Machine Element Design (MED)

National Institute of Transport-NIT

Delivered by:

By Mr. Lucas Chacha Mwita
Mechanical and Environmental Engineer
Email: lucaschachamwita@gmail.com
Phone: +255 752 024 320 / +255 786 422 541

Lecture 3

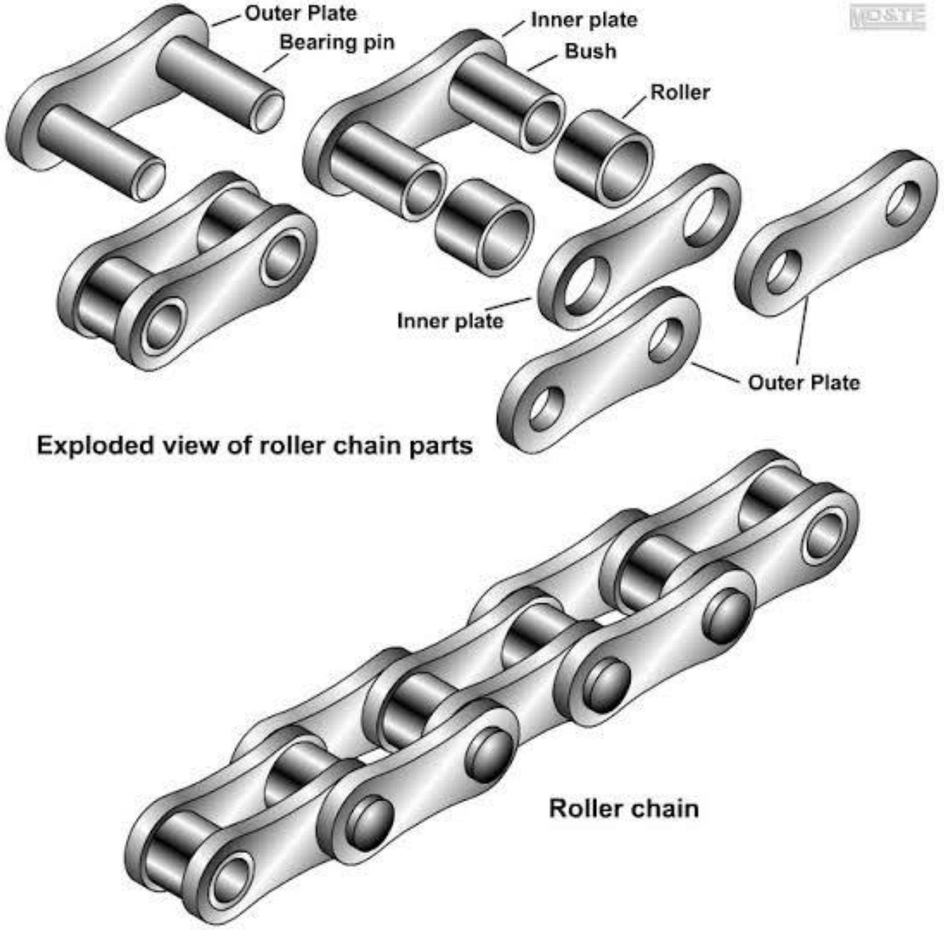
Chain Drives

Chain Drives

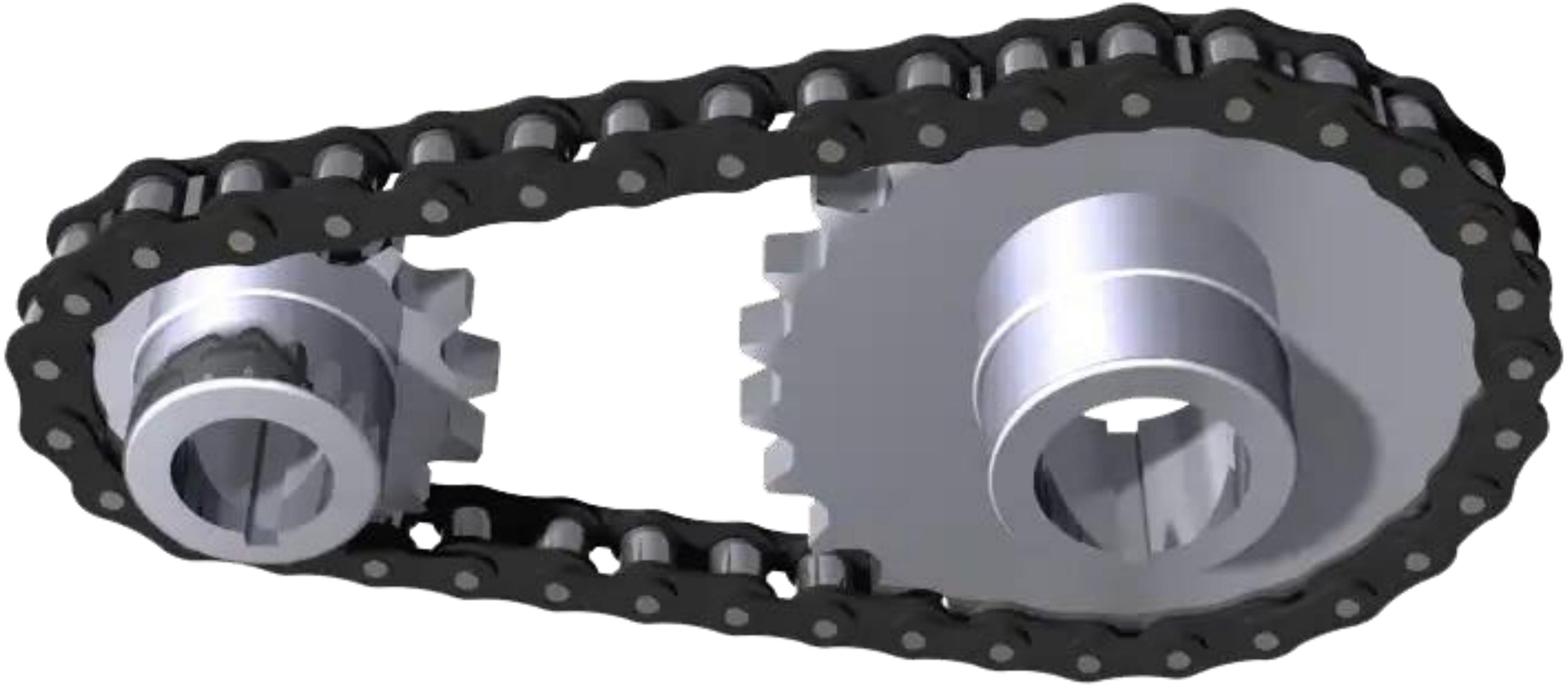
In rope and belt drives slip may occur during operation.

