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COMPARISON OF DYNAMIC INTERACTIONS IN THE DRIVE SYSTEM OF ELECTRIC LOCOMOTIVE EU07 BEFORE AND AFTER THE MODERNIZATION DRIVE UNIT

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Abstract: *This paper presents a research tool allowing to determine the state of the load in the drive system of electric locomotives. This tool was used to compare dynamic interactions in the drive system of locomotive EU07, where as a result of the modernization of the existing DC motors were replaced with AC induction motors. Developed models of combined engine were coupled to a rail vehicle model developed in the class of multibody sytem dynamics. Load the system comes from the moments generated by the electric motors and the forces generated at the interface between the wheels with guide rail. Developed mathematical models were implemented in Matlab / Simulink. Numerical simulations allow to determine the load of drive system for various vehicle dynamic states (startup, steady-state operation) depending on the locomotive load.*

Keywords: Rail vehicle, Electromechanical drive system, Vector control system.

1. Introduction

Since the beginning of the use of electric traction, DC motors are used to the drive rail vehicles. The main advantage of these drives is the control with ease in a wide speed range with high electromagnetic torque and the major disadvantage of these engines is to have a mechanical commutator and brushes, which is the cause reducing their durability and increases the need for regular maintenance and repairs. Lack of funds for the purchase of new rolling stock compels carriers to renovation and maintenance old ones. Modernization also concerns the drive system an example of it becomes installation of asynchronous motors in place of the DC motors in order to improve the operational performance, such as reducing failure and extending life. Replacement old one booting system based on resistance with new booting system based on frequency can yield significant energy savings. Determination of the actual state of charge the drive system on the basis of numerical simulations can be useful in planning modernizing the of the drive unit. This makes it necessary to construction of models which reflect the operation of a vehicle similar to the real ones. It was therefore necessary to use the at modernization with new approaches to the use of techniques and software tools that allow the use of modeling and simulation techniques, with a view to adjusting the drive model and vehicle model to the existing conditions at the operation.

2. Modelling the Electromechanical System of an Electric Locomotive

The electromagnetic and mechanical systems of the electric rail vehicle powertrain couple mutually through electromagnetic torque (Me) and angular rotor velocity (ω). Because of the rail vehicle system, an analysis of dynamics in railway vehicles and the driving system coupled with it must take into account the analysis of electromagnetic and mechanical systems.

Taking into account the unique character of the solution for the electric locomotive driving system (type of its electric motor, number of motors and the configuration of their connections), further down the paper presents an electromagnetic model of the locomotive chosen for further analysis. For this purpose electric locomotive type EU07 has been chosen. Drive systems of the presented locomotives are DC motors,

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which as a result of modernization have been replaced by AC induction motors. Location of individual motors in carriers were shown in Fig. 1.

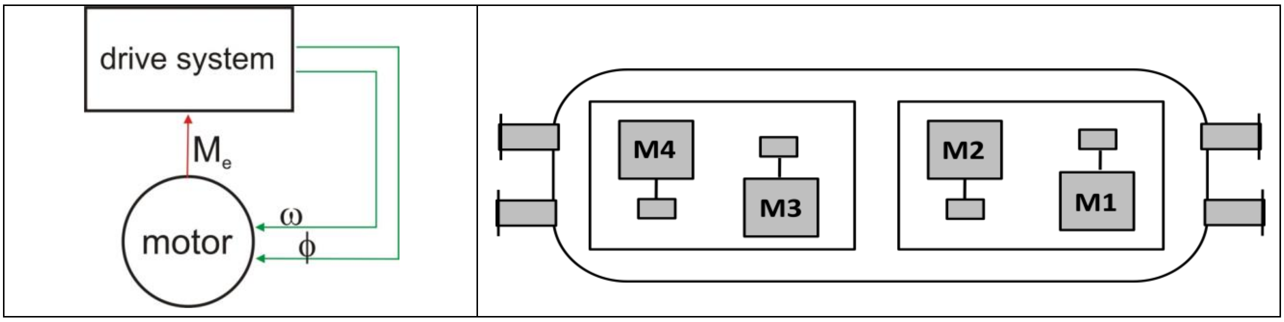

Fig. 1: Model of electromechanical system, structure of a driving system.

3. Development of Models of Electric Drives

In an operating cycle, the traction motors of the EU07 locomotive operate in two configurations. During the start-up phase, four motors are connected in series and, subsequently, to increase the voltage, switched over into a parallel circuit of two motors per branch. Equations describing the currents in electrical circuits, electromagnetic torque generated by the individual motors are further presented in (Duda, 2007).

As a result of the modernization drive systems EU07 locomotive used AC motors (locomotive EP07) in the modified current commutator motor housing. Proposed drive system of locomotives consists of following components: induction squirrel cage motor, mechanical system of wheels (with torque transmission chain) and inverter with control circuit. The internal couplings occurred in such a system are presented in Fig. 2.

