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Active control of torsional vibrations in rotating systems by means of the driving asynchronous motor

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1. Abstract

Majority of industrial machinery and several mechanisms are driven by asynchronous motors. Such electro-mechanical systems are often affected by detrimental torsional vibrations, suppression of which is commonly performed by more or less effective passive, semi active and active dampers. In this paper there is proposed an alternative method of attenuation of torsional vibrations in such objects. Here, an asynchronous motor under the proper vector control can simultaneously operate as a source of drive and actuator. Using this approach, transient and steady-state torsional vibrations of the driven mechanical system can be effectively suppressed as well as its precise operational motion can be assured. The theoretical investigations are carried out by means of an advanced structural mechanical model of the drive system and circuit model of the asynchronous motor controlled using two methods: the direct torque control (DTC-SVM) and the rotational velocity controlled torque method (RVCT) originally developed in this paper. In the computational examples performed for three representative drive systems torsional vibration control ability is analyzed for various dynamic properties of the mechanical part and several parameters of the asynchronous motor control. From the obtained results it follows that for majority of tested parameters, transient torsional vibrations excited by step-wisely disturbed loadings of the driven object are successfully attenuated using both abovementioned vector control strategies. However, a suppression effectiveness of resonant steady-state torsional vibrations by means of these methods depends on the specific case of an asynchronous motor with a given electromagnetic stiffness in the stable operational range of its static characteristics.

2. Introduction and description of the problem

From among various kinds of vibrations occurring in mechanisms and structures the torsional ones are very important as naturally associated with their rotational motions. Torsional vibrations are a source of additional oscillatory angular displacements superimposed on the nominal rotational motions of objects in question. On the one-hand-side, this phenomenon results in severe dynamic overloads leading to dangerous material fatigue of the most heavily affected and responsible elements of these mechanical systems and structures, e.g. shaft segments, joints and couplings, in too fast wear of gear stage teeth as well as in harmful noise generation and unexpected loss of transmitted energy.

In the presented paper an attenuation of torsional vibrations of machines driven by an asynchronous motor is going to be carried out using an active control. The investigations will be performed by means of structural hybrid mechanical models of the machine drive systems, wherein geometrical dimensions and material constants of the shaft line segments are thoroughly taken into consideration. These systems are driven by various asynchronous motors equipped with control units of a cascade structure consisting of the electromagnetic torque inner loop control and the rotational speed outer loop control. Contrary to the methods of active control of asynchronous motors applied so far, the motors of the tested systems are powered using power electronic converters with the 6-transistor IGBT bridge systems, which directly control the electromagnetic moment of the electric motors using the DTC-SVM control strategy. Alternatively, the standard DTC-SVM method will be properly modified using an additional driven machine input rotational speed control loop, which leads to a cascade and branched control structure containing two major control loops. Namely, the standard DTC-SVM approach is realized by the inner control loop performing motor torque regulation, and is cascaded by the outer loop providing in this way an additional rotational velocity control according to a given reference value. This modified approach will be called further “the method of rotational velocity controlled torque” (RVCT).

3. Results of investigations

In the computational examples an influence of dynamic properties of the driven mechanical system and characteristics of driving motor on a vector control effectiveness will be tested. The abovementioned vector control methods are going to applied for three different electromechanical systems consisting each of an asynchronous motor driving a machine by means of an elastic coupling and transmission shaft segments. The examined static characteristics of such motor differ in a more or less stiff stable operation part, as "soft", "medium" and "stiff" shown in Fig. 1a. In turn, the driven mechanical object can be relatively more massive or “lighter” than the driving motor, which has been expressed by different fundamental eigenforms depicted

