第八章 Chain drives 链传动

§8-1 General considerations 概述

- Characteristics and applications
  特点和应用
- Types of chain drives
  链传动分类

一、 Characteristics and application

特点和应用

1 、 Advantages 优点

★ In comparison to belt drive

与带传动相比：

① Absence of slippage 无滑动

② Smaller overall size 尺寸小

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③Small tension force

→Small forces acting on the shaft 张紧力F_0小→压轴力小

④High efficiency 工作效率高， $\eta \approx 98$%

⑤Can be used under higher temperature and humidity

能在较高温度和湿度下工作

❖★ In comparison to toothed drive Can be used for larger centre-to-centre distances

与齿轮传动相比：中心距a可以很大（8m）

2、 Drawbacks 缺点

① Used only for parallel shafts

只用于平行轴

② The velocity of the chain is not constant

→ Leading to larger impact, vibration and noise

$i_{瞬}$变化→高速时冲击、振动、噪音大.

3、 Applications 应用

（ For low speed and severe operation condition 适用于低速，胜任恶劣工况）

二、 Types of chain drives 链传动分类

①传动链：Power transmission chains 传递动力

- Bushing chains 套筒链：
  Higher sliding speeds 、Severe wear
- Roller chains 套筒滚子链：
  Are extensively applied 应用广泛
- Silent chains 齿形链（无声链）：
  Less noise 无噪音， High cost 价格高

