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Study on Clutch Characteristics and Joint Control Law

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Abstract: Clutch is an important part of the automobile transmission system, is the engine and the transmission power transmission bridge, the engagement and separation, decided to vehicle driving force, so clutch during vehicle starting and shifting process plays a important role. In order to realize the automatic connection and separation of AMT clutch and need to clutch design actuators, and execution mechanism design need to the working characteristics of the clutch is designed on the basis. Therefore, this paper on the clutch characteristics research; to obtaining the clutch engagement control scheme, we need to determine the engagement control rules. Therefore, this paper will also on the clutch rules of engagement is studied.
Keywords: AMT, characteristic, transmission power transmission, analy, maximum joint velocity model

I. INTRODUCTION

Clutch is an important part of automobile transmission system, is also the engine and transmission power transmission of the bridge,its engagement and separation, Determine whether the driving force of the car, therefore, the clutch plays an important role in the process of starting and shifting of the car.In order to realize the automatic engagement and separation of the AMT clutch, the clutch actuating mechanism is needed to be designed, and the design of the actuating mechanism needs to be designed according to the working characteristic of the clutch. Therefore, in order to obtain the clutch engagement control scheme, we need to determine the joint control law in order to obtain the clutch engagement control law, so this chapter will study the clutch engagement law.

II. CLUTCH ENGAGEMENT CONTROL LAW

2.1 Clutch Control Evaluation Index

Clutch control evaluation index, mainly from the impact of the impact, friction work and the joint time to measure three aspects [1].

(1) Impact degree

In vehicle starting and shifting process, to ride comfort requirements are very high, and the measure of smooth indicator is the degree of impact,the degree of impact is too general to influence driving comfort and occupant comfort,serious when will lead to engine flameout, this is not appear in traffic. Therefore, the degree of impact is evaluate clutch control performance is good or bad is the most important index.

The impact degree is defined as the rate of change of acceleration in the longitudinal direction of the vehicle:

$$J_t = \frac{\mathrm{d}a}{\mathrm{d}t} = \frac{\mathrm{d}^2 v}{\mathrm{d}t^2} \tag{2-1}$$

By the formula (2-30) can be seen, degree of impact can be expressed as the speed of the second derivative, and the parameters of speed and the transmission system of vehicle and clutch engagement speed on and its parameters will through the dynamics analysis, we found that fixed vehicle, parameters are fixed, so it can be through the control of the clutch engagement speed to realize the impact of control. At present, the international impact degree limiting for $10\mathrm{m/s}^3$, That is $J_t < 10\mathrm{m/s}^3$.

(2) Sliding friction work

Clutch in the half engagement stage, the master slave disk will be friction, resulting in heat, so the friction plate will wear, affecting the life of the clutch. In order to clutch in the process of repeated work, it is not because the temperature is too high to cause the clutch failure, need to control the sliding friction work.

The friction work is defined as the friction sliding friction. The size of sliding friction degree to evaluate the clutch, the calculation formula is as follows:

$$W = \int_0^t T_c \left(\omega_e - \omega_c \right) \mathrm{d}t \qquad (2\text{-}2)$$

Type, ω_e - Drive speed;

ω_c - Speed of driven disk.

(3) Joint time

Due to the clutch engagement time affect driving performance and so on clutch control quality also have an impact, however, good driving performance and the impact of conflict, but the degree of impact of control is the first. Therefore, this paper to the maximum degree of impact restrictions, strive to bonding time shortest.

2.2 Clutch engagement process analysis

Clutch engagement process refers to the clutch driven disk from completely separated to joint end between the process, can be divided into complete separation stage, half engagement stage and jointing stage. Below the clutch bonding process were analyzed to determine the clutch engagement control law [2-3].

