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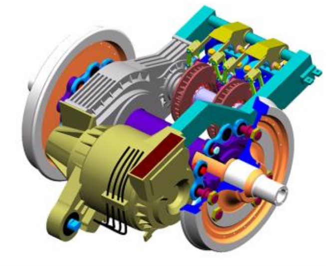
An influence of electromechanical coupling effects on stability of the drive systems of HST driven by electric motors

1. Introduction

The knowledge about torsional vibrations in drive transmission systems of railway vehicles is of a great importance in the fields dynamics of mechanical systems [1,2]. At the design stage or upgrading the traction drive is necessary to choose such of its elastic and dissipative parameters in which the oscillations are not possible or minimalize. Thus, the task of choosing rational parameters of the traction drive is to ensure the stability of a dynamical system with respect to the frictional self-excited vibration.



The object of considerations is a typical railway train driving system whose scheme shown in Fig. 1. In this drive system the there-phase induction traction motor with a gearbox creates an integrated drive unit. The output driving torque from an electric motor is transmitted via coupling multirod to the hollow shaft, which surrounds the wheelset axle.

Fig. 1. Example construction of full sprung wheelset drive for a high-speed train.

2. Mathematical modelling of the considered driving system

A traction drive model is defined by a torsionally vibrating system represented in the form of a four-mass rotating system (Fig. 2), whose motion is described by a system of differential equations:

$$\mathbf{I}\varphi\ddot{\varphi}(\mathrm{t}) = (\mathbf{C}_{e-m} + \mathbf{C}_{gear} + \mathbf{C}_{shaft} + \mathbf{C}_{wheelset})\,\dot{\varphi}(\mathrm{t}) + (\mathbf{K}_{e-m} + \mathbf{K}_{gear} + \quad (1)$$

$$+ \mathbf{K}_{shaft} + \mathbf{K}_{wheelset})\,\varphi(\mathrm{t}) = \mathbf{T}_M + \mathbf{M}_{creep} \quad ,$$

where $\mathbf{I}$ denotes the mass matrix containing mass moments of inertia of rotating elements of the drive system, the matrixes, $\mathbf{C}_{e\text{-}m}$, $\mathbf{C}_{clutch}$, $\mathbf{C}_{shaft}$, $\mathbf{C}_{wheelset}$, $\mathbf{K}_{elm}$, $\mathbf{K}_{clutch}$, $\mathbf{K}_{shaft}$ and $\mathbf{K}_{wheelset}$ represent the torsional damping and stiffness properties of rotor shaft, the gearbox wheel, the hollow join shaft and the wheelset, respectively. Vector $\mathbf{T}_M$ contains the electromagnetic torque generated by a synchronous motor described in the following part of the paper and vector $\mathbf{M}_{creep}$ contains the traction torque generated by longitudinal tangential loads in the wheel-rail zones.

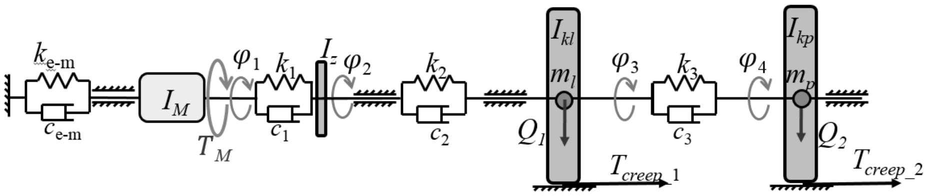


Fig. 2. Model of torsional vibration of the full sprung wheelset drive system with electromechanical coupling.

The wheelset drive system under steady-state harmonic oscillations with circular frequency ω is characterized by a fluctuation component of the electric motor rotor current angular displacement $\varphi(t)$ as well as by a fluctuation component of the electromagnetic torque $T_M(t)$. Then, it is possible to express amplitudes of these components in the following complex form, [3]:

$$\varphi^{\mathrm{var}}(\omega)=U(\omega)+jW(\omega)\,,\qquad T_M^{\mathrm{var}}(\omega)=S(\omega)+jT(\omega)\,,\tag{2}$$

where $U(\omega)$, $W(\omega)$ and $S(\omega)$, $T(\omega)$ are respectively the mutually orthogonal amplitude components of the vibratory rotor angular displacement and of the electromagnetic motor torque and j denotes the imaginary number. The fluctuation components of motor rotor angular displacement φ^{var} and of the motor electromagnetic torque T_M^{var} depend on each other due to an electromechanical interaction between torsional vibrations of the drive train and oscillations of electric currents in the motor windings According to [3] the considerations performed above, in steady-state operating conditions a dynamic interaction of the asynchronous motor with the drive system can be reduced to a visco-elastic clamping of the motor rotor with the immovable stator by means of this electromagnetic spring of stiffness $k_{\mathrm{e\text{-}m}}(\omega)$ and damping coefficient $c_{\mathrm{e\text{-}m}}(\omega)$ expressed by formulae (3).

$$k_{\mathrm{e-m}}(\omega)=-\mathrm{Re}\left[\frac{T_M^{\mathrm{var}}(\omega)}{\varphi^{\mathrm{var}}(\omega)}\right],\qquad c_{\mathrm{e-m}}(\omega)=-\frac{1}{\omega}\mathrm{Im}\left[\frac{T_M^{\mathrm{var}}(\omega)}{\varphi^{\mathrm{var}}(\omega)}\right].\tag{3}$$

3. Conclusions

The analysis of stability the High Speed Train traction drive with electromechanical coupling has been done. Using the energy balance of the natural modes of vibration for the model of the drive system leads to determining the influence of electromagnetic parameters on its stability in relation to self-excited vibrations induced by friction.

References

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