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② Lifting chain 起重链：

Suspending loads 提升重物

③ Hauling chain 曳引链：

Carrying loads 移动重物

三、 Roller chains 套筒滚子链

1、 Structure 结构：

Bushings 套筒4、
inside link plates 内链板1：

Pin 销轴3、
Outside link plates 外链板2：

Interference fit

过盈配合

Bushings 套筒、 Tolerance fit

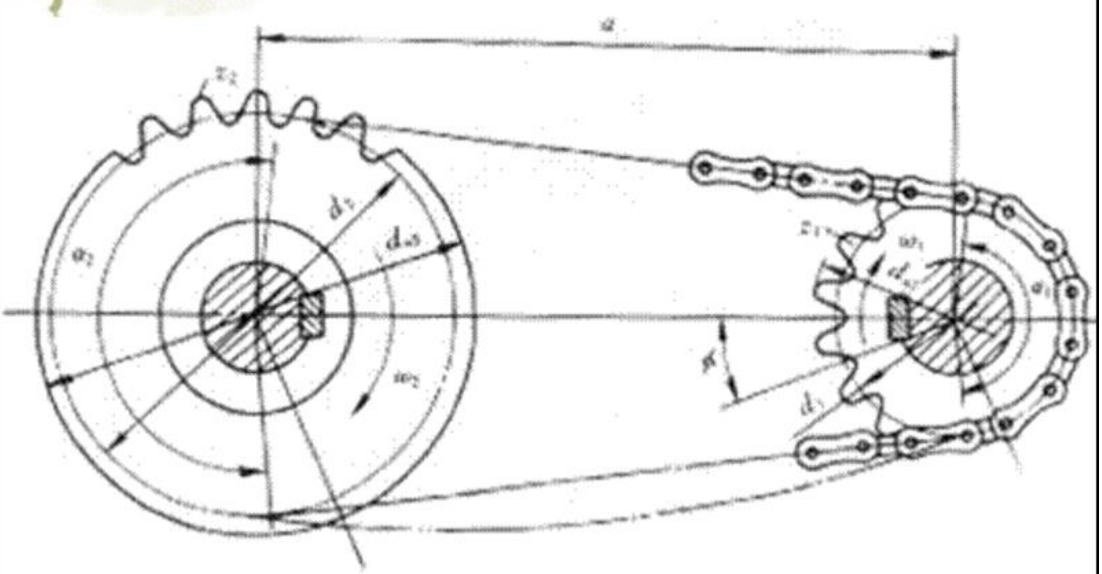
Rollers 滚子： 间隙配合

The pin pass through the bushings of adjacent links to form swivel joints

套筒、销轴相对转动

→ 链节屈伸

元件结构图



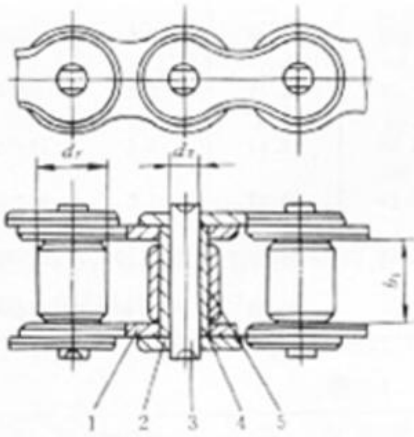


图 7-2 滚子链

1—内链板 2—外链板 3—销轴 4—套筒 5—滚子

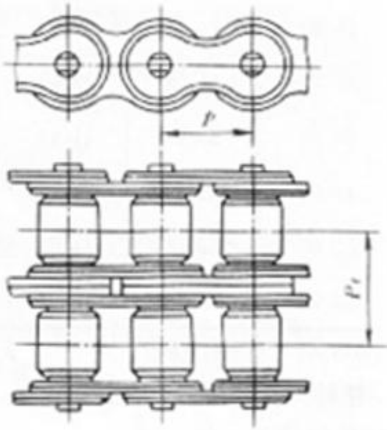


图 7-3 双排链

2、 Joints 接头形式

With an even number of links

链节数L_p是偶数：

- Large pitch 大节距 P： Cotter pins 开口销
- Small pitch 小节距 P： Spring clamp 弹簧夹

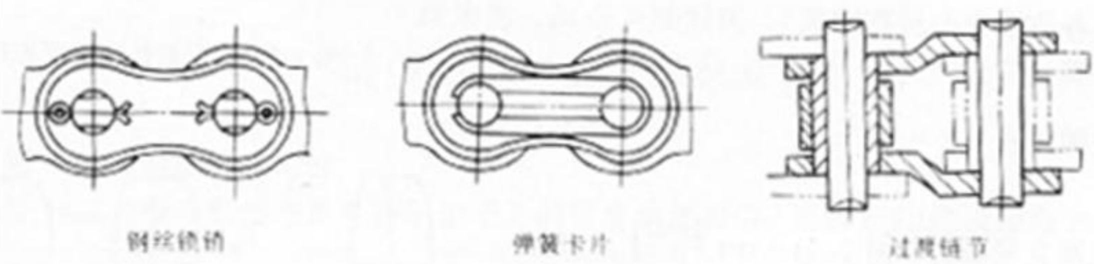
With an uneven number of links: Offset link

链节数L_p是奇数： 过渡链节

（ Which, however, is weaker than the main links. Therefore, designers try to use chains with an even number of links

附加弯矩，导致链条抗拉强度下降，

最好不用）



§8—2 Motion features of chain drives 链传动的运动特性

- Variation in speed ratio
  运动不均匀性
- Dynamic load
  动载荷

一、 Variation in speed ratio
运动不均匀性

- The velocity of the chain and speed ratio is not constant upon uniform rotational speed of the small sprocket.