Therefore, we use steel chains to avoid slipping.

The chains are made up of rigid links which are hinged together in order to provide the necessary flexibility for warping around the driving and driven wheels.

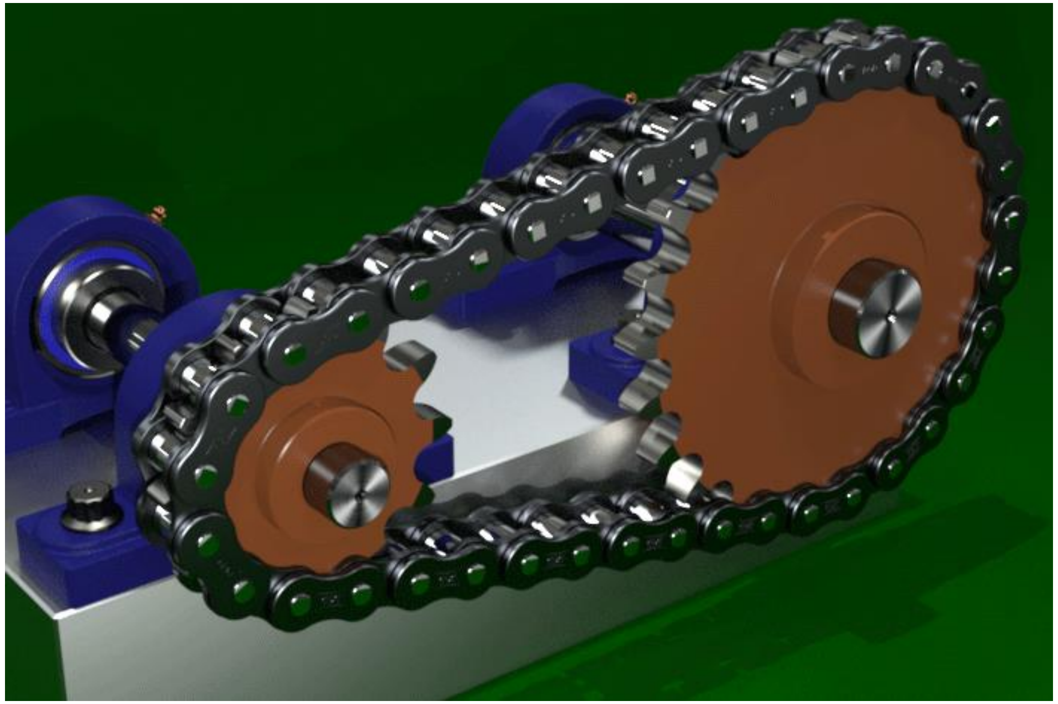


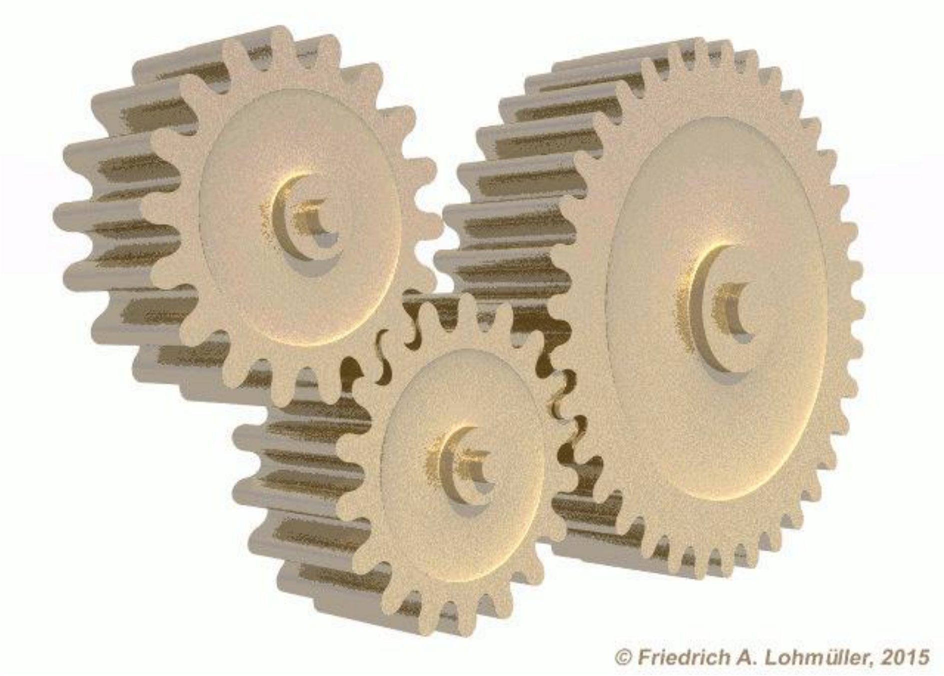
The wheels have projecting teeth and fit into the corresponding recesses, in the links of the chain



The wheels and the chain are thus constrained to move together without slipping and ensures perfect velocity ratio.

The toothed wheels are known as sprocket wheels or simply sprockets. These wheels resemble to spur gears





The chains are mostly used to transmit motion and power from one shaft to another, when the distance between the centers of the shafts is short such as in:

- Bicycles
- Motor cycles
- Agricultural machinery
- Road rollers, etc.

Advantages of
Chain Drive Over Belt or Rope Drive

- As no slip takes place during chain drive, hence perfect velocity ratio is obtained.
- Since the chains are made of metal, therefore they occupy less space in width than a belt or rope drive.
- The chain drives may be used when the distance between the shafts is less.

- The chain drive gives a high transmission efficiency (up to 98 per cent).

- The chain drive gives less load on the shafts.

- The chain drive has the ability of transmitting motion to several shafts by one chain only.

