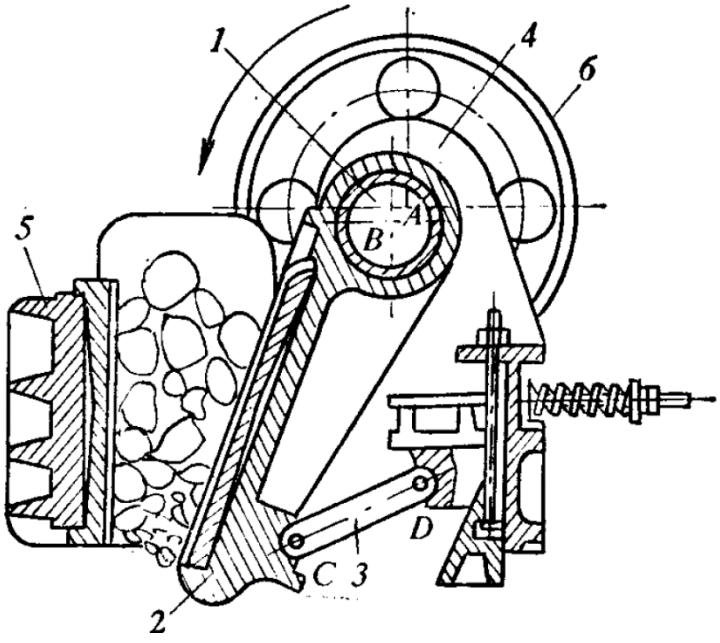
ME311 Quiz 3/3

本试卷共（4）大题，满分（100）分，请用中文或英文作答，将答案单独写在答题纸上，在答题纸右上角标注姓名学号，仅提交答题纸，注意字迹清晰。

There are 4 problems in total for 100 points. Write answers in a separate sheet in Chinese or English. Identify your name and student number on the top right corner of your answer sheets. Submit answer sheet only. Write clearly.

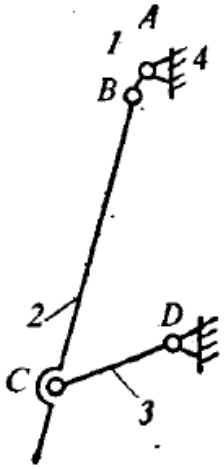
1. （20 分）如右图所示为一颚式破碎机。电动机通过带轮 6 驱动偏心轴 1 运动时，带动动颚板上的连杆 2 摆动,从而将落入动颚板 2 及定颚板 5 工作空间内的矿石轧碎。
   绘制此破碎机的机构运动简图。
   As shown in the figure, it is a jaw crusher. When the motor drives the eccentric shaft 1 through the pulley 6, it causes the connecting rod 2 (movable jaw plate) to swing. This, in turn, crushes the ore that falls into the workspace between the movable jaw plate 2 and the fixed jaw plate 5.
   Draw the kinematic diagram of the jaw crusher.



答案：（每个转动副 5 分）

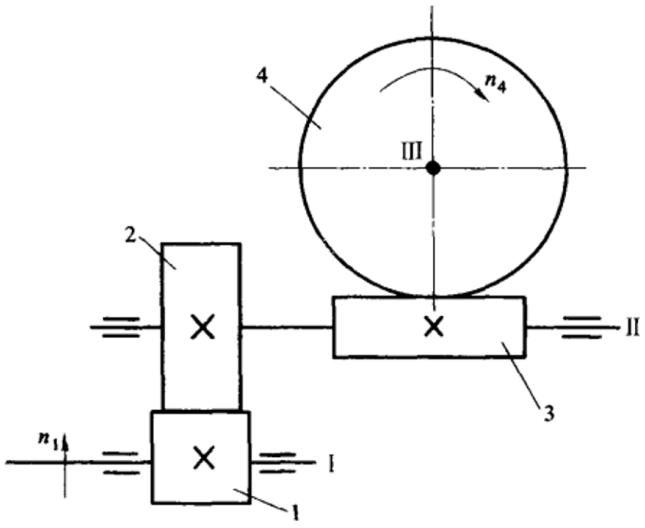
根据绘制机构运动简图的步骤，先找出破碎机的原动部分为偏心轴 1,执行部分为动颚板 2。然后循着运动传递的路线可以看出,它是由偏心轴 1,动颚板 2,摇杆 3 和机架 4 四个构件组成的。其中偏心轴 I 和机架 4 在 A 点构成转动副;偏心轴 1 与动颚板 2 在 B 点构成转动副,动颚板 2 与播杆 3 在 C 点构成转动副,摇杆 3 与机架 4 在 D 点构成转动副。