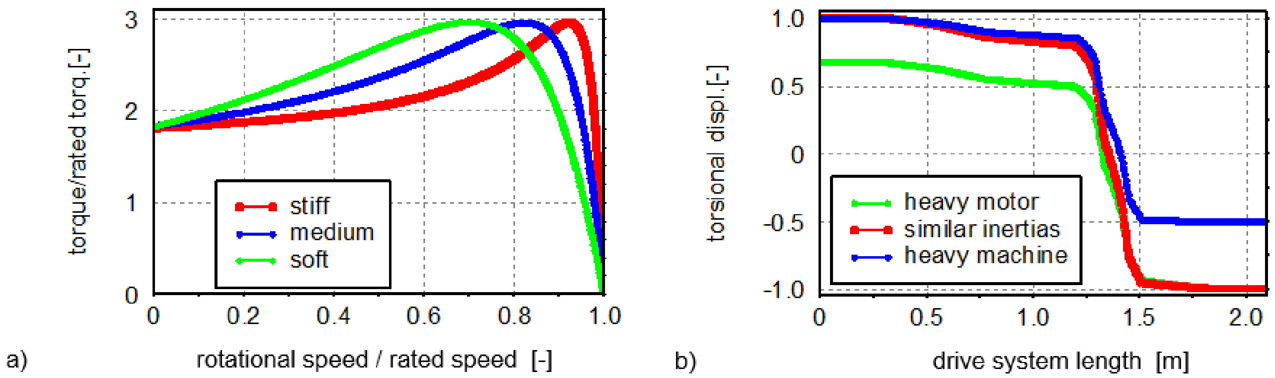

Figure 1: Static characteristics of the asynchronous motor (a) and variants of the fundamental torsional eigenmode of the drive system (b).

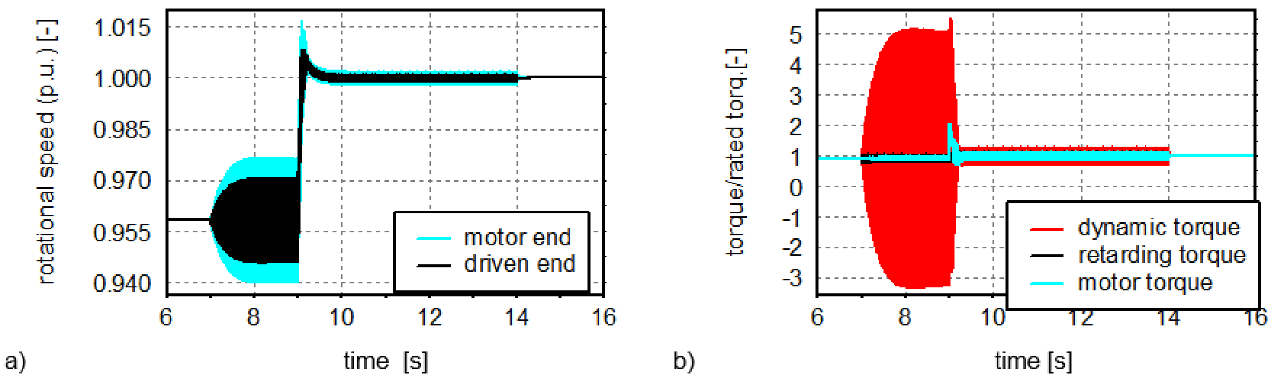

Figure 2: Controlled torsional response due to resonant harmonic excitation in the form of time histories of the system rotational speeds (a) and electromagnetic, retarding and dynamic torque (b).

in Fig. 1b. Here, the driven objects are loaded by step-wisely variable torques and harmonically oscillating torques with resonant frequencies. When assessing the simulation results, the main focus will be on ensuring that both vector control methods enable the best possible precision of steady-state movement and the highest degree of attenuation of resonant vibrations. In Fig. 2 there are plotted exemplary time-histories of the effectively controlled resonant response of one of the electromechanical systems under study in the form of rotational speeds respectively on the motor end and the driven end (Fig. 2a) as well as dynamic, electro-magnetic and retarding torques transmitted by the drive system (Fig. 2b). Summing up, it should be stated that the both mutually compared approaches of vector control of the asynchronous motors are promising, but they require experimental verifications in order to be successfully used in an industrial practice.