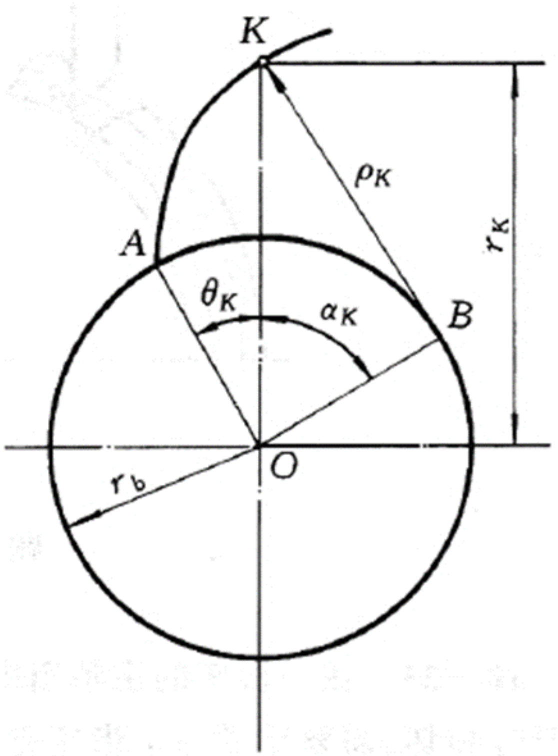
HW03
第03章 齿轮传动设计
参考答案

所有作业要求手写

Autumn 2024

HW 03.1

- 如图所示，已知基圆半径 $r_b = 50$ mm， $r_k = 65$ mm。
  （1）描述渐开线齿廓形成的过程，并画出K点的压力角
  （2）求渐开线角 θ_k，渐开线压力角 α_k，曲率半径 ρ_k.
- As shown in the figure, it is known that basic circle radius $r_b = 50$ mm, $r_k = 65$ mm.
  (1) Describe the process of tooth profile formation of involute and draw the pressure angle of point K
  (2) Try to find Involute angle θ_k, Pressure angle of involute α_k, and Curvature radius ρ_k.



HW 03.1

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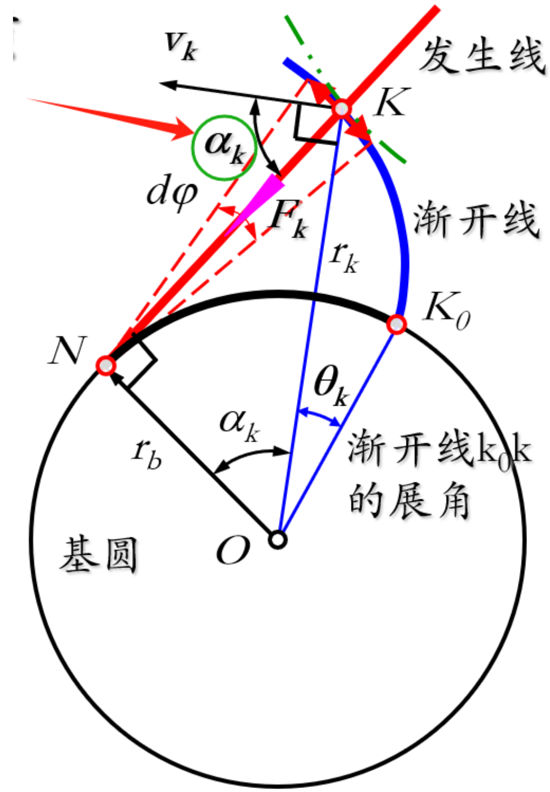
  （1）描述渐开线齿廓形成的过程，并画出K点的压力角。

  （1） Describe the process of tooth profile formation of involute and draw the pressure angle of point K