Complete separation stage, this stage clutch slave dynamic disk completely separated. There is no master-slave dynamic disk rotation speed difference much, regardless of their engagement speed is much, will not have an impact and friction work, from the most short bonding time angle to consider, at this stage of the engagement speed should be as fast as possible. Half engagement stage, this stage clutch slave dynamic disk began to joint, friction, early because the clutch transmission torque is less than the driving resistance moment, the vehicle is stationary, produce friction work, but there is no impact. With the clutch driven disk to engage, when the clutch transmission torque and driving resistance torque equal, the vehicle starts to move, the clutch transmission torque continues to increase, the vehicle began to accelerate. This stage is impact of the main stage, so it is clutch to control the most important stage, because of the degree of impact is due to the acceleration caused by the increase of, so control the clutch engagement speed can effectively achieve the control on the degree of impact.

Fully engaged stage, this stage clutch slave dynamic disk to fully engage, to the same speed, release bearing to engage, no further increase in the clutch transmission torque, this stage will not impact and sliding friction work, to the joining the shortest process time should be to the fastest speed to complete the joint.

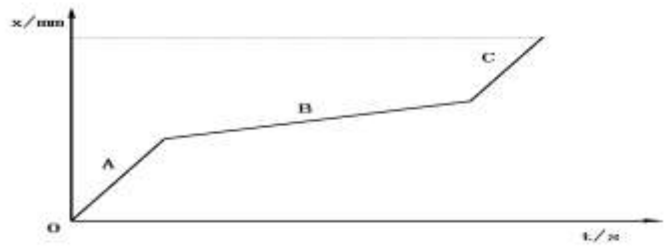

Fig. 2-1 Best Law of Clutch Engaging Process

Seen from the above analysis, clutch the best rules of engagement should be as shown in Figure 2-1, namely in complete separation stage and jointing stage, the clutch slave dynamic disk should be to the fastest engagement speed joint and in semi jointing stage, we should focus on control the degree of impact, bonding and bonding speed is the key factor to the index. In order to get better clutch to the rules of engagement, it is necessary to further study of vehicle system dynamics. Kinetic study consists of two parts, respectively is study on the relationship between the interior of the vehicle transmission system interaction studies and vehicle and the external force.

(1) Clutch system power

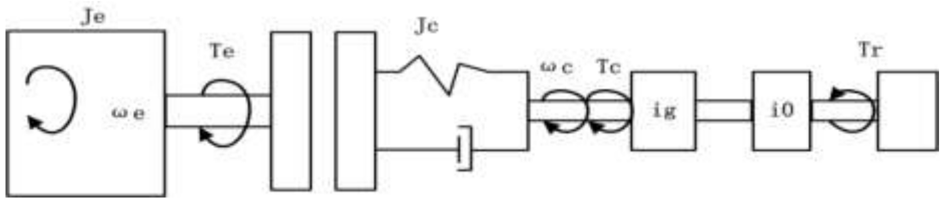

Fig. 2-2 Dynamics Model of Clutch System

For clutch system dynamics research, clutch system simplified, as shown in Figure 2-12, engine power through the crankshaft flywheel reach clutch drive plate, after a master-slave disc engagement, transmits the power to the transmission, and finally arrived at the wheel. In which, for the clutch the active part including clutch cover and the pressure plate, driven part including plate and the driven friction plate. Will engine and the flywheel moment of inertia equivalent to clutch drive plate, the resistance equivalent to the clutch slave disc, the following stage analysis.

①Complete separation phase:

$$T_c = 0, \quad J_e \cdot \dot{\omega}_e = T_e - \beta_e \cdot \omega_e \tag{2-3}$$

②Half bonding stage:

$$\begin{cases} J_e \cdot \dot{\omega}_e = T_e - \beta_e \cdot \omega_e - T_c \\ J_c \cdot \dot{\omega}_c = T_c - \beta_c \cdot \omega_c - T_r \end{cases} \tag{2-4}$$

③Complete bonding stage:

$$(J_e + J_c) \cdot \dot{\omega}_c = T_e - \beta_e \cdot \omega_e - T_r \tag{2-5}$$

e, J_e —engine、flywheel and clutch driving disc equivalent moment of inertia（kgm^2）;