According to the steps for drawing the kinematic diagram, the driving component of the crusher is the eccentric shaft 1, and the executing component is the movable jaw plate 2. Following the motion transmission path, it can be seen that the mechanism consists of four components: the eccentric shaft 1, the movable jaw plate 2, the rocker 3, and the frame 4. Among them, the eccentric shaft 1 and the frame 4 form a revolute pair at point A; the eccentric shaft 1 and the movable jaw plate 2 form a revolute pair at point B; the movable jaw plate 2 and the rocker 3 form a revolute pair at point C; and the rocker 3 and the frame 4 form a revolute pair at point D.



2、（25 分）图为一级斜齿圆柱齿轮加一级蜗杆传动。斜齿轮 1 由电动机驱动。已知当斜齿轮 1 按图示方向转动时，蜗轮输出轴按图示的顺时针转动。试分析为使轴Ⅱ轴向力较小，合理确定出斜齿轮 2 轮齿旋向和蜗杆螺旋线旋向:分别面出斜齿轮 1、2 的轮齿旋向，并判断出蜗轮的轮齿旋向，画出各传动件啮合点受力方向。

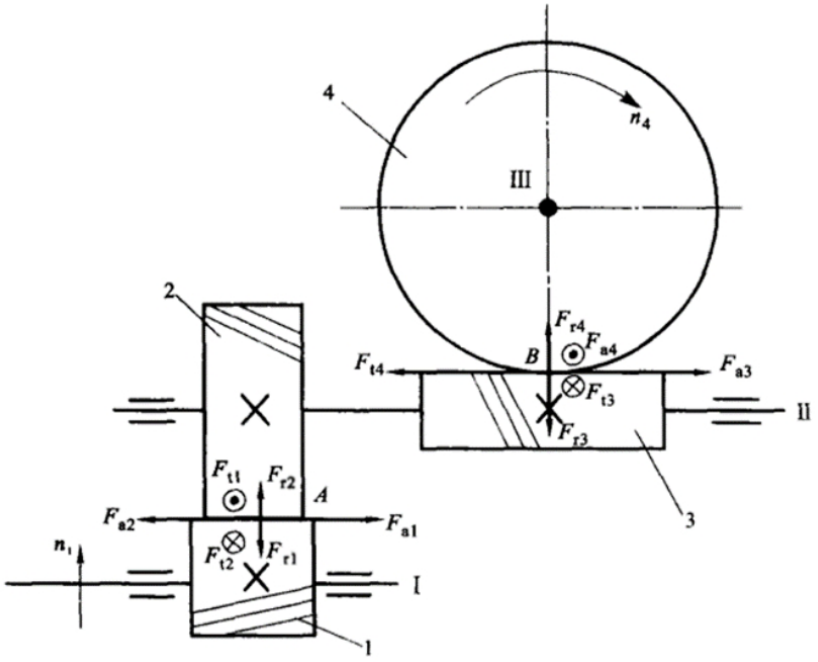
A diagram shows a single-stage helical gear and a single-stage worm gear transmission. The helical gear 1 is driven by an electric motor. It is known that when the helical gear 1 rotates in the direction shown in the diagram, the output shaft of the worm gear rotates clockwise as shown in the diagram. Analyze to determine the reasonable direction of the helical teeth of gear 2 and the spiral direction of the worm to minimize the axial force on shaft II: draw the direction of the helical teeth for gears 1 and 2, and determine the direction of the teeth on the worm gear, illustrating the force direction at the meshing points of each transmission component.