小链轮转速ω_1是常数 时，瞬时链速V和瞬时传动比i都是周期性变化的。

1、The chain velocity 瞬时链速V

（为便于分析，设紧边处于水平位置）

① The velocity of the joint of the link

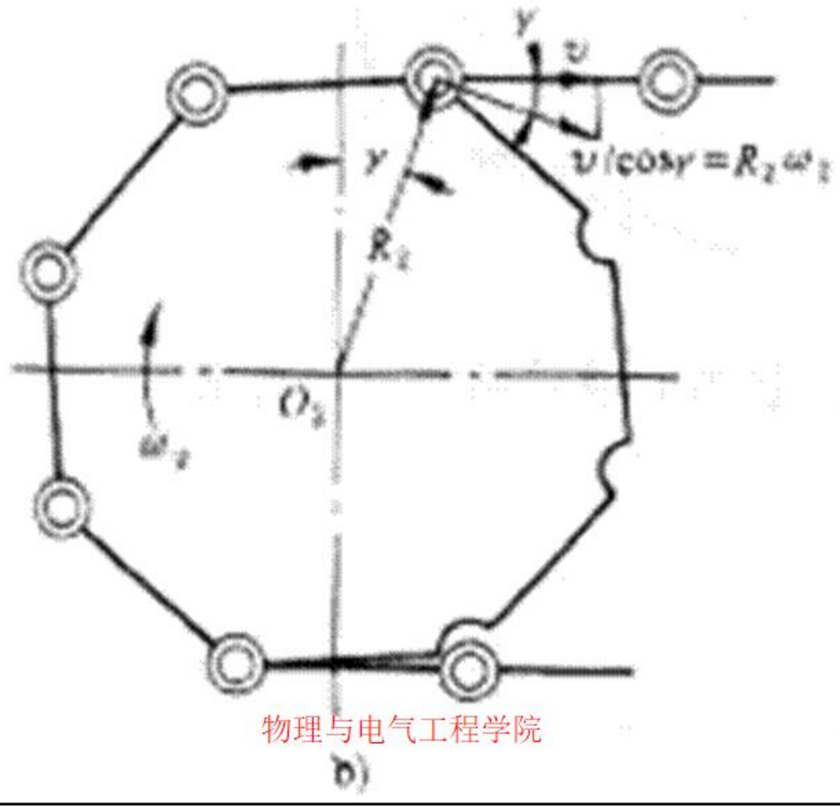
销轴中心$V_A = \omega_1 R_1$

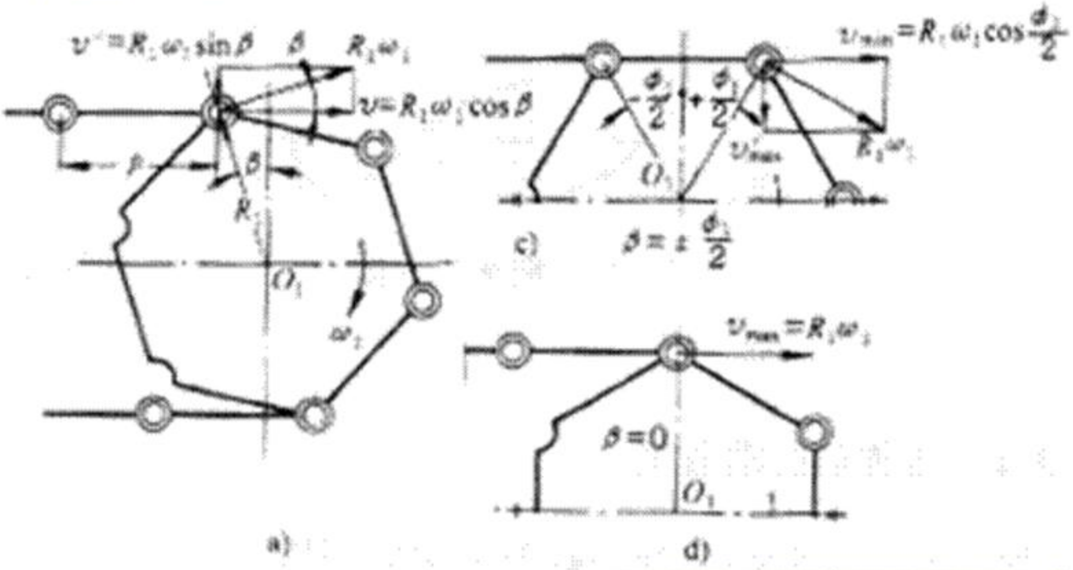
② The velocity of chain 链速

$V = V_A \cos\beta = \omega_1 R_1 \cos\beta$

（The velocity of vertical motion of the chain 链条上下垂直运动速度

$V' = \omega_1 R_1 \sin\beta$ ）





③

$$\beta = \left[-\frac{\varphi_1}{2}, \frac{\varphi_1}{2}\right] \qquad \varphi_1 = \frac{360^\circ}{Z_1}$$

$$\beta = -\frac{\varphi_1}{2} \qquad V_{min} = R_1\omega_1\cos\frac{\varphi_1}{2}$$

$$V'_{max} = R_1\omega_1\sin\frac{\varphi_1}{2}$$

$$\beta = 0^\circ \qquad V_{max} = R_1\omega_1$$

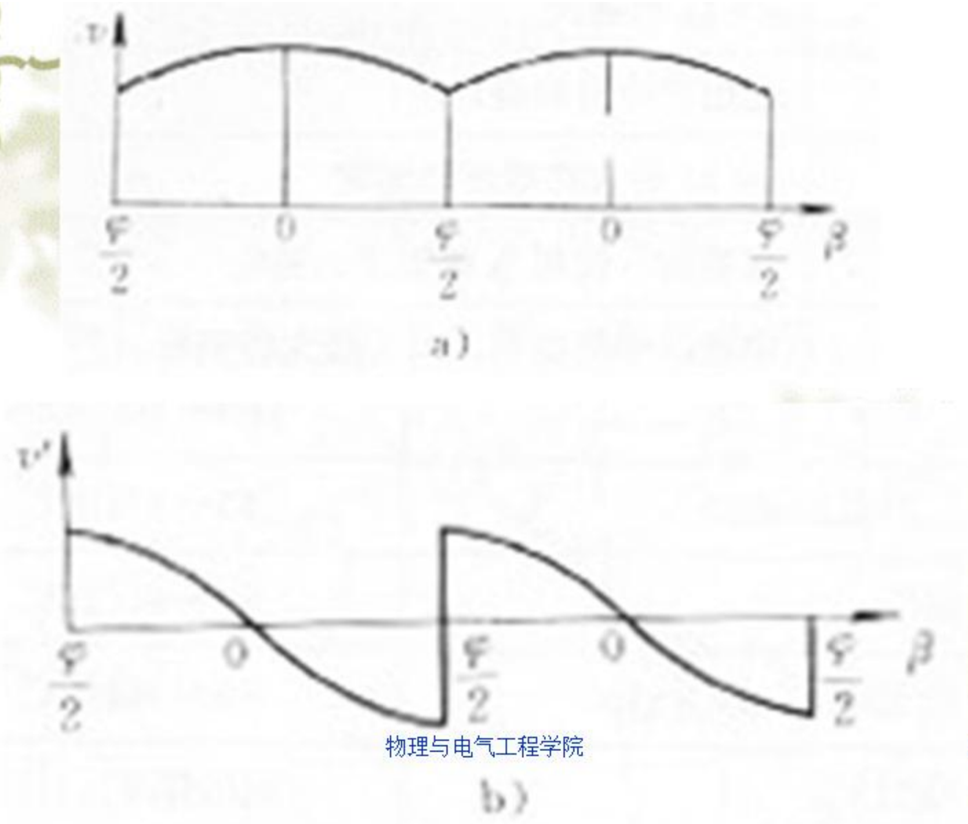
$$V'_{min} = 0$$

$$\beta = \frac{\varphi_1}{2} \qquad V_{min} = R_1\omega_1\cos\frac{\varphi_1}{2}$$

$$V'_{max} = -R_1\omega_1\sin\frac{\varphi_1}{2}$$

Since angle β varies, the chain velocity varies.