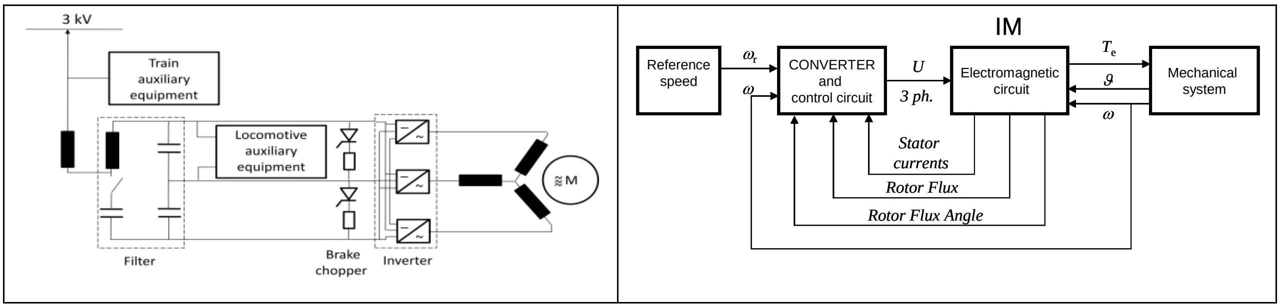

Fig. 2: Mutual coupling in drive system of locomotive with induction motor.

The electromagnetic circuit of induction machine is coupled with mechanical system by electromagnetic torque, angular displacement (of the rotor) and angular speed (Mezyk et al., 2007). Considering in mathematical model of drive system additional coupling, represented by angular displacement, gives more flexible chance to mathematical modeling of induction machine. It allows for taken into consideration mathematical models of induction machine which allows for electromagnetic reluctance or electromagnetic parasitic torque influence investigation on drive system properties. It is assumed that induction machine is fed from converter with vector control algorithms - so-called rotor field oriented control (RFOC). Practical realization of RFOC control system results in following couplings between induction motor, mechanical system and converter: as a input signal to converter are necessary stator currents, rotor flux and rotor flux angle (rotor flux vector may also be estimated based on stator voltage, currents and speed), and angular speed of the rotor.

Currently a complex study of the mechanical system – the rail – rail vehicle can be provided by numerical simulations, by using a computer as a tool. The numerical simulations of rail vehicles require implementing a mathematical model of the vehicle in a computer program that would describe it with a reasonable precision. Using the methods based on multibody system dynamics makes a very convenient approach for developing such models (Shabana et al., 2008). Model of the drive system together with the model of railway vehicle was developed using environment Matlab / Simmechanics in multibody convention (Duda, 2013).

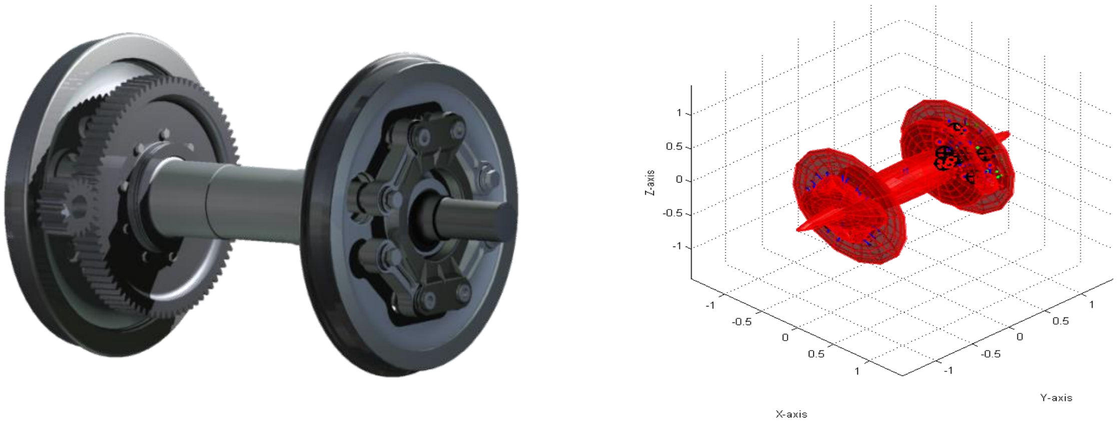

Fig. 3: CAD model of the driving system, visualization of multibody model of the driving system in Matlab/Simmechanics.

4. Numerical Simulation of a Rail Vehicle Travel and Dynamic Interactions in Drive System Kinematic Pairs

Studying the dynamics of electric rail vehicles requires creating three intercoupled models: a vehicle model including drive system models, a rail model, and a model for the wheel – rail interface. At the first stage of rail vehicle modeling process, during its travel on the railway track the subsystem models are built separately. Then, the models are interconnected to make a complete system. This method was implemented in proprietary software created in the Matlab environment.

