

# The control system of synchronous movement of the gantry crane supports

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**Abstract.** The paper presents study findings on synchronization of the gantry crane support movement. Asynchrony moving speed bearings may lead to an emergency mode at the natural rate of deformed metal structure alignment. The use of separate control of asynchronous motors with the vector control method allows synchronizing the movement speed of crane supports and achieving a balance between the motors. Simulation results of various control systems are described. Recommendations regarding the system further application are given.

## 1. Introduction

Gantry and bridge cranes are intended for performing most of lifting and transportation work in various enterprises. They do not only accomplish support functions, but are often engaged directly into the manufacturing process itself. Their safe and uninterrupted operation affects the enterprise performance, its technical and economic indicators as well as its staff safety.

The increase in the reliability and operation safety of gantry and bridge cranes is largely determined by the mechanism specifics and quality indicators and also its electric drive. Due to their high responsibility in work site operations, electrical motor drives of bridge and gantry cranes are imposed a number of stringent requirements. The most essential of them are to provide high-performance and continuity in the work, to guarantee service security and to permit ease of operation and maintenance.

The operation of electrical equipment and the electric motor drive of cranes is typical of some specific features, such as: intermittent operation, frequent changes in rotation direction, significant overloads, vibration, hindered access for inspection and repair, as well as work in the conditions of pollution, humidity or significant temperature drop. Therefore, electric gantry cranes are to be highly safe and reliable. These requirements correspond to machines and a special crane performance apparatus.

However, despite high safety requirements for hoisting machines, numerous accidents take place. High injury and accident rates are primarily conditioned by the continued aging of the vehicle fleet.

A considerable part of accidents is associated with crane metal fatigue. Fatigue failure can be caused by: stress, for example, due to defects in welded joints in the form of lack of fusion and undercut; low quality metal, its poor weldability; crane operation in heavier duty than the passport one; damage and defects acquired in the course of equipment installation or operation, etc.

Supervisory institutions impose mandatory requirements to introduce crane safety devices and

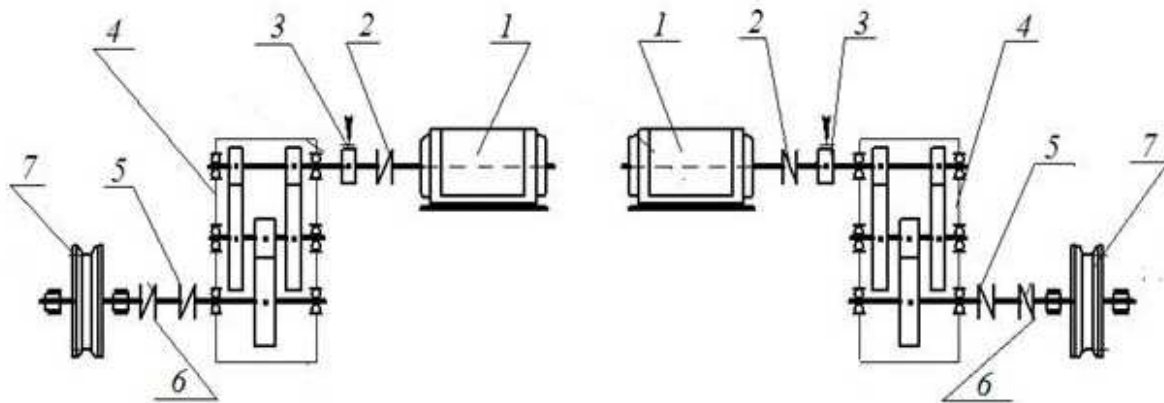


detectors, especially to cranes which have exceeded their standard lifetime. Crane load capacity reduction can considerably increase crane's service life; on the other hand, fatigue defects in the valve crane metal keep the problem unsolved. The defects described are quite difficult to reveal; so any further operation of such equipment, particularly in conditions of neglecting safety precautions, disables the users in eliminating accidents [1-5, 9].