J_c —Equivalent moment of inertia of driven disk（kgm^2）;

ω_e —Active disk angular velocity（rad/s）;

ω_c —Angular velocity of driven plate（rad/s）;

β_e —Equivalent damping coefficient of engine（Nms）;

β_c —Drag torque on the output shaft（Nms）;

T_e —Engine output torque（Nm）;

T_c —Friction torque of clutch transmission（Nm）;

T_r —Equivalent damping coefficient of the driven plate（Nm）;

η —Efficiency of transmission system.

2）Dynamic Analysis And Modeling Of Transmission System

Auto power refers to the vehicle along the traveling direction of movement. Thus, the first step is to research vehicle in the driving direction acting on the car to a variety of external force, including the driving force and running resistance. The driving force is by the engine torque via the clutch, gearbox, transmission shaft, the main reducer transmission to the wheels can be expressed as:

$$F_t = \frac{T_e i_g i_0 \eta_T}{r} \tag{2-6}$$

Type, T_e —engine torque (Nm);

i_0 —Transmission ratio of main reducer;

i_g —Transmission ratio;

η_T —Mechanical efficiency of transmission system.

Running resistance is the sum of resistance from the ground and air,including the rolling resistance, air resistance, the resistance of the ramp and the acceleration resistance, I used to denote respectively F_f, F_w, F_i, F_j ., So the total running resistance is

[4]: F_f, F_w, F_i, F_j

$$\sum F = F_f + F_w + F_i + F_j \tag{2-7}$$

①Rolling resistance:

When I was rolling resistance(F_f) wheel rolling, tire and road surface contact area method to produce, cut to the interaction, expressed as
:

$$F_f = G \cdot f \cdot cos\alpha \qquad (2\text{-}8)$$

Type, G —gross vehicle weight(N);
α —Slope angle(°);
f —Tyre rolling resistance coefficient.

② **Air resistance**

Air resistance is the air force of the car is on a straight road is running in the direction of the force. In this paper, we mainly consider in the condition of no wind clutch engagement and separation process. At the same time, the air resistance said:

$$F_w = \frac{C_D A u_a^2}{21.15} \qquad (2\text{-}9)$$

Type: C_D —Air resistance coefficient;
A —Frontal area（m^2）;
u_a —Motor speed（km/h）.

③**Grade resistance**

Slope resistance refers to when the car uphill driving, car gravity along the ramp angle(@) I component, it is expressed as::

$$F_i = G\sin\alpha \qquad (2\text{-}10)$$

④ **Acceleration resistance**

The acceleration resistance is overcome by the inertia force produced by the quality of the vehicle when the vehicle is accelerated:

$$F_j = \delta m \frac{\mathrm{d}u}{\mathrm{d}t} \qquad (2\text{-}11)$$

Type

δ —Rotary mass transfer coefficient of automobile, $\delta = 1 + \frac{\sum J_w}{mr^2} + \frac{J_e i_g^2 i_0^2 \eta_T}{mr^2}$,

J_w -Wheel moment of inertia (kgm^2)

J_e _Engine flywheel moment of inertia (kgm^2),

η_T - Automobile transmission efficiency, r - tire size (m);

u —Speed（m/s）。

In summary, total running resistance:

$$\sum F = Gf\cos\alpha + \frac{C_D A}{21.15}u_a^2 + G\sin\alpha + \delta m\frac{\mathrm{d}u}{\mathrm{d}t} \qquad (2\text{-}12)$$

As a result, the vehicle dynamics equation is:

$F_t = \sum F$	(2-13)
$\frac{T_{ed} i_g i_0 \eta_T}{r} = Gf\cos\alpha + \frac{C_D A}{21.15}u_a^2 + G\sin\alpha + \delta m\frac{\mathrm{d}u}{\mathrm{d}t}$	(2-14)

