THE AUTOMATIC LOAD TRANSPORTATION BY WIND DISTURBANCE.

Jerzy Tomczyk, Jacek Cink

Institute of Engineering Design, Technical University of Lodz,
Stefanowskiego Str. 1/15, 90-924 Lodz, Poland
Email: ikmsekr@mrinh1.p.lodz.pl

Abstract: The idea of the automatic handling of the flexible suspended load by cranes working in different air condition has been presented in the paper. The microprocessor control systems worked out for cranes give the possibility to automatic position the handling load in the every point of the three dimensional transport space with simultaneous elimination of the load oscillations after the starting and braking periods. It has been achieved without the necessity of usage other mechanical damping devices and without the feed back from load oscillations which is the essence of the worked out handling technology. The system has been supplied with compensation of the wind action giving possibility to handling of the loads in different air condition. The problems connected with the wind disturbance acting on the drive and control system and results of the simulation dynamic tests have been described in the paper.

Keywords: cranes, handling materials, automation, control, microprocessor, wind disturbance.

1. INTRODUCTION

Cranes are machines, which are used, for handling materials in the sea harbors, in overloading terminals and within factories. The characteristic work of these machines is the vertical lifting of the load before the horizontal transportation by means of slew and tilting jib movements (jib cranes) or by means of perpendicular horizontal movements of the bridge and block carriage (overhead cranes).

Presently, the microprocessors and frequency converters give an opportunity to develop the construction of cranes control systems. The possibility of the numerical continuous control by means of speed movement of the crane mechanisms, which are driven by squirrel cage electric motors, supplied from frequency converters, allows to solve the present problems of the cranes.

Oscillations of the load, flexible suspended on the rope and limiting in many cases the slew and travelling movements speed, the bevelling on the truck of the overhead crane bridge with big span, causing the friction of the wheel flanges and disturbance produced by wind belong to the main problems. They can be solved by automatic or semiautomatic control of the crane and transport process, supporting the work of the operator.

New technologies of the handling materials by crane have emerged recently. The technology worked out at the Technical University in Lodz in Poland solves the basic technical overhead problems gives possibility to increase velocity of the overhead crane work movements with simultaneous limitation of the dynamic overloads at the acceleration and deceleration of the crane. The first overhead crane, controlled by microprocessor, built in the University laboratory in Poland, is shown in fig. 1.

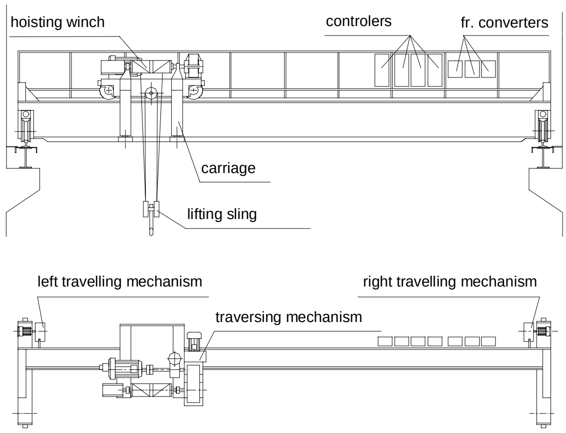

Figure 1. The laboratory overhead crane control by means of microprocessor.

The hoisting winch contains the constant power regulation system and the position regulation system. The first one better allows to use the power of the electric motor and to move the smaller loads with the higher speed. The position control system lets deliver the load to the chosen transport level.

The travelling and the traversing mechanism control systems demand the control function that must be worked out by computer and sent to the controller, which is the main element of the control system. The control function is delivering in the real time when the mechanism works in the automatic mode. The control system contains the continuously working speed and displacement regulators. They allow to deliver the load to the chosen position and the shape of the control function gives the possibility to damp the load oscillations after the acceleration and braking phase. Additionally, the control system of the travelling mechanism lets limit the bevel angle of the bridge during the duty motion. The computer chooses the proper horizontal way, which can be realised by simultaneous work of the travelling and traversing mechanisms according to the transport level and obstacles connected with it.

2. THE GENERAL CRANE AUTOMATIC CONTROL SYSTEM

The block scheme of the control system of the overhead crane (as the example) is shown in the fig. 2.