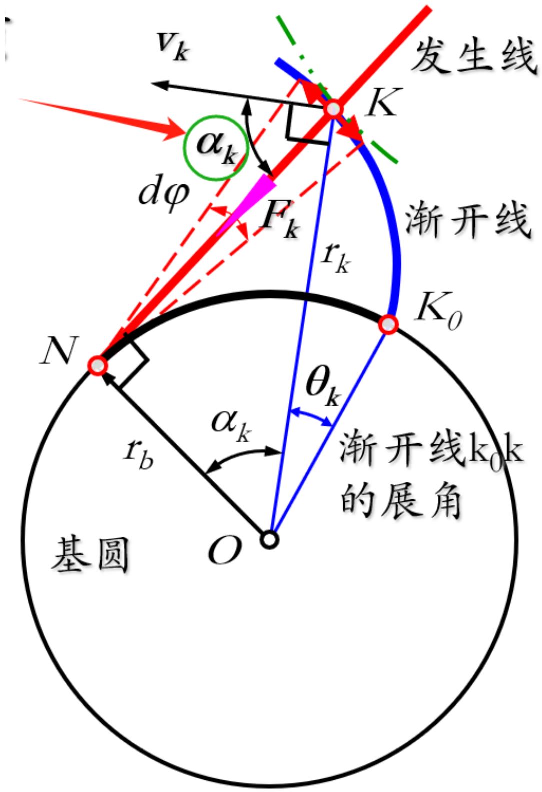


- 当直线沿一圆周作 相切纯滚动时，直线上任一点 在与该圆固连的平面之上的相 应轨迹，称为该圆的渐开线
- When a straight line rolls tangently along a circle, the corresponding trajectory of any point in the straight line on the plane firmly connected to the circle is called the involute of the circle or a curve traced by a point on a taut string as it unwinds from a circle.

- K点的压力角α_k如图所示
- the pressure angle α_k of point K is shown in the figure.

HW 03.1

- 如图所示，已知基圆半径r_b =50mm， r_k =65mm。试着求渐开线角θ_k ，渐开线压力角α_k ，曲率半径ρ_k .
- As shown in the figure， it is known that basic circle radius $r_b = 50$ mm, $r_k = 65$ mm. Try to find Involute angle θ_k, Pressure angle of involute α_k, and Curvature radius ρ_k



- $\begin{cases} r_k = r_b/\cos\alpha_k \\ \theta_k = inv\alpha_k = \tan\alpha_k - \alpha_k \end{cases}$

$$\alpha_k = \cos^{-1}\frac{r_b}{r_k} \approx 0.6931(rad) \approx 39.71^\circ$$

$$\theta_k = \tan 0.6931 - 0.6931 \approx 0.1375 \approx 7.87^\circ$$

$$\rho_k = \sqrt{r_k^2 - r_b^2} = \sqrt{65^2 - 50^2} \approx 41.53\text{mm}$$

HW 03.2

- 图示齿轮减速机构，其中齿轮 1、2 为直齿轮，齿轮 3、4 为斜齿轮，试求：

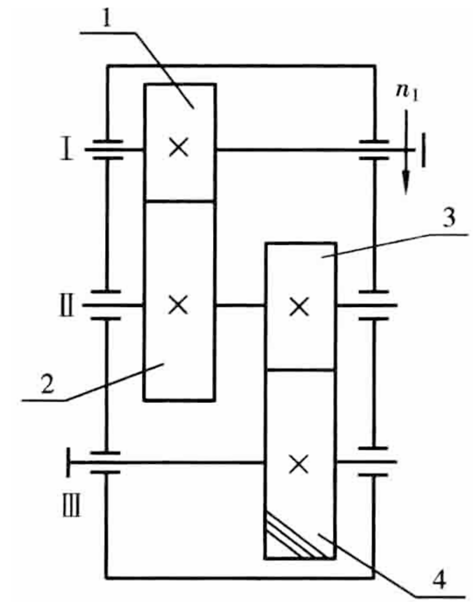
  （1）轴 II、III 的转向；

  （2）在图中标出齿轮 1、2 和齿轮 3、4 的受力方向。

- The figure shows a gear reduction mechanism, in which gears 1 and 2 are spur gears and gears 3 and 4 are helical gears. Please determine:

  (1) the direction of rotation of shafts II and III;

  (2) mark the force directions of gears 1 and 2 and gears 3 and 4 in the figure.



