CHAIN CONVEYOR

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1. Definition / Description

The term chain conveyor means a group of different types of conveyors used in diverse applications, characterised by one or multiple strands of endless chains that travel entire conveyor path, driven by one or a set of sprockets at one end and supported by one or a set of sprockets on the other end.

Materials to be conveyed are carried directly on the links of the chain or on specially designed elements attached to the chain. The load carrying chain is generally supported on idle sprockets or guide ways. The endless chains are kept taught by suitable chain tensioning device at the non-driven end.

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2. General Characteristics

Different types of chain conveyors are used in wide varieties of applications. It is, therefore, not possible to have a set of common characteristics for all these chain conveyors. Special characteristics of individual type of chain conveyors have been described while discussing them. Chain, compared to belts of a belt conveyor, have certain advantages as well as disadvantages. The major advantages are that the chain easily wraparound sprockets of small diameter, and the drive is positive i.e. no slippage takes place between chain and sprocket. The chain stretch is also little. The disadvantages of chain are its high weight, high initial cost, higher maintenance cost and most importantly, limited running speed because of dynamic loading that come into play in chain-sprocket drive causing intensive wear at high speeds. Maximum length and maximum lift of chain conveyors are limited by the maximum allowable working tension of the chain used.

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3. Types of Chain Conveyors

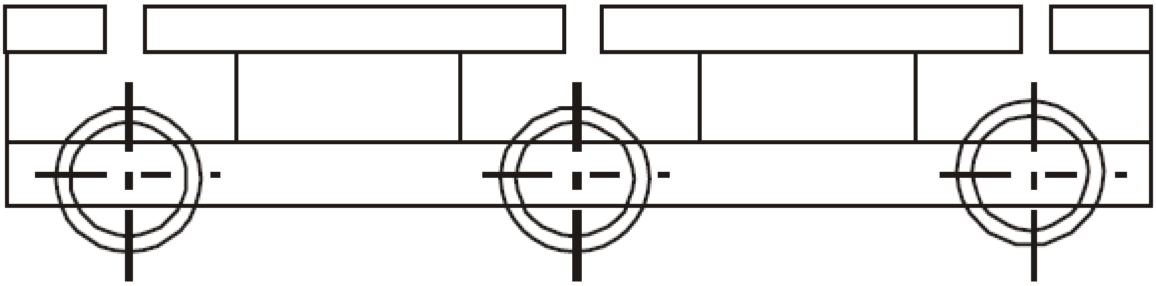
Apron or Pan Conveyor: This is the most common type of chain conveyor. It consists of one or more strands of endless chain, usually link plate roller type, running in steel guides. Rollers ensure minimum pulling effort in the chain, while roller guides supported on the superstructure of the conveyor, carry the entire load of the materials and chains. The carrying surface of the conveyor is composed of a series of plates or shapes called **apron**, which are attached to the links of the chains through cleats. The bed created by the aprons is used for carrying bulk materials as well as unit loads. When the conveyor aprons have vertical flanges on all sides to form a pan like shape, if is specifically called a **pan conveyor**. Materials carried by the apron is discharged over the sprockets at the driven end, and the conveyor chain with aprons comes back empty on its return Journey. These are generally slow speed conveyors with a speed range of 20 to 35 mpm. Arrangement of a typical apron conveyor is shown in Fig. 1.

Fig. 1. Photographs of typical apron conveyor

Applications: Generally apron and pan conveyors are used to perform severe duties of conveying large quantities of bulk load such as coal, ore, slag, rock, foundry sand etc. These are frequently used for feeding materials to large crushers, breakers, grinders and similar machines. Specially designed aprons are used for conveying unit loads, coils, hot forgings. Part of an apron conveyor may be run through a liquid or water bath for washing of the materials and then allow drainage of liquid from wet materials. Apron conveyors can have flexible layout to follow combined horizontal and inclined movement in the same vertical plane. **Apron/pan design:** Depending on the nature of materials to be conveyed, different designs of apron and pan are used. Some of the common designs are:

Flat, spaced apron: Conveyor with rectangular shaped flat steel or wooden slat aprons with small gaps between them, providing a flat surface for carrying unit loads are specifically called ‘‘**slat conveyor**’’ [Fig. 2 (*a*)]. Some other designs of flat and spaced aprons with cleats for carrying different shaped object are shown in Fig. 2 (*b*) and (*c*).

