



§5 Belt drives 带传动

§5-1 General considerations 概述

§5-2 Belt drive theoretical basis 带传动理论基础

§5-3 V-Belt drive design 带传动设计 (V带)

§5-4 Tension device of the belt drive 张紧装置

Belt drive design example 带传动设计实例

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§5-1 General considerations

★ 特点和应用

Characteristics and applications of the belt drive

★ 分类 Types of the belt drive

★ 带的结构、型号和长度

Composition, section and length of the V—belt

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一、特点和应用

1、优点

- ★是挠性传动，有缓冲减振作用，传动噪声低；
- ★对摩擦式带传动，有过载保护作用；
- ★可传递两个或多个相距较远轴之间的运动；
- ★不需润滑，环境易清洁；
- ★结构简单，维修方便，成本较低；
- ★适用于较高速传动。

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2、缺点

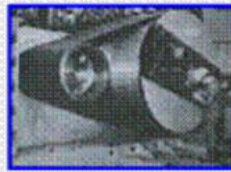
- ★有弹性滑动现象，传动比不准确，不宜用于对传动比有准确性要求的场合；
- ★与链传动和齿轮传动相比，带传动结构较大，并且强度较低、疲劳寿命较短；
- ★因摩擦生电，一般不宜用于有易燃物场所。

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3、Applications



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二、Types



普通V带
Standard V-belt



窄V带



齿形V带



宽V带



汽车V带



平带



多楔带



同步带

Flat belt

Multiple V belt

Toothed-belt drive

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三、Composition、section and length of the belt

带的结构、型号和长度

1. 普通V带 Standard V-belt
2. 平形带 Flat-belt
3. 多楔带 Multiple V belt drive
4. 同步齿形带 Toothed belt drive

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1. Standard V-belt 普通V带

型号 Y Z A B C D E

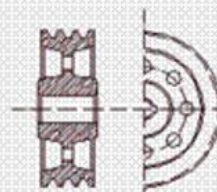
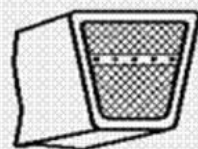
标记方法 A 1400 GB1171-89 (例)

现行国标 GB1171-89

特点说明

在一般机械传动中应用最为广泛的一种带传动，传动功率大，结构简单，价格便宜。由于带与带轮间是槽面摩擦，故可产生比平型带更大的有效圆周力（约为3倍）。

普通V带有包布型V带和切边型V带两类。



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2、Flat-belt 平形带



规格 按纵向拉伸强度和宽度

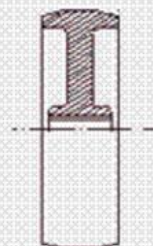
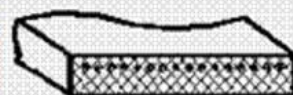
标记方法 包括拉伸强度、宽度或内周长

现行国标 GB524-89

特点说明

平带由多层覆胶帆布粘合在一起而构成，其形式分切边式和包边式。

- 切边式：各层帆布不包叠，侧面为切割而成的平面。
- 包边式：最外层或数层帆布包叠，侧面为弧形面。



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3、多楔带 Multiple V belt drive



型号 PH PJ PK PL PM

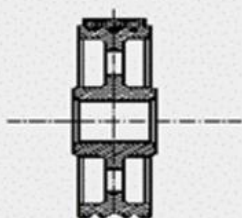
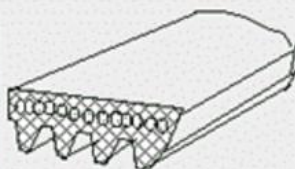
标记方法 10 PM 3350 (例)

现行国标 GB/T16588-1996

特点说明

多楔带兼有V带和平带二者的优点，既有平带的柔软、韧性好的特长，又有V带结构紧凑、高效率的优点。因此应用广泛，其主要特点有：

- 1、带体为整体，传动时长短不一现象可消除，充分发挥了胶带的作用；
- 2、空间相同时，多楔带比普通V带的传动功率提高30%；






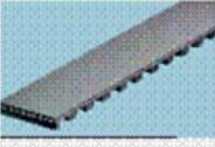
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4、toothed belt drive 同步齿形带



		型号 MXL XXL XL L H XH XXH
		标记方法 980H200; DA980XXH300
		现行国标 GB11361-89
		特点说明 同步带传动综合了带传动、链传动和齿轮传动的优点。 同步带现已在各种仪器、计算机、汽车、工业缝纫机、纺织机和其它通用机械中得到广泛应用。