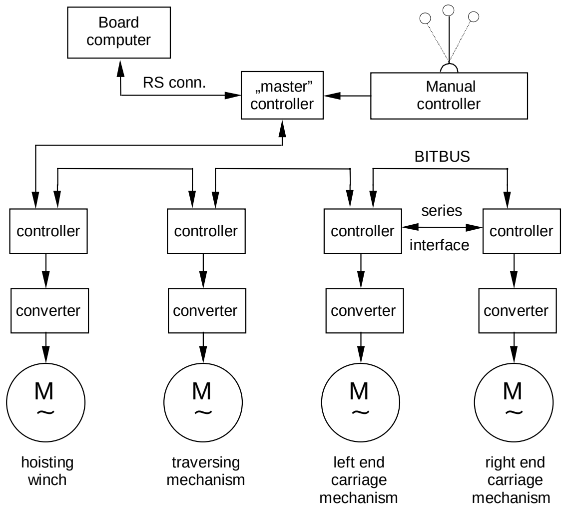

Figure 2. The general block scheme of the control system.

All the mechanisms are driven by the asynchronous electric motors powered from the frequency converters. The microprocessor control system was used in the hoisting winch, in the traversing mechanism and in individual travelling mechanisms connected with the end carriages. The work of each mechanism is organised by the microprocessor controller, which realises all demanded functions of the control and regulation system. The main controller, called „master", manages the work of all the controllers lets communicate each other by „BITBUS" network and co-operates with the board computer in the automatic work mode. All the mechanisms can be controlled by the determined programs.

The scheme of the traversing and travelling mechanism control system of the overhead crane, substantial for this paper, is shown in the fig. 3.

The speed of the carriage and the speed of each end carriage of the bridge must be still controlled to damp the load oscillations after the acceleration and braking phase.

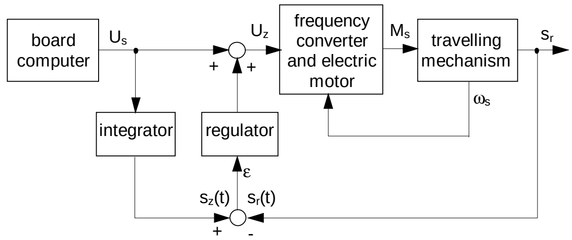

Figure 3. The block scheme of the traversing and travelling mechanism.

The time run of the input control function U_s (proportional to the given speed of the mechanism) is worked out by the board computer, sent and stored to the microprocessor controller and delivered in the real time when the mechanism works in the automatic mode. The control system contains the continuously working electric motor angular velocity regulator and displacement regulator. The displacement regulation system compares the real displacement of the carriage and end carriages s_r with their given displacement s_z got by the integration of the input control signal U_s. The difference ε between the displacements s_z and s_r amplified by the proportional regulator corrects the input signal before its sending to the frequency converter.

The worked out input control signal $U_s(t)$ sent to the control system gives the following possibilities:

- the damping of the load oscillations after the acceleration and braking phase achieved by the proper shape of the control function,
- the stopping of the load at the chosen position achieved by the calculated proper area under the time plot of the control function over the duty motion,
- the elimination of the bevel angle of the bridge by sending the same control function to the each end carriage travelling mechanism.

Fig. 4 depicts the duty cycle, composed of acceleration, steady motion and deceleration. The displacements of the load against the overhead crane are presented by means of the ball suspended on the overhead bridge.

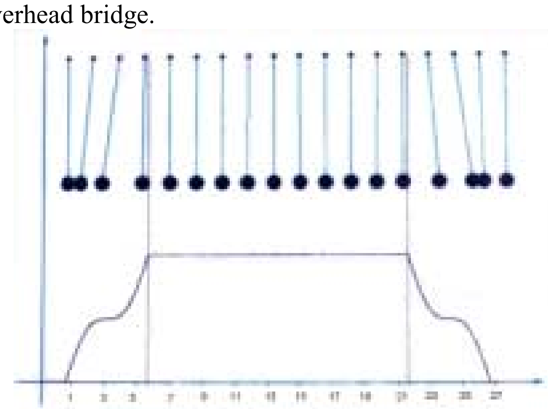

Fig. 4. The dumping of the load oscillation at the horizontal load transport.

The overhead board computer supplied with the data concerning the mass and suspending height of the load, works out an appropriate shape of the variable travelling overhead crane function for acceleration and braking phases. It limits to minimum (practically eliminates) the load oscillation. The load is moves with the overhead bridge after the acceleration, during the steady motion and there are no oscillations after stopping the crane. The lowering of the load is possible immediately after stopping the crane in a chosen position of the load delivering (automatic positioning).