答案：

1. 蜗杆的螺旋线方向： 根据蜗杆的转动方向及承受的轴向力方向判断蜗杆的螺旋线方向为右旋。（5 分）
2. 齿轮 2 的轴向力方向： 为使轴II受轴向力最小，齿轮 2 所受的轴向力方向应与蜗杆的轴向力方向相反。（5 分）
3. 齿轮 2 的轮齿旋向： 齿轮 2 的转动方向与蜗杆相同，因此该齿轮的轮齿旋向为右旋。（5 分）
4. 蜗轮的轮齿旋向： 根据蜗杆的螺旋线方向和蜗轮的转动方向，判断蜗轮的轮齿旋向。（5 分）
5. 各传动件啮合点受力方向： 画出各传动件啮合点受力方向，确保分析准确。（5 分）

1. Worm Gear's Helix Direction:Determine the worm gear's helix direction as right-handed based on the worm's rotation direction and the direction of the axial force it experiences.(5 points）
2. Axial Force Direction on Gear 2:To minimize the axial force on shaft II,the axial force direction on gear 2 should be opposite to that of the worm.(5 points)
3. Helical Tooth Direction of Gear 2:Since gear 2 rotates in the same direction as the worm,the helical tooth direction of gear 2 should be right-handed.(5 points)
4. Helical Tooth Direction of Worm Wheel:Determine the helical tooth direction of the worm wheel based on the worm's helix direction and the worm wheel's rotation direction.(5 points)
5. Force Direction at Meshing Points:Illustrate the force direction at the meshing points of each transmission component,ensuring accurate analysis.(5 points)