§ 2-2 Belt drive theoretical basis

带传动理论基础

★ 受力分析

Forces in belts

★ 应力分析

Stresses in belts

★ 带的滑动现象

Creep and slipping of the belt

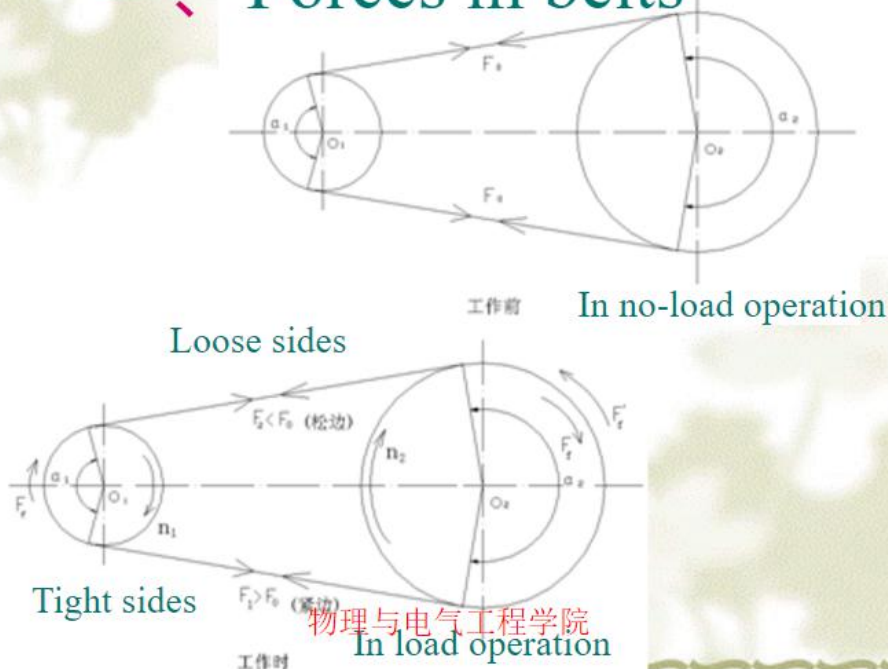
★ 失效形式和计算准则

Types of failure & design criteria

★ 承载能力确定

Load-carrying capacity

一、 Forces in belts





1、带传递的力

有效拉力 F_e = 两边拉力差

$$F_e = F_1 - F_2 = \frac{1000P}{v}$$

2、有效拉力 F_e 由带和轮之间接触弧上摩擦力的总和 F_f 承受

$$F_e = F_f$$

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3、 $F_e \uparrow \rightarrow F_f \uparrow$ ，始终保证 $F_e = F_f$ 。

然而，在一定条件下，

F_f 有一极限值 $F_{f \max}$ 。

当 $F_e > F_{f \max}$ 时，导致打滑失效。

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4. F_{emax} calculation

(开始打滑时, F_1 、 F_2 之间关系)

$$F_{\text{emax}} = 2(F_0 - qv^2) \frac{e^{\mu\alpha} - 1}{e^{\mu\alpha} + 1}$$

此时:

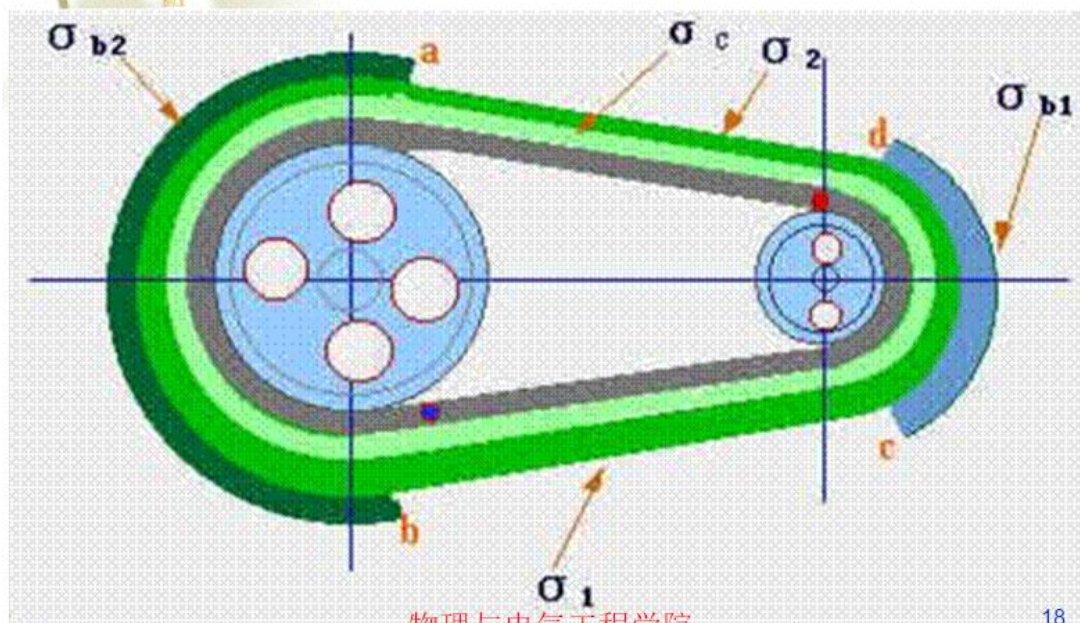
$$F_1 = F_0 + \frac{F_{\text{emax}}}{2} = \frac{F_{\text{emax}} e^{\mu\alpha}}{e^{\mu\alpha} - 1} + qv^2$$