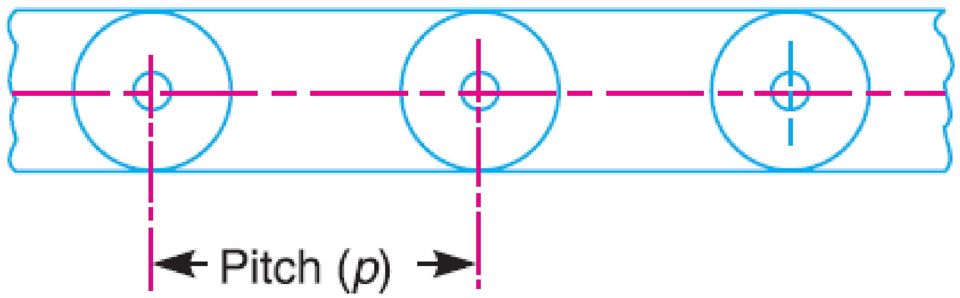
Disadvantages of
Chain Drive Over Belt or Rope Drive

- The production cost of chains is relatively high.
- The chain drive needs accurate mounting and careful maintenance
- The chain drive has velocity fluctuations especially when unduly stretched

Terms Used in Chain Drive

1. Pitch of the chain

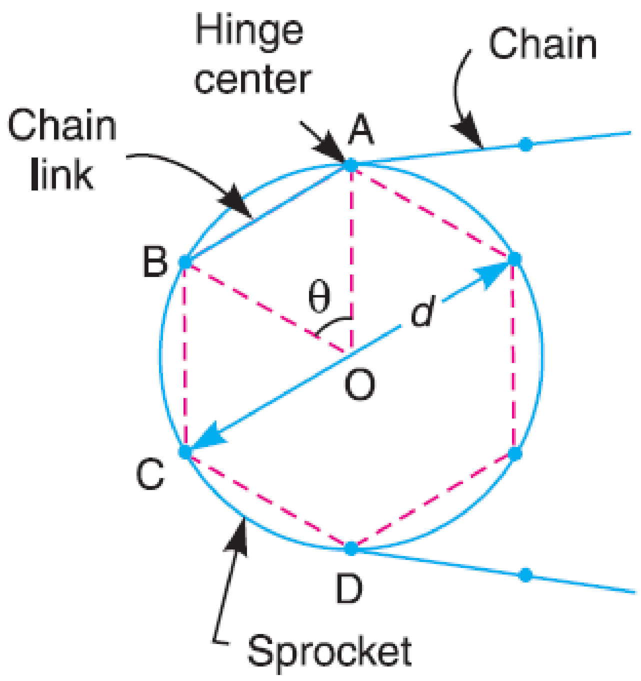
It is the distance between the hinge center of a link and the corresponding hinge center of the adjacent link. It is usually denoted by p



Terms Used in Chain Drive

2. Pitch circle diameter of the chain sprocket.

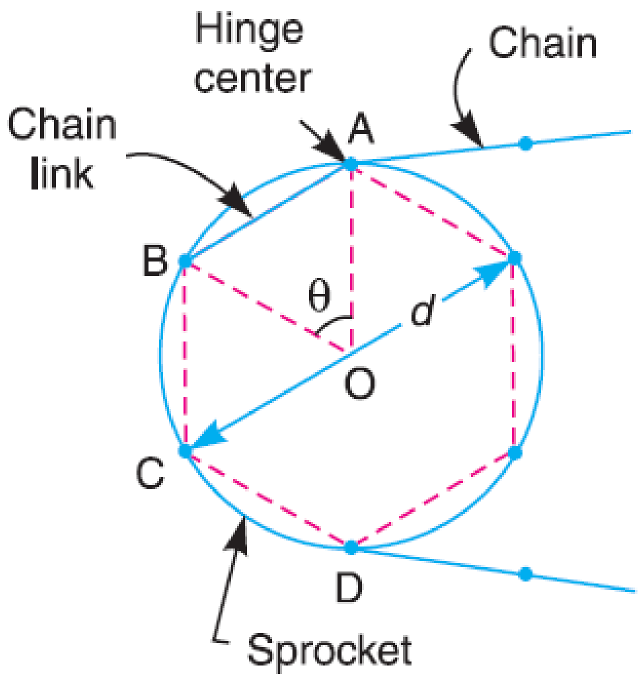
It is the diameter of the circle on which the hinge centers of the chain lie, when the chain is wrapped round a sprocket.



The points $A, B, C,$ and D are the hinge centers of the chain

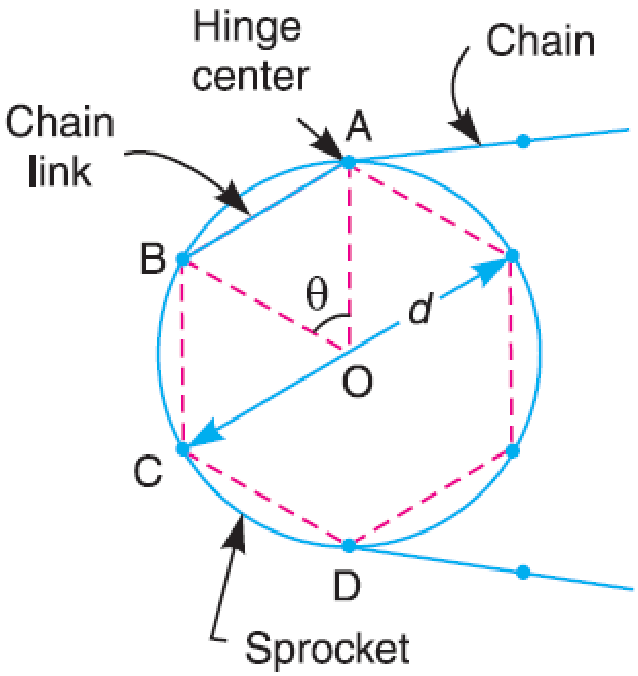
The circle drawn through these centers is called pitch circle, and

Its diameter (d) is known as pitch circle diameter.



