CONSTRUCTION MACHINE TOOL DESIGN USING MATLAB

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Abstract

When designing a machine tool, it is necessary to start from desired machine output parameters. It is advisable to check the dynamic behavior of the machine tool before making constructional design, which is combined with dimensional and strength calculation of individual machine parts. By dynamic behavior of the machine, we mean determining the time flow of trajectories, velocities, or accelerations, and arisen forces and torques of individual output working parts of the machine tool. We assume that dynamic behavior will be assessed using a suitably built machine tool model, which describes the machine tool itself as closely as possible. The model then can by described by system of motion equations, which we solve numerically using Matlab. Based on the results calculated, we asses the most often generated inappropriate vibrations of individual machine parts. By simulating input parameters, or respectively, by change of structure, we try to minimize such vibrations. The described procedure is demonstrated by an example of a lifting unit design.

1 Model of the machine

The model of the lifting (Fig. 1) consist from a winch 1 (radius r) with moment inertia I_T , a rope 2 lifting a load mass 3 m_2 a gear 4 unit with gearing i, a clutch 5 with torsion stiffness k_M, and an electromotor 6 (moment inertia I_M) with driving moment M_M. The whole unit is placed on a board fastened to a console 7 with total mass m_1, mounted on a firm wall 8. We consider rope stiffness k_2 and console stiffness k_1.

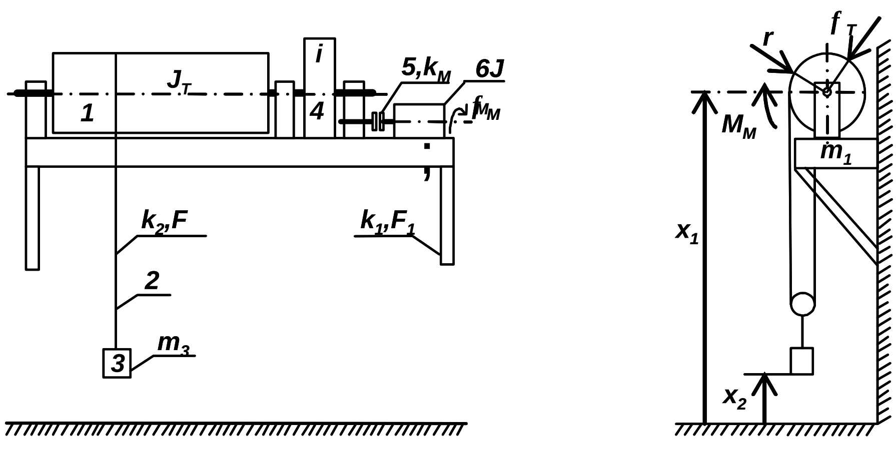

Figure 1: Model of the lifting

The lifting unit model is described by a system of 4 differential equations with 4 degrees of freedom: x_2 - load trajectory, x_1 - console displacement, φ_T - the angle of winch rotation a φ_M - the angle of electromotor shaft rotation:

$$m_1\ddot{x}_1 + k_1 x_1 + k_2(x_1 - x_2 + \frac{r\varphi_T}{2}) = 0, \quad m_2\ddot{x}_2 + k_2(x_1 - x_2 + \frac{r\varphi_T}{2}) + m_2 g = 0,$$
$$J_T\ddot{\varphi}_T + k_2 r(x_1 - x_2 + \frac{r\varphi_T}{2}) - ik_M(\varphi_M - i\varphi_T) = 0, \quad J_M\ddot{\varphi}_M + k_M(\varphi_M - i\varphi_T) = M_M. \tag{1}$$

It is possible to determine force F acting drag rope from relation:

$$F = k_2(x_1 - x_2 + \frac{r\varphi_T}{2}). \tag{2}$$

Force F_1 acting on consoles is given by relation:

$$F_1 = -k_1 x_1 = m_2(g + \ddot{x}_2) + m_1\ddot{x}_1. \tag{3}$$

The relations determining driving moment M_M and torsion moment M_T in the clutch are given as follows:

$$M_M = M[\frac{\pi}{2} - \exp(-\frac{t}{t_k})], \qquad M_T = k_M(\varphi_M - i\varphi_T) \tag{4}$$

By solving the above system of differential equations using Matlab, we determine courses of x_2, x_1, φ_T, φ_M, F, F_1, M_T. Then, we try to reduce the undesired vibrations by simulating parameters. The numerical solution was provided with MATLAB and will be shown on the charts in the article.