$$F_2 = F_0 - \frac{F_{\text{emax}}}{2} = \frac{F_{\text{emax}}}{e^{\mu\alpha} - 1} + qv^2$$

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二、应力分析 Stresses in belts



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1 拉应力

Tensile stress

$$\begin{cases} F_1 \rightarrow \sigma_1 = \frac{F_1}{A} \\ F_2 \rightarrow \sigma_2 = \frac{F_2}{A} \end{cases}$$

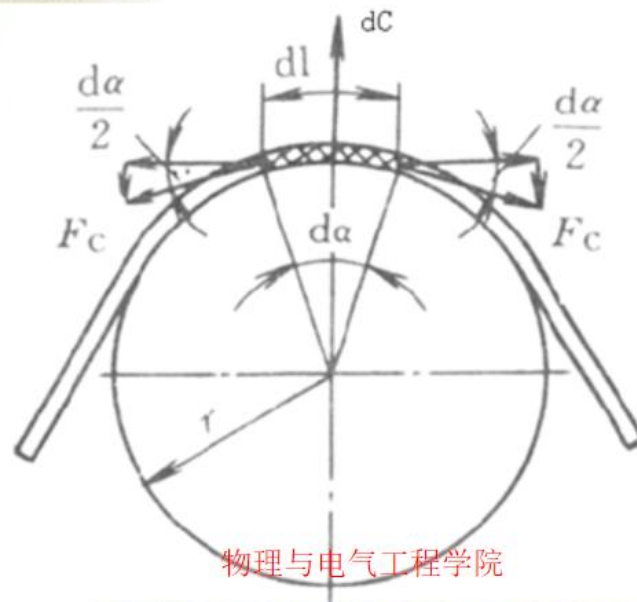
As the belt runs over the driving pulley, tensile stress changes from σ_1 to σ_2

(带绕过小轮时, 拉应力由 $\sigma_1 \rightarrow \sigma_2$)

(带绕过大轮时, 拉应力由 $\sigma_2 \rightarrow \sigma_1$)

As the belt runs over the driven pulley, tensile stress changes from σ_2 to σ_1 .

2. 离心应力 Centrifugal stress



①带沿弧面运动，微段 $d\alpha$ 产生离心力 dC :

As the belt runs over arc of the pulley, centrifugal force dC is acting on an elementary arc $d\alpha$.

$$dC = q(Rd\alpha) \frac{v^2}{R} = qv^2 d\alpha \quad (q: \text{kg/m})$$

②根据力平衡关系:

Take into account the condition of static equilibrium

$$2F_c \sin \frac{d\alpha}{2} = qv^2 d\alpha \left(\sin \frac{d\alpha}{2} \approx \frac{d\alpha}{2} \right)$$

$$\Downarrow$$

$$F_c = qv^2 \text{ (离心拉力) } \text{ Centrifugal tensile force}$$

{ 离心力 dC 发生于圆周部分
 { 离心拉力 F_c 作用于整个带长

Centrifugal force dC acting on the arc parts on the belt

Centrifugal tensile force F_c acting on the arc parts and straight portions of the belt

③离心应力: Centrifugal stress

$$\sigma_c = \frac{F_c}{A} = \frac{qv^2}{A} \quad (\text{作用于全带长,})$$

F_1, F_2 中包含 $F_c = qv^2$, σ_1, σ_2 中包含 σ_c 。)

Centrifugal stress σ_c acts on every part of the belt.

**Because F_c is contained in F_1 or F_2 , σ_c is contained in σ_1 or σ_2 .

Centrifugal stress σ_c acts on every part of the belt.