周期性变化，导致V不均匀性



④ Deceleration in rising

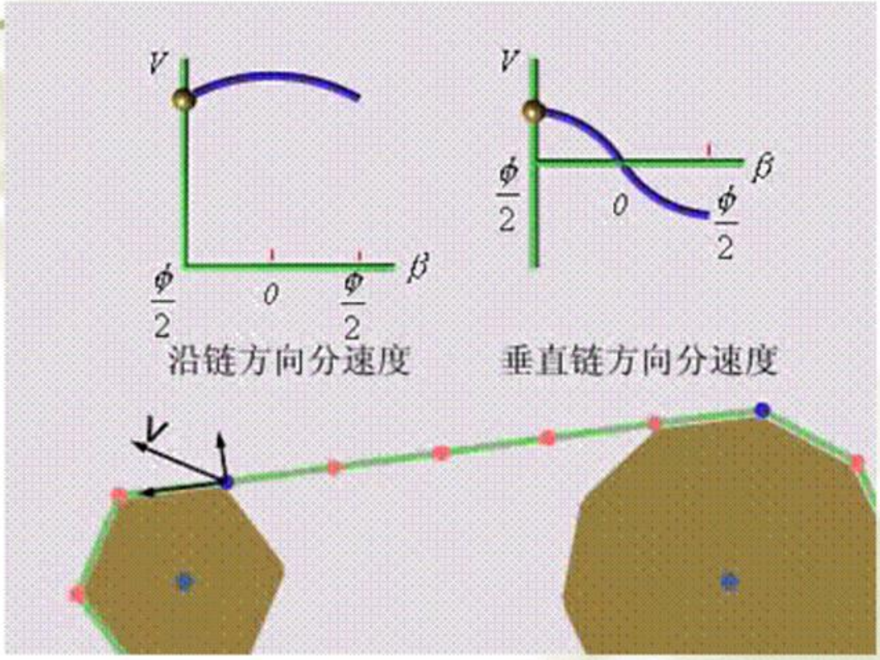
When rising, the chain suddenly falls and vice-versa

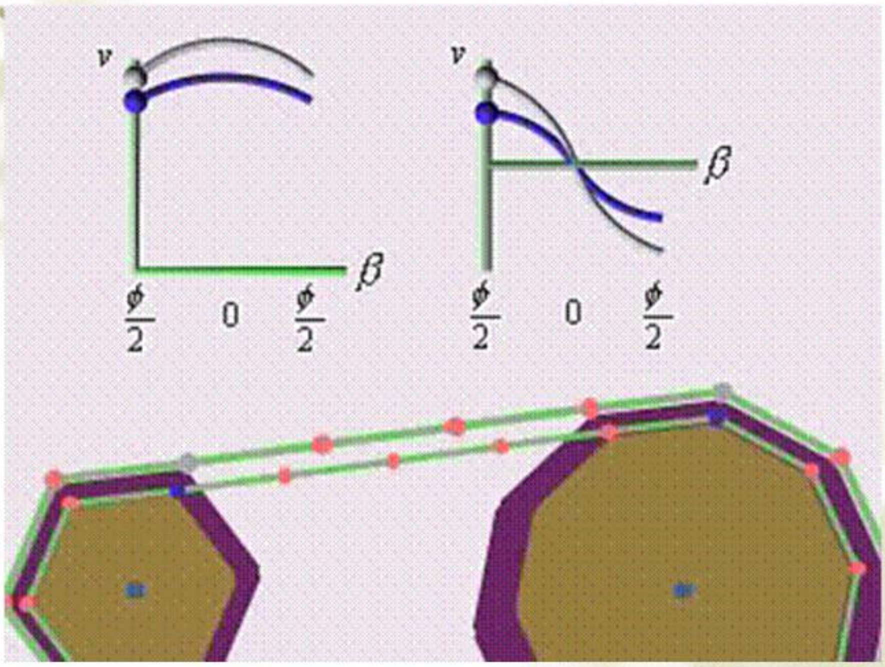
Unsteady motion and vibration

$$V':\begin{cases}\left[-\varphi_1/2,\ 0\right]: \text{减速上升}\\ \left[0,\ \varphi_1/2\right]: \text{加速下降}\end{cases}$$ 忽上忽下，忽快忽慢 ⇒ 不平稳，振动

Acceleration in falling

Quick motion suddenly changes into slow motion and vice-versa


V
β
$\frac{\phi}{2}$
0
$\frac{\phi}{2}$
沿链方向分速度
V
β
$\frac{\phi}{2}$
0
$\frac{\phi}{2}$
垂直链方向分速度
V


v
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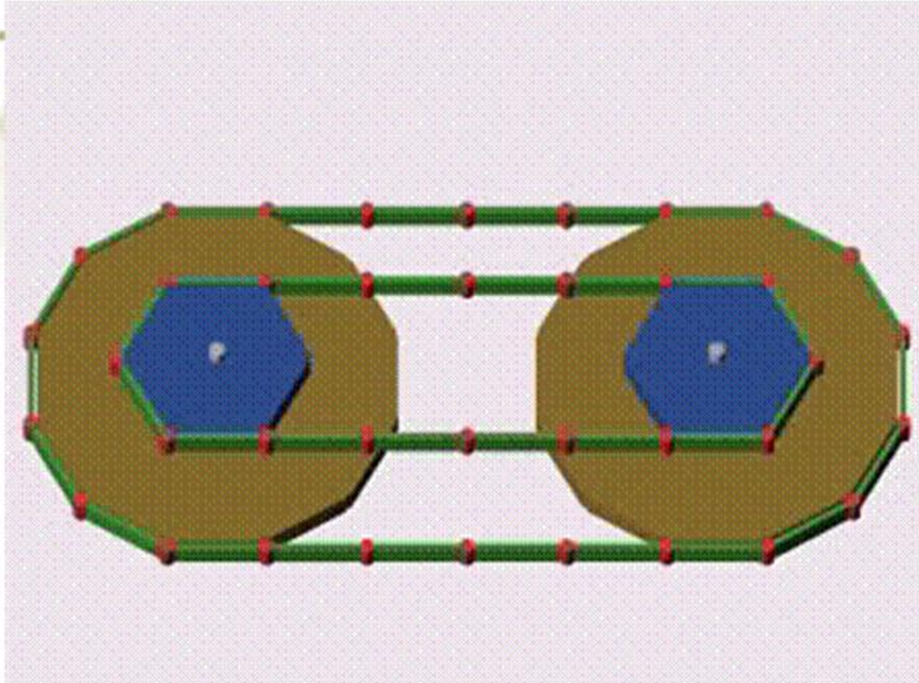