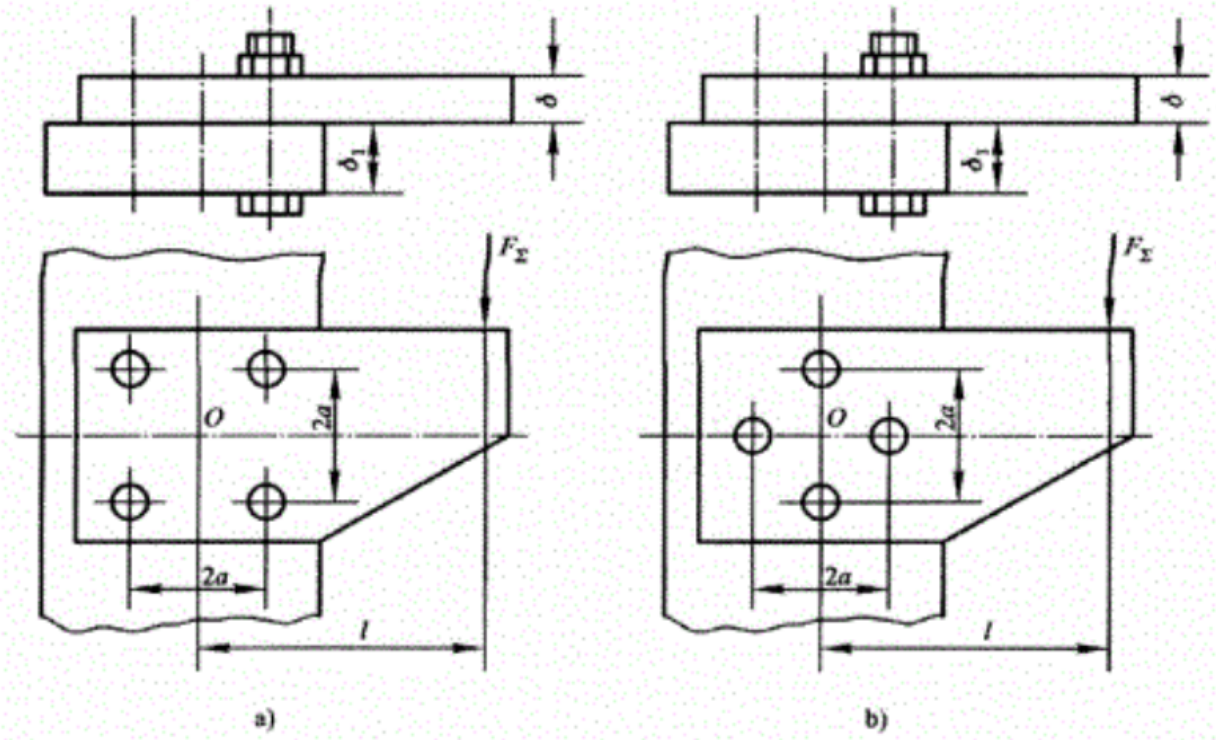


3、（25 分）一厚度 δ =12 mm 的钢板用 4 个螺栓固连在厚度 δ_1=30 mm 的铸铁支架上，螺栓的布置有(a)、(b)两种方案，如图所示。试比较哪种螺栓布置方案合理?

已知：载荷 F_Σ=12000N，尺寸 l=400mm，a=100mm。

A steel plate with a thickness of δ =12mm is fixed on a cast iron bracket with a thickness of δ_1=30mm with 4 bolts. There are two bolt arrangements (a) and (b), as shown in the figure. Try to compare which bolt arrangement is reasonable?

Known: load F_Σ=12000N, size l=400mm, a=100mm.

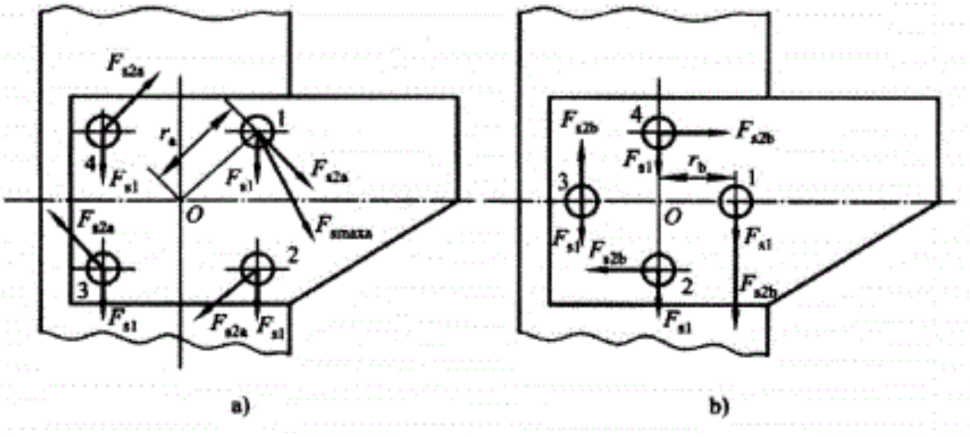


Ans.

确定各个螺栓所受的横向载荷：

Determine the lateral load on each bolt

$$F_{s_1} = \frac{F_\Sigma}{4} = 3000N$$



对于方案(a)，各螺栓中心至形心 0 点的距离为

For scheme (a), the distance between the center of each bolt and the centroid point 0 is:

$$r_a = \sqrt{2a^2} = \sqrt{2 * 100^2} = 141.1mm$$

$$F_{s_{2a}} = \frac{T}{4r_a} = \frac{4.8 * 10^6}{4 * 141.4} = 8487N$$

由图解 (a)可知，螺栓 1 和 2 所受两力的夹角 a 最小，故螺栓 1 和 2 所受横向载荷最大，即:

It can be seen from diagram (a) that the Angle a between the two forces on bolts 1 and 2 is the smallest, so bolts 1 and 2 are subjected to the largest lateral load, that is:

$$F_{s\,max\,a} = \sqrt{F_{s_1}^2 + F_{s_{2a}}^2 + 2F_{s_1}F_{s_{2a}}cosa} = 10820N$$

对于方案(b)，各螺栓中心至形心 0 点的距离为:

For scheme (b), the distance between the center of each bolt and the centroid point 0 is:

$$r_b = a = 100mm$$

$$F_{s_{2b}} = \frac{T}{4r_b} = \frac{4.8 * 10^6}{4 * 100} = 12000N$$

由图解二(b)可知，螺栓 1 所受横向载荷最大，即:

As can be seen from Figure II (b), bolt 1 is subject to the largest lateral load, i.e:

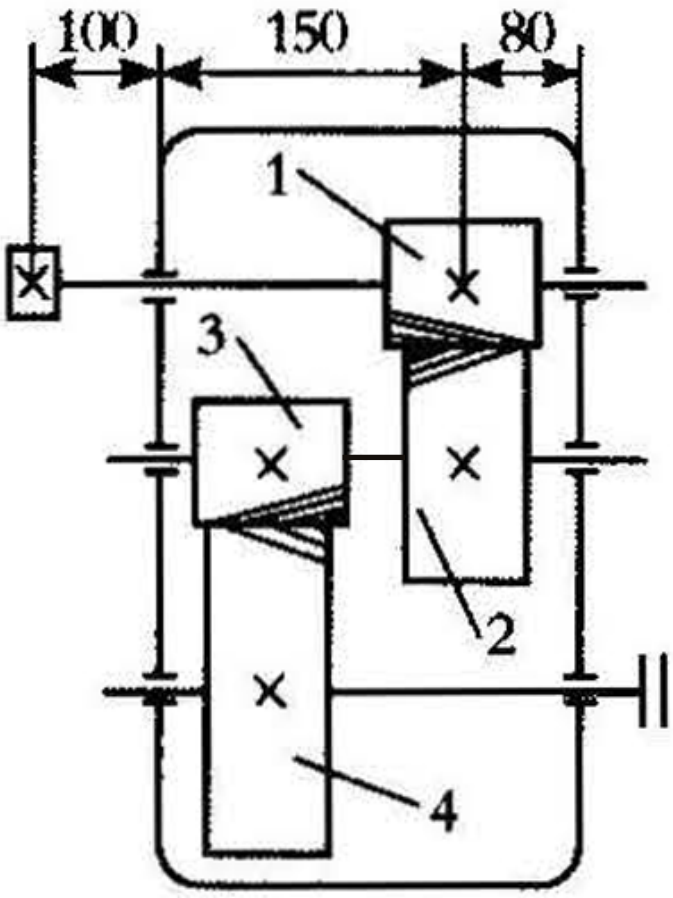
$$F_{s\,max\,b} = F_{s_1} + F_{s_{2b}} = 15000N$$

在螺栓布置方案(a)中，受力最大的螺栓 1 和 2 所受的总横向载荷$F_{s\,max\,a} = 10820N$;而在螺栓布置方案(b)中，受力最大的螺栓 1 所受的总横向载荷$F_{s\,max\,b} = 15000N$。因此方案(a)比较合理。