The system can be used for crane working in the close area and should be supplied whit additional system for compensation of the wind disturbance acting on the load for cranes operating in the open area.

3. THE SYSTEM OF THE WIND DISTURBANCE COMPENSATION

The idea of compensation of the wind disturbance is shown in fig. 5. When the speed and direction of the wind is known the point of rope hanging is moved opposite the wind so far that the horizontal component of the force in ropes compensates the wind acting and the load stays in the same place it would stay without wind.

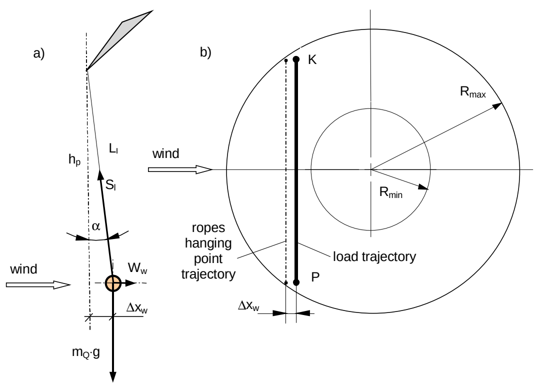

Figure 5. Compensation of wind disturbance.

The conception of control system which compensates the wind acting was worked out for simultaneous work of travelling and traversing mechanisms of overhead crane and for slew and jib mechanisms of haven jib crane. The mechanisms co-operate with frequency converters so the speed can be controlled continuously. They are included in control and regulation systems shown in fig. 3.

There was taken the assumption that in every moment the speed and direction of the wind is determined and the surface of the load wind acting is the same for all the wind directions. The wind compensation system is similar to the one shown in fig. 3. The difference is that the given displacement s_z of the mechanism is corrected about Δx_w (fig. 5) calculated according to wind speed and direction, load surface and ropes length. The correction of the displacement for every mechanism is worked out automatically by the system in real time. It causes such the motion of the ropes hanging point by the wind acting that the load moves along the determined way.

The block scheme of the wind compensation system for the travelling and traversing mechanisms of overhead crane is shown in fig. 6.

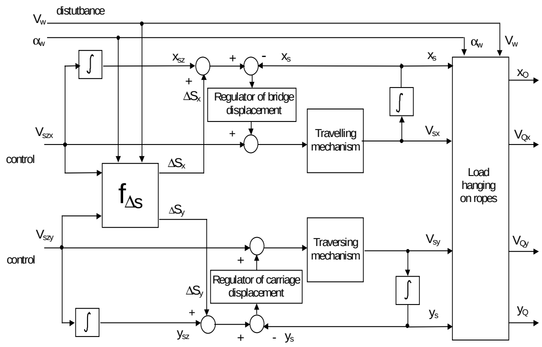

Figure 6. The block scheme of the wind compensation system.

Signals of given speed of travelling v_{szx} and traversing v_{szy} mechanisms are introduced to the block $f_{\Delta s}$ which takes also the signal of speed and wind direction. The block calculates in real time displacement correction Δs_x i Δs_y for both mechanisms. They correct the input signals for position regulators. The regulator output signals correct given speed signals in such the way that the real speed of travelling and traversing mechanism v_{sx} and v_{sy} tend to the given speed and displacement of the ropes hanging point which automatically guarantee the motion of the load along the determined trajectory.

The way of determination of wind correction is shown in fig. 7.

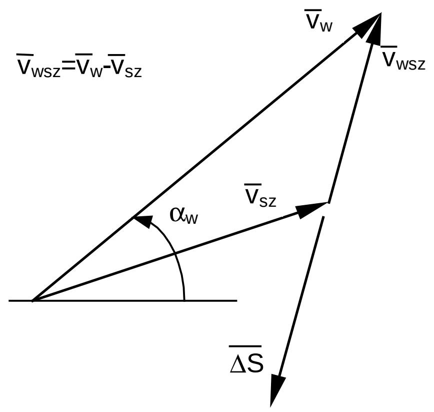

Figure 7. The way of determination of wind correction.

If the value and direction of correction $\overline{\Delta s}$ is known the corrected position and speed of ropes hanging point can be determined. The problem for the haven jib crane is explained in fig. 8.