Crane support uneven movements are considered one of the factors affecting the deterioration of the crane steel structures which is especially true for gantry cranes. Uneven movement of crane supports might be triggered by an irregular wheel diameter, for instance due to their uneven deterioration; wind effects; wheel slip at start-up; gantry crane movement with a loaded cart, located on its edge; changes in the drive motor characteristics in due course. Thus, synchronous movement of the crane supports will reduce stress in the crane steel without interfering with its mechanical design.

## 2. Methods

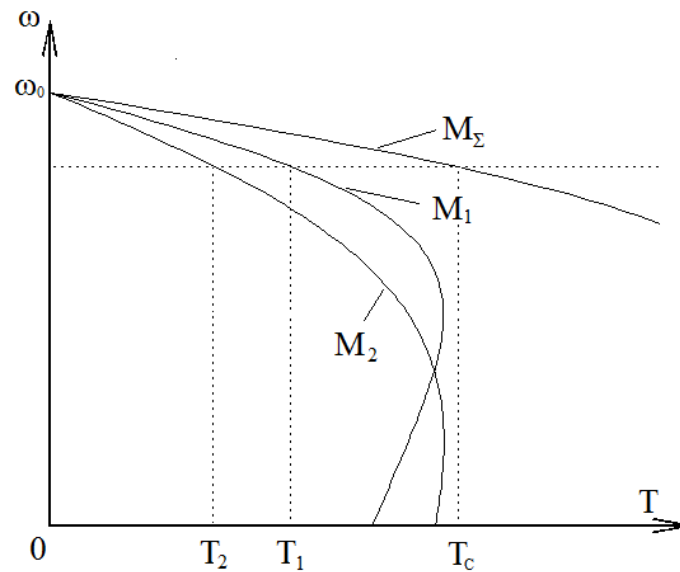
Gantry crane movement mechanisms, as a rule, designed as multi-engine, i.e., in order to provide separate control of each support of the crane by means of an individual electric drive. Figure 1 shows the kinematic scheme of a gantry crane movement mechanism with separate control.



**Figure 1.** The kinematic scheme of a gantry crane movement mechanism

There are two coherently working gantry crane movement mechanisms in the scheme. Each mechanism includes motor 1 connected through coupling 2 to multistage gear 4. Further movement is transmitted from the gearbox to drive wheels 7. The shaft of the wheel drive is connected to the low-speed shaft of gearbox intermediate shaft 6 and gear couplings 5. Brakes 3 are mounted on the high-speed shaft of the gearboxes. The advantages of individual drives are: compactness of the entire movement mechanism, a small size of a flywheel torque of the motor and reduced start-up time. Two electric drives working independently and the only mechanical connection between them is a metal structure of the gantry crane. Accordingly, if for any reason, there appears the uneven distribution of the loads between the two supports, the motor speed with a large load will be less than that of the engine with a fewer load. In this case, one of the crane supports will be ahead of the other. After the transition process, the speed of the two supports of the crane is equalized, because the metalwork will take an effort to distribute loads between the supports. Such natural alignment of loads can be used in a multiple ratio span crane to its base not more than 6. If a multiple ratio is more than 6, the deformation of the metal exceeds the permissible limits, and additional structural reinforcement would cause unjustified increase in the weight of the crane and its cost as well.

Another significant drawback of free alignment of the load, in addition to crane steel structure being deformed, is that the electric motors start working with different loads at the same time. It can be clearly seen in Figure 2. Different parameters of winding and uneven deterioration of mechanical parts lead to different load torques  $T_1$  and  $T_2$ . This fact leads to excessive heating of one of the engines.