F_c is a part of both F_1 and F_2 , while σ_c is a part of σ_1 and σ_2

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3. 弯曲应力 The bending stress

(发生于带与带轮接触的圆弧部分)

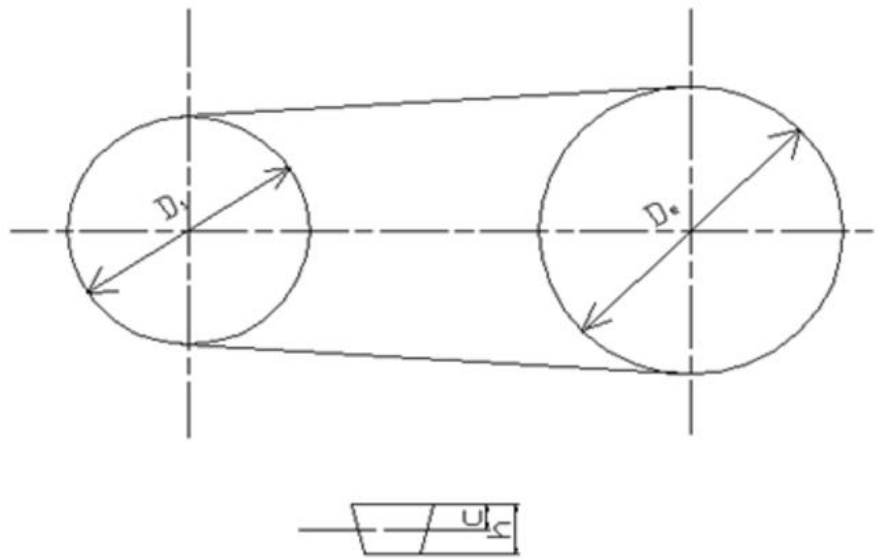
Acting on the arc of contact on the pulley

$$\sigma_b = E \frac{2c}{D}$$

$$D \downarrow \Rightarrow \sigma_b \uparrow \quad \therefore \sigma_{b1} > \sigma_{b2}$$

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4. The total stress

- ❖ The total stress in the belt is equal to the sum of the bending stress plus the tensile stress which contains the centrifugal stress .
- ❖ Maximum stress is at the point where the tight side of the belt runs onto the smaller driving pulley.

4. 总应力:

等于拉应力（包括离心应力）与弯曲应力之和；

最大应力发生于紧边进入小带轮处。



$$\begin{aligned}\sigma_{\max} &= \sigma_1 + \sigma_{bl} = \frac{F_1}{A} + \sigma_{bl} \\ &= \frac{1}{A} \left(\frac{Fe^{\mu\alpha}}{e^{\mu\alpha} - 1} + qv^2 \right) + \sigma_{bl} \\ &= \frac{1}{A} \left(\frac{Fe^{\mu\alpha}}{e^{\mu\alpha} - 1} \right) + \sigma_c + \sigma_{bl}\end{aligned}$$

三、带的滑动现象 Creep and slipping of the belt

1. 带的弹性滑动 Creep of the belt (固有的、不可避免的正常现象)

The operation of an elastic belt is associated with creep of the belt on the pulleys .It is inevitable.

$$\textcircled{1} \begin{cases} \text{紧边应变: } \varepsilon_1 = \frac{\sigma_1}{A} & \text{The tight side strain} \\ \text{松边应变: } \varepsilon_2 = \frac{\sigma_2}{A} & \text{The loose side strain} \end{cases} \quad \varepsilon_1 > \varepsilon_2$$

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$$\textcircled{2} \begin{cases} \text{带绕过主动轮: } \varepsilon_1 \rightarrow \varepsilon_2 \text{ (逐渐缩短), 沿轮面滑动 } \rightarrow v_{\text{带}} < v_1 \\ \text{带绕过从动轮: } \varepsilon_2 \rightarrow \varepsilon_1 \text{ (逐渐伸长), 沿轮面滑动 } \rightarrow v_{\text{带}} > v_2 \end{cases}$$

- ❖ As the belt runs over the driving pulley, ~~that~~ it becomes shortened and creeps along the pulley.
- ❖ As the belt runs over the driven pulley, ~~that~~ it is elongated and creeps along the pulley.

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❖ 由于带的弹性和拉力差引起的带与带轮之间的滑动，称为弹性滑动

The creep of the belt on the pulleys is caused by elasticity of the belt and the difference between tensile forces of the tight and the loose sides. It is known as the elastic slip.

③后果：a. 效率降低；b. 带磨损；c. 带温升高；d. $v_2 < v_1$ 传动比不准确

❖ Results of the creep: a. efficiency drops.
b. belt wear. c. temperature of the belt grows.
d. the speed ratio is not precise.