HW 03.2

- 图示齿轮减速机构，其中齿轮 1、2 为直齿轮，齿轮 3、4 为斜齿轮，试求：

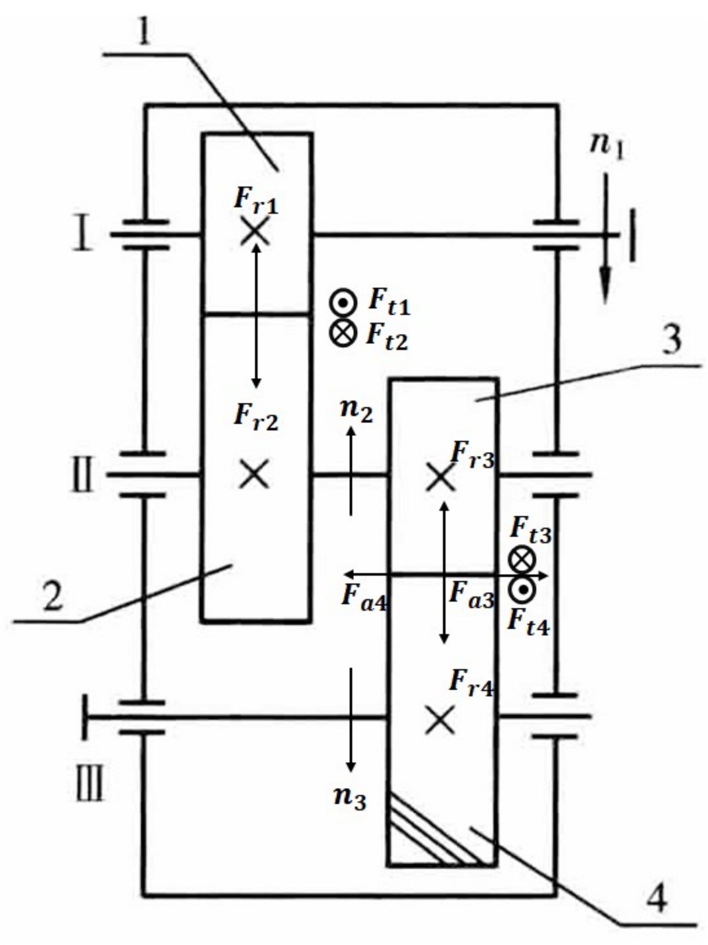
  （1）轴 II 与轴 I 旋向相反，齿轮 3、4 属于外啮合，因此轴 III 与轴 II 旋向相反。

  （2）径向力 Fa 根据螺旋角旋向和转动方向确定，主动件的圆周力与转动方向相反，被动件的圆周力与转动方向相同。各部分受力方向如图所示。

- The figure shows a gear reduction mechanism, in which gears 1 and 2 are spur gears, and gears 3 and 4 are helical gears. Please find:

  (1) Shaft II and shaft I have opposite rotation directions, and gears 3 and 4 are external meshing, so shaft III and shaft II have opposite rotation directions.

  (2) The radial force Fa is determined according to the rotation direction of the helix angle and the direction of rotation. The circumferential force of the active part is opposite to the direction of rotation, and the circumferential force of the passive part is the same as the direction of rotation. The force directions of each part are shown in the figure.



HW 03.3

- 一对直齿圆柱齿轮传动装置的参数如下：
  - 小齿轮齿数 $Z_s = 20$，大齿轮齿数 $Z_d = 40$
  - 齿轮传动的中心距 $a = 200\ mm$
  - 小齿轮的转速 $n_s = 1500\ rpm$
  - 齿轮模数 $m = 5\ mm$
  - 接触疲劳极限 $\sigma_H = 1000\ MPa$
  - 轮齿重合度 $\varepsilon = 1.8$
  - 载荷分布系数 $K_m = 1.2$，动力系数 $K_v = 1.1$
  - 齿轮宽度 $b = 20\ mm$
  - 额定载荷下，小齿轮的圆周力 $F_t = 5000\ N$
- 试求：
  1. 计算大齿轮的转速 n_d 和传动比 i。
  2. 计算齿轮的圆周速度 v。
  3. 根据给定的接触疲劳极限，计算齿轮的接触应力 σ_H，并判断是否满足接触疲劳强度要求。