(*a*) Slat Conveyor



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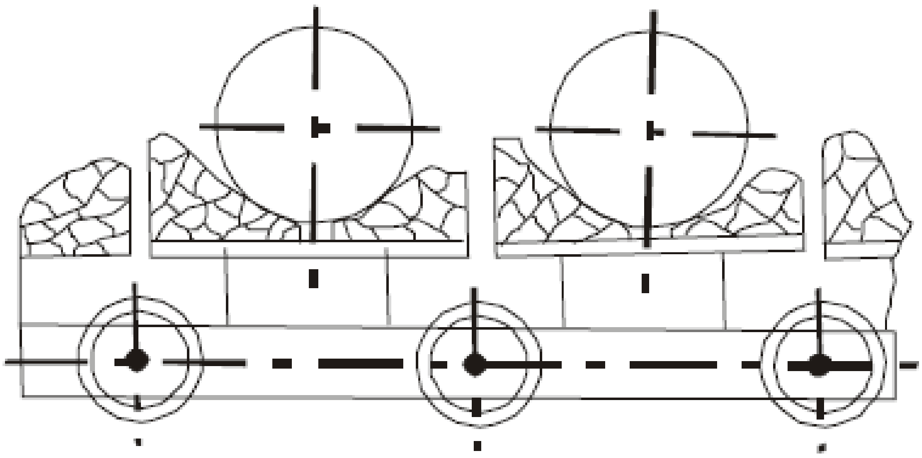

(*c*)

Fig. 2. Flat spaced apron conveyor

Corrugated apron: These are the most common type of apron, made of formed steel, with front and rear edges beaded so that one overlaps the other to form a continuous bed or trough. The overlaps are so made that during turning of the chain over sprockets, the apron ends move relative to each other without creating a gap for leakage of materials or a jamming of adjoining aprons or pans. Fig. 3 shows corrugated aprons of different styles. Some of the aprons are plain while some are provided with overlapped vertical end plates to form pans. Corrugated aprons or pans may be fabricated or cast from gray or malleable iron. The pans are designated as leakproof (for carrying fines), shallow, deep and hinged (for carrying chips, trimmings, scrap etc.). Deep pans may be used for carrying materials at an inclination of upto 45°.

