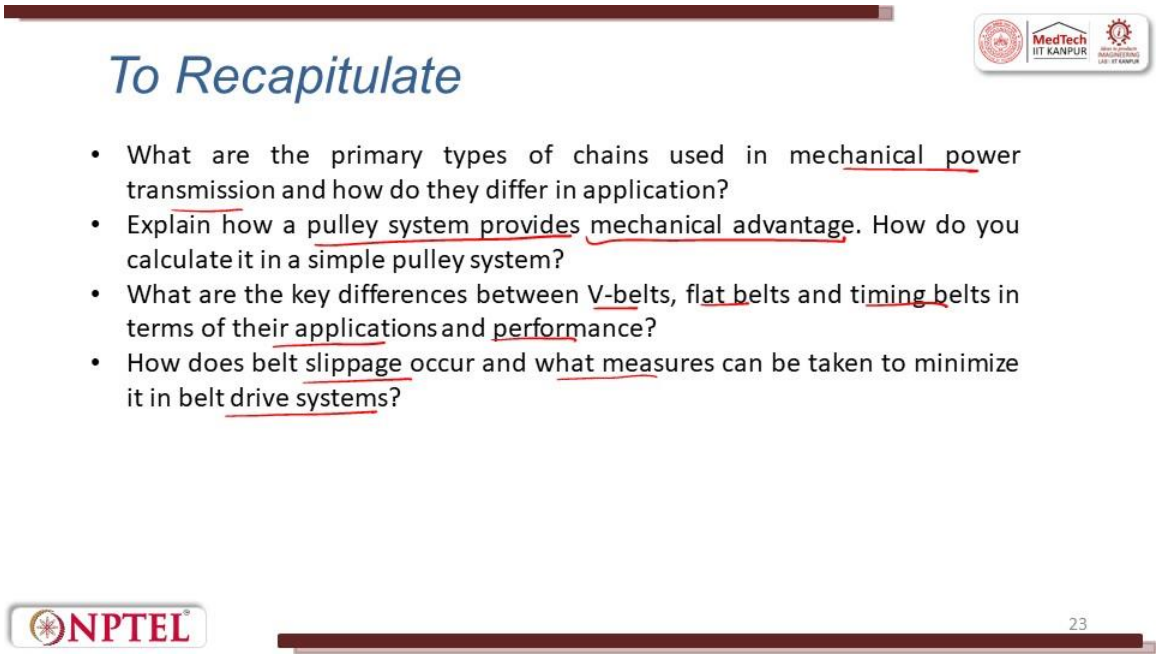
- **Slippage:** Belts can slip, leading to inefficiencies in power transmission, especially in high-load or high-torque applications.
- **Stretching:** Belts do stretch over time, requiring tension adjustments or replacement.
- **Efficiency Loss:** Belt drives are less efficient than chain drives or direct coupling due to friction and slippage.

So, what are the advantages or disadvantages of using belt drives with this I will close my presentation. Advantages of using belt drive is these are Cost-Effective, these have Noise Reduction, Flexibility is there, Shock Absorption is there. Belt drives are cheaper than chain drives that is it is Cost-Effective and these are even cheaper there in the gear systems as well. Noise reduction belts operate more quietly than chains or gear because these are belts made out of material that is generally polymer, rubber or leather. So, mechanical meshing of components are not there.

So, these are more quiet. Flexibility belts can transmit power over long distances and around obstacles using idler pulleys. That is, if there is a long distance, this is the driven system. I would say D2, this is the driving system. D1, if distance is very long and there is a belt drive running through it, so we can put in between idler pulleys so that the belt does not have any warpage.

So, these are all idler pulleys. Shock absorption belts provide cushioning against sudden load changes so that is shock absorption is there, that is why slippage helps to counter the shock that could be there. Disadvantages are Slippage, belts can slip which leads to inefficiencies in power transmission especially in high load or high torque applications. Stretching: belts do stretch over time because again these are made out of leather, rubber, these material could stretch with time. Therefore, requiring tension adjustments is always there or replacement could also be have been made at certain intervals.

Efficiency Loss: belt drives are less efficient than chain drives or direct coupling due to friction and slippage. With this, we have covered about chains, pulleys and belts in this lecture.



To recapitulate, I will just go through certain questions. What are primary types of chains used in mechanical power transmission and how do they differ in application? Explain how a pulley system provides a mechanical advantage.

How do you calculate it in a simple pulley system? What are the key differences between V-belts, flat belts, timing belts in terms of their applications and performance? How does belt slippage occur and what measures can be taken to minimize it in belt drive systems? This is to recapitulate your content covered in this lecture. You can try to answer these questions and try to prepare for the final exam that is going to happen after the 12th week is delivered. So, with this, I am closing this lecture. We will keep talking about the machines, the theory of machines, the design elements in the coming lectures.

Thank you.