⑤

$$\varphi_1 = \frac{360^o}{Z_1} \qquad Z_1\downarrow \rightarrow \text{链速不均匀性}\uparrow$$

Nun uniformity of the velocity for the chain

2、 Instantaneous speed ratio 瞬时传动比

①

$$\omega_2 = \frac{V}{R_2\cos\gamma} \qquad i_{12} = \frac{\omega_1}{\omega_2} = \frac{R_2\cos\gamma}{R_1\cos\beta}$$

②

$\omega_1 = const$　　　i_{12}变化→i_{12}，ω_2不均匀

③ Only at :

$Z_1 = Z_2$ （ $R_1 = R_2$ ）

There is exactly a whole number of links in the driving side of the chain

只有当$Z_1 = Z_2$,紧边长度恰为P的整数倍时 （β，γ随时相等）

⟹ $i_{12} \equiv 1$ （$\omega_1 \equiv \omega_2$）

3、Average velocity of the chain& average speed ratio 平均链速V和平均传动比 i

$$V=\frac{Z_1Pn_1}{60\times1000}=\frac{Z_2Pn_2}{60\times1000}\quad(m/s)$$

（链轮转一周，随之转 过链长为ZP）

$$i=\frac{n_1}{n_2}=\frac{Z_2}{Z_1}$$

When the sprocket turn 360^0, the length of the chain running over the sprocket is z_p.

Z—齿数　　　P—节距

Number of teeth of a sprocket　　Chain pitch

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二、 Dynamic load 动载荷

1、No uniformity of the motion → Dynamic load 运动不均匀性→动载荷

i, ω_2 Periodic change→Acceleration → Dynamic load 周期性变化→加速度→动载荷

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①

$$a = dV/dt = -R\omega_1 \sin\beta \frac{d\beta}{dt} = -R\omega_1^2 \sin\beta$$

②

$$\beta = \pm \varphi_1/2 \text{时，} a_{max} = \pm R_1\omega_1^2 \sin\frac{\varphi_1}{2} = \pm R_1\omega_1^2 \sin\frac{180^\circ}{Z_1}$$

$$\because R_1 \sin\frac{\varphi_1}{2} = P/2\text{，则} a_{max} = \pm\frac{P}{2}\omega_1^2$$

❖③ ω_1↑ P↑(Z_1↓) →

It is favorable to select small pitch and large number of teeth from the point of view of decreasing dynamic load

动载荷↑宜采用小节距P大齿数Z_1

2、Periodic change

V′ 周期性变化→Cross vibration

横向振动 →Dynamic load

动载荷

3、Mesh impact→ Dynamic load

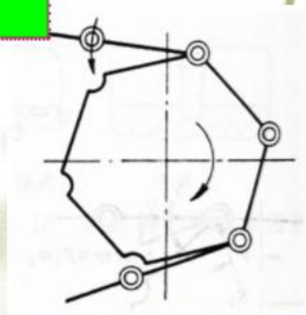
冲击→动载荷

Impacts of the chain links on the sprocket teeth as new links come into engagement

链节进入链轮时，以一定相对速度相啮合→冲击→动载荷

❖Impact energy of motion 冲击动能

$$U = \frac{qP^3n^2}{C} \qquad C - const$$



In order to reduce impact

为减小冲击 { Reduce 减小P，n
　　　　　　{ Reduce 减小q

（Mass per m 线密度）

§8—3 Roller chain drive design 套筒滚子链设计计算

❖Principal parameters 参数选择

❖Types of failure 失效形式

❖Limit power curve and allowable power curve 极限功率曲线和许用功率曲线

❖Design 设计计算

一、Principal parameters 参数选择

1、$i \leqslant 8$（Usually 2～3.5）

i↑ → α_1↓ →Number of meshing teeth 啮合齿数↓→ Wear of the sprocket 轮齿磨损→ Shift outward upon the sprocket teeth profiles