2 Results and conclusion

To determine deviation x_2 of load 3 and deviation x_1 of console 7, Simulink scheme (Fig. 2) was put together using Matlab solution of differential equation system (1), Input parameters were simulated in a manner that minimizes the named deviations.

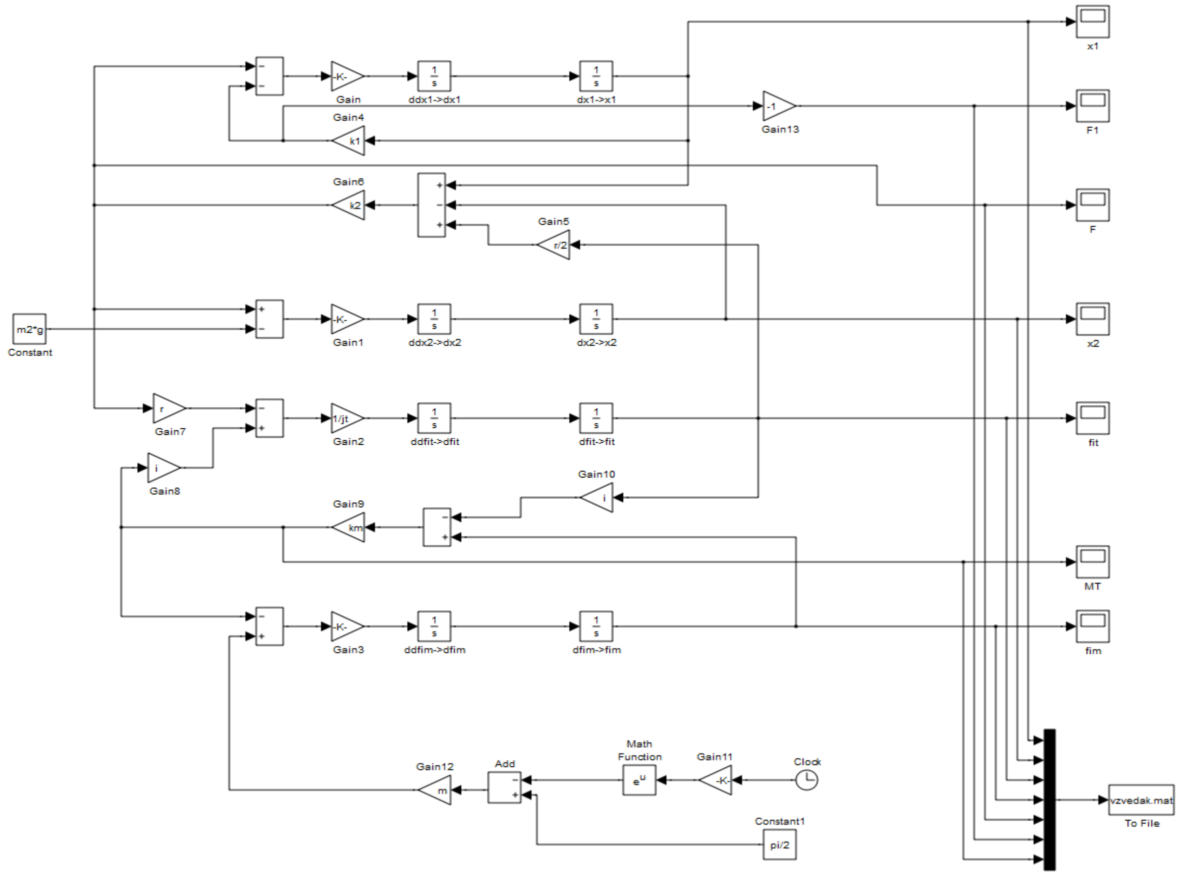

Figure 2: Simulink scheme of equations system solution (1)