HW 03.3

- The parameters of a pair of spur gear transmission are as follows:
  - Number of teeth of small gear $Z_s = 20$, number of teeth of large gear $Z_d = 40$
  - Center distance of gear transmission $a = 200\ mm$
  - Speed of small gear $n_s = 1500\ rpm$
  - Gear module $m = 5\ mm$
  - Contact fatigue limit $\sigma_H = 1000\ MPa$
  - Gear tooth overlap $\varepsilon = 1.8$
  - Load distribution coefficient $K_m = 1.2$, dynamic coefficient $K_v = 1.1$
  - Gear width $b = 20\ mm$
  - Under rated load, the circumferential force of small gear $F_t = 5000\ N$
- Try to find:

  1. Calculate the rotational speed n_d and transmission ratio i of the large gear.

  2. Calculate the circumferential speed v of the gear.

  3. According to the given contact fatigue limit, calculate the contact stress σ_H of the gear and determine whether it meets the contact fatigue strength requirements.

HW 03.3

1. 大齿轮的转速n_d和传动比i

齿轮传动比 i 的计算公式为

$$i = \frac{Z_d}{Z_s} = \frac{40}{20} = 2$$

根据传动比，计算大齿轮的转速 n_d：

$$n_d = \frac{n_s}{i} = \frac{1500}{2} = 750 \text{ rpm}$$

2. 齿轮的圆周速度v

圆周速度的计算公式为

$$v = \frac{\pi d_s n_s}{60}$$

其中，小齿轮的节圆直径d_s为:

$$d_s = mZ_s = 5\times 20 = 100\text{min}$$

代入公式计算圆周速度:

$$v = \frac{\pi\times 100\times 1500}{60} = 7.854 \text{ m/s}$$

3.接触应力的计算

根据接触应力的计算公式

$$\sigma_H = \sqrt{\frac{F_t K_m K_v}{d_s b\varepsilon}}$$

将已知数据代入计算:

$$\sigma_H = \sqrt{\frac{5000\times 1.2\times 1.1}{100\times 20\times 1.8}} \approx 297\text{MPa}$$

由于计算得到的接触应力$\sigma_H = 297\text{MPa}$，远小于给定的接触疲劳极限$\sigma_H = 1000\text{MPa}$，因此齿轮满足接触疲劳强度的要求。

HW 03.3

1. Speed of large gear n_d and transmission ratio i

The formula for calculating gear transmission ratio i is

$$i = \frac{Z_d}{Z_s} = \frac{40}{20} = 2$$

According to the transmission ratio, calculate the speed of large gear n_d:

$$n_d = \frac{n_s}{i} = \frac{1500}{2} = 750\ rpm$$

2. Circumferential speed of gear v

The formula for calculating circumferential speed is

$$v = \frac{\pi d_s n_s}{60}$$

Among them, the pitch diameter of the pinion d_s is:

$$d_s = mZ_s = 5\times 20 = 100\,\text{min}$$

Substitute into the formula to calculate the circumferential speed:

$$v = \frac{\pi\times 100\times 1500}{60} = 7.854\ \frac{m}{s}$$

3. Calculation of contact stress

According to the calculation formula of contact stress

$$\sigma_H = \sqrt{\frac{F_t K_m K_v}{d_s b \varepsilon}}$$

Substitute the known data into the calculation:

$$\sigma_H = \sqrt{\frac{5000\times 1.2\times 1.1}{100\times 20\times 1.8}} \approx 297\text{MPa}$$

Since the calculated contact stress $\sigma_H = 297MPa$ is much smaller than the given contact fatigue limit $\sigma_H = 1000MPa$, the gear meets the contact fatigue strength requirements.

HW 03.4

一对标准圆柱齿轮传动，传动比为2，试问：

1. 哪一个齿轮的齿根应力大？为什么？
2. 若大、小齿轮的材料、热处理硬度均相同，小齿轮的应力循环次数 $N_1 = 10^6 < N_0$，则它们的许用弯曲应力是否相等，为什么？

A pair of standard cylindrical gears, with a transmission ratio of 2, ask:

1. Which gear has a larger root stress? Why?
2. If the material and heat treatment hardness of the large and small gears are the same, and the number of stress cycles of the small gear is $N_1 = 10^6 < N_0$, are their allowable bending stresses equal? Why?