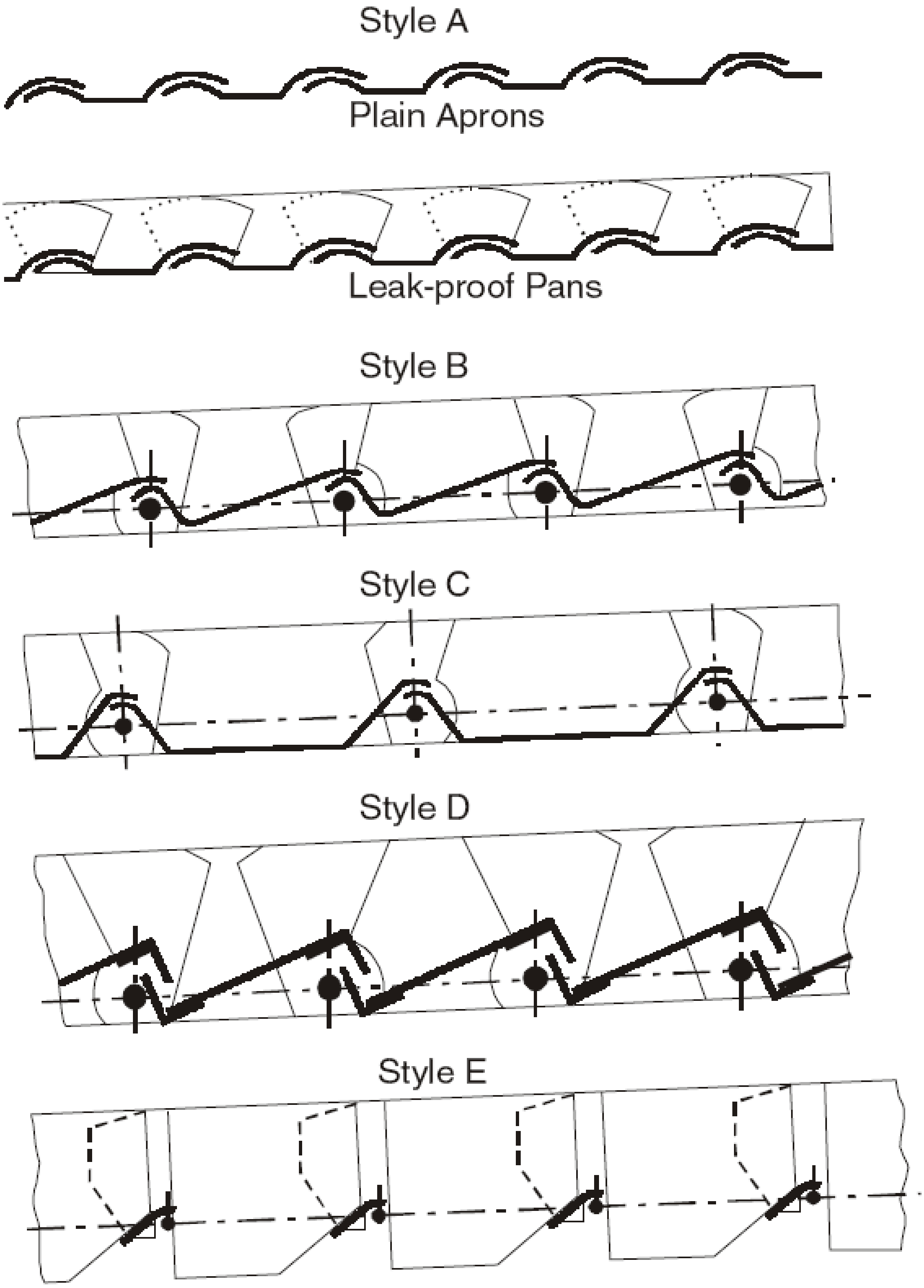

Fig. 3. Corrugated aprons of different styles

Special types: These are used in special applications and are too numerous to be discussed in limited space. Some of the typical examples are the four compartment cast-metal pans used for pig casting. Beaded aprons are used in sugar mills. When deep loads are carried on an apron conveyor, stationary side plates called skirt plates are provided on both sides, fixed to the conveyor frame.

Cross-Bar or Arm Conveyor: This type of conveyor consists of a single or two strands of endless chain, to which are attached spaced, removable or fixed arms (or cross members) from which materials are hung or festooned. The arms may be replaced by shelves/trays to support packages or objects to carry them in a vertical or an inclined path. Special arms are designed to suit specific load configuration. Depending on the design of arms, they are called by different names, some of which are: pendent conveyor, pocket conveyor (shown in Fig .4), wire mesh deck conveyor, removable-crossbar conveyor, fixed cross-bar (or arm) conveyor, swing tray conveyor.

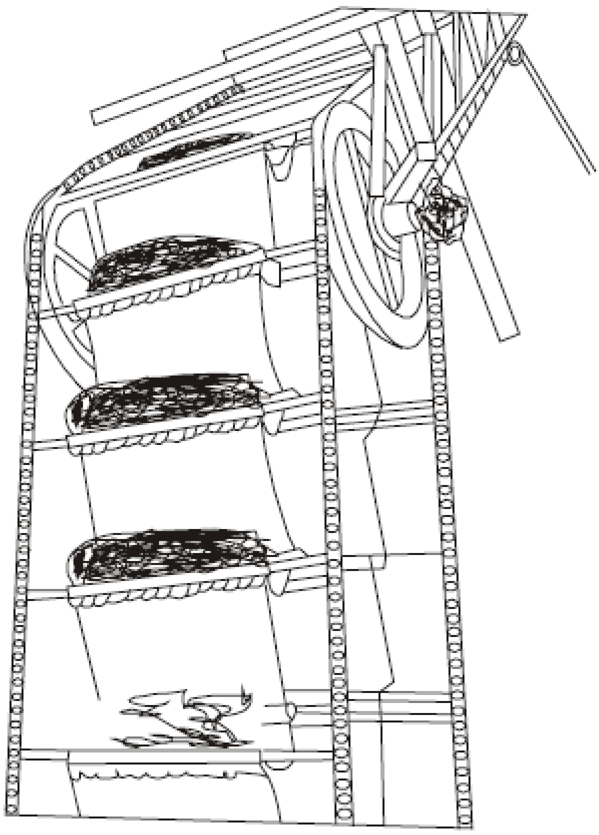

Fig. 4. Pocket type arm conveyor

Applications: Crossbar conveyors are used for conveying and elevating or lowering unit loads like barrels, drums, rolls, bags, bales, boxes etc. The conveyors may be loaded/unloaded manually or at automatic loading / discharging stations.

Cross-bar conveyors are also used in a wide range of process applications such as dipping, washing, spraying, drying and assembly etc.

Flat-Top chain Conveyor is a particular group of carrier chain conveyors, may be rolling or sliding type, with specially designed chain links or with flat plate attached to the chain links so as to provide a continuous, smooth, level top surface to carry small articles like bottles, cans, etc. at a high speed. These conveyors are widely used in canning and bottling plants.

Different types of chains and/or attachments are used such as hinged-joint continuous flattop sliding type (Fig. 5), plate-top sliding or rolling type, crescent-shaped plate top type. The crescent plate design is particularly suitable for carousel-type operation to turn in a horizontal curve, a typical example being the baggage handling conveyors in the arrival section of an airport.

