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试卷装订线  
装订线内不要答题，不要填写考生信息  
试卷装订线

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|------------|---------------|
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# Wuhan University of Technology, Examination Paper (A)

Academic Year 2018-2019 Second Semester Vehicle Design Closed Book

Time: 120minutes Credit: 5 Total Marks: 100 June 2019

| Question   | I  | II | III | IV | V  | VI | VII | VIII | Total | Teacher |
|------------|----|----|-----|----|----|----|-----|------|-------|---------|
| Full marks | 14 | 13 | 13  | 12 | 12 | 12 | 12  | 12   | 100   |         |
| Marks      | 14 | 13 | 11  | 10 | 12 | 7  | 11  | 10   | 88    |         |

Marks 14

## Question I Overall Design

The battery electric vehicle parameters are as follows: total vehicle mass  $m$  is 1800kg, air resistance coefficient  $C_D$  is 0.3, frontal area  $A$  is 2.8m<sup>2</sup>, rolling resistance coefficient  $f$  is 0.02, transmission efficiency  $\eta_T$  is 90%, wheel radius  $r$  is 0.288m, the maximum vehicle speed  $u_{a_{max}}$  is 120km/h, and the acceleration of gravity  $g$  is 9.8m/s<sup>2</sup>. The layout of the drive system is shown in Figure 1, where D is the differential, FG is final drive and M is the motor.

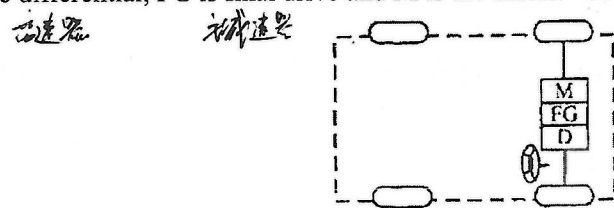


Fig. 1 Layout of Drive System for Battery Electric Vehicle

1. Please calculate the required motor power in order to achieve the maximum vehicle speed. (5 marks)

2. Please describe the name, advantages and disadvantages of its drive system layout (驱动系统布置型式). (9 marks)

Solution: 1.  $P_{emax} = \frac{1}{\eta_T} \left( \frac{g f m u_{a_{max}}}{3600} + \frac{C_D A u_{a_{max}}^3}{76140} \right) = \frac{1}{0.9} \left( \frac{1800 \times 9.8 \times 0.02 \times 120}{3600} + \frac{0.3 \times 2.8 \times 120^3}{76140} \right)$   
 $= 34.25 \text{ kW}$

2. 这种驱动系统布置型式为前置前驱式

- 优点:
1. 动力总成布局紧凑
  2. 有利于提高乘坐的舒适性
  3. 使汽车具有一定的不足转向
  4. 越过障碍的通过性高
  5. 有利于汽车的机械性
  6. 散热性良好

- 缺点:
1. 转向和工作环境恶劣
  2. 汽车的侧倾能力差
  3. 汽车与其它物体发生正面碰撞时, 发动机损坏严重, 维修困难, 且对前排人员造成较大伤害
  4. 发动机横向布置时因空间限制, 保养与维修接迎性差

Marks 13

## Question II Clutch Design

1. Please indicate which is the push-type (推式) diaphragm spring clutch and which is the pull-type (拉式) diaphragm spring clutch in Figure 2. Please explain the reason why the pull-type diaphragm spring clutch is better than the push-type diaphragm spring clutch. (5 marks)