Relation Between Pitch and Pitch Circle Diameter

Since the links of the chain are rigid, therefore pitch of the chain does not lie on the arc of the pitch circle



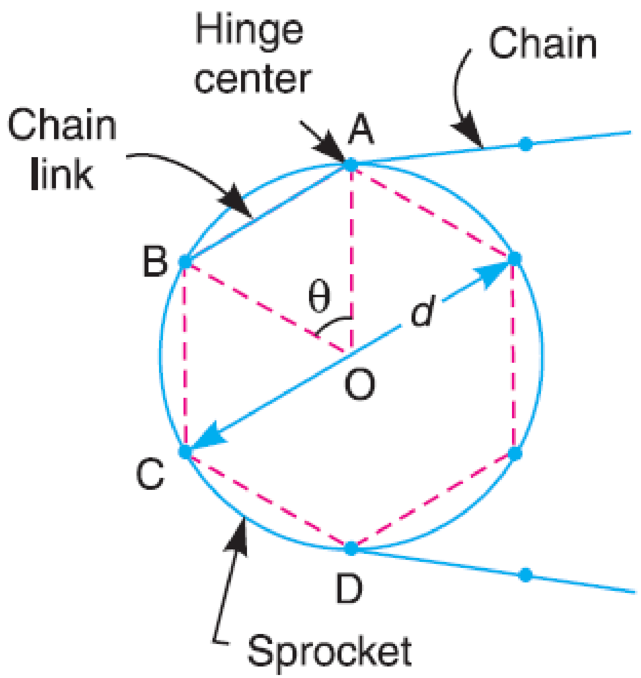
The pitch length becomes a chord

Consider one pitch length, AB of the chain subtending an angle θ at the centre of sprocket (or pitch circle).

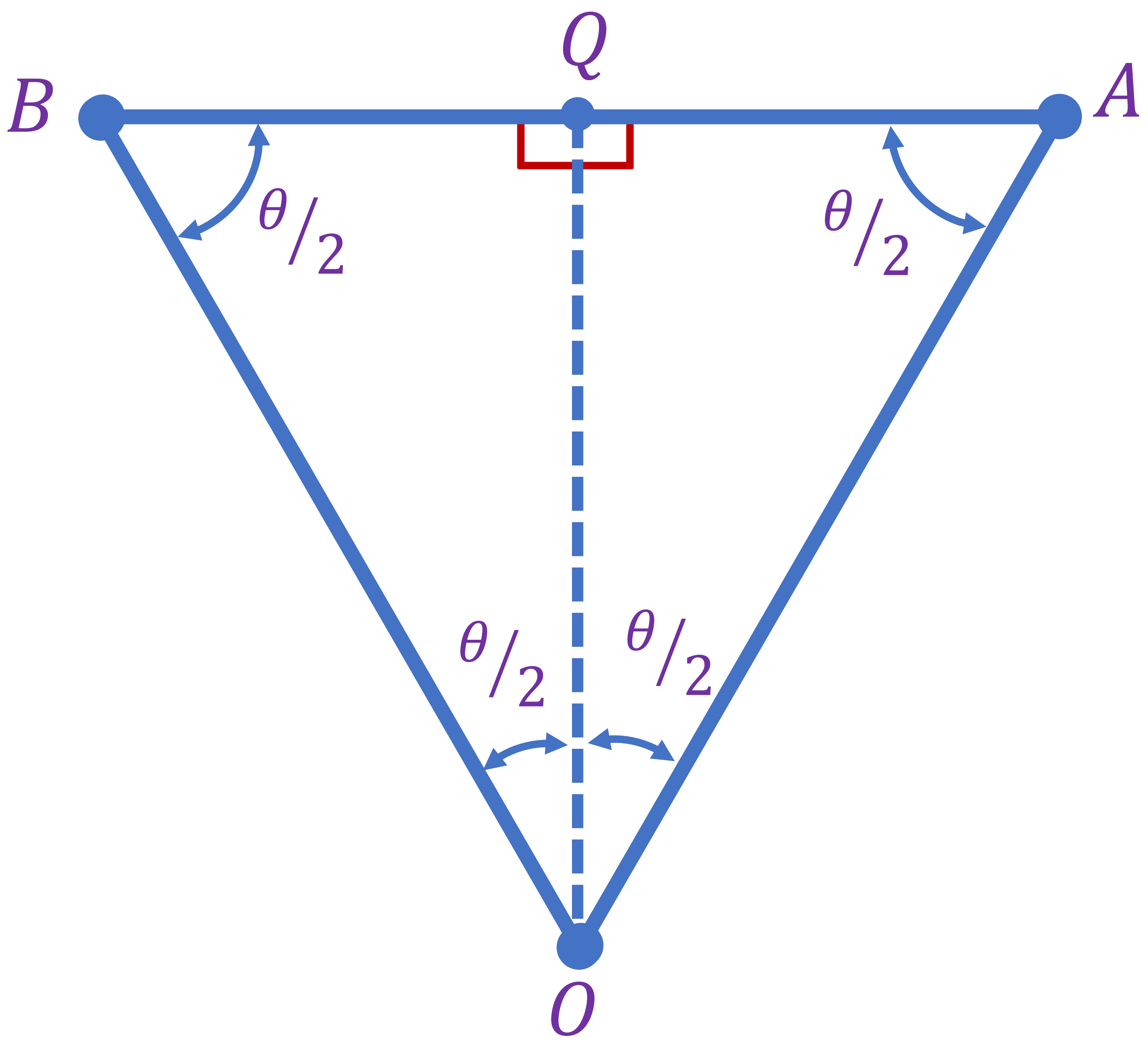
Let:

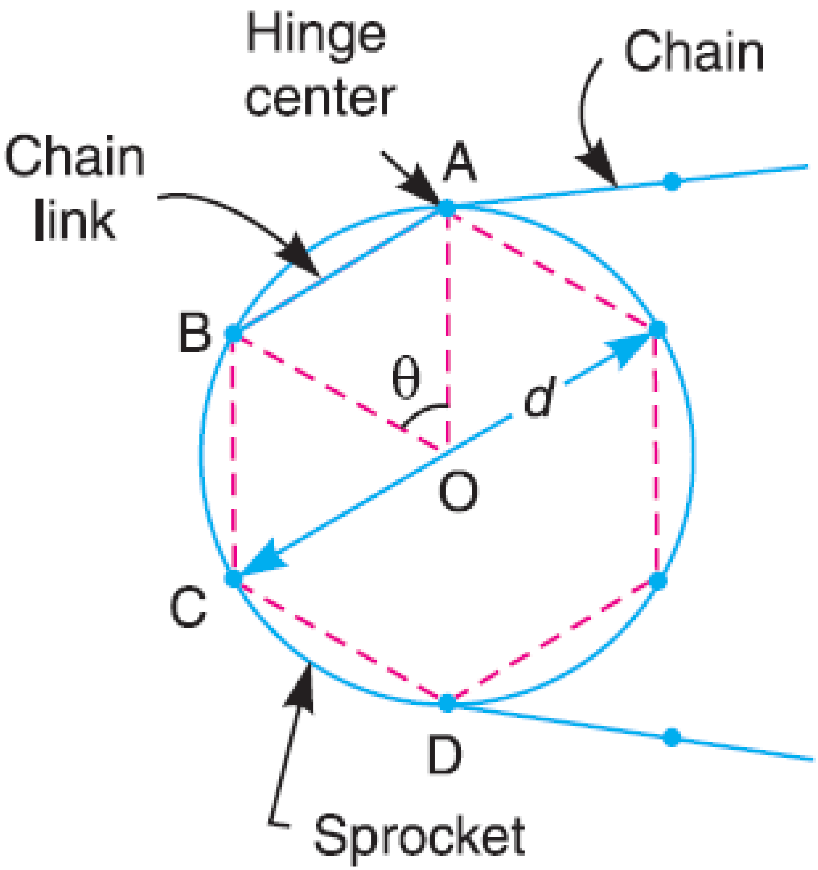
d = Diameter of the pitch circle, and

T = Number of teeth on the sprocket.

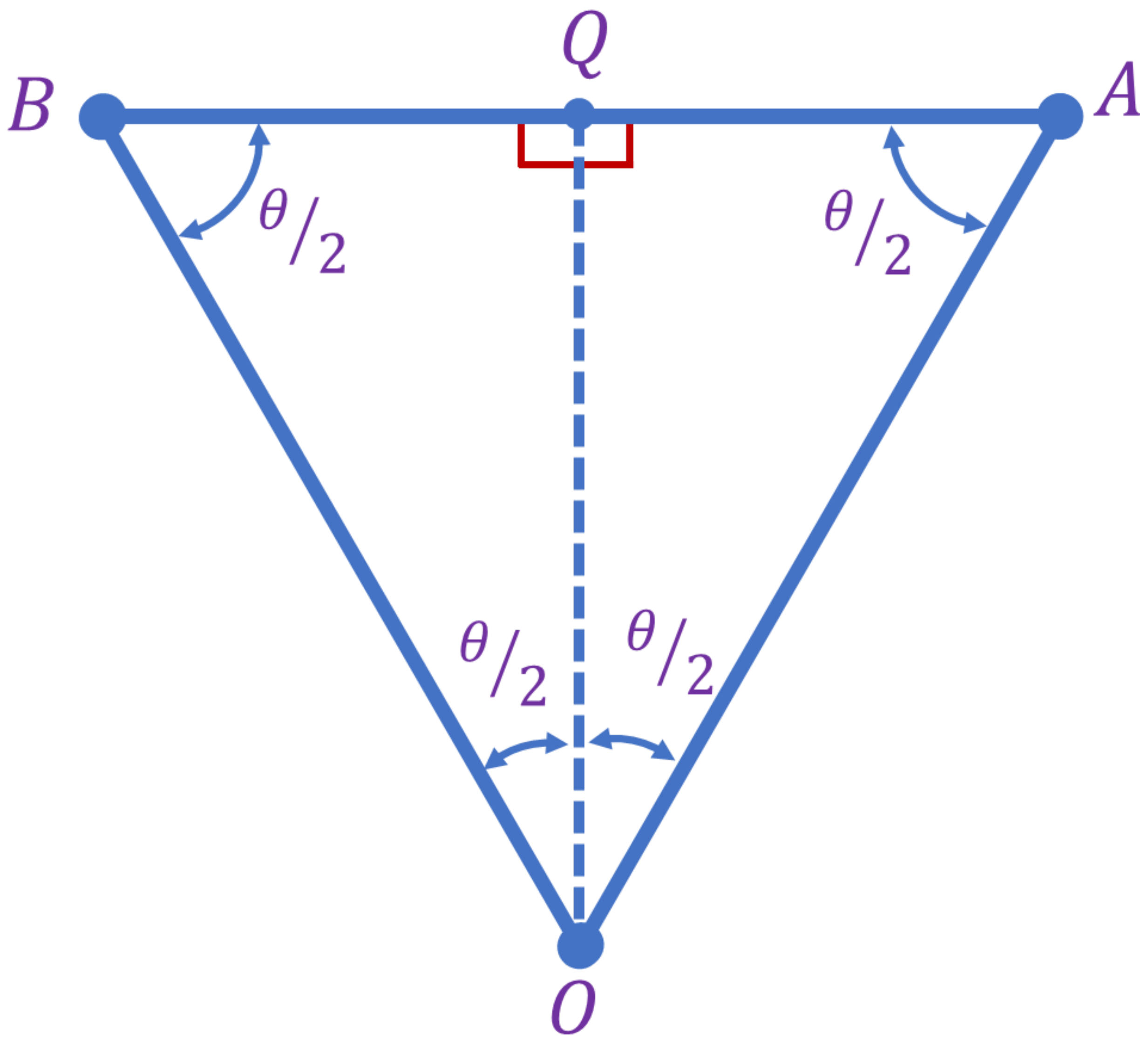


Consider Triangle AOB





Pitch of the chain can be given as:



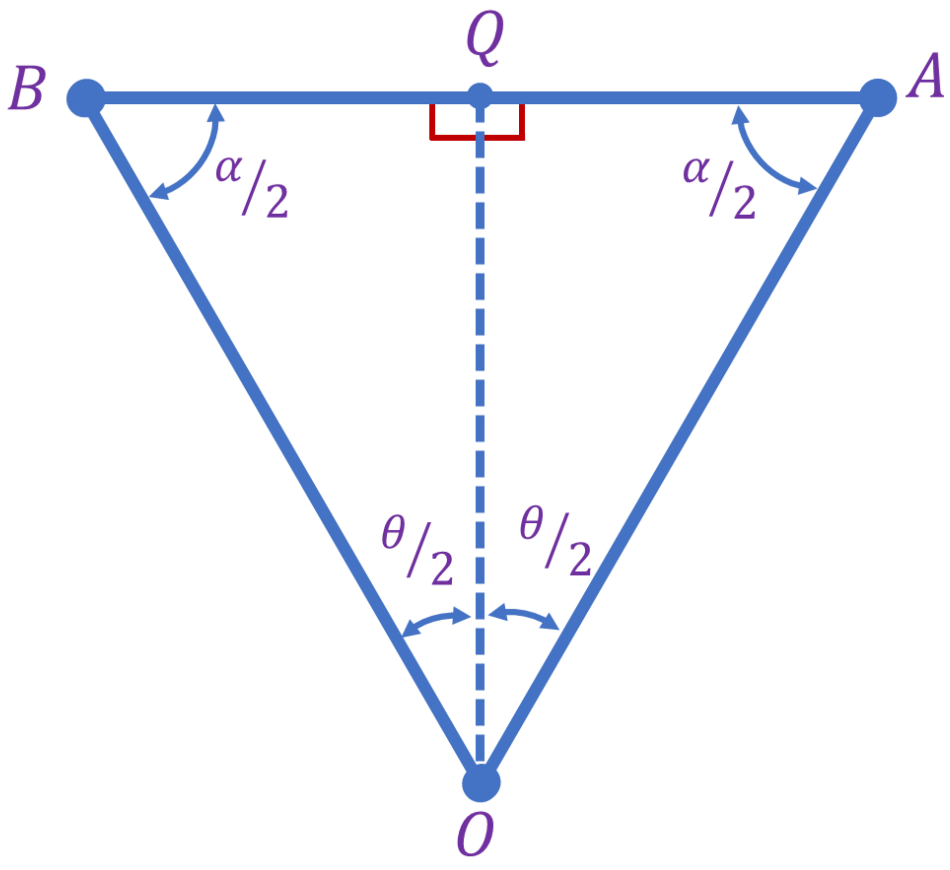
$$p = AB = 2QA \text{ or } 2QB$$

$$\sin\left(\frac{\theta}{2}\right) = \frac{QA}{AO}$$

$$QA = AO * \sin\left(\frac{\theta}{2}\right)$$

$$QA = \frac{d}{2} * \sin\left(\frac{\theta}{2}\right)$$

Pitch of the chain can be given as:



$$p = AB = 2 * \frac{d}{2} * \sin\left(\frac{\theta}{2}\right) = d * \sin\left(\frac{\theta}{2}\right)$$

We know, that:

$$\theta = \frac{360°}{T}$$

$$p = d * \sin\left(\frac{360°}{2T}\right) = d * \sin\left(\frac{180°}{T}\right)$$

$$d = p * \operatorname{cosec}\left(\frac{180°}{T}\right)$$

Relation Between
Chain Speed and Angular Velocity of Sprocket

Since the links of the chain are rigid, therefore they will have different positions on the sprocket at different instants.

The chain speed (v), and angular velocity of the sprocket (ω), also varies with the angular position of the sprocket.

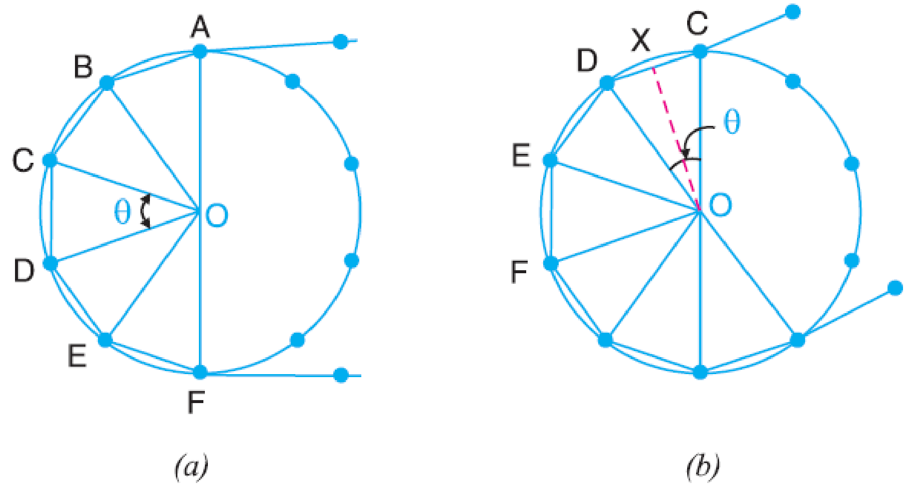


Fig. 11.26. Relation between chain speed and angular velocity of sprocket.

For the angular position of the sprocket, as shown at (a)

$$v = \omega * OA$$

For the angular position of the sprocket, as shown at (b)

$$v = \omega * OX = \omega * OC * \cos\left(\frac{\theta}{2}\right) = \omega * OA * \cos\left(\frac{\theta}{2}\right)$$

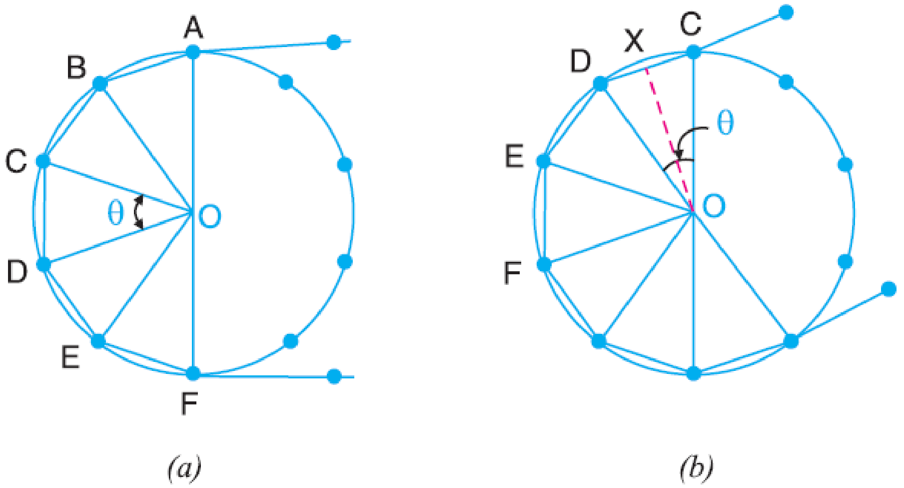


Fig. 11.26. Relation between chain speed and angular velocity of sprocket.

Classification of Chains

Chains are classified according to their basis:

1. Hoisting and hauling (or crane) chains,

2. Conveyor (or tractive) chains, and

3. Power transmitting (or driving) chains.

Hoisting and Hauling Chains

Hoist

A hoist is a device used for lifting or lowering a load by means of a drum or lift-wheel around which rope or chain wraps.

It can be manually operated, electrically or pneumatically driven and may use chain, fiber or wire rope as its lifting medium

Hoisting and Hauling Chains

Haul

Means, pull or drag with effort or force, e.g. vehicle can pull an attached trailer or carriage behind it.