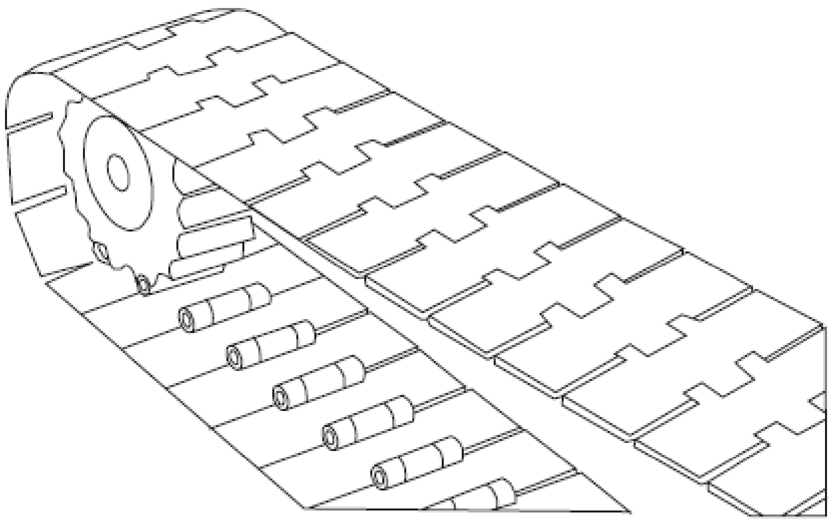

Fig. 5. Hinged joint continuous flat-top sliding conveyor

The above figure shows a variation of flat-top conveyor which consists of flat hinged plates so designed that the hinge barrels are driven by the specially designed sprocket. No actual chain is used in this conveyor which is widely used in canning and bottling plants.

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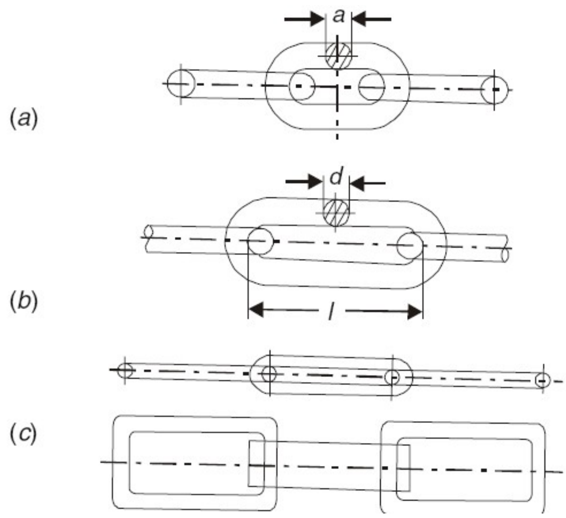
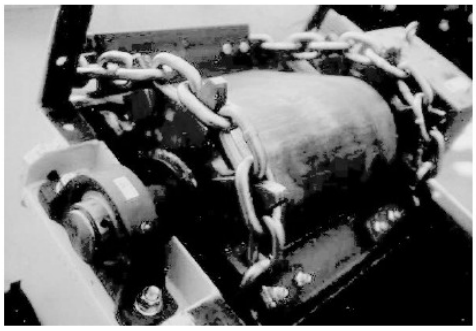
4. Components of Chain Conveyor

The major components of a chain conveyor are : Pulling chain, Sprocket to drive and support the chain, Take-up arrangement, Drive arrangement and Various other components specific to various type of chain conveyors.

Pulling Chains: Different types of chains are used in chain conveyors, which have their merits and demerits, briefly discussed below:

Round-link chains (Fig. 6) are low in cost and high flexibility in all directions. This have flexibility which is particularly desirable in trolley conveyors. However, limitations of this chain are less contact area, high stretch under load and rapid wear.





Short or long-linked welded Round-link chain being driven by sprocket

Fig. 6. Round-link chain

Combination chains (Fig. 7) are widely used in many different conveyors. The links are generally of cast malleable iron construction with machined steel pins and may be with or without roller.

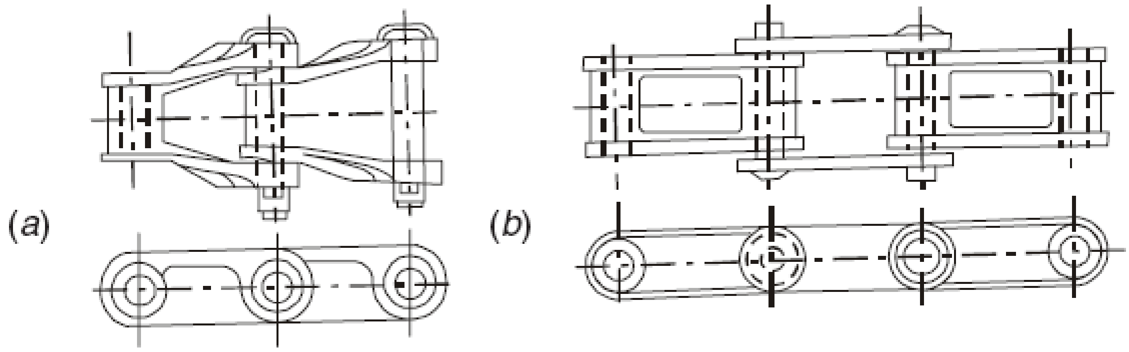
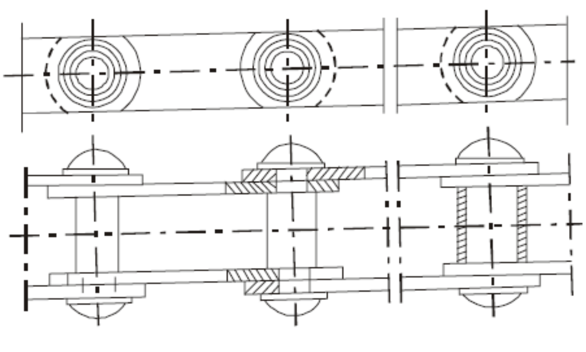
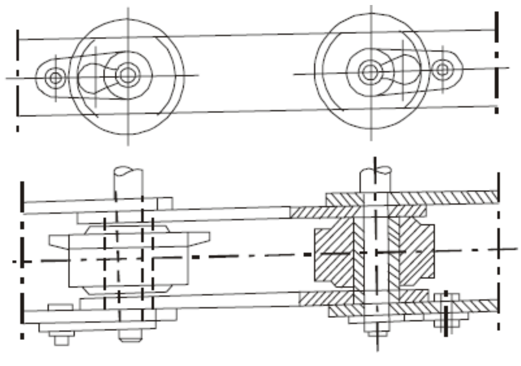