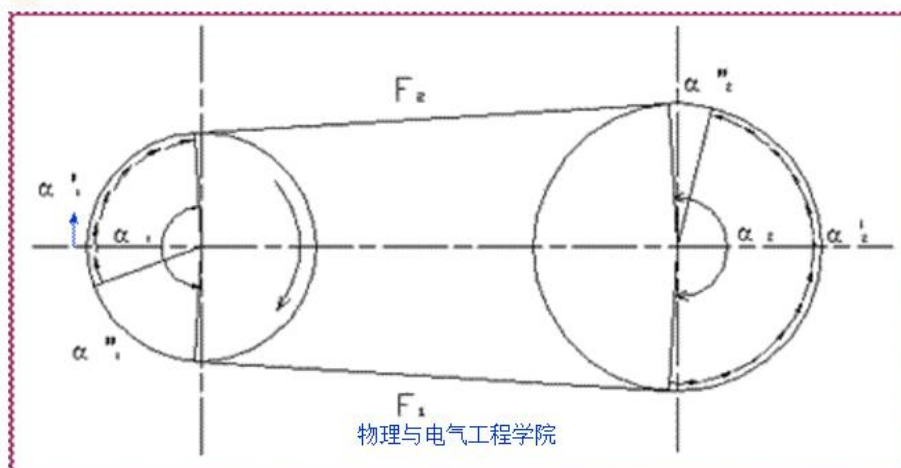
从动轮相对于主动轮的圆周速度相对降低率称为**滑动率**：

The relative creep factor is :

$$\varepsilon = \frac{v_1 - v_2}{v_1} = \frac{\pi n_1 D_1 - \pi n_2 D_2}{\pi n_1 D_1} =$$

$$1 - \frac{D_2 n_2}{D_1 n_1} = 1 - \frac{D_2}{D_1} \frac{1}{i} \quad (\text{一般为} 1 \sim 2\%)$$

2. 打滑 Slip （过载失效，必须避免）
(It is a kind of failure. And it should be avoided)



带在带轮上全面滑动，导致带严重磨损、带的运动处于不稳定状态，这种现象称为打滑。



Slip occurs on smaller pulley

③ $\alpha_1 < \alpha_2$

产生在小带轮处

打滑



四、失效形式和计算准则 Types of failure & design criteria

失效形式
Types of failure :
打滑、带疲劳破坏
Slip fatigue failure

2. 计算准则 **design criteria** :

在不打滑前提下，具有一定的
疲劳强度和寿命。

**No slip and ensuring
necessary service life and
fatigue strength.**

五、承载能力确定

Load-carrying capacity

(受两种失效形式制约 It is limited by two types of failure)

1. 单根V带在特定条件下，能传递的功率 P_0

Power transmitted by a single V-belt under special conditions

❖(1)不打滑条件下，带传递的最大载荷：

Without slipping, the maximum useful load transmitted by the belt is calculated as follows:

$$F_{\text{max}} = F_{\text{min}} = 2(F_0 - qv^2) \frac{e^{\mu\alpha} - 1}{e^{\mu\alpha} + 1} = (F_1 - qv^2) \left(1 - \frac{1}{e^{\mu\alpha}}\right)$$

$$\uparrow \qquad \qquad \qquad = (\sigma_1 A - qv^2) \left(1 - \frac{1}{e^{\mu\alpha}}\right)$$

$$(F_1 = F_0 + \frac{F_{\text{max}}}{2})$$

❖ (2) 保证带具有一定疲劳强度:

In order to ensure necessary fatigue strength, the maximum stress of the belt is also limited:

$$\text{❖ } \sigma_{\text{max}} = \sigma_1 + \sigma_{b1} \leq [\sigma]$$

Using the maximum value

$$\text{❖ 取峰值 } \sigma_1 = [\sigma] - \sigma_{b1}$$



(3)不打滑且有一定的疲劳强度时，传递的功率 P_0 ：

In order to prevent slipping and ensure necessary fatigue strength, transmitted power is limited as follows:

$$P_0 = \frac{F_{\text{emax}} v}{1000} = \frac{(\sigma_1 A - q v^2)}{1000} \left(1 - \frac{1}{e^{\mu \alpha}}\right) v = \frac{A([\sigma] - \sigma_{b1} - \sigma_c)}{1000} \left(1 - \frac{1}{e^{\mu \alpha}}\right) v \quad (\text{KW})$$

(4)特定条件下

Under special conditions

(载荷平稳 Steady load、

$\alpha_1 = 180^\circ$ $i=1$ 、特定长度
Conditional length) \Leftrightarrow

试验 \longrightarrow $[\sigma]$ + 计算 \longrightarrow P_0 列表

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2. 单根V带实际能传递功率 P'

Actual power transmitted by a single V-belt

$$P' = (P_0 + \Delta P_0) \times K_\alpha K_L$$

(1) ΔP_0 —— 功率增量 Power increment

($i \neq 1 \rightarrow \sigma_{b2} \downarrow$,

则相同寿命时,可以增加P

Under the same service life, Power
transmitted can be increased)

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$$\diamond \Delta P_0 = 0.0001 \Delta T \times n_1$$

❖ (ΔT : 扭矩修正值

The torque correction factor)

❖ (2) K_α ——包角系数

Contact angle factor)