Input parameters are:

$$m_1 = 18500kg, \quad m_2 = 1600kg, \quad J_T = 6km^2, \quad J_m = 0{,}8km^2, \quad r = 0{,}25m,$$
$$i = 75, \quad k_1 = 1{,}6\,10^7\,Nm^{-1}, \quad k_1 = 10^7\,Nm^{-1}, \quad k_M = 30Nmrad^{-1}, \quad M = 366Nm,$$
$$t_k = 0{,}2s, \quad c = 12m/\min.$$

Initial solution conditions:

$$x_1 = x_2 = \varphi_T = \varphi_M = 0, \quad \dot{x}_1 = \dot{x}_2 = 0, \quad \dot{\varphi}_T = \dot{\varphi}_M = \frac{c}{r} = 0{,}8s^{-1}.$$

In Fig. 3, deviation x_2 of load 3 is depicted. Fig. 4 demonstrates deviation x_1 of console 7. Deviations φ_T, φ_M of the winding drum 1 and motor shaft 6 are manifested in Fig. 5 and Fig. 6. Also, courses of force F acting in rope 2 (Fig. 7), force F_1 straining console 7 (Fig.8), and torque M_T acting on the shaft of electromotor 6 (Fig. 9) were determined from equations (2, 3, 4),

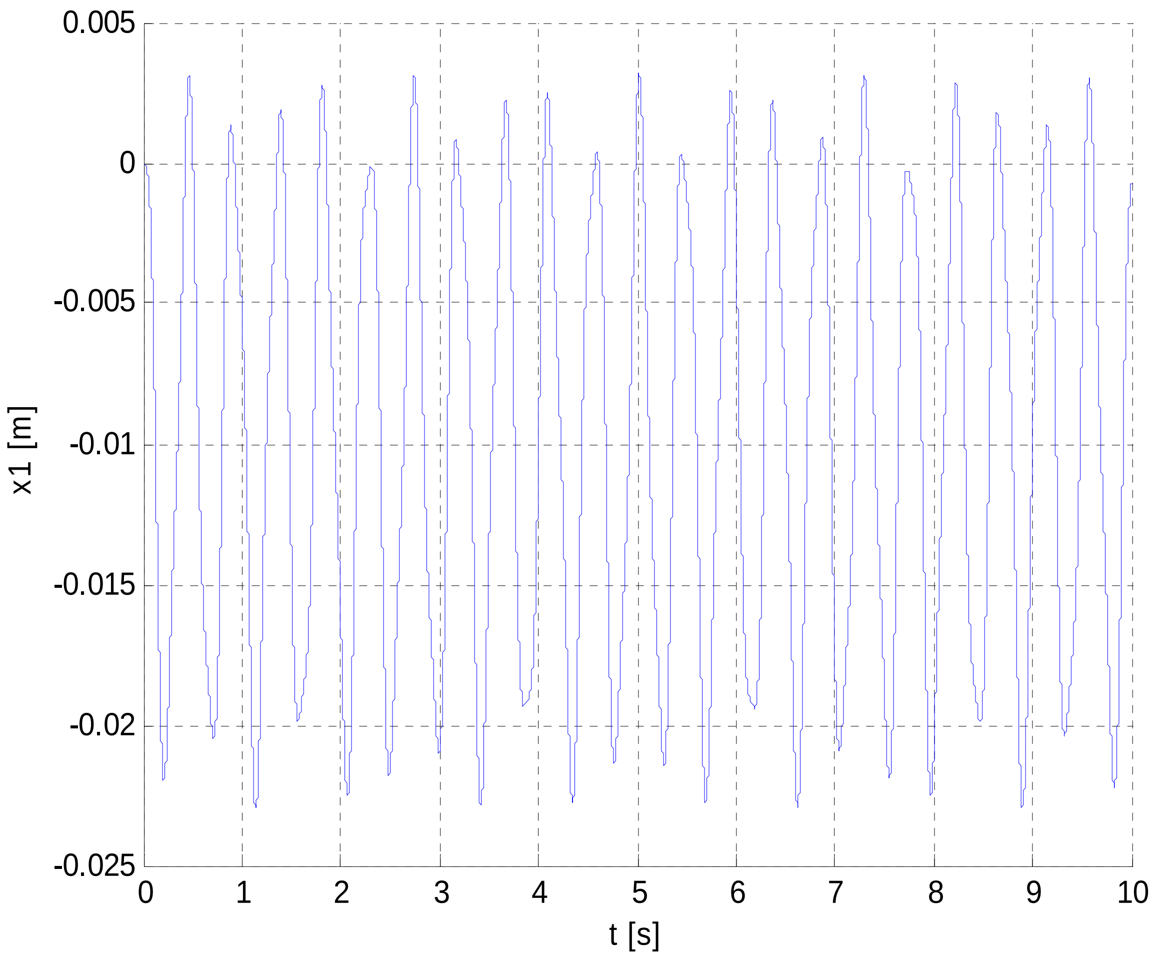

Figure 3: Course of deviation x_2 of load 3

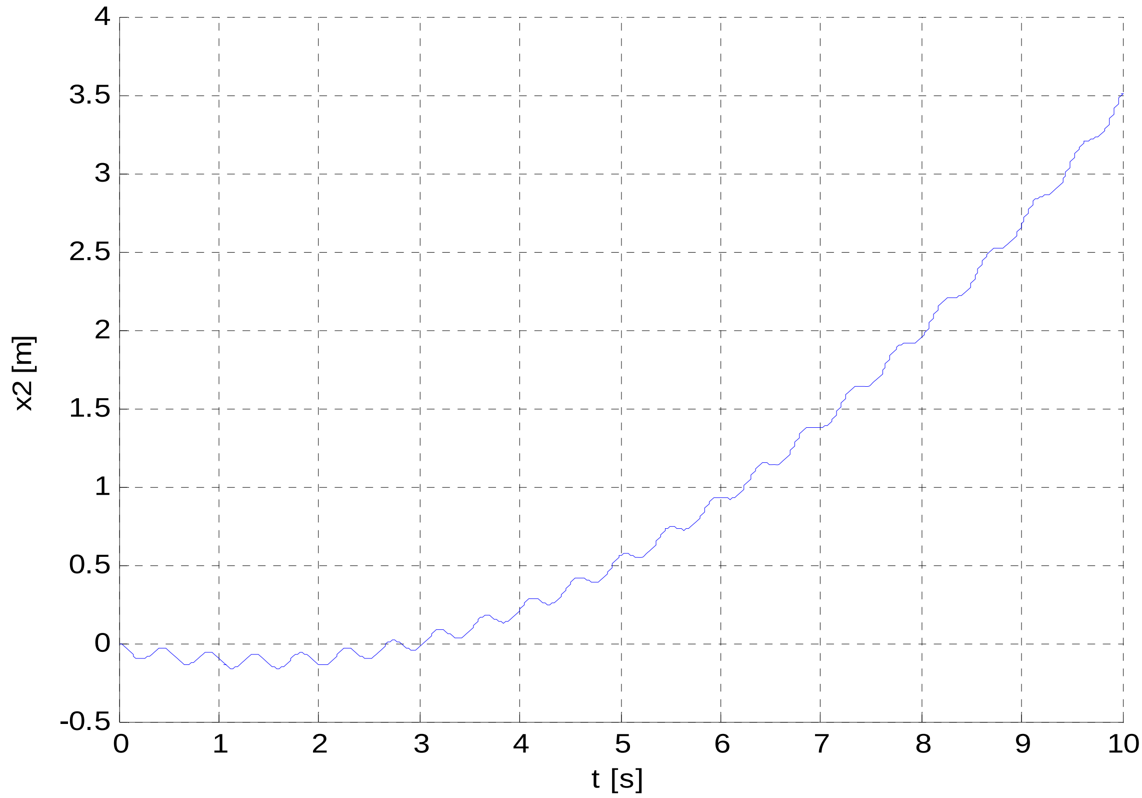

Figure 4: Course of deviation x_1 of console 7

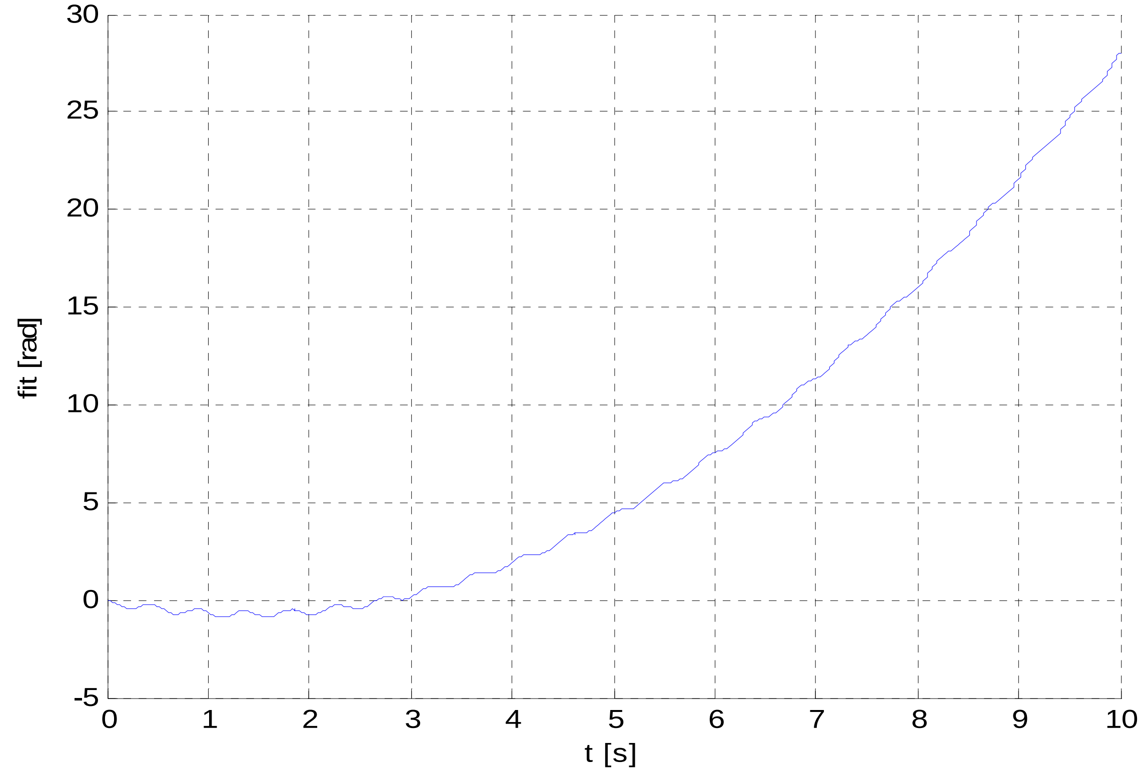

Figure 5: Course of deviation φ_T of winding drum 1