Fig. 7. Combination chain (*a*) without rollers, (*b*) outer link plates of steel

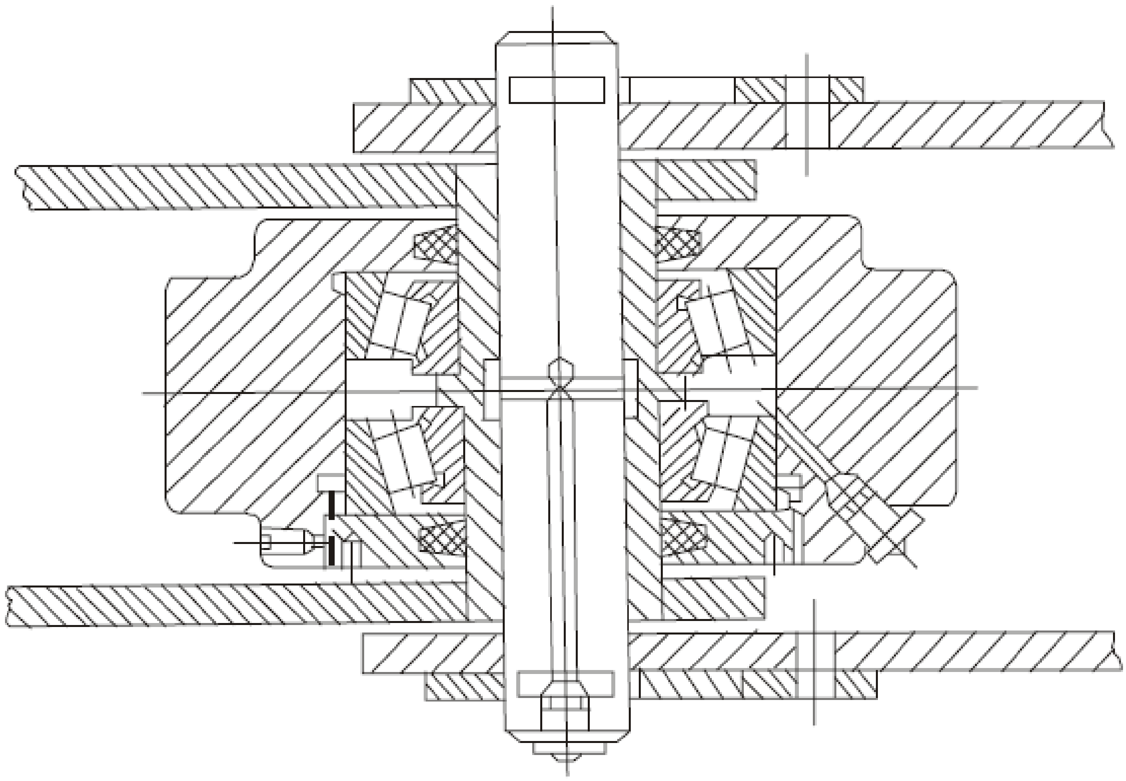
Link-plate chains (Sometimes called leaf chain) are the most common type used in chain conveyors. The link plates allow different types of attachments to be fitted in the chains. The pitch of the chain may be made large enough (pitch usually vary from 65 mm to 1250 mm) by making the links from steel plates.

Constructionally the link-plate chains may be bush-less chain with or without rollers, and bushed chain with or without rollers, as shown in Fig. 6.2.18. The bushes decrease the wear at the link joints. The rollers fitted with bushes or with antifriction bearing for large size chain (Fig. 8) generally run on guided tracks or toughs which carry the entire weight of the chain and load being carried, thereby reducing the pull in the chain. Because of these advantages, chain with bush and roller are the preferred ones.





Bushless with or without roller　　　　Bushed with roller



Antifriction bearing roller assembly

Fig. 8. Link plate chains

Chain selection is based on largest practical pitch (being cheaper than the shorter pitch chain of equal strength), allowable tension load, capital cost and degree of maintenance needed.