❖ (3) K_L ——长度系数

Length factor ($L_d' \neq L_d \rightarrow P \uparrow$

或 P_z 根V带传递功率 P_z

Power transmitted by z V-belts

$$P_z = Z \times P' = Z (P_0 + \Delta P_0) \times K_\alpha K_L$$

§ 5-3 带传动设计 (V带)

V-Belt drive design

★ 参数选择

Parameter determination

★ 带型号、长度和根数确定

Section, length and number of belt

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一、参数选择

Parameters determination

1. 最小带轮直径 D_{\min}

Minimum diameters of small pulley

$D \downarrow \rightarrow \sigma_b \uparrow \rightarrow \text{寿命 Service life} \downarrow$

\therefore 规定 D 有最小值; The minimum value of D is given.

$D \uparrow \rightarrow \text{尺寸 Overall size} \uparrow \therefore$ 不宜过大

Oversize diameters are unsuitable。

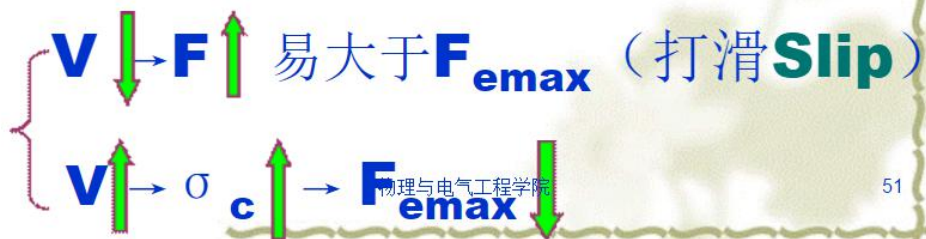
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❖ 2. 带速 The peripheral velocities of belt:

❖ 5~25m/s (The optimal values: 10~15m/s 最佳)

❖ ∴ $P = F_v / 1000$ 



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3. 中心距 The centre-to-centre distance:

$$0.55 (D_1 + D_2) + h \leq a \leq 2 (D_1 + D_2)$$



$L_d \downarrow \rightarrow V/L \uparrow$ (带单位时间
内绕过带轮的次数

running over
 a ↓
time)

Times

pulley in one unit of

→ 寿命

Service life ↓

$\alpha_1 \downarrow \rightarrow F_{\max} \downarrow$

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$a \uparrow$

overall size $\uparrow \rightarrow$

工作

时

拍击、颤动

Shocks and flapping

occur in

operation

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4. 包角 Contact angle

$\alpha_1 \geq 120^\circ$ (70° V
带) $\downarrow \rightarrow F_{\text{emax}} \downarrow$, 容易打滑