跳链 $\alpha_1 \geqslant 120°$ → i= 2～3.5

2、Z_1，Z_2

(1) Z_1

Z_1↓ →

Nonuniformity of the motion and dynamics load

运动不均匀性、动载荷↑

The links turn 增大链节相对转角

→Power losses 功率损耗↑

pressure increased acting on the pins

增大铰链承压面压强→Wear 磨损↑

$Z_1 \geqslant 9$

$Z_1 = f(i)$

表 7-6 小链轮齿数 z_1

传动比 i	1~2	3~4	5~6	>6
Z_1	31~27	25~23	21~17	17

Chain is easily fall off sprocket

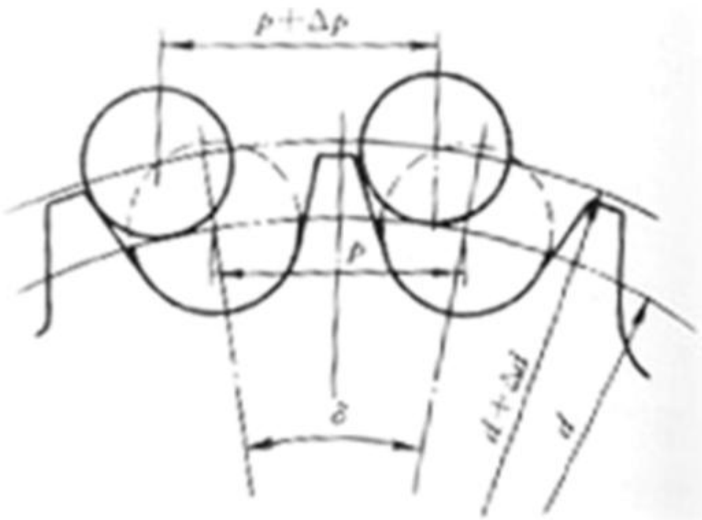
(2) $Z_2 = i Z_1 \leqslant 120$ $Z_2 \uparrow \rightarrow$ 易跳链

$$d' = \frac{P + \Delta P}{\sin\frac{180^\circ}{Z}} \qquad d = \frac{P}{\sin\frac{180^\circ}{Z}} \qquad \Delta d = \frac{\Delta P}{\sin\frac{180^\circ}{Z}}$$

$\Delta P = const$, $Z\uparrow \rightarrow \Delta d \uparrow \rightarrow$ 易跳链

(3)When the number of the chain links is the even number, In order to facilitate more uniform wear, It is preferable to select uneven number of teeth for the sprockets or to select the number of teeth from the series of prime numbers.

链节数Lp为偶数时，为均匀磨损， Z最好为质数或不能整除链节数的数



3、P（ pitch节距）

P ↑ →Size 尺寸 ↑

- Load carrying increases 承载能力增大
- Nonuniformity of the motion and dynamic load increase
- 运动不均匀性、动载荷增大

- High speed and heavy load : Small pitch and multiple- width chain drive 高速重载:小节距P多排

- Low speed and light load : Large pitch and single-width chain drive 低速重载:大节距P单排

It is best practice to elect a chain with the minimum allowable pitch for the given load

节距P 尽量小，但排数≤3~4（均匀）

4、Centre-to-centre distance 中心距a

The number of the chain links 链节数 L_p

(1)$a=(30\sim50)P$ （$a_{max}=80P$）

a ↓→V不变时，单位时间内同一链节屈伸次数↑→磨损↑

a↑→松边上下颤动，不平稳

(2)L_p（链条长度用链节数表示）

$L=L_pP$

$$L_p = L/P$$

$$L = \frac{\pi(D_1+D_2)}{2} + 2a + \frac{1}{4a}(D_2-D_1)^2$$

$$D = PZ/\pi \text{ 代入}$$

$$L_P = \frac{Z_1 + Z_2}{2} + 2\frac{a}{P} + \left(\frac{Z_2 - Z_1}{2\pi}\right)^2 \frac{P}{a}$$

L_p Round →The even number 偶数Lp′ → Actual centre-to-centre distance实际中心距a′

$$a' = \frac{P}{4}\left[\left(L_P' - \frac{Z_1 + Z_2}{2}\right) + \sqrt{\left(L_P' - \frac{Z_1 + Z_2}{2}\right)^2 - 8\left(\frac{Z_2 - Z_1}{2\pi}\right)^2}\right]$$

❖二、 Types of failure 失效形式

1、 Fatigue breakage of the chain

链条疲劳破坏

(chain plates, surfaces of the bushings and rollers)

（链板、套筒和滚子表面）

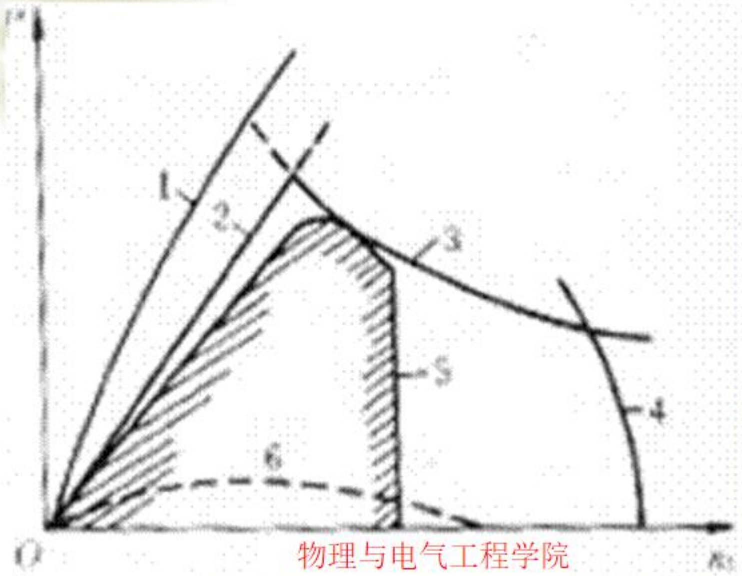
2、Wear of the hinge for the chain链
铰链磨损→Out off sprocket 脱链

3、Seizure of the hinge for the chain
链条胶合（ At high speed 高速 ）

4、 Overload breakage of the chain
链条过载拉断

5、Wear of the sprockets 链轮磨损

❖ 三、Limit power curve and allowable power curve 极限功率曲线和许用功率曲线



- 1— Limit of the wear failure 磨损破坏极限
- 2—Limit of the fatigue failure of the chain plates 链板疲劳破坏极限
- 3— Limit of the impact fatigue failure 套筒、滚子冲击疲劳极限

4— Limit of the seizure of the hinge between bushings and pins

套筒、销轴胶合极限

5— Allowable power curve ,operating inside the range is safe

许用传动功率曲线，在此范围内为安全区.