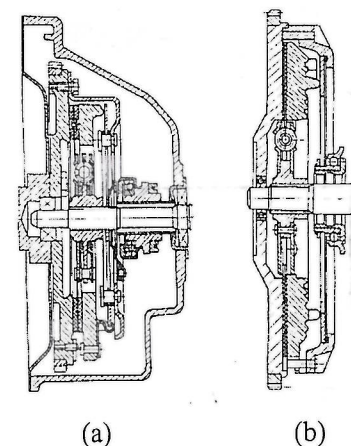
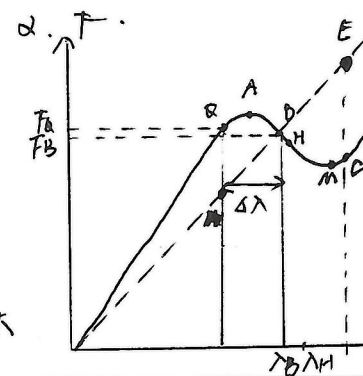


Fig. 2 Diaphragm Spring Clutch

2. Please draw the elastic characteristic curve (弹性特性曲线) of diaphragm spring, describe its advantages, and illustrate how to determine the suitable position of its working point. (8 marks)

Solution: 1. (a) is the push-type diaphragm spring clutch and (b) is the pull-type diaphragm spring clutch.

- 拉式优点:
1. 取消了中间双联, 结构简单
  2. 拉式膜片弹簧中部与压盘接触, 可采用较大的膜片弹簧, 压紧力大
  3. 拉式离合器盖刚度大, 变形小, 分离轴承高
  4. 拉式离合器占用空间较小, 对于汽车的总体布置更简单



如图所示, H为离合器的平衡状态点, 一个新的离合器工作点应取在A到H之间, 并靠近H, 是因为要在尽可能大的行程范围内, 力F<sub>B</sub>与F<sub>D</sub>相差小,  $x_B \approx 10.8-11 \text{ mm}$ , 同时离合器分离点C应在H点后, 可以使踏板力更加轻便。相对于普通的圆柱螺旋弹簧, 在B点对应的力过大, 则离合器踏板行程, 而在离合器分离点对应的点, 弹簧力过大, 则离合器踏板行程将不轻便。

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| Marks | 11 |
|-------|----|

### Question III Transmission Design

The transmission of Jetta car is shown in Figure 3. Whether is it a two-shaft transmission or a three-shaft transmission? How many forward gears (前进挡) does it have? What kind of shift mechanism (换挡机构) is used in each gear (各挡) including reverse gear (倒挡)? Please mark the position of each gear in Figure 3 and draw the transmitting route (传动路线) of the third gear (III 挡). (13 marks)

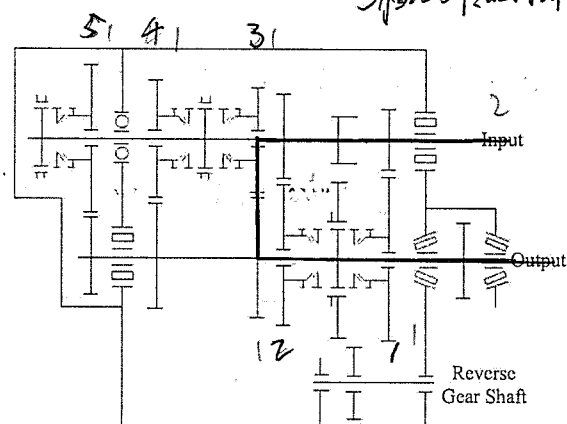


Fig. 3 Schematic Diagram of Transmission of Jetta Car

Solution: 这是一个二轴式变速器，一共有5个前进挡。

换挡机构：倒挡：直齿滑动齿轮换挡机构。  
5挡、4挡、3挡、2挡、1挡都是使用同步器换挡机构。

三挡传动路线：如图所示，从图中各挡标注

由输入轴输入到图中3挡齿轮外，动力传至输出轴上的三挡齿轮。

再通过输出轴，传出变速器。

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| Marks | 10 |
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### Question IV Universal Joint and Transmission Shaft Design

1. What type of universal joint (万向节) is used in Figure 4? What are the conditions for their constant speed transmission (等速传动)? (5 marks)
2. What is the critical speed (临界转速) of transmission shaft (传动轴)? How to calculate it? When the vehicle wheelbase (轴距) needs to be increased greatly, how to adjust the structure of the transmission shaft? (7 marks)