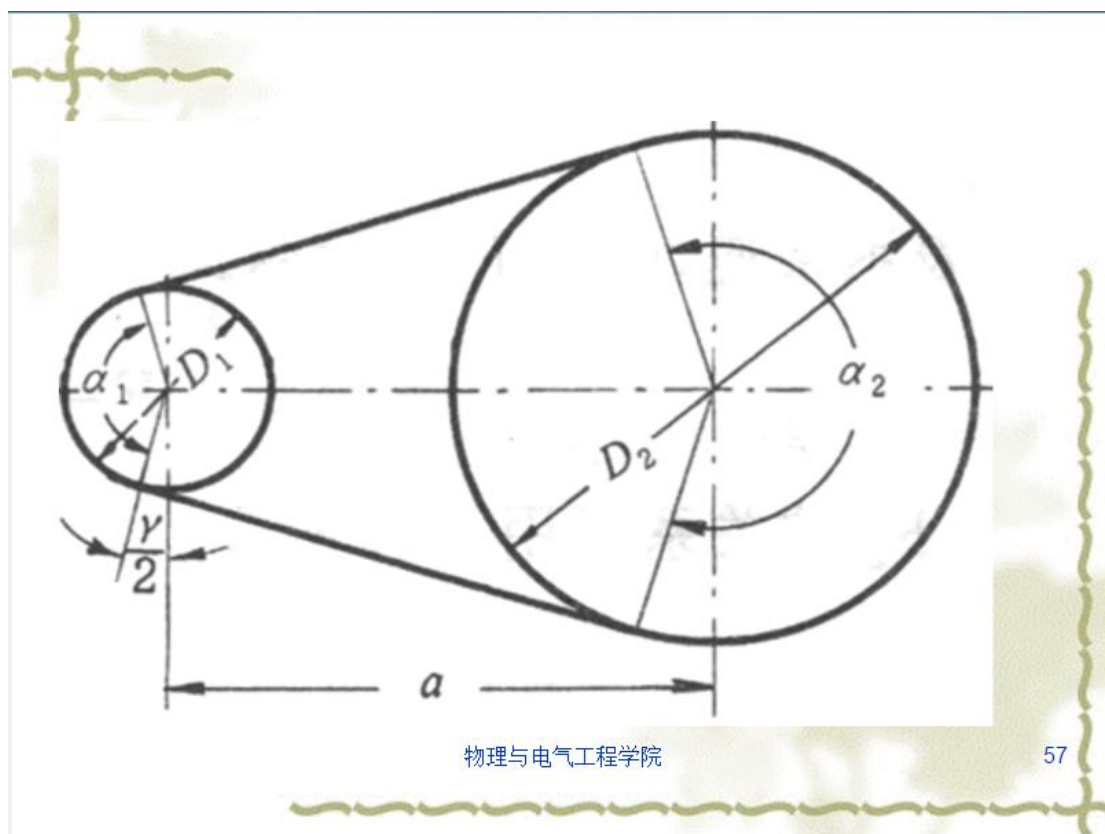
Possibility of slipping
increases。



$$\alpha_1 = 180^\circ - \gamma$$

$$\frac{\gamma}{2} \approx \sin \frac{\gamma}{2} = \frac{D_2 - D_1}{2a} \times \frac{180^\circ}{\pi}$$

$$\alpha_1 \approx 180^\circ - \frac{D_2 - D_1}{a} \times 60^\circ$$



$$\begin{cases} a \downarrow \rightarrow \alpha_1 \downarrow \\ i \uparrow \longleftrightarrow (D_2 - D_1) \uparrow \rightarrow \end{cases}$$

$$\alpha_1 \downarrow \quad (i \leq 7)$$

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5. 初拉力 The initial tension F_0
和

压轴力 The force acting on the
shafts F_r

$F_0 \uparrow \rightarrow$ 磨损 Wear \uparrow 、应力
Stress \uparrow

$F_0 \downarrow \rightarrow$ 容易打滑
Possibility of slipping
increases

$$F_0 = 500 \frac{P_d}{vZ} \left(\frac{2.5 - K_a}{K_a} \right) + qv^2$$

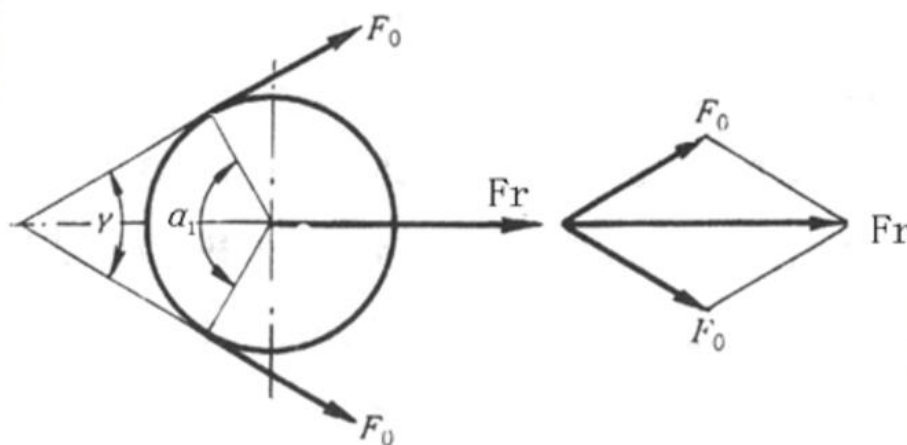
计算功率 $P_d = K_A P$ (P — 传递功率、 K_A — 载荷系数)

The design power

The nominal power

The load factor

$$F_r = Z \times 2F_0 \cos \frac{\gamma}{2} = 2ZF_0 \sin \frac{\alpha_1}{2}$$



二、带型号、长度和根数确定

Sections, length and numbers of the belt

1. 型号Sections : 型号 = $f(P_d, n_1)$

$P_d \uparrow$ 、 $n_1 \downarrow$ (低速重载 Low-speed and heavy-load) \rightarrow 选截面较大的V带

Select V-belts of larger cross-sectional dimensions: C、D、E型

$P_d \downarrow$ 、 $n_1 \uparrow$ （高速轻载

High-speed and light-load) → 选截面较小的V带 Select V-belts of smaller cross-section dimensions : Y、Z、A型