Sprockets: The sprockets are made of good grade cast iron with chilled hardened teeth or from cast steel or plate steel. The teeth are machined to suit type of chain used. The advantage of using a large sized sprocket with greater number of teeth is to obtain smoother operation. However, larger the size of sprocket, costlier it is and taking larger space. Thus a compromise is made in selecting the size of a conveyor sprocket.

Take-up arrangements: The most common type of take-ups is ***adjusting screw type*** for positioning the bearing blocks supporting the takeup sprocket shaft. The range of adjustment should be sufficient to permit initial slack-off of the conveyor chains for joining of two links to make them endless and ample adjustment for initial stretch and subsequent wear / elongation.

The alternative design is ***counterweighted-type***, providing automatic constant tension in chain. This type provides constant chain tension under variable temperature conditions also.

Drive arrangement: Drive for a conveyor generally consists of an electric motor coupled to a speed reduction gear unit which in turn is coupled to the driving sprocket. For a conveyor having a simple configuration (as in an apron conveyor), the drive is located at the sprocket at the end of loaded strands of chain. For conveyors like trolley, car, tray etc. having a complicated path of motion, the drive location is determined by analysis of tension variation in the path of conveyor motion.

Drives may have fixed or variable speed. Variable speed may be achieved by using a variable speed gear box or change speed gear box or multiple speed motor or by having an electrical speed control system.

For a long chain conveyor, synchronously working multiple motor drives at different sections are employed which decrease the total tension in the chain.

Frame structures: Frame structures supporting the entire conveyor, chain guide rails or troughs, skirt plates are the other components which are common to most type of chain conveyors. Frame structures are generally custom designed to suit the location and application. The frames may be floor supported, set below the floor, be hung from the roof or bracket from wall / columns, as required by the different types of conveyor.

Different types of chain conveyors may need other specific components and structural arrangements, which have been mentioned in the discourse on the individual type of conveyor.

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5. Aspects of Chain Conveyor Design

Dynamic Phenomena in Chain Conveyors: In a chain-sprocket drive, engagement of sprocket to chain being discontinuous in nature, the linear velocity of the chain between two successive engagements with sprocket teeth becomes non-uniform. The reason for this is that the chain does not wrap around the driving sprocket on the pitch circle, but traces a pitch polygon, a phenomenon known as *chordal action*. The period of irregularity is equal to the time taken by the sprocket between two successive engagements (*i.e.* time taken by the sprocket to rotate by one pitch), $t_0 = \frac{2\pi}{\omega z}$

where , ω = angular velocity = $\frac{2\pi n}{60}$

z = number of sprocket teeth

n = rpm of sprocket

Fig. 9 shows a chain running on a sprocket. In the position pictured in the diagram, the pull is transmitted by the tooth 1, is in mesh with chain link 1′. As the sprocket rotates clockwise, tooth 2 engages with link 2′, then tooth 3 with link 3′ etc.