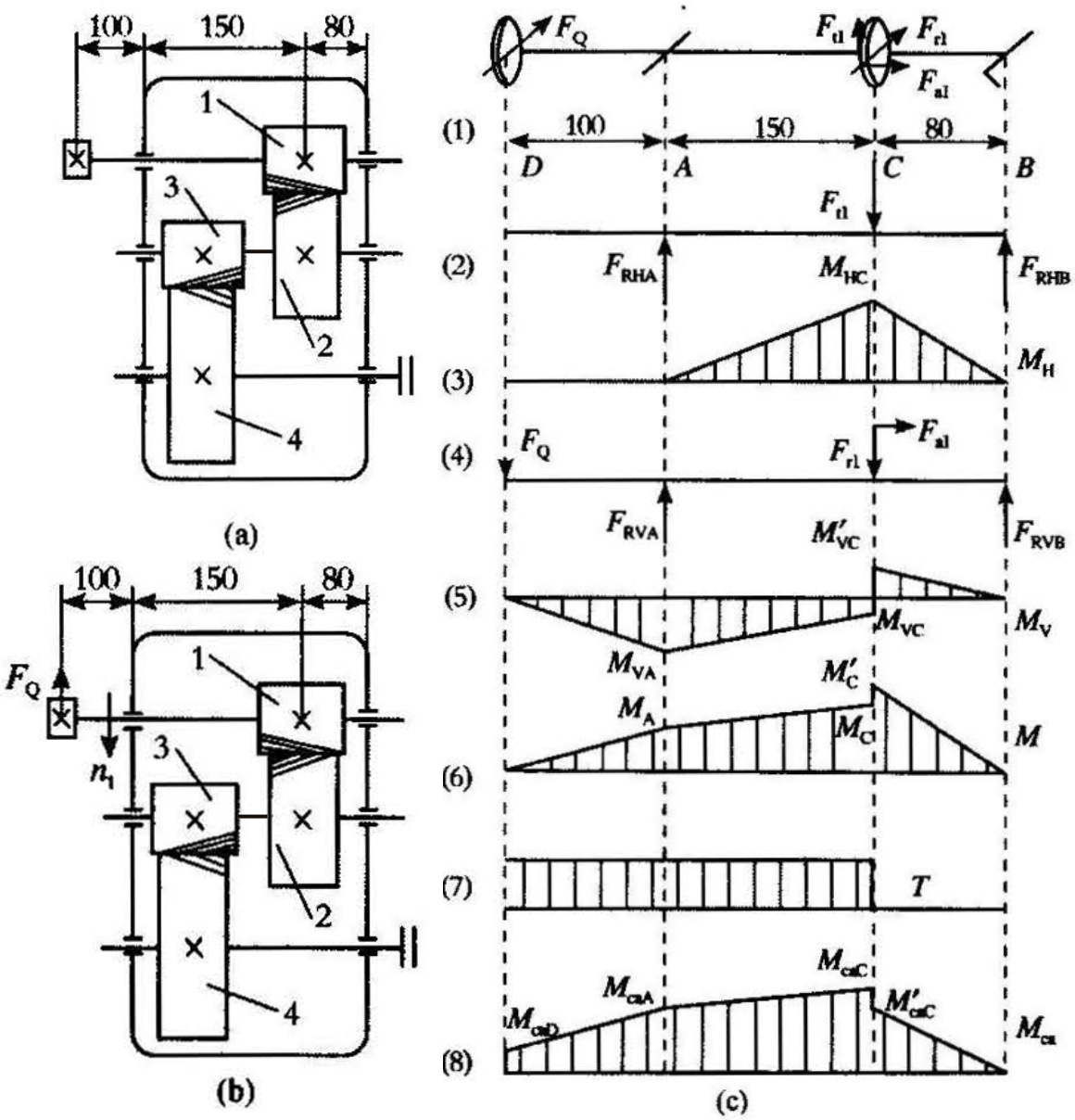
In bolt arrangement scheme (a), the total transverse load $F_{s\,max\,a} = 10820N$ on bolts 1 and 2 with the greatest force; In bolt arrangement scheme (b), the total transverse load $F_{s\,max\,b} = 15000N$ on bolt 1 with the greatest force. Option (a) is therefore more reasonable.

4、（30 分）有一带宽式输送机的二级斜齿圆柱齿轮减速器，功率由带轮输入。已知带传动为水平布置，V 带对轴的作用力为 $F_Q = 2300N$（与 F_{r1} 在同一平面内，且方向相同）。主动轮 1 的分度圆直径 $d_1 = 120mm$，$F_{t1} = 5000N$，$F_{r1} = 1800N$，$F_{a1} = 760N$。计算输入轴的支反力，并画出轴的受力图、弯矩图、扭矩图及当量弯矩图（扭转切应力为脉动循环变压力时取 $a = 0.6$）。

There is a two-stage helical gear reducer with a wide belt conveyor, and the power is input by the pulley. It is known that the belt drive is arranged horizontally, and the force of the V-belt on the shaft is $F_Q = 2300N$ (in the same plane as F_{r1} and in the same direction). The pitch circle diameter of the driving wheel 1 is $d_1 = 120mm$, $F_{t1} = 5000N$, $F_{r1} = 1800N$, $F_{a1} = 760N$. Calculate the support reaction force of the input shaft, and draw the force diagram, bending moment diagram, torque diagram and equivalent bending moment diagram of the shaft (6 points each, 30 points in total) (when the torsional shear stress is a pulsating cyclic variable pressure, take $a = 0.6$).