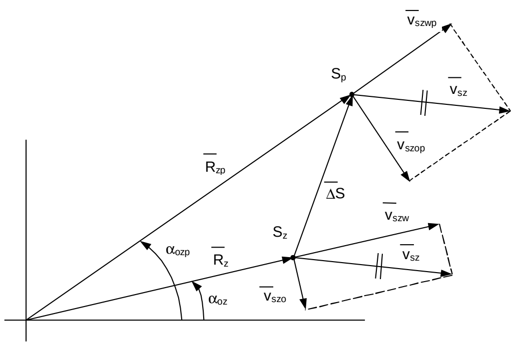

Figure 8. The corrected position and speed of top roller of jib crane.

The position of top roller is corrected by $\Delta \bar{S}$ from point S_z to point S_p. The value and direction of resultant total speed of top roller does not change. However, the speed of slew and jib mechanism must be corrected according to the corrected position of top roller.

4. THE CONTROL FUNCTION OVER THE DUTY MOTION

The control should provide the horizontal motion of the load along the straight line from start point P to endpoint K. Control function is determined in the same way as for the system without wind. The correction signal is calculated and input automatically.

The total speed of ropes hanging point is geometrical sum of their components: travelling and traversing mechanism for overhead crane or speed of the top roller in slew and jib direction for haven jib crane. The vector of total speed should be pointed to K so one component must be limited. Fig. 9 explains the situation when the speed of travelling mechanism of overhead crane is maximum and the speed of traversing is limited.

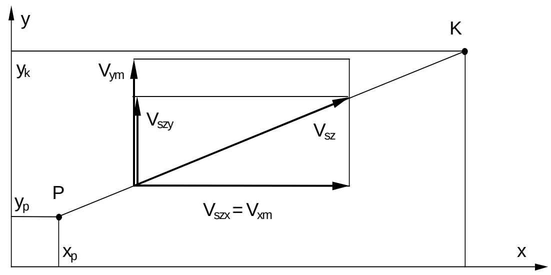

Figure 9. Components of total speed of ropes hanging point for overhead crane.

The plot of total horizontal speed of ropes hanging point over duty motion is shown in fig. 10.

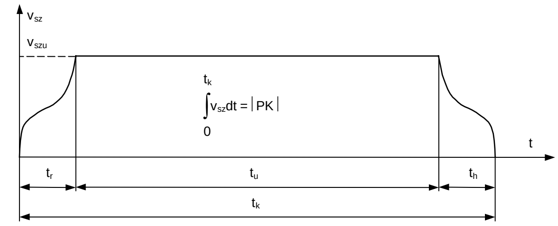

Figure 10. Total speed of ropes hanging point over duty motion.

The run includes three phases:

- acceleration phase in time t_r,
- steady motion phase in time t_u,
- braking phase in time t_h.

The start and braking are leading by using optimum control which guarantees dumping the load oscillations after these phases. The time of steady motion t_u has such the value that the displacement of ropes hanging point is equal to the length of interval $|PK|$. The maximum speed during the steady motion must be attainable in every point of line PK. According to current position the speed of mechanisms which work simultaneously is determined.

5. SIMULATION TESTS

The simulation tests were done to research the quality the system by different wind disturbance. The results of simulation tests of duty motion by simultaneous work of travelling and traversing mechanism of overhead crane are shown in figures 11 and 12. Every figure includes two parts: time plots and phase diagrams.

The first one shows plots of following variables:

v_{szx} - given speed of the travelling mechanism,
v_{sx} - real speed of the travelling mechanism,
x_{sz}-x_Q - load displacement in travelling direction relatively to given displacement of bridge,
x_s-x_Q - load displacement in travelling direction relatively to real displacement of bridge
x_{sz}-x_s - difference between given and real displacement of bridge
v_w - speed of the wind.

In the phase diagrams in x, y coordinates – relatively in travelling and traversing directions – the following trajectories are shown:

- given displacement of ropes hanging point (line „z”),
- real displacement of ropes hanging point (line „s”)’
- displacement of load (line „q”).

The initial conditions were determined in such the way to the load was positioned in point P and the system was in state of balance.

For the situation shown in fig. 11 the wind is perpendicular to line PK and its speed varies according to trigonometric function from $v_{wmin} = 5$ m/s to $v_{wmax} = 22$ m/s with frequency 0.1 Hz.