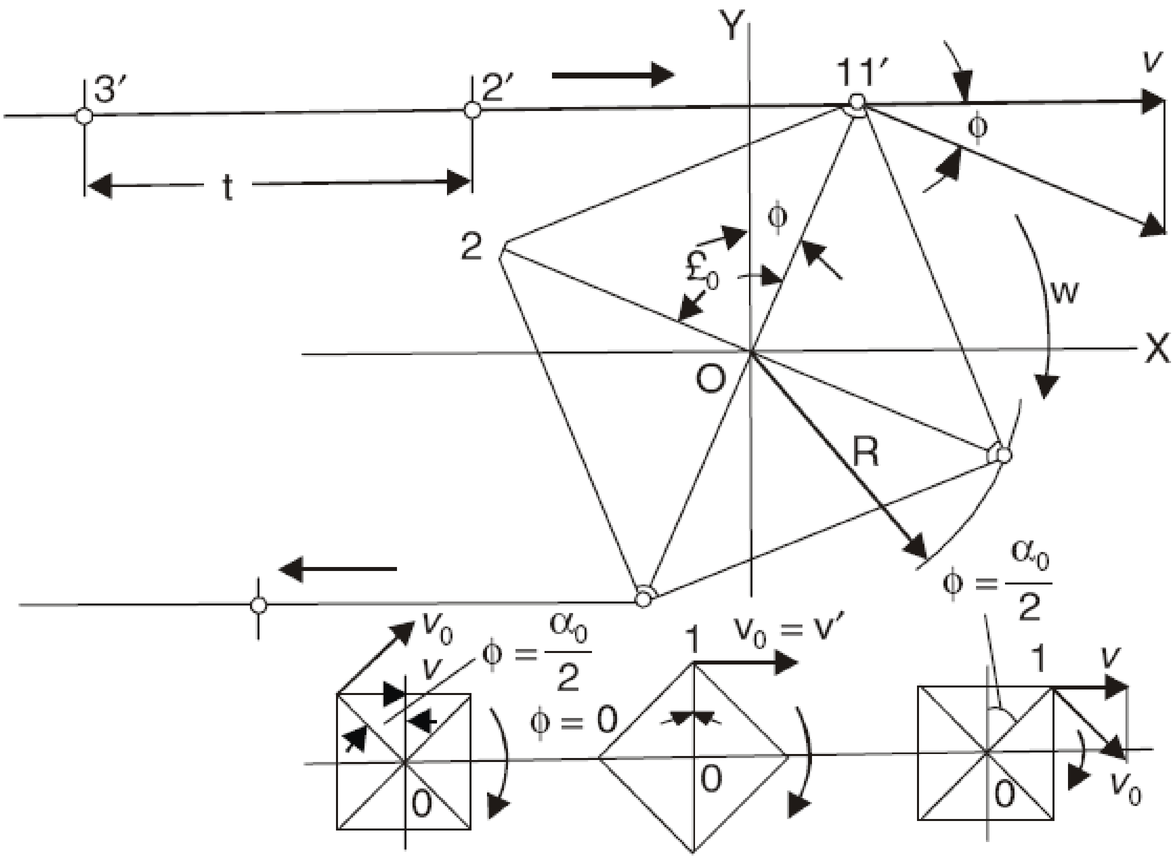

Fig. 9. Analysis of chain movement over sprocket

At constant angular velocity of the sprocket, the peripheral speed of the tooth remains constant ie $v_0 = \omega R$ while the chain translatory speed in the direction of the chain movement will be $v = v0 \cos \varphi = \omega R\cos \varphi$, where φ is the variable angle formed by the contacting tooth radius O1 with vertical axis OY.

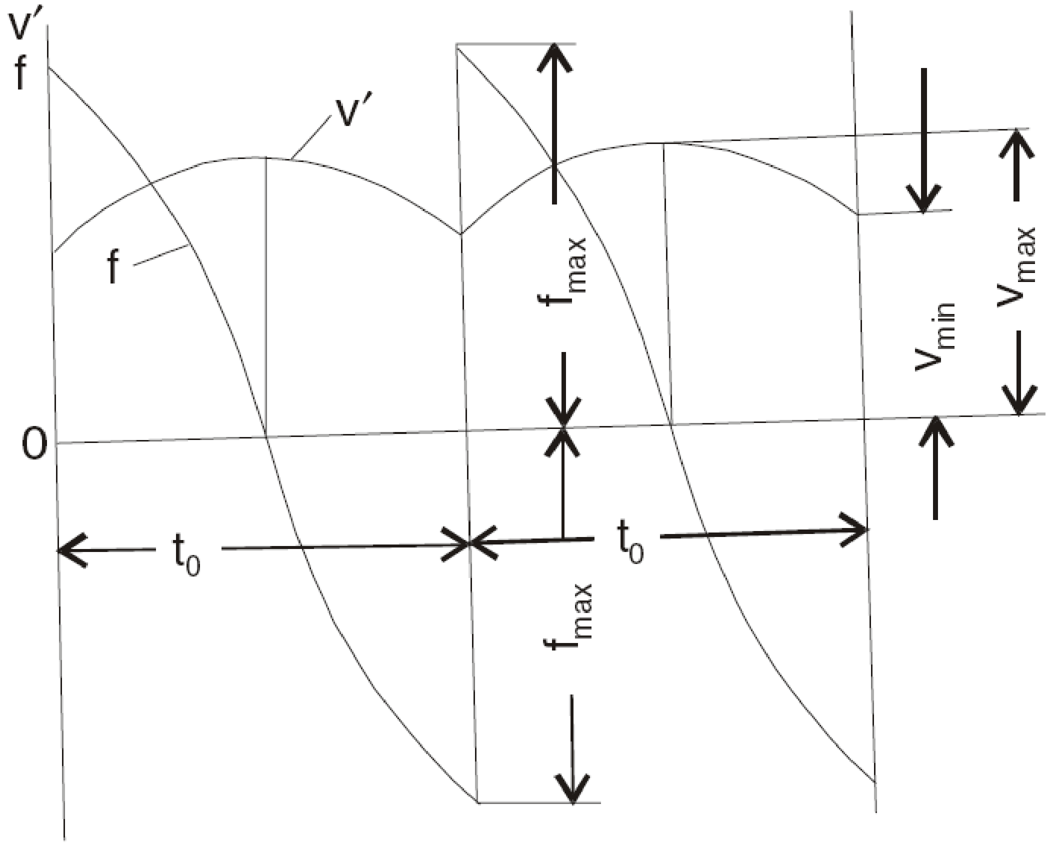

Fig. 10. Diagram of chain speed and acceleration

The chain speed reaches its peak value, $v_{max} = v0 = \omega R$ when $\phi = 0$, and its minimum when $\varphi = -\frac{\alpha_0}{2}$ and $\varphi = \frac{\alpha_0}{2}$. The acceleration 'f ' of the chain can be determined as the first derivative of the speed with time, or as the projection of centripetal acceleration $f_0 = R\omega^2$ to the direction of chain travel (tangential acceleration being zero). $f = f_0 \sin \phi = R\omega^2 \sin \phi$.

