REPRESENTATION OF A TRANSMISSION MODEL WITH CONTINUOUS POWER FLOW IN STATE SPACE

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I. INTRODUCTION

Continuous flow power transmissions are widely used in the construction of land vehicles operating in difficult operating conditions. The dual-clutch transmission can also be used on robotic vehicle modifications. Comparative analysis of various types of double-flow clutches shows the preference of using wet double-flow clutches in high-power transport complexes [1].

In this paper, a model of a two-stream transmission was considered, designed to build an integrated control system for the power units of a heavy vehicle for the most efficient movement, including in a semi-autonomous mode.

II. MODELLING

The presence of a detailed model of the dual-clutch transmission makes it possible to switch to a simplified model with linearization of characteristics for the synthesis of an adaptive control system. In addition, the detailed model can be used to verify adequacy.

A scheme was used in which the components of the transmission can be described in the form of elements characterized by either inertia or compliance: J_e is the moment of inertia of the engine, J_{cl1}, J_{cl2} is the moment of inertia of the 1st and 2nd clutch, respectively, J_{g1}, J_{g2} is the moment inertia for transmission channels of odd and even series, respectively, J_3 is the moment of inertia of the wheel drive, J_v is the moment of inertia of the center of mass of the vehicle, ω_e is the angle of rotation of the crankshaft of the internal combustion engine, $\omega_{cl1}, \omega_{cl2}$ is the angle of the input shaft of the 1st and 2nd clutches, ω_{g1}, ω_{g2} is the angle of rotation of the intermediate shaft of the transmission, ω_3 – the angle of rotation of the wheel drive, ω_v – the angle of the longitudinal axis of the vehicle.

Vibrations in such a description are reflected through the coefficients of stiffness and damping, which occur at certain sections of the joint [2].

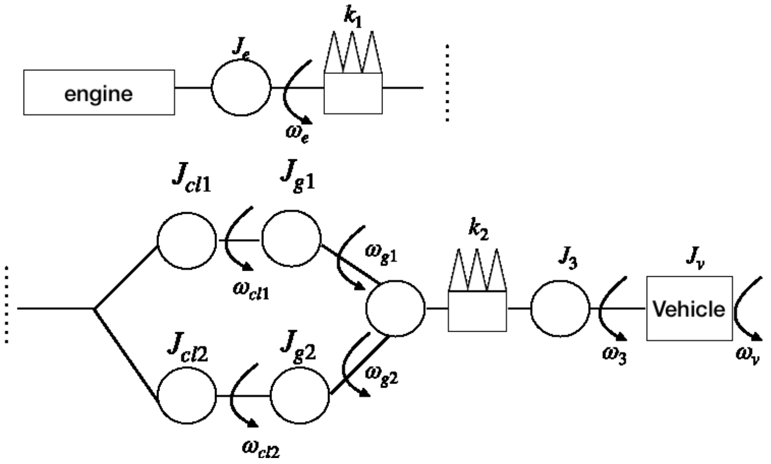

Figure 1. Dual clutch transmission diagram

Equations of moment equilibrium for the links shown in Figure 1:

$$J_e\ddot{\omega}_e = T_e - T_{cl1,2} \quad (1)$$

$$J_c\ddot{\omega}_c = T_{cl1} - k_1(\omega_{cl1} - \omega_{g1}); J_{g1}\ddot{\omega}_2 = k_1(\omega_{cl1} - \omega_{g1}) - i_{2n-1}k_2(i_{2n-1}\omega_{g1} - \omega_3), \quad (2)$$

$$J_c\ddot{\omega}_c = T_{cl2} - k_1(\omega_{cl1} - \omega_{g2}); \; J_{g2}\ddot{\omega}_2 = k_1(\omega_{cl1} - \omega_{g2}) - i_{2n}k_2(i_{2n}\omega_{g2} - \omega_3) \quad (3)$$

$$J_3\ddot{\omega}_3 = k_2(i\omega_{g2} - \omega_3) - b(\dot{\omega}_3 - \dot{\omega}_v) - F_{r\,driving}R_\omega; \quad (4)$$