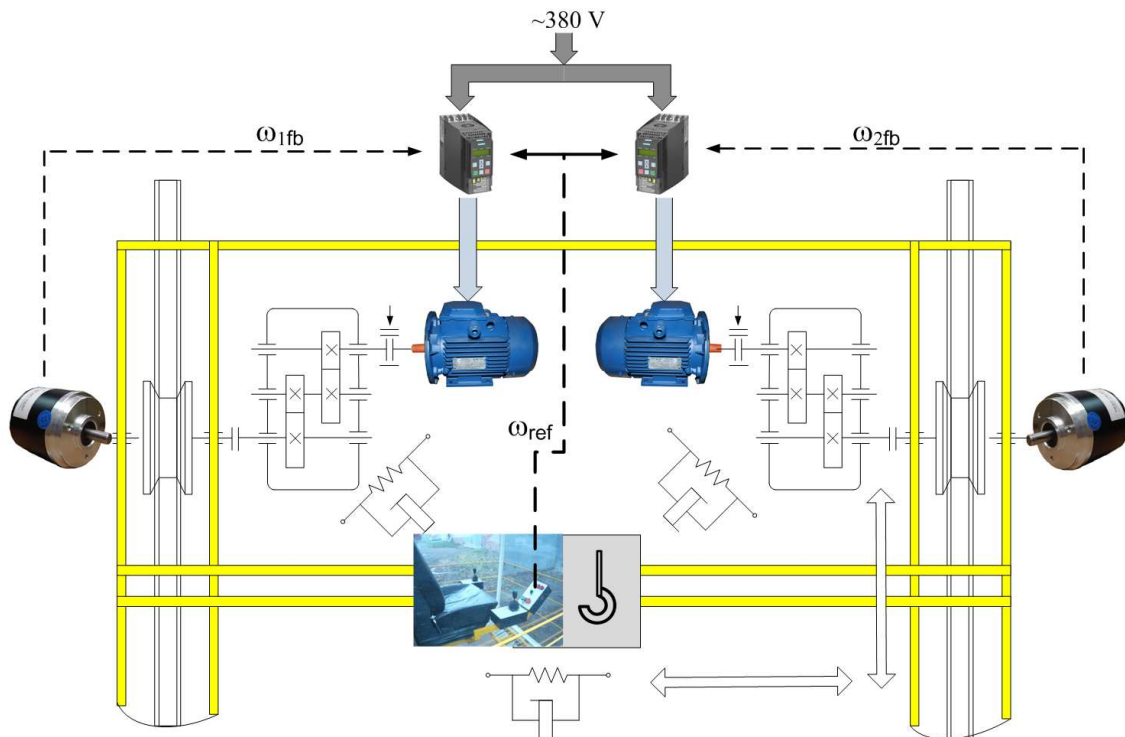
**Figure 2.** Load distribution in the drive with two asynchronous motors M1 and M2

Nowadays there are many ways to synchronize speeds and load equalization of multi-motor drives, for example, due to the use of asynchronous motors with slip-ring motors and the use of the relay-contact and choke circuits. But now there is a steady trend towards the introduction of frequency converters, which have several advantages: smooth speed control, energy saving and active safety functions. Let us consider some options to synchronize the speed of the gantry crane supports on the basis of the frequency inverter [7-10].

### 2.1. The functional scheme of the mechanism of gantry crane support movement

There are various options for system performance controlling for a twin-engine electric drive. Let us consider the case when electric power is obtained from individual inverters. This implementation provides a more flexible control of the crane mechanism. Figure 3 demonstrates the functional scheme of the mechanism of gantry crane support movement. The scheme includes two asynchronous motors, each of which drives the wheels through a corresponding gantry crane reducer. A speed sensor is installed on each wheel, the information from which ( $\omega_{1fb}$  и  $\omega_{2fb}$ ) is sent to the appropriate converter and the remote operator sets speed  $\omega_{ref}$  for both converters. The system works at a voltage of 380 Volts.

To choose the control law of the mechanism of supports movement of the gantry crane, it is necessary to study the system on a simulation model designed in Matlab software. The model in the simulation model of the electric induction motor is presented in a two-phase coordinate system and the mechanical part is represented in the form of a two-mass elastic system. The resilient units are indicated in the diagram. Imitation asymmetry of two supports of the crane is taken into account with unequal coefficients of elasticity of the mechanical part and the different parameters of the windings of the two motors [10].