Acceleration diagram is also shown in Fig. 11. It becomes zero when $\phi = 0$ and reaches its peak value at

$$\varphi = -\frac{\alpha_0}{2} \text{ and } \frac{\alpha_0}{2}. \quad \therefore \quad f_{max} = \pm R\omega^2 \sin\frac{\alpha_0}{2}.$$

Fig. 11 also shows that at the point of next sprocket 2 engaging the chain, the acceleration changes abruptly from – fmax to + fmax. If 'M' is the reduced mass of the moving parts of the conveying machine and the load, the inertial force at the moment is 2Mfmax. As the force is applied instantaneously, the dynamic inertial force FA = 2 × 2Mfmax = 4Mfmax. This inertial force is to be added to the static tight side tension of the chain to obtain the total theoretical tensile effort, the chain is subjected to.

To keep the variation of tension in the chain to a tolerable limit, the speed of the chain conveyor is kept low. Chordal action of chain links when going round the sprocket also imparts a pulsating motion at right angles to direction of chain, to the conveyor chain. This is more pronounced when sprockets with fewer teeth i.e. increased pitch angle α_0 is used. When conveyor centre distance is short, the pulsation is less noticeable.

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6. Chain Pull and Conveyor Horsepower

The entire weight of materials and the moving parts of a chain conveyor is pulled by the chain or chains employed. It is, therefore, important to calculate the tension of each chain and select the chain with adequate strength to work safely under the working pull, the chain will be subjected to. The tension or pull necessary to move conveyor chains is sum total of live load *i.e.* the force required for conveying the material plus the dead load and the resistance to the movement of conveyor parts.

Thus, the total chain pull = Force required to raise material up an inclination + Force required to raise conveyor parts up the inclination + Frictional resistance to the movement of loaded conveyor parts in the carrying run + Frictional resistance of empty conveyor parts during return run.

If the various factors are represented with following notations:

T = Total chain pull, Newton

f = Coefficient of friction of moving chain on runways.

L =Length of conveyor centers, m.

H = Horizontal projection of the conveyor, m.

V = Vertical projection of the conveyor, m.

m_G = Mass of load per meter of conveyor, kg/m.

m_C = Moving mass of conveyor per meter, kg/m.

S = Velocity of conveyor, m/min.

Then,

$$T = m_G.g.V + m_c.g.V + m_G g.fH + 2m_c.g.f.H - m_c.g.V$$
$$= m_G.g(V + f.H) + m_c.g.(V+f.H) + m_c.g.(f.H - V)$$

If V in the quantity mcg (fH – V) exceeds fH, the conveyor return run will move down the inclination owing to the gravitational pull overcoming the frictional resistance of the return run. In this condition the term mcg(fH – V) is taken to be zero. If fH > V, then this additional pull is necessary to pull the return part of the conveyor.

If ‘C’ is capacity of the conveyor in tonnes /hr, we can write m_G = 16.66C/S , kg/m Thus eqn. may be rewritten as,

$$T = 16.66 \times \frac{C.g}{S}(V + f.H) + m_c.g(V + f.H) + mc.g(f.H - V)$$

The frictional coefficient ‘f’ depends whether the chain is sliding or rolling. For non-roller flat linked chain, sliding on steel track or trough, the value of ‘f’ may be taken as 0.2 and 0.33 for well lubricated and dry run respectively. The rolling friction depends on roller size, condition of track etc. For 50mm diameter it is 0.15 while for 150mm it can be taken as 0.06. When the load on conveyor passes through stationary skirt plates as in a deep apron or pan conveyor, additional frictional pull due to rubbing, must be added to the chain pull ‘T’ obtained from above formula. If this pull is ‘‘Y’’ in Newton per meter length of skirt plate, then

$$Y \cong 2.3h^2/k$$

where h = height of materials rubbing in skirt in cm, and k is a factor depending on material as given in the Table.

Materials	K
Iron ore, crushed	4
Cement clinker	8
Gravel or stone	8
Coal, fines and lumps mixed	30
Chips, pulpwood	48
Sugar cane	80

The basic power for driving the conveyor is calculated by the formula:

$$P = \frac{1.15 \times S \times [\text{Total chain pull} - m_{c.g}\ (v - fH)]}{1000 \times 60}, \text{kw}$$

This formula takes care of 10% headshaft and 5% tailshaft friction. However, for actual motor power calculation, the efficiency of the drive system consisting of gearbox, pulley and belt, coupling etc. have to be considered.

The drive is generally applied to the delivery end. The required power is practically same if drive is applied to the tail end. The advantage of a head-end drive is that, only the active side of the chain is under maximum load. A tail end drive will put the entire length of the chain under this maximum tension and this causes greater friction at the head shaft and greater wear of the chain.

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