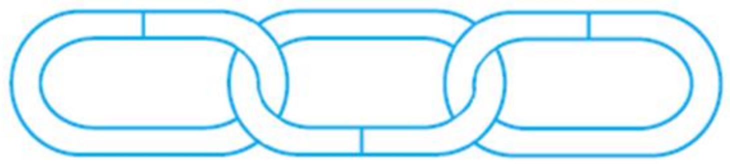
Hoisting and Hauling Chains

These chains are used for hoisting and hauling purposes, are of the two types:

1. Chain with oval links.

The links of this chain are of oval shape. The joint of each link is welded.

Used only at low speed e.g. chain hoist and in anchors for marine work



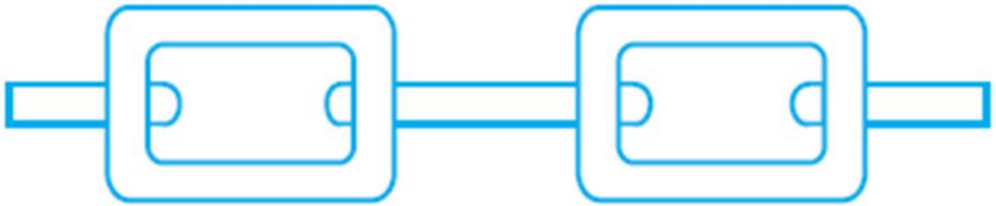
(*a*) Chain with oval links.

2. Chain with square links.

The link of this chain are of square shape. The joint of each link is welded.

Used in hoists, cranes and dredges *(equipment for bringing up objects or mud from a river or seabed by scooping or dragging)*

They are cheap as compared to oval links,



(*b*) Chain with square links.

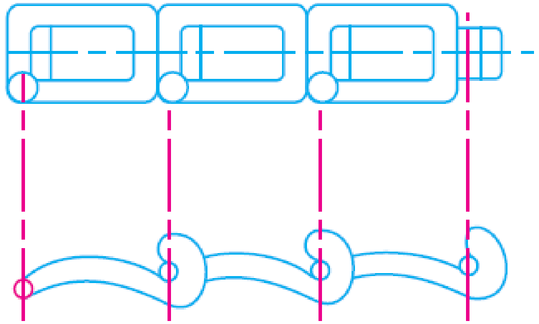
Conveyor (or tractive) chains

These chains are used for elevating and conveying the materials continuously.

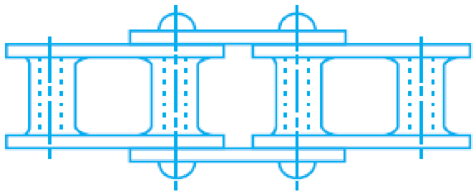
There are two types of Conveyor Chains:

- ❑ Detachable or hook and Closed joint type chain

Conveyor chains are usually made of malleable and cast iron. Don’t have smooth running qualities, and runs at low speed of about $3\ {}^{m}/_{s}$



(*a*) Detachable or hook joint type chain.



(*b*) Closed joint type chain.

Power Transmitting Chains

These chains are used for transmission of power, when the distance between the centers of shafts is short.

There are three types of power transmitting chains:

1. Block chain.

2. Bush roller chain.

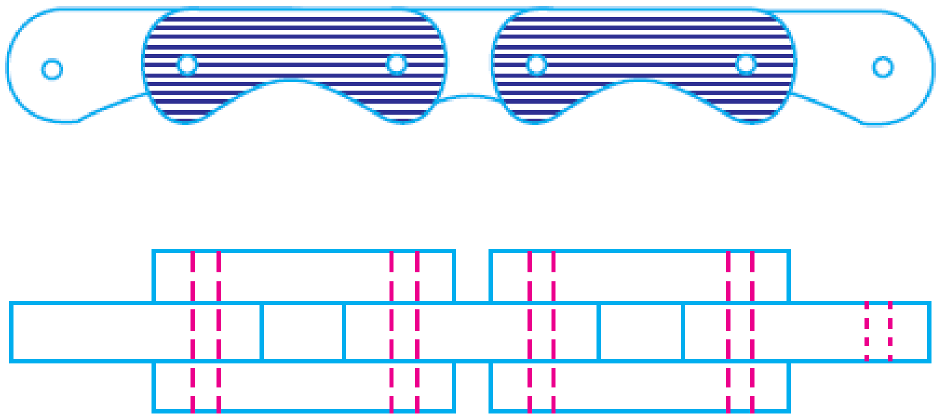
3. Inverted tooth or silent chain.

1. Block chain.

A block chain is also known as *bush chain*. This type of chain was used in the early stages of development in the power transmission.

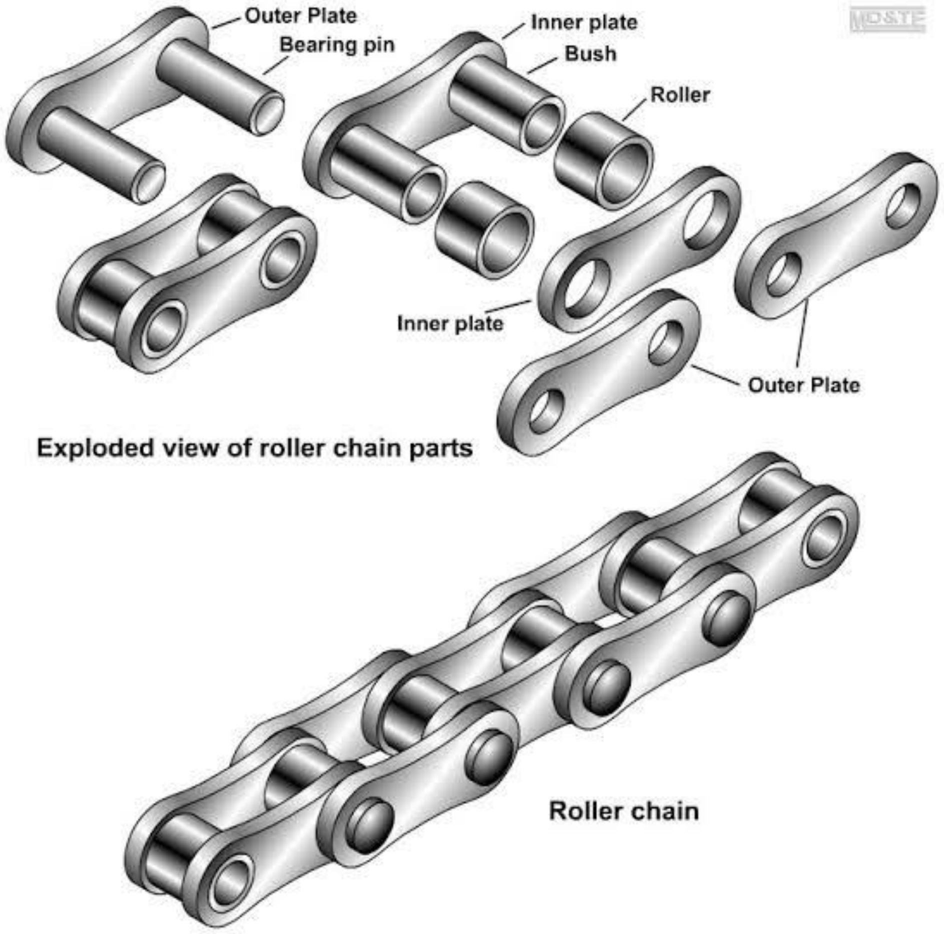
Produces noise when approaching or leaving the teeth of the sprocket due to rubbing between the teeth and the link.