答案：



(1) 确定 V 带对轴的作用力F_Q的方向，如图 b 所示。（2 分）

Determine the direction of the force F_Q exerted by the V-belt on the shaft, as shown in Figure b.

(2) 作轴的空间受力简图，如图 (c) (1) 所示。（4 分，每个正确的力 1 分）

Draw a spatial force diagram of the shaft, as shown in Figure (c) (1).

（关于F_{t1}等力对应的啮合点可以与上图一致或者在其他合理处绘制）

(3) 求水平面内支反力，作水平面内弯矩图，水平面内受力情况如图 (c) (2) 所示。（6 分，每处计算 2 分）

1) 求水平面内 A、B 的支反力

水平面内 A、B 的支反力分别为

Calculate the support reaction force in the horizontal plane, draw the bending moment diagram in the horizontal plane, and the force situation in the horizontal plane is shown in Figure (c) (2).

1) Calculate the support reaction force of A and B in the horizontal plane

The support reaction forces of A and B in the horizontal plane are

$$F_{\mathrm{NHA}}=\frac{80F_t}{150+80}=\frac{80\times 5000}{230}\,\mathrm{N}=1739\,\mathrm{N}$$

$$F_{\mathrm{NHB}}=F_t-F_{\mathrm{NHA}}=(5000-1739)\,\mathrm{N}=3261\,\mathrm{N}$$

2) 求水平面弯矩

绘制弯矩图，如图 (c) (3) 所示。

水平面内 C 的弯矩为

Calculate the bending moment in the horizontal plane

Draw a bending moment diagram as shown in Figure (c) (3).

The bending moment of C in the horizontal plane is

$$M_{\mathrm{HC}}=80F_{\mathrm{NHB}}=80\times 3261\mathrm{N}\cdot\mathrm{mm}=260880\mathrm{N}\cdot\mathrm{mm}=260.88\mathrm{N}\cdot\mathrm{m}$$

(4) 求竖直面内支反力，作竖直面内弯矩图，竖直面内受力情况如图 (c)(4) 所示。（6 分，支反力 3 分，弯矩 3 分）

l) 求竖直面内 A、B 的支反力

竖直面内 A、B 支反力分别为

Calculate the support reaction force in the vertical plane, draw the bending moment diagram in the vertical plane, and the force situation in the vertical plane is shown in Figure (c)(4).

l) Calculate the support reaction force of A and B in the vertical plane

The support reaction forces of A and B in the vertical plane are

$$F_{\mathrm{HVA}}=\frac{80F_{r1}+330F_Q-\frac{d_1}{2}F_{a1}}{230}=\frac{80\times 1800+330\times 2300-\frac{120}{2}\times 760}{230}\mathrm{N}=3728\mathrm{N}$$

$$F_{\mathrm{HVB}}=F_Q+F_{r1}-F_{\mathrm{HVA}}=(2300+1800-3728)\mathrm{N}=372\mathrm{N}$$

2) 求竖直面内弯矩

绘制弯矩图，如图 (c) (5) 所示。

竖直面内 A、C 的弯矩分别为

Calculate the bending moment in the vertical plane

Draw the bending moment diagram as shown in Figure (c) (5).

The bending moments of A and C in the vertical plane are

$$M_{VA} = -100F_Q = -100 \times 2300\text{N} \cdot \text{mm} = -230000\text{N} \cdot \text{mm} = -230\text{N} \cdot \text{m}$$
$$M'_{VC} = 80F_{HVB} = 80 \times 372\text{N} \cdot \text{mm} = 29760\text{N} \cdot \text{mm} = 29.76\text{N} \cdot \text{m}$$
$$M_{VC} = M'_{VC} - \frac{d_1}{2}F_{a1} = (29760 - 60 \times 760)\text{N} \cdot \text{mm} = -15840\text{N} \cdot \text{mm}$$
$$= -15.84\text{N} \cdot \text{m}$$

(5) 求合成弯矩，作合成弯矩图，如图 (c)(6) 所示。（6 分，每处弯矩 2 分）

A、C 的合成弯矩分别为

Calculate the resultant bending moment and draw the resultant bending moment diagram as shown in Figure (c)(6).