In researches shown in fig. 12 the constant speed of wind was assumed by the direction varying regularly with angular velocity 5 rpm.

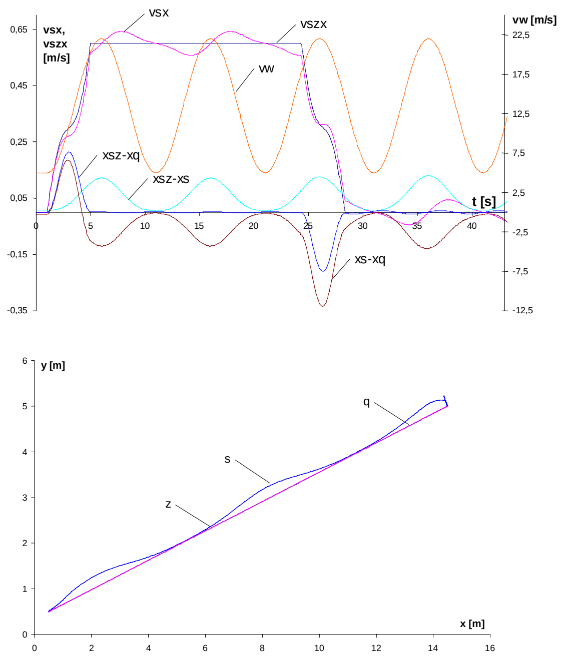

Figure 11. Tests of wind compensation system. Varying wind speed.

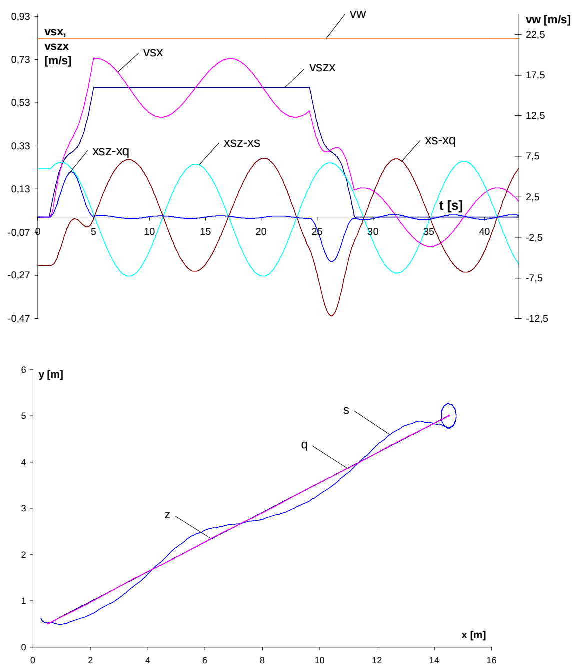

Figure 12. Tests of wind compensation system. Varying wind direction.

6. CONCLUSIONS

The simulation tests of wind compensation system confirmed its correct working. The main advantage of the system is that the control function is determined by assumption the wind is not acting and displacement correction is worked out automatically in real time.

The system provides such trajectory of ropes hanging point that the load moves along determined straight line by wind disturbance.

The system guarantees damping load oscillations by optimum control and load positioning with high accuracy in chosen point of working area.

For right functioning of the system the speed and direction of the wind must be known in every moment of duty motion. These variables should be measured to calculate them and send proper signals in real time to the control system.

Presently the experimental stand is being built to confirm advantages of the system in the experimental way.

REFERENCES

[1] Cink J., Tomczyk J.: „Kompensacja zakłóceń działaniem wiatru w ruchu roboczym żurawia portowego". V Konferencja Okrętownictwo i Oceanotechnika – Maszyny i Systemy Transportowe,. Szczecin – Międzyzdroje, czerwiec 2000, (s. 31-42).

[2] Cink J., Tomczyk J.: „Zakłócenia spowodowane działaniem wiatru w automatycznym sterowaniu maszyn roboczych". Problemy Maszyn Roboczych, Zeszyt 13, 1999, (s. 93-101).

[3] Tomczyk J. i inni: „Eliminacja wahań ładunku i pozycjonowanie dźwignic o ruchach obrotowych i wypadowych sterowanych za pomocą mikroprocesorów". Prace dla Komitetu Badań Naukowych. Łódź, 1999.

[4] Tomczyk J.: „Modele dynamiczne elementów i układów napędów hydrostatycznych". WNT, Warszawa 1999.