Used to some extent as conveyor chain at small speed.



2. Bush roller chain.

A bush roller chain consists of outer plates or pin link plates, inner plates or roller link plates, pins, bushes and rollers



A bush roller chain is extremely strong and simple in construction

It gives good service under severe

It produces little noise due to impact of the rollers on the sprocket wheel teeth

Used where there is a little lubrication.

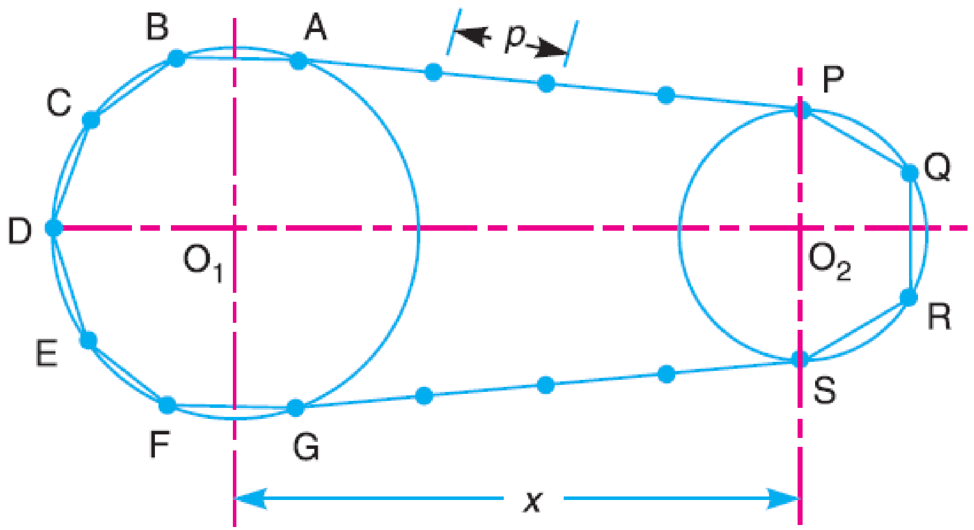
3. Inverted tooth or silent chain.

An inverted tooth or silent chain, it is designed to eliminate the evil effects caused by stretching and to produce noiseless running

When lubricated, the chain gives durable service and runs very smoothly and quietly

Length of Chain

An open chain drive system connecting the two sprockets



Length of the chain

The length of an open belt drive connecting two pulleys of r_1 and r_2

$$L = \pi(r_1 + r_2) + 2x + \frac{(r_1 - r_2)^2}{x}$$

The pitch lines, A, B, C, D, E, F, G and P, Q, R, S of the sprockets are the parts of a polygon and not that of a circle.

Let:

T_1 =Number of teeth on the larger sprocket,

T_2 =Number of teeth on the smaller sprocket, and

p =Pitch of the chain.

The diameter of the pitch circle:

$$d = p * \operatorname{cosec}\left(\frac{180°}{T}\right) \; or \; r = \frac{p}{2} * \operatorname{cosec}\left(\frac{180°}{T}\right)$$

For larger sprocket:

$$r_1 = \frac{p}{2} * \operatorname{cosec}\left(\frac{180°}{T_1}\right)$$

For smaller sprocket:

$$r_2 = \frac{p}{2} * \operatorname{cosec}\left(\frac{180°}{T_2}\right)$$

Given that:

$$\pi(r_1 + r_2) = \frac{p}{2}(T_1 + T_2)$$

The length of the chain:

$$L = \pi(r_1 + r_2) + 2x + \frac{(r_1 - r_2)^2}{x}$$

$$L = \frac{p}{2}(T_1 + T_2) + 2x + \frac{\left(\frac{p}{2} * \operatorname{cosec}\left(\frac{180°}{T_1}\right) - \frac{p}{2} * \operatorname{cosec}\left(\frac{180°}{T_2}\right)\right)^2}{x}$$

Assume: $x = m * p$

$$L = \frac{p}{2}(T_1 + T_2) + 2mp + \frac{\left(\frac{p}{2} * \operatorname{cosec}\left(\frac{180°}{T_1}\right) - \frac{p}{2} * \operatorname{cosec}\left(\frac{180°}{T_2}\right)\right)^2}{mp}$$

$$L = \frac{p}{2}(T_1 + T_2) + 2mp + \frac{\left(\frac{p}{2} * \operatorname{cosec}\left(\frac{180°}{T_1}\right) - \frac{p}{2} * \operatorname{cosec}\left(\frac{180°}{T_2}\right)\right)^2}{mp}$$

$$L = p\left[\frac{(T_1 + T_2)}{2} + 2m + \frac{\left[\operatorname{cosec}\left(\frac{180°}{T_1}\right) - \operatorname{cosec}\left(\frac{180°}{T_2}\right)\right]^2}{4m}\right]$$

$$K = \left[\frac{(T_1 + T_2)}{2} + 2m + \frac{\left[\operatorname{cosec}\left(\frac{180°}{T_1}\right) - \operatorname{cosec}\left(\frac{180°}{T_2}\right)\right]^2}{4m}\right]$$

$L = pK$, where K = Multiplying Factor