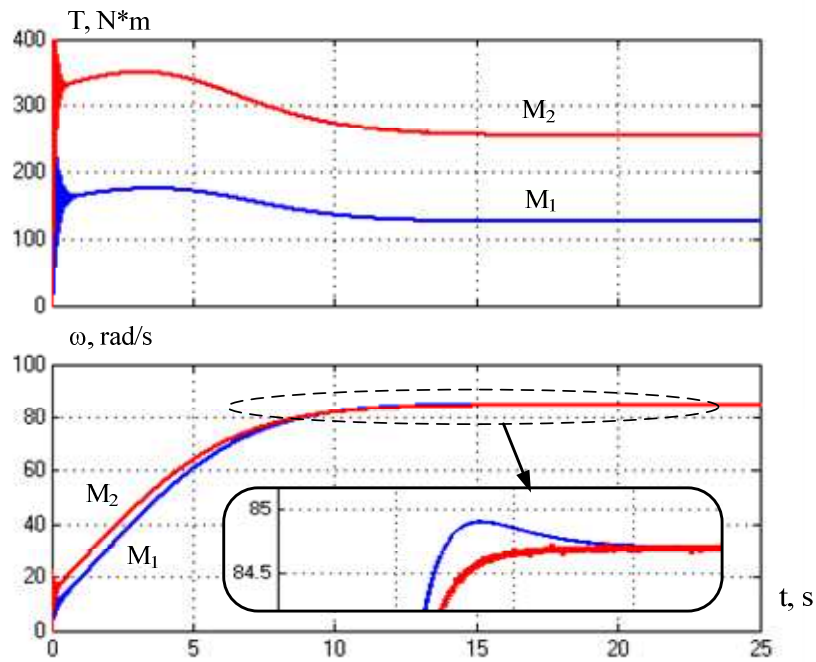


**Figure 3.** A functional scheme of the mechanism of supports movement of the gantry crane

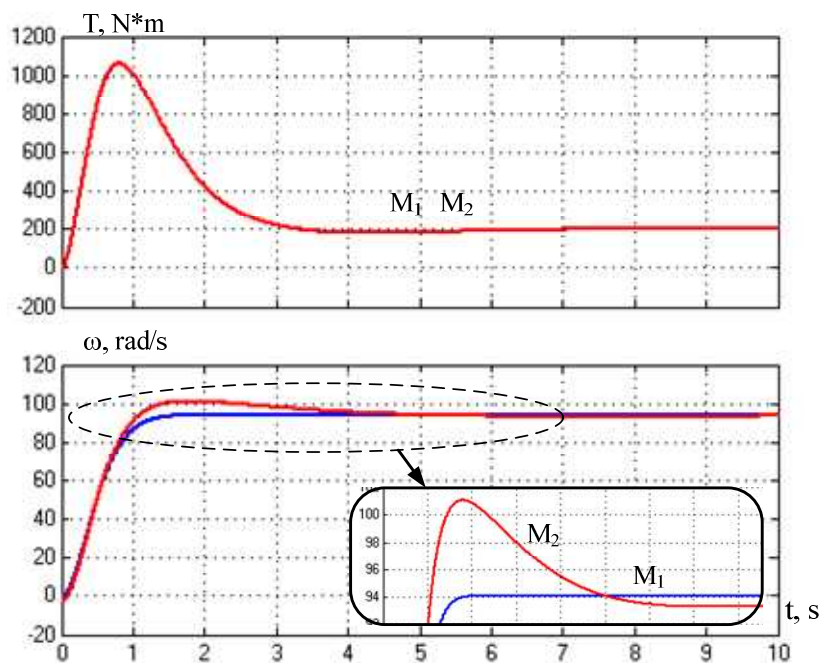
### 3. Results

The simplest way to implement a separate control of the crane support movement is to use the scalar method of control of the inner induction motor. Such a relatively simple method allows realizing a smooth start and eliminating wheel spin and to improve energy efficiency. Figure 4 shows the results of twin-engine electric start simulation. In the first phase, during the start, the movement speeds of the two supports are different. Here the rate of equalization is performed gradually; the transition process is oscillating and decaying. Although there is an asymmetry of induction motor performance in the mechanical parts in the simulation model, the speed of the two supports are equal. This fact has become possible due to the redistribution of loads between the two engines. Figure 2 presents the static characteristics of this fact. As Figure 4 indicates, there is a two-time difference in engine moments, so it could lead to overheating of motor M2 and the low efficiency of motor M1 [6-8].