HW 03.4

- 1.小齿轮的弯曲应力大。

$\sigma_{\mathrm{F}}=\frac{2KT_1Y_{\mathrm{Sa}}Y_{\mathrm{Fa}}}{bd_1m}$其中$Y_{Fa}$,与齿数$Z$有关，$Z$越大$Y_{\mathrm{Fa}}$越小且小齿轮的分度圆直径小。

因此，小齿轮的弯曲应力大。

- 2. 根据公式：$[\sigma_{\mathrm{F}}]=\frac{k_{\mathrm{N}}\sigma_{\mathrm{Flim}}}{S}$

两齿轮硬度相同，即实验齿轮的弯曲疲劳极限$\sigma_{\mathrm{Fliml}}=\sigma_{\mathrm{Flim2}}$。但由于工作循环次数 N1>N2,且寿命系数$k_{N1}<k_{N2}$,故小齿轮的许用弯曲应力

$$\sigma_{\mathrm{Fl}}<\sigma_{\mathrm{F2}}$$

- 1. The bending stress of the pinion is large.

$\sigma_F=\frac{2KT_lY_{Sa}Y_{Fa}}{bd_lm}$where $Y_{Fa}$is related to the number of teeth Z. The larger the Z, the smaller the $Y_{Fa}$and the smaller the pitch circle diameter of the pinion.

Therefore, the bending stress of the pinion is large.

- 2. According to the formula: $[\sigma_F]=\frac{k_N\sigma_{Flim}}{S}$

The hardness of the two gears is the same, that is, the bending fatigue limit of the experimental gear $\sigma_{Fliml}=\sigma_{Flim2}$. However, since the number of working cycles N1>N2 and the life coefficient $k_{N1}<k_{N2}$, the allowable bending stress of the pinion

$$\sigma_{Fl}<\sigma_{F2}$$

Thank you~

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附加题 03.1

- 生活中处处是连杆。
- 1.请扫描绿色二维码，或观察学校校园巴士后门的对开车门连杆系统，画出机构运动简图，并在机构简图中大致画出车门处危险区。
- 2.如橙色和蓝色二维码，是深圳公交E11的公交车门开关门动作。请你画出这类四连杆车门的机构运动简图。（不需要画齿轮机构）
- 3.接上题，在蓝色二维码对应视频中，可以观察到该车门关门结束时候有一个抬升动作，请你分析这一动作对应的功能，是否有其他办法实现这一功能?

关于附加题的批改与答疑，请联系：
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附加题 03.1

- Life is full of linkages.
- 1. Please scan the green QR code, or observe the opposing door linkage system at the rear door of the campus bus of the school, draw a sketch of the movement of the mechanism, and roughly draw the danger zone at the door in the sketch of the mechanism.
- 2. As shown in the orange and blue QR codes, it is the opening and closing door movement of the bus door of Shenzhen Bus E11. Please draw this type of four-link door of the mechanism motion sketch. (It is not necessary to draw the gear mechanism)
- 3. Following the previous question, in the video corresponding to the blue QR code, it can be observed that there is a lifting action at the end of the door closing, please analyze the function corresponding to this action, is there any other way to realize this function?

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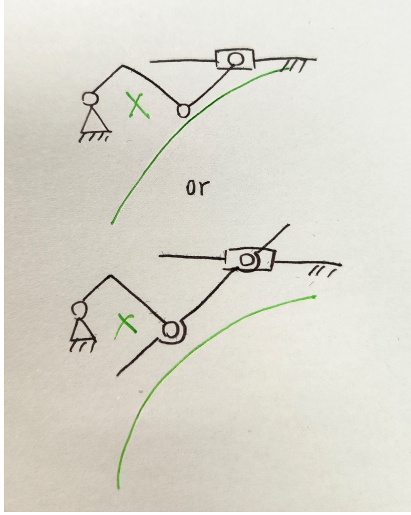
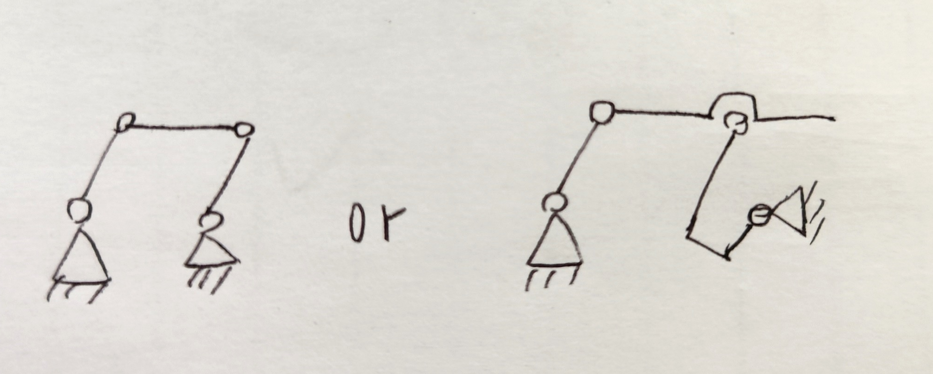
附加题 03.1