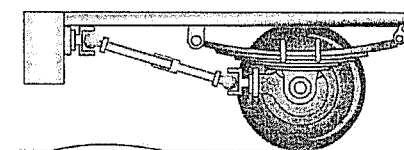


Fig. 4 Schematic Diagram of Rear Wheel Drive System

Solution: 1. 两个十字轴式万向节。

等速传动条件：1) 与传动轴相连的两个万向节应安装在同一平面。

2) 与传动轴相连的两个万向节与传动轴之间的夹角应相等。

2. 临界转速是指传动轴因各种物理性质、材料限制保持正常工作而不出意外的最高转速。用  $n_k$  表示。

$$n_k = 1.2 \times 10^8 \times \frac{\sqrt{d_e^2 + d_o^2}}{L_e^2}$$

$L_e$  为传动轴的有效长度 (mm),  $d_e, d_o$  为传动轴的内、外径 (mm)。

轴距增大时，从纵向来看，应增大  $\beta_1$  或减小  $\beta_2$ ，使得主销后倾角符合要求。

Marks 12

### Question V Drive Axle Design

1. Please describe the offset type (偏移类型) of the hypoid gear (双曲面齿轮) of the final drive (主减速器) in Figure 5, the helix angle direction (旋向) of the driving gear (主动齿轮) and the driven gear (从动齿轮), and the direction of the axial force (轴向力) acting on the driving gear. (4 marks)

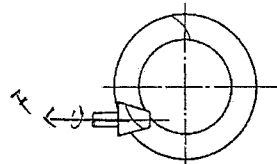


Fig. 5 Hypoid Gear Drive

2. A truck uses a friction disc type differential (摩擦片式差速器), and its locking coefficient  $k$  equals 0.6. One wheel 1 of the drive axle is on the snow-covered pavement, and its road adhesion coefficient  $\phi_{\min}$  equals 0.2. Another wheel 2 of the drive axle is on the wet concrete pavement, and its road adhesion coefficient  $\phi_{\max}$  equals 0.8. The drive axle load  $G_2$  equals 175000N. Please calculate the maximum driving force of this drive axle. (8 marks)

最大驱动力

Solution: 图中双曲面齿轮偏移类型为上偏移。

主动齿轮的旋向为右旋；从动齿轮的旋向为左旋。

主动齿轮的轴向力方向沿着主动齿轮轴线水平向左。如图所示。

$$K_b = \frac{1+k}{1-k} = \frac{1+0.6}{1-0.6} = 4$$

$$\text{即 } K_b = \frac{T_2}{T_1} = 4$$

根据题意  $\phi_{\min} = 0.2$ 。此轮提供最大驱动力  $F_{\min} = \frac{1}{2} G \phi_{\min} = \frac{1}{2} \times 175000 \times 0.2 = 17500 \text{ N}$

$\phi_{\max} = 0.8$ 。此轮提供最大驱动力  $F_{\max} = \frac{1}{2} G \phi_{\max} = \frac{1}{2} \times 175000 \times 0.8 = 70000 \text{ N}$

若:  $T_1 = 17500 \text{ N}$  则  $T_2 = 17500 \times 4 = 70000 > 17500$  故不作考虑。(舍去)

则  $T_1 = 17500 \text{ N}$ 。  $T_2 = 17500 \times 4 = 70000 = 70000 \text{ N}$ 。

此时最大驱动力为  $F = 70000 + 17500 = 87500 \text{ N}$ 。

Marks 7

### Question VI Suspension Design

1. What is the basis (依据) for choosing different guiding mechanisms (导向机构) for suspension (悬架)? (7 marks)

2. What kind of guide mechanism is usually suitable for the front suspension of ordinary car? Explain the reason. (5 marks)