The resultant bending moments of A and C are

$$M_A = M_{VA} = 230\text{N} \cdot \text{mm}$$

$$M_C = \sqrt{M_{\text{HC}}^2 + M_{\text{VC}}^2} = \sqrt{260.88^2 + (-15.84)^2}\text{N} \cdot \text{m} = 261.36\text{N} \cdot \text{m}$$

$$M'_C = \sqrt{M_{\text{HC}}^2 + M'^2_{\text{VC}}} = \sqrt{260.88^2 + 29.76^2}\text{N} \cdot \text{m} = 261.57\text{N} \cdot \text{m}$$

(6) 求转矩，作转矩图，如图 (c)(7) 所示。

Calculate the torque and draw the torque diagram as shown in Figure (c)(7).

$$T = F_{t1} \cdot \frac{d_1}{2} = 5000 \times \frac{0.120}{2}\text{N} \cdot \text{m} = 300\text{N} \cdot \text{m}$$

(7) 求当量弯矩，作当量弯矩图，如图 (c)(8) 所示。（6 分，公式 4 分结果 2 分）

根据轴的工作情况可知，扭转切应力为脉动循环变压力，取$a = 0.6$。

A、C 的当量弯矩分别为

Calculate the equivalent bending moment and draw the equivalent bending moment diagram as shown in Figure (c)(8).

According to the working conditions of the shaft, the torsional shear stress is a pulsating cyclic variable pressure, and a=0.6 is taken.

The equivalent bending moments of A and C are

$$M_{\mathrm{AA}} = \sqrt{M_A^2 + (aT)^2} = \sqrt{230^2 + (0.6 \times 300)^2}\mathrm{N \cdot m} = 292\mathrm{N \cdot m}$$

$$M_{\mathrm{CC}} = \sqrt{M_C^2 + (aT)^2} = \sqrt{261.36^2 + (0.6 \times 300)^2}\mathrm{N \cdot m} = 317.37\mathrm{N \cdot m}$$

$$M'_{\mathrm{CC}} = M'_C = 262.57\mathrm{N \cdot m}$$

$$M_{\mathrm{CaD}} = 0.6 \times 300\mathrm{N \cdot m} = 180\mathrm{N \cdot m}$$

附加题（可选做，不计入总分）：设有一零件受变应力作用,已知变应力的平均应力σ_m=189MPa,应力幅σ_a=129MPa,试求该变应力的循环特征 r。

Extra Problem (Optional, not counted in final marking) There is a part subjected to variable stress, known as the average stress of variable stress σ_m = 189MPa, stress amplitude σ_a= 129MPa, try to find the cyclic characteristics of the variable stress r.

答案：最大应力为 $\sigma_{max} = \sigma_m + \sigma_a = (189 + 129)\text{MPa} = 318\text{MPa}$

最小应力为 $\sigma_{min} = \sigma_m - \sigma_a = (189 - 129)\text{MPa} = 60\text{MPa}$

σ_{max}、σ_{min}在横坐标的同侧。

循环特征为

$$r = \frac{\sigma_{min}}{\sigma_{max}} = \frac{60}{318} = 0.1887$$

The maximum stress is$\sigma_{max} = \sigma_m + \sigma_a = (189 + 129)\text{MPa} = 318\text{MPa}$

The minimum stress is$\sigma_{min} = \sigma_m - \sigma_a = (189 - 129)\text{MPa} = 60\text{MPa}$

σ_{max}, $\sigma_{min}$are on the same side of the horizontal coordinate.

The cycle is characterised by

$$r = \frac{\sigma_{min}}{\sigma_{max}} = \frac{60}{318} = 0.1887$$