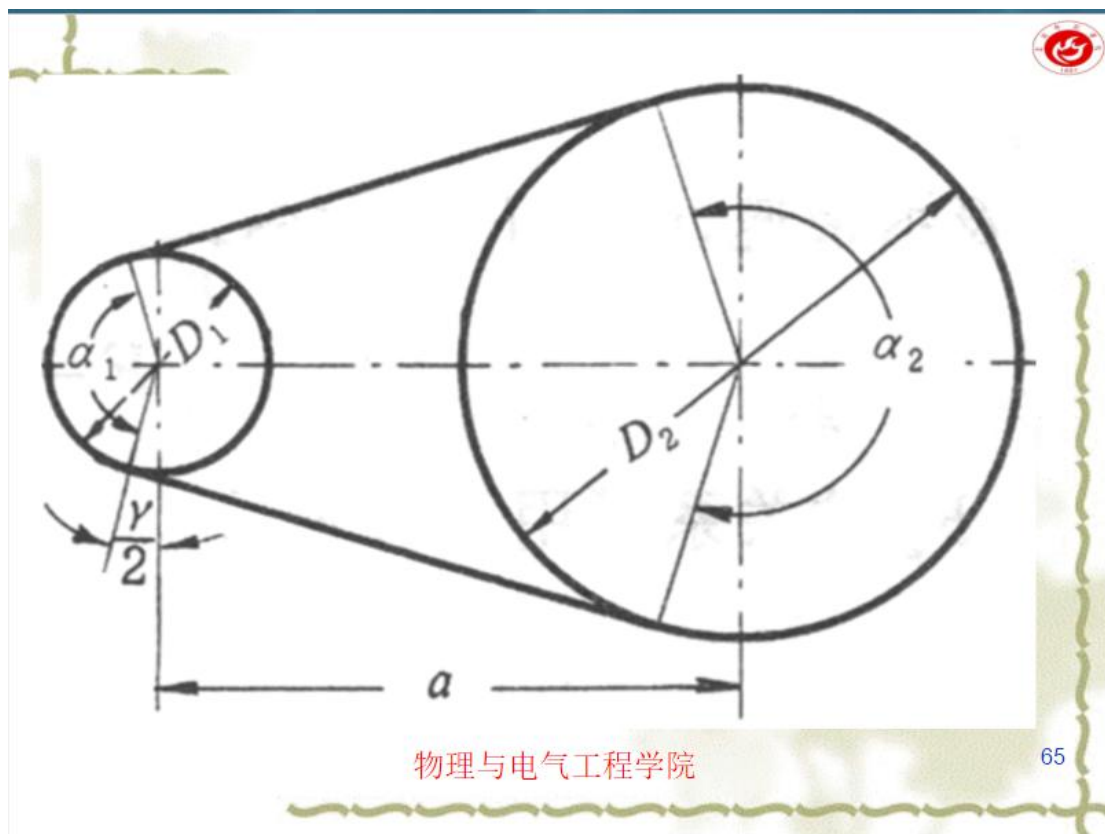
2. 长度 Length

$$L_0 = 2a \cos \frac{\gamma}{2} + \frac{D_2}{2} (\pi + \gamma) + \frac{D_1}{2} (\pi - \gamma)$$

$$= 2a \cos \frac{\gamma}{2} + \frac{\pi}{2} (D_1 + D_2) + \frac{\gamma}{2} (D_2 - D_1)$$

$$\cos \frac{\gamma}{2} = 1 - \frac{1}{2} \left(\frac{\gamma}{2} \right)^2 \quad \frac{\gamma}{2} \approx \frac{D_2 - D_1}{2a}$$

$$L_0 = 2a + \frac{\pi}{2} (D_1 + D_2) + \frac{(D_2 - D_1)^2}{4a}$$



设 $D_m = \frac{D_1 + D_2}{2}$ $\Delta = \frac{D_2 - D_1}{2}$

① $L_0 = 2a + \pi D_m + \frac{\Delta^2}{a}$ The nearest standard belt length is selected

② 根据标准，取最接近的基准长度 L_d

③ 修正中心距 a : $a = a_0 + \frac{L_d - L_0}{2}$

或者 $a = \frac{L_d - \pi D_m}{4} + \frac{1}{4} \sqrt{(L_d - \pi D_m)^2 - 8\Delta^2}$

The final centre-to-centre distance is determined from the standard belt length.

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3. 根数 Numbers

$$Z = \frac{K_A P}{(P_0 + \Delta P_0) K_\alpha K_L} < 10 \sim 12$$

(否则, 受力不均较严重)

Otherwise, nonuniform load exerted on the V-belts of a set will become very obvious.

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§ 5-4 张紧装置

Tension device of the belt drive

一、原因 Purpose:

带传动工作一定时间之后 A belt drive runs for a long time → 带的塑性伸长、松弛 Excessive stretch → $F_0 \downarrow$ → 重新张紧 Once again tension

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二、方式 Methods:

定期张紧 Periodic tension:

中心距可调 The distance between pulleys can be adjusted

中心距不可调 The distance between pulleys can not be adjusted
(张紧轮 Idler)

自动张紧 Automatic tension :

中心距可调 The distance between pulleys can be adjusted

中心距不可调 The distance between pulleys can not be adjusted
(张紧轮 Idler)