Solution: 悬架导向机构设计要求 =

1) 在前轴时 ① 是架上车荷发生变化时, 前轮轮距变化在 40mm 以内。轮距变化过大, 会导致轮胎早期磨损。

② 是架上车荷变化时, 车轮相对于车身相对跳动。前轮定位参数应保证合理的特性, 且不应产生纵向加速度。

③ 在汽车转弯时, 车身侧倾角不应过大。在侧向 0.4g 加速度的作用下, 车身侧倾角  $< 6^\circ$ 。且应使车轮与车身侧倾同向, 未增加不足转向特性。

④ 制动时, 应使车身有抗前俯作用。加速时, 应使车身有抗后仰作用。

2) 在后轴时, ① 是架上车荷发生变化时, 轮距不应发生明显变化。

② 汽车转弯时, 车厢侧倾角应足够小, 且使车厢与车轮侧倾反向, 以减少过多转向特性。

2. 一般汽车悬架导向机构可选用表 8-1 所示 3 种类型。某侧倾中心高度较高, 则侧向力和侧倾力矩较大。则更加轻便。轮距较小, 则某侧倾角也较小。

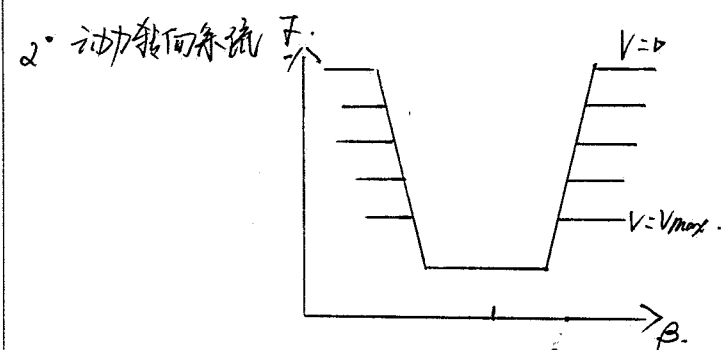
侧倾角较小, 侧倾角刚度和横向刚度都比较大。

Marks //

### Question VII Steering Gear Design

1. According to the reverse efficiency (逆效率) of steering gear (转向器), what are three kinds of steering gear? (3 marks)
2. How to design the power assisting characteristics (助力特性) of power steering system (动力转向系统), in order to achieve enough steering portability (轻便性) at low speed and good road feeling (路感) at high speed? (9 marks)

Solution: 1. 根据逆效率, 转向器可分为可逆式、极限可逆式、不可逆式。



如图所示为车速感应助力特性。车速为零时，相当于汽车在原地转向。此时对于驾驶员来说，轻便性更重要。故从图中可知，车速为零的曲线最高，此时转向助力最大。

图示曲线，车速从上至下越来越大，当车速达到最大时，此时对驾驶员来说路感更重要。根据图示，此时助力大小最小，而此时路感强度达到最大值。

Marks 10

### Question VIII Brake Design

1. What are the advantages and disadvantages of disc brakes compared to drum brakes? (6 marks)
2. What is the brake efficiency factor (制动器效能因数)? Please compare the brake efficiency factor and its stability of disc brakes and drum brakes. (6 marks)

Solution: 1. ① 水温稳定性好。  
② 热稳定性好。  
③ 盘式制动器制动效能不随汽车的运动方向而受影响。  
④ 易于构成双向制动系统，结构简单。  
⑤ 制动衬块易于更换。  
⑥ 尺寸小，质量小，散热良好。  
⑦ 工作面积大，接触均匀，则制动衬块的磨损较均匀。  
⑧ 制动间隙小，则制动调整时间短。  
⑨ 制动间隙便于自动调整。

2. 制动器效能因数  $K = \frac{F}{F_0}$ ， $F$  为制动器制动力， $F_0$  为输入力，如下图所示。

6. 制动器效能因数从大到小是双向增力式、双领蹄式、领从蹄式、双从蹄式。

盘式制动器比鼓式制动器制动效能因数要低，但盘式具有很多优点。以上所述盘式制动器的效能稳定性也比较好。