- 6—Wear breakage limit under poor lubrication and severe operating condition

润滑不良、工作环境恶劣的磨损极限

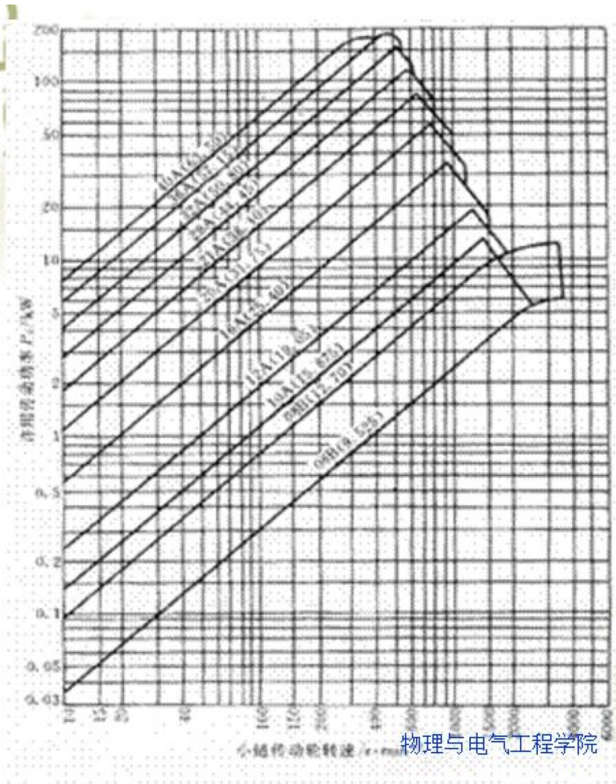


图 7-12 滚子链许用传动功率曲线

Experimental conditions

试验条件：

$Z_1 = 19 \quad L_p = 100$

Single-width

单列

Steady load

载荷平稳

四、 Design 设计计算

❖ 1、The power which can be transmitted by a chain drive under actual working conditions is determined by multiplying the tabular value by the correction factors

实际工作中与上述试验条件不同时，对工作功率P和许用功率P_0进行修正：

K_P K——Load factor 载荷系数

$K_Z K_L K_P P_0$

- $Z_1 \neq 19 \rightarrow K_Z$（ Small sprocket tooth number factor 小链轮齿数系数）
- $Lp \neq 100 \rightarrow K_L$（ Chain length factor 链长系数）
- 多排链→ K_P（ Multiple-width chain factor 多排链系数）

Design criteria 设计依据:

$K_P \leqslant K_Z K_L K_P P_0$

$$\frac{KP}{K_Z K_L K_P} \leq P_0$$

2、V<0.6m/s（ Low speed drive 低速传动）

Principal failure is overload breakage ：

主要失效形式过载拉断

→ Static strength check 静强度校核

Safety factor $安全系数S=\frac{Z_P Q_B}{KF}\geq 7$

Z_P — The width number of chain 链排数

Q_B — Breaking load of single - width chain 单排链极限拉伸载荷

F — The total force of driving side 紧边总拉力

§ 8-4 Forces in the chain drives 链传动受力分析

1、Useful load 工作拉力

$$F_1 = 1000P/V$$

2、Centrifugal tension 离心拉力

$$F_2 = qV_2$$

3、Weight tension 垂度拉力 $F_3 = K_f qga$

For a horizontal drive 水平传动 ： $K_f = 6$

For an angle of inclination of the drive to the horizontal up to 40^0 倾角<40° ： $K_f = 4$

For over 40^0 倾角>40° ： $K_f = 2$

For a vertical drive 垂直传动 ： $K_f = 1$

$$\left(F_3 f = \frac{qga}{2}\frac{a}{4} \qquad F_3 = \frac{1}{8\left(\frac{a}{f}\right)}qga\right)$$

