Dynamic modeling of sliding clutches

Ph.D. dissertation, summary

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Operation of sliding clutches in mechanical drivelines could be divided into three different states:

1. Totally open state,
2. Sliding state,
3. Totally closed state.

The torque transferred by the clutch in the first two states is determined by characteristics of the clutch parallel to the conditions of its actuating mechanism, while in the third state it is determined by the drive system independent from the clutch itself. The clutch is a special non-linear element in the drive system.

The previously published studies, within the period 1972-2007, were dealing with the problem to model clutches, no one of found models could give a correct common description for both sliding and totally closed states. This fact assigns the up-to-date necessity of this investigation, namely to create a reliable calculation model for clutches and to testify the suitability of its application in the engineering practices.

In the first part of the dissertation two new procedures implementing the suggested model of clutches by found technical papers were worked out to aid the modeling of drives consisting clutches, namely the method of acceleration matrix and the method of intersection serving the calculation of the unknown clutch torque in the closed state. A new thesis was established and proved for the acceleration matrix method.

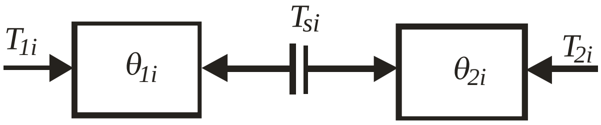
Further on a new clutch model was created to handle clutches as separate objects of the drive system. The suitability of this new model is proved through mathematical calculations and real laboratory tests. Simulation results obtained by using this new clutch model were compared to results of tests of other investigators and proved reliability and preciseness of the model.

The new model handles the clutch a separate object as an imagined black-box characterizing its state by the relative angular displacement (φ) and having its torque-capacity (T_s) as representative of the operational condition. Using this clutch model object the so-called complicated clutch states investigating algorithm is neglected, which were necessary in all previous methods.

The widest range of drives containing clutches is the field of vehicle drives, that is the reason of selection of examples raised from this field to prove the many-sided usage of this integrated clutch model. The examples of dynamic simulations show the new clutch model is suitable for dynamic investigation of powertrain with both traditionally constructed cylindrical and planetary gear transmission systems. At the example of the planetary gear transmission over the modeling of clutches the model also proved to be suitable for modeling the brakes.

Theses

1. A clutch unit is defined according to the following figure as essential element for building clutches into drives. Drive chains can be built up using these essential elements by connecting them in series or parallel, directly or in series with another elements representing permanent gearing ratios.



The dynamic equations at input and output shafts characterizing the drive systems built up by connecting essential clutch units and drives with permanent gearing ratios according to any arbitrary topology have the following shape:

$$\dot{\omega}_1 = a_1 T_1 + b_1 T_2 + \underline{c}_1^* \underline{T}_s ,$$

$$\dot{\omega}_2 = a_2 T_1 + b_2 T_2 + \underline{c}_2^* \underline{T}_s ,$$

where $\dot{\omega}$: angular acceleration, T: torque, a,b: constants, $\underline{c}$: vector containing constants, $\underline{T}_s$: sliding torque vector, *1, 2*: suffixes indicating input or output shafts, the “*” sign means the transposed vector.

2. The method of intersection was worked out to determine the unknown transferred torque at the drivelines of transmissions using clutches upon the linear effect of clutch torque acting on the dynamic of the drive system.

3. The acceleration matrix method was worked out for dynamic modeling of drivelines with transmissions using clutches, which makes possible the automatic generation of the state-equations describing the dynamic of the system.

4. A new mathematically closed dynamic model for clutches was created, which is able to describe all the operational states including the open, sliding, and totally closed states as well as the transition from one to the other state. The model radically reduces the dynamic modeling of drives pure because no algorithm to investigate the operational states of clutches is needed.

5. The created model is suitable to model clutches for dynamic modeling of the drivelines of vehicles using mechanical transmissions, including to model brakes in the planetary transmissions too.