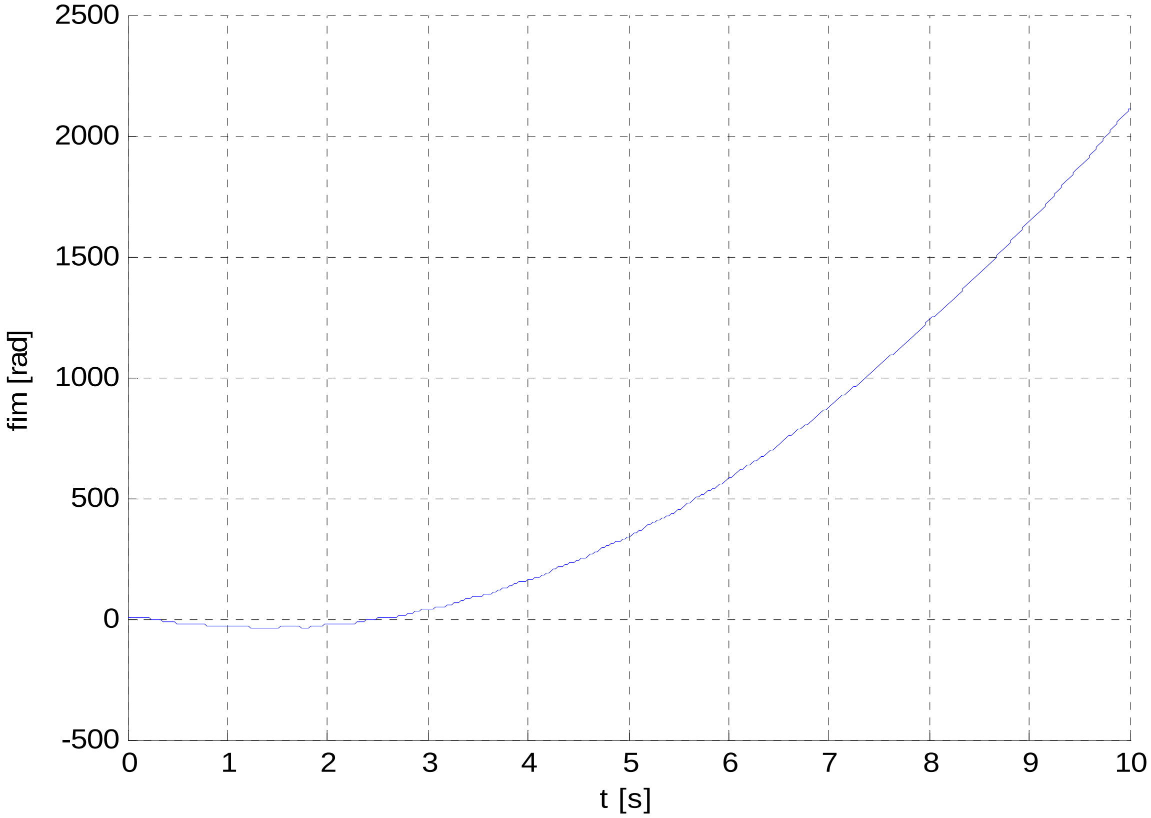

Figure 6: Course of deviation φ_M of motor shaft 6

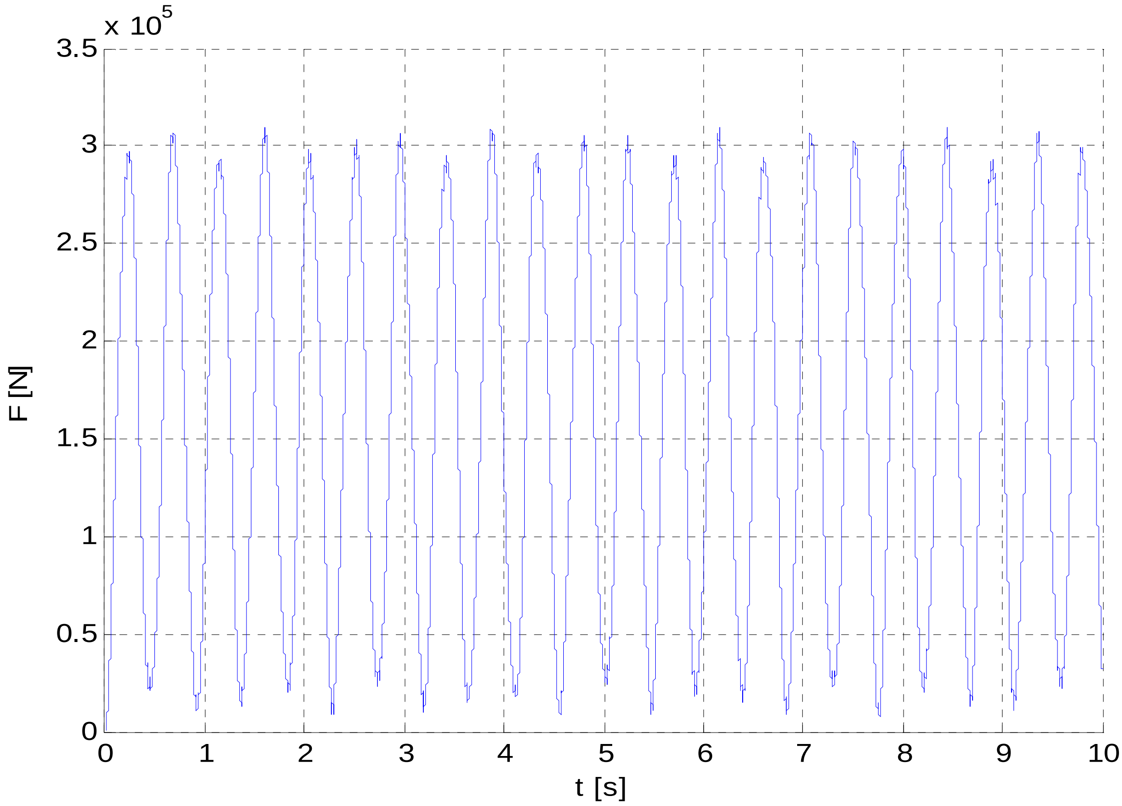

Figure 7: Course of force F acting in rope 2

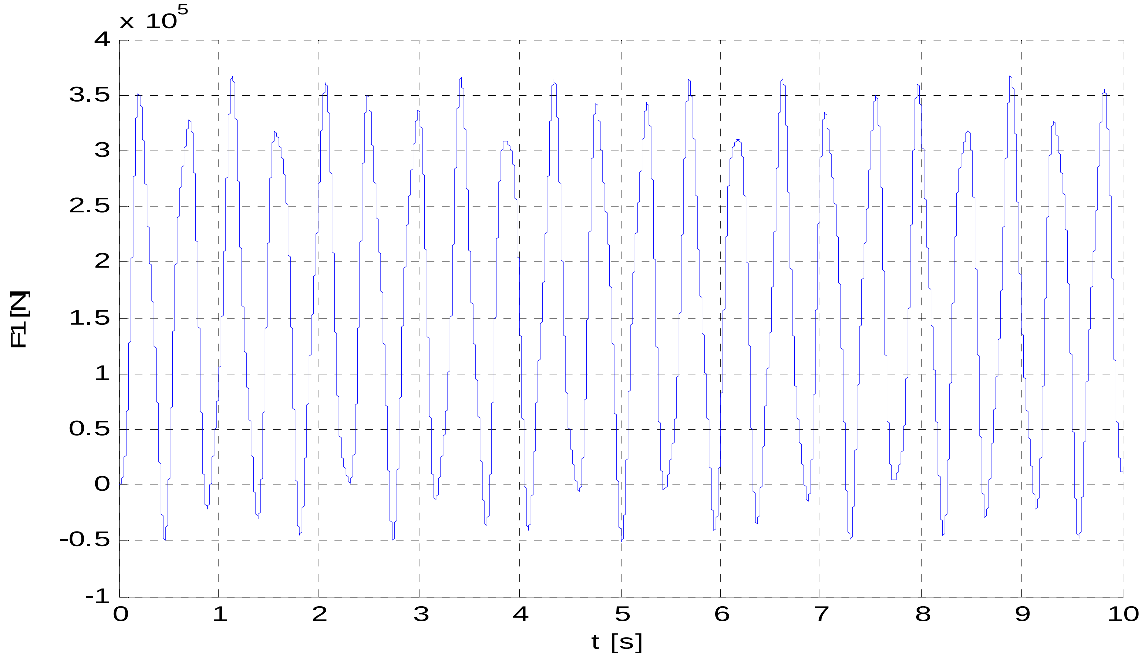

Figure 8: Course of force F_I straining console 7

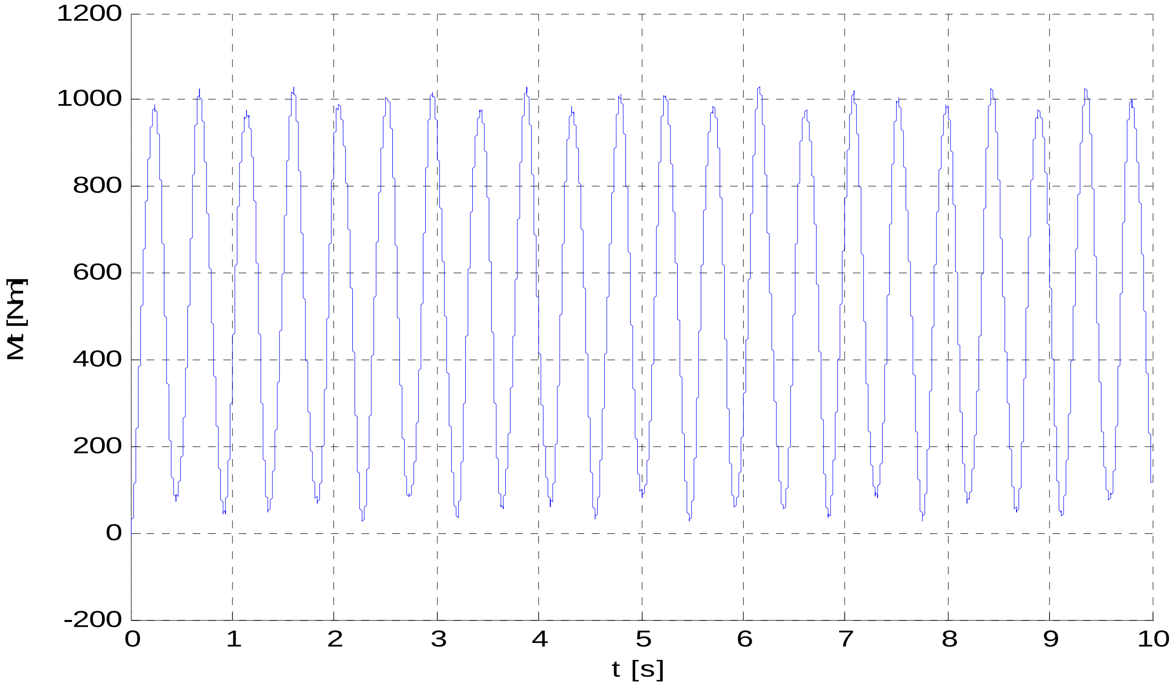

Figure 9: Course of torque M_T acting on the shaft of electromotor 6

It is necessary to base the design of the rope lifting the load on the determined maximum force in the rope F=3 10^5 N (Fig. 7). Also, maximum force acting on F_I=3,5 10^5 N (Fig. 8) facilitates the calculation of bearing components of console 7. The design of shaft and clutch between the motor and gearbox is then based on the determined maximum torque M_T´1000 Nm (Fig. 9).

References

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[2] E. Thöndel, *Design and Optimal Control of Linear Electromechanical Actuator for Motion Platforms with Six Degrees of freedom* Intelligent Automation and Systems Engineering, Springer New York, 2011

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