- 答:
- 1.如左图，绿色弧线的打叉一侧是危险区。
- 2.如右图。
- 3.这个动作其实是车门的锁定动作，抬起车门的动作将车门上的楔形锁舌压入门框上的锁扣板，保证车门不会在高速行驶时意外开启。其他锁定机构亦可实现这一功能，言之有理即可。





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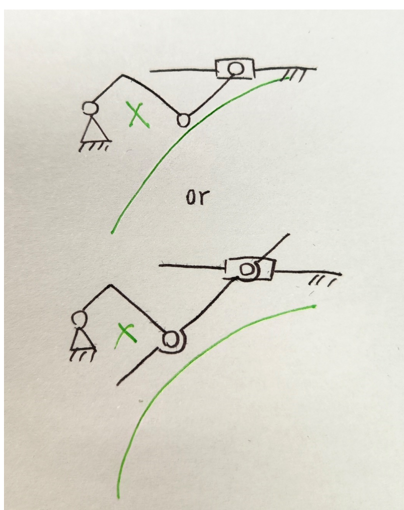
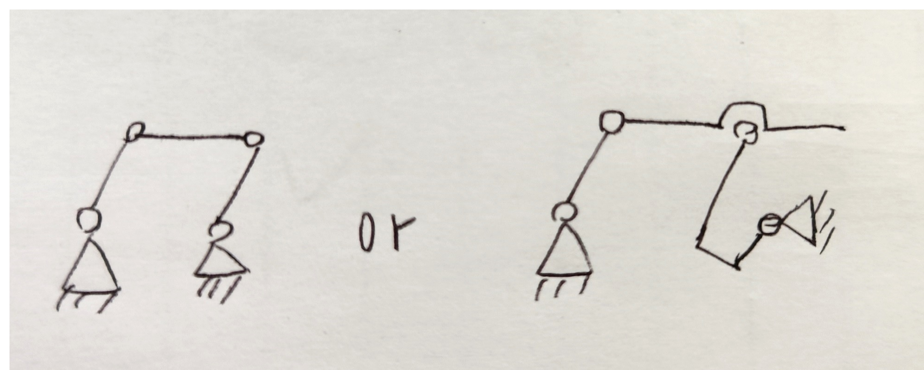
附加题 03.1

- Answer:
- 1. As shown on the left, the forked side of the green arc is the danger zone.
- 2. As shown on the right.
- 3. This action is actually the locking action of the door. Lift the door, the wedge-shaped latch on the door is pressed into the door frame on the latch plate, to ensure that the door will not accidentally open at high speed. Other locking mechanism can also realize this function, the words can be justified.





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附加题 03.2

- 人字齿轮具有斜齿轮的优势，同时又可以防止齿轮之间发生轴向位移，但为什么行星轮减速箱里面不用人字齿轮呢?
- Herringbone gear has the advantage of helical gear, and can prevent the axial displacement between the gears, but Why do we use ordinary helical gears instead of herringbone gears in the planetary gear reducer?

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附加题 03.2

- 答:
- 1. 人字齿轮成本更高
- 2. 人字齿轮装配难度大
- 3. 一对螺旋方向相反的普通斜齿轮配合也可抵消轴向力

- 1. Herringbone gear costs more
- 2. Herringbone gear is difficult to assemble
- 3. A pair of ordinary helical gears with opposite helical directions also counteracts the axial force

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