$$J_v\ddot{\omega}_v = b(\dot{\omega}_3 - \dot{\omega}_v) - T_l \quad (5)$$

where T_e – is the torque transmitted by the crankshaft of the internal combustion engine, $T_{cl1,2}$ is the torque transmitted by the first and second clutches, respectively, $\boldsymbol{T_l}$ is the load moment from the side of the vehicle, i_{2n-1}, i_{2n} are the gear ratios of the even and odd series; k_1 – input shaft torsional stiffness, k_2 – wheel drive shaft torsional stiffness, b – damping coefficient between wheel drive and vehicle inertia, $F_{r\,driving}R_\omega$ – road drag force.

The approach, described in the study by F. Garofalo [3], was taken as a basis for the formation of state matrices that describe the phases of coupling and uncoupling. This model has been modified for continuous power transmission. The control vector in this system is the signals of the internal combustion engine torque T_e and the torque coming from the first or second clutch, $T_{cl1,2}$. Other vector and matrix parameters of the equations in the state space for the transmission as part of the system "engine – clutch – gearbox – wheel drive – car", where the dynamics of the car itself is considered simplified, take the form

$$x = \begin{pmatrix} \dot{\omega}_e \\ \omega_e - \omega_{cl} \\ \dot{\omega}_{cl} \\ \omega_{cl} - \omega_{g1,2} \\ \dot{\omega}_{g1,2} \\ k_2(i_{g1,g2}\omega_{g1,2} - \omega_3) \\ \dot{\omega}_3 \\ \dot{\omega}_v \end{pmatrix}, u = (T_e \quad T_{cl1,2})$$

$$A_{sl} = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -k_1/J_{cl1} & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & k/J_2 & 0 & -i_{g1,2}/J_2 & 0 & 0 \\ 0 & 0 & 0 & 0 & k_2 i_{g1,2} & 0 & -k_2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1/J_3 & -b/J_3 & b/J_3 \\ 0 & 0 & 0 & 0 & 0 & 0 & b/J_v & -b/J_v \end{pmatrix}, \ B_{sl} = \begin{pmatrix} 1/J_e & -1/J_e \\ 0 & 0 \\ 0 & 1/J_c \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{pmatrix},$$

$$A_{st} = \begin{pmatrix} 0 & 0 & 0 & -k_1/(J_e+J_c) & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & k_1/(J_e+J_c) & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & k/J_2 & 0 & -i_{g1,2}/J_2 & 0 & 0 \\ 0 & 0 & 0 & 0 & k_2 i_{g1,2} & 0 & -k_2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1/J_3 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & b/J_v & -b/J_v \end{pmatrix}, \ B_{st} = \begin{pmatrix} 1/(J_e+J_c) & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{pmatrix}$$

The ratio $k_2(i_{g1,2}\varphi_1 - \varphi_2)$ characterizes the passage of the torque through an even or odd row with a shaft stiffness k_2. Introduced shift parameter *d* - to describe the clutch in the engaged and disengaged states. The general description of the transmission of torque through the transmission units during the operation of the two clutch modes is carried out using the state variables $\dot{x}_{even}$, $\dot{x}_{odd}$:

$$\dot{x}_{even} = dA_{sl_{even}}x + (1-d)A_{st_{even}}x + dB_{sl_{even}}u + (1-d)B_{st_{even}}u + f(t);$$

$$\dot{x}_{odd} = (1-d)A_{sl_{odd}}x + dA_{st_{odd}}x + (1-d)B_{sl_{odd}}u + (1-d)B_{st_{odd}}u + f(t);$$

where $f(t) = (0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad -\frac{T_l}{J_v})$ – vector describing the vehicle load.

III. CONCLUSIONS

A dynamic transmission model was built with a continuous flow of power into the state spaces, taking into account the stages of clutching and decoupling of the discs for each row of gear ratios. This model makes it possible to estimate the angular velocities of the transmission elements; in the future, it can be used to develop a control system.

REFERENCES

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