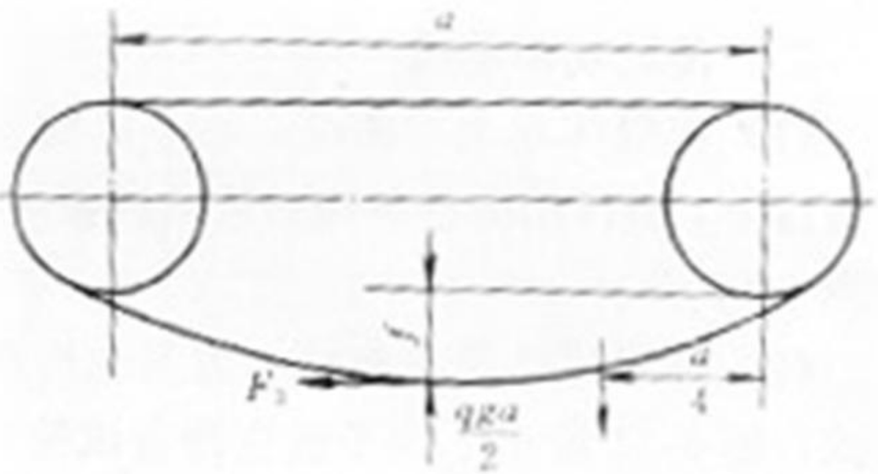


图 7-10 垂度拉力计算简图

4、The total force of driving side

紧边总拉力 $F = F_1 + F_2 + F_3$

↓

The total force of driven side

松边总拉力 $F' = F_2 + F_3$

The force acting on the shaft

压轴力 $Q = F + F'$

（Except the centrifugal tension 离心拉力应除外）

$Q = F_1 + 2F_3 \approx 1.2F_1$ （F_3不大）

§8—5 Tension and arrangement of the chain drive 链传动的布置与张紧

- Arrangement 布置
- Tension 张紧

一、Arrangement 布置

① Two sprockets rotates inside the one plane

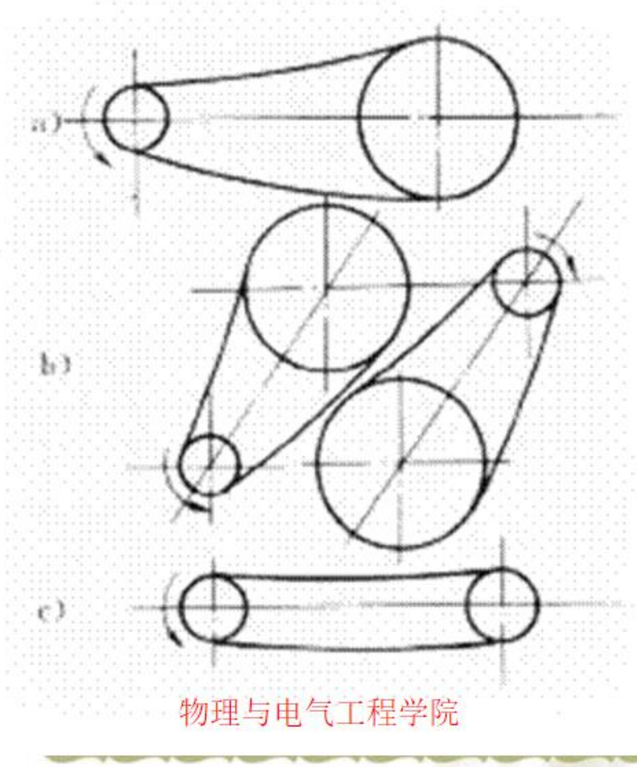
两链轮回转平面在同一垂直平面内

（Otherwise， Out off sprocket and severe wear

否则,脱链、不正常磨损）

② It is best practice to arrange centreline between two sprockets horizontally or at an angle of inclination to the horizontal up to 45°

两链轮中心线最好为水平的或与水平面成45°以下倾角



二、Tension 张紧

① Causes 目的（Differ from the tension of the belt drive 与带不同）

Decide the sag value

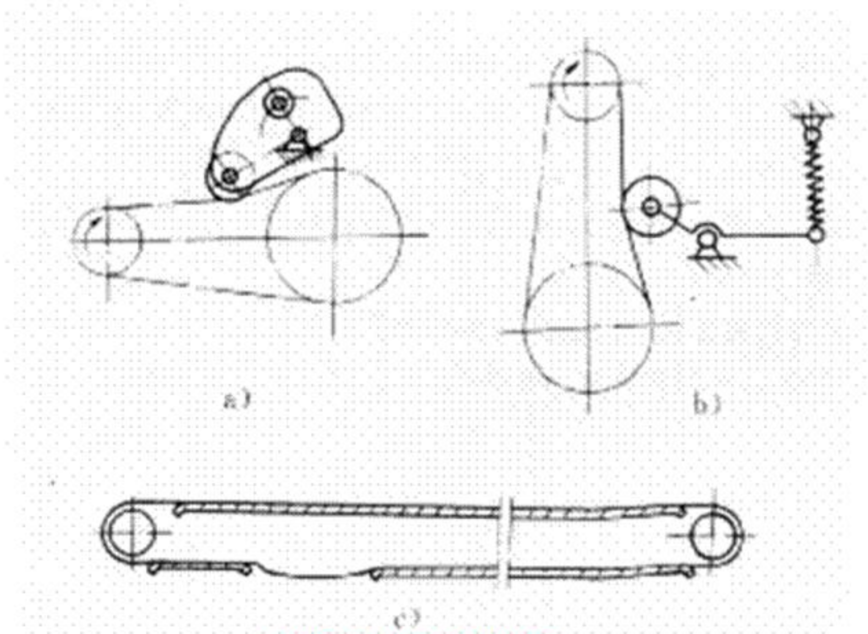
决定垂度f大小 $\begin{cases} f\uparrow & \text{Bad mesh 啮合不良} \\ f\downarrow \to F_3\uparrow \to \text{磨损}\uparrow \to Q\uparrow \end{cases}$

② Methods 方法

(1) Increase the centre-to-distance 增大中心距

(2) When the centre-to-distance can not changed, tension wheel should be used.

当中心距不可调的时候 采用张紧轮、压板、托板（大中心距时）


a)
b)
c)