Parameter	Numerical value	Parameter	Numerical value
Vehicle kerb	1460 kg	Frontal area	2.018 m^2

mass			
Transmission gear transmission ratio	3.455	Efficiency of transmission system	0.92
Main reduction ratio	4.111	Rotational mass transfer coefficient	1.5117
Flywheel moment of inertia	0.218 kgm^2	Rolling radius	0.288 m
Air resistance coefficient	0.37	Wheel moment of inertia	2.352 kgm^2

Further analysis shows that, when the vehicle is traveling, equivalent to the resistance torque of the clutch plate for i:

$$T_r = \frac{r}{i_g i_0 \eta_T}\left[Gf\cos\alpha + \frac{C_D A}{21.15}u_a^2 + G\sin\alpha + \delta m\frac{\mathrm{d}u}{\mathrm{d}t}\right] \quad (2\text{-}14)$$

The formula (2-14) shows that the torque of the driving resistance is transferred to the clutch output shaft, which is the basis of the study of the dynamics of the clutch. Table 2-1 is the value of the specific structure parameters of the vehicle. T_r

2.3 Maximum joint velocity calculation

In the semi bonding stage, the maximum joint speed of the clutch is required to control the impact degree in order to effectively control the impact degree. The maximum joint speed of the clutch is obtained by calculating the impact degree.

On the dynamics of the upper segment, $F_t = 45.37T_c$， The vehicle parameters into the formula $F_t = F_f + F_w + F_i + F_j$， The calculating formula of acceleration for I:

$$a = \frac{45.37T_c(t) - 0.4575v(t)^2 - 286.2}{2215.55} \quad (2\text{-}16)$$

Because the impact is defined as the rate of change of acceleration, $j = \frac{\mathrm{d}a}{\mathrm{d}t}$ ， from $T_c = 0.0437 f(\frac{x-2}{3.188})$， Into the formula(2-16)

$$\frac{\mathrm{d}a}{\mathrm{d}t} = (8.306(\frac{x-2}{3.188})^2 - 1.744(\frac{x-2}{3.188}) + 0.958)\frac{\mathrm{d}x}{\mathrm{d}t} \quad (2\text{-}17)$$

From the analysis above, the impact of limit values for I, according to the formula (2-17)the separation velocity of the bearing should meet the following conditions:

$$\frac{\mathrm{d}x}{\mathrm{d}t} < \frac{10}{8.306(\frac{x-2}{3.188})^2 - 1.744(\frac{x-2}{3.188}) + 0.958} \quad (2\text{-}18)$$

By the formula (2-18) can be obtained, the maximum clutch engagement speed fori:

$$v_{\max} = \frac{10}{8.306(\frac{x-2}{3.188})^2 - 1.744(\frac{x-2}{3.188}) + 0.958} \quad (2\text{-}19)$$

III. CONCLUSION

The above request for semi engagement phase of maximum engagement speed, changes with the separation bearing displacement changes.Because AMT gearbox and clutch diaphragm spring used in conjunction with, AMT clutch control to considering the nonlinear characteristic of the diaphragm spring, with respect to the clutch control have been difficult, the need to increase more work to study the operating characteristics of the diaphragm spring clutch, this paper to the working characteristics of the clutch and the control rule were studied. Specific content as follows: On the basis of detailed analysis of the structure and working principle of clutch, the elastic properties of diaphragm spring are studied by A-L method, and the clutch torque transfer model is established. According to the control target evaluation of clutch, totally separated phase, half engagement stage and is fully engaged in three stages to analyze the clutch bonding process obtains the optimal clutch control rules. In order to better achieve the best control rules, the clutch and the transmission of kinetic studies, established the dynamic model of the clutch and transmission system. In order to effectively control the impact degree at the half bonding stage, the maximum joint velocity model of the isolated bearing with maximum impact degree is established. The control scheme is proposed by studying the characteristics of the clutch and the control law.

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