The calculation algorithm used to analyze the rail vehicle travel on any railway track is presented in the form of a schematic diagram in Fig. 4.

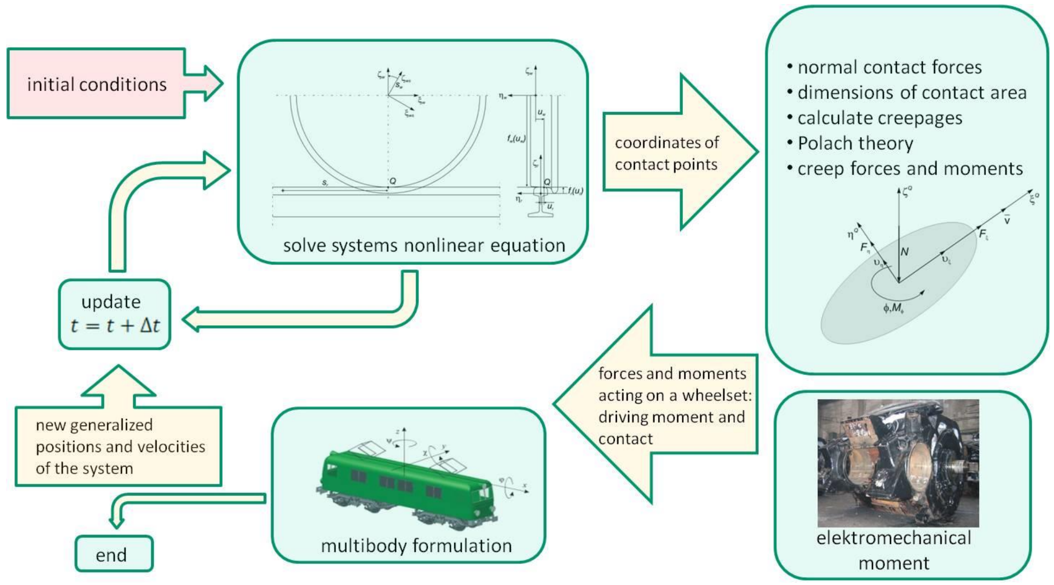

Fig. 4: Calculation algorithm used to analyze the rail vehicle travel dynamics on any railway track.

The presented algorithm (Fig. 4) used to develop the computer program for analyzing the rail vehicle travel dynamics on any railway track was developed based on literature (Lankarani et al., 1990), (Pombo et al., 2003) and (Polach, 1999).

The tool for simulating the travel of rail vehicles has been used to test various cases, showing the potential of the presented method in a variety of situations. These cases included the analysis of EU07 rail vehicle dynamics (before – DC motors and after modernization – asynchronous motors) during its travel on a straight railway track at various conditions.

In Fig. 5 the torques of DC motor and AC motor during start of locomotive are presented.

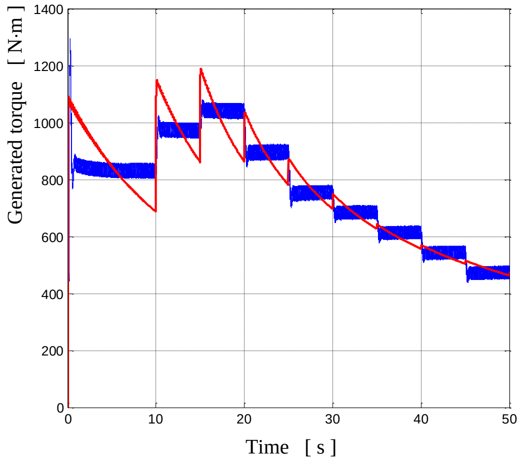

Fig. 5: Sawtooth like curve (red curve) - DC motor torque, square like curve (blue one) - AC motor torque.

5. Final Conclusions

Each mechanism has its operating life. Therefore, for economic reasons it is important to properly determine the dates of overhauls or just for routine periodic inspections. It can be obtained by having a thorough knowledge of dynamic phenomena occurring in the system under analysis, by applying numerical simulations performed on the adequate vehicle model. One of the most susceptible to wear and tear and important part of a rail vehicle is its drive system.

Using the methods of numerical modeling and simulation to provide dynamic analyses in the kinematic pairs of electric rail vehicle makes it possible to identify the state of loads for system components under different operating conditions and it can constitute a basis for forming vehicle traction characteristics effectively. Such studies can be successfully used both to modify the existing objects and to assist the design-construction process for the prototypes of new vehicles.

The developed models allow for the testing of dynamic phenomena occurring in power transmission systems, especially in transient states such as start-up or the change of loading conditions. The models serve the determination of optimal traction parameters for locomotives by e.g. the selection of the gear ratio of the power transmission system gear.

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