Let us consider the use of vector control of the asynchronous electric drive for the moving mechanism of the crane supports with a typical multi-loop structure of the slave control system. Since the crane movement mechanism is the one the system has been studied with one common circuit speed while the output of the speed loop is determined for each individual current loop [2]. The simulation results are shown in Figure 5. Vector control ensures the required transitional processes in dynamic conditions. During the whole drive acceleration due to current feedback, it is possible to get the same moments of the two engines. From the point of view of load balancing such a system is perfect. But as there is an asymmetry in the mechanical system, the speed of one of the supports will be greater, because of applying the equal force to both supports as shown in Figure 5; so one of the supports performs at a larger overshoot. The speed difference has turned out to be more than in scalar control, so this option is not acceptable from the point of view of reducing the strain in the steel crane.



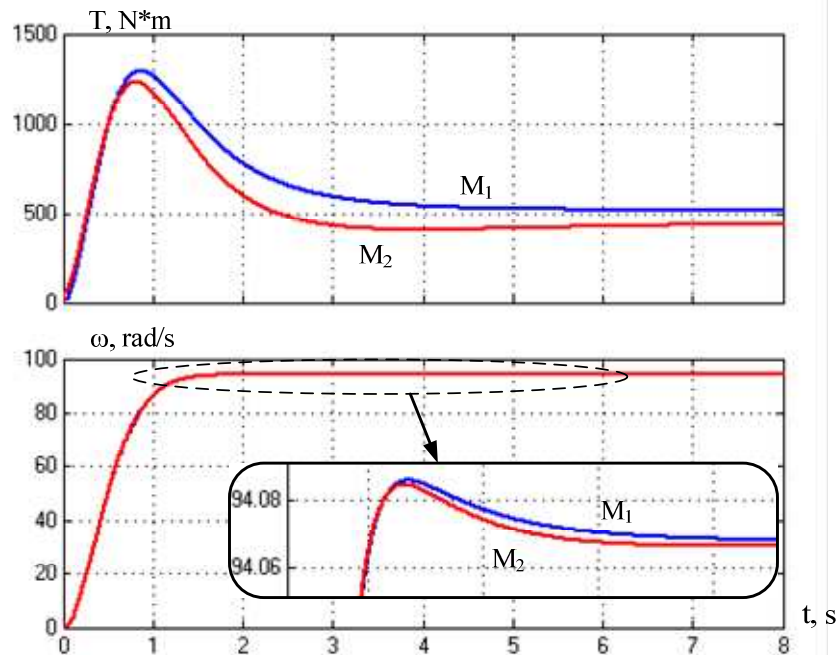
**Figure 4.** Graphs of transients processes at the scalar multi-motor drive control.



**Figure 5.** Graphs of transient processes in vector control of a twin-engined drive and with a common circuit speed

Consider the vector control in movement mechanism of an electric twin-engined drive with two circuits speed. The signal of the speed on both circuits is set by an operator from the remote control. Figure 6 shows the graphs of transient processes. The adjustment of each support speed loop separately led to the fact that the rate turned out to be almost the same (speed difference is less than

0.5%), and the load will vary slightly.



**Figure 6.** Graphs of transient processes of vector control in a twin-engined drive and with individual rate circuits

#### 4. Conclusion

The movement mechanism of the scalar control induction motor of the gantry crane supports leads to a natural equalization rate. But this fact causes a large difference between the load torques, which has a negative impact on the motors.

Vector control with a common loop rate allows aligning the load between the engines, but is not able to synchronize the rate of the crane supports.

The use of vector control with an individual circuit rate for each drive solves the problem of the simultaneous movement of each support issue. At the synchronous movement of supports, the deformation in the valve metal reduces, thus there is an equalization between the motor loads. However, the problem with initial conditions remains unsolved. In the simulation model, the gantry crane is aligned, so the deformation of the metal is equal to zero, therefore, the method of the synchronous movement of crane supports can be used after the alignment of the gantry crane. To register the effect of deterioration of mechanical components and other factors affecting the uneven loading of the supports of the gantry crane, a rate sensor must be put on gantry crane wheels.

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