I. ADAPTATION CONTROL TECHNIQUE OF OVERHEAD CRANE MECHANISMS

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***Abstract* - The paper is focusing on investigated adaptation control technique based on fuzzy approach used in overhead travelling cranes. It has been presented model of crane control movement mechanisms and results of exploitation investigations' of overhead crane.**

***Index terms* - adaptation control, fuzzy logic, cranes**

II. INTRODUCTION

Increasing demands for the overhead cranes in the field of precision and time performances, demands for operational safety and reliability are orientated at minimizing undesirable effects of exploitation device, swing of the load suspended on the rope of variable length and twisting of the bridge. The great undesirable effects of exploitation an overhead travelling crane are caused by motion mechanisms of the trolley, bridge and hoisting or lowering in non-stationary states (starting and braking).

In the most common case a machine operator is responsible for control and decides about the shape of starting and braking characteristics of torque by choosing times of switching additional resistors that are joined to the rotor winding (Szpytko, *et al.*, 2000b). In a sense, an operator of overhead crane is an independent *fuzzy* control system. His experience, knowledge as well as his current predisposition, influence the proper exploitation of the device.

The problem of minimizing swing of the suspended load and its precisely positioning by means of *fuzzy* and *neuro-network* control systems has been mentioned in publications (Mendez, *et al.*, 1999; Moreno, *et al.*, 1998; Benhidjeb and Gissinger, 1995; Manhfouf, *et al.,* 2000). The investigations are usually carried out on two-mass model (trolley and pendulum) with two or three degree of freedom and with DC-motor. In this publication the *fuzzy* controllers are based on the Mamdani's inference system.

The use of *fuzzy* logic control system in motion mechanisms of the overhead crane seems to be accurate. The construction of the *fuzzy* controller (*Base of Rule*) allows to formulate control strategy in easy way, without precise knowledge about mathematical describe of an object. The control strategy is described by *fuzzy* rules, type of IF-THAN (Driankov, *et al.*, 1996; Yager and Filev, 1995; Zadech, 1965). Using the nature language while building controllers allow taking advantage of heuristic and knowledge of the engineer-operator's process. Performance of the *fuzzy* system in form of the neural-network system allows making optimisation controller's parameters by means of gradient's methods.

The aim of this study is to present the results of researches carried out on the control system of motion mechanisms of the real overhead crane taking advantage of *fuzzy logic*. Three-mass, electromechanical model of the device with asynchronous motors and inverters was worked out for the investigation. The control system of the motion mechanisms is based on *fuzzy* controllers type of Sugeno-Takagi-Kanga (STK) (Szpytko and Smoczek, 2000a).

The choice of this type of controller allows avoiding the complicated phase *defuzzyfication* and simplifies the control system for choosing the controller for a given working point (phase space of controller). It gives the possibility of building so-called ANFIS's model (*Adaptive Neuro-Fuzzy Inference System*) to optimise parameters of the controller.

The crane mechanisms control system based on fuzzy approach have been satisfactory tested both of the real and virtual crane device. The obtained results have been presented and discussed.

III. MODEL OF CRANE CONTROL MOVEMENT MECHANISMS

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The design strategy for loads` shifting process in workspace by use of overhead cranes/ robot, can be described by means of an algorithm that comprises:

1. specifying the task for realisation: *what*, *where from*, *where to* plus the additional requirements concerning shifting,
2. describing the workspace map of 3D type based on the plant, where the load will be transported,
3. planning the load's movement trajectory and its optimisation,
4. planning the individual mechanisms` movements.

Realisation of points 1 to 3 of the above algorithm by use of the available digital techniques is relatively easy, whereas point 4 requires building an expert decisive system that respects the random character of device - operating subject interactions owing to: load's mass, load's position in vertical direction (height, OZ axis), and surrounding. The assumed indicators that enable task's realisation is: time, load positioning accuracy, device's exploitation costs. Device's exploitation costs comprise operating and maintenance. For decision-making system, concerning working movements' control, of a specific crane's task realisation, the algorithm that makes use of fuzzy logic theory has been applied. The block diagrams of movement mechanism control have been presented in Figure 1.

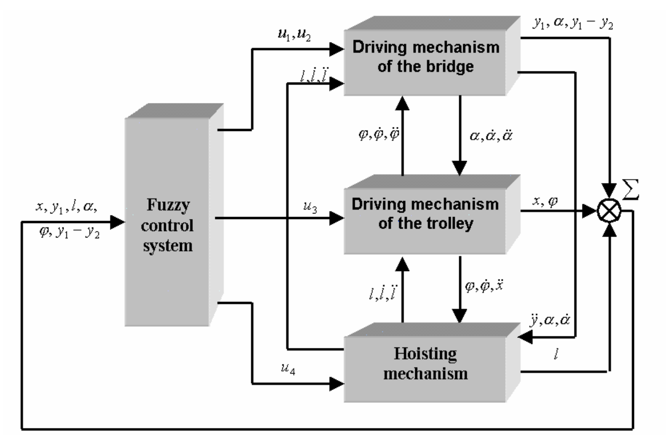

Figure 1. The block diagram of movement mechanisms control

The control system of the overhead crane consists of six controllers of Sugeno-Takagi-Kanga (STK) type (Yager et al. 1995) signed, from FLC1 to FLC 6 (crane bridge's movement FLC1- 2, trolley movement FLC3-4, hoisting mechanism FLC5-6). The membership functions of triangle types were used in the process of *fuzzyfication*. For input signals, the linguistic terms: N (negative), Z (zero) and P (positive) were assigned.

The example rule base of controller FLC3/ FLC4, which is controlling speed of crane trolley, is composed of 27 rules fuzzy and IF – THEN type. The fuzzy rule base is possible to present in tables, which are presenting the dependence between input signals of the controller. The phase's space of the controller is composed from many subspaces, which are characterised with fuzzy set.

When φ is Negative

	N	Z	P
N		f_{22}	f_{21}
Z	f_{23}	f_{24}	f_{23}
P	f_{21}	f_{22}	f_{21}

When φ is Zero

	N	Z	P
N		f_{26}	f_{25}
Z	f_{27}	f_{28}	f_{27}
P	f_{25}	f_{26}	f_{25}

When φ is Positive

	N	Z	P
N		f_{22}	f_{21}
Z	f_{23}	f_{24}	f_{23}
P	f_{21}	f_{22}	f_{21}

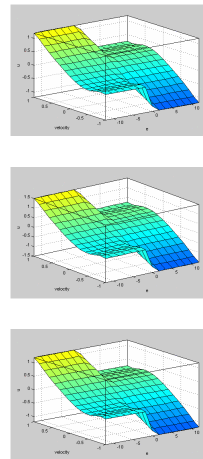

Figure 2. The fuzzy rules and phase space of controller STK types: FLC3/4 - driving mechanism of crane trolley

IV. EXPLOITATION INVESTIGATION OF OVERHEAD CRANE

The developed model of cranes' mechanisms controls with use of STK type controller then was the object of exploitation investigation on overhead travelling crane: both real objects and their virtual prototypes (Figure 3). The technical data of investigated overhead crane is setting-up in Table 1. In investigations the designed multipoint monitoring system of selected exploitation parameters of crane has been implemented. Monitoring system is supported by measurement card PCL 818HG type by Advantech used to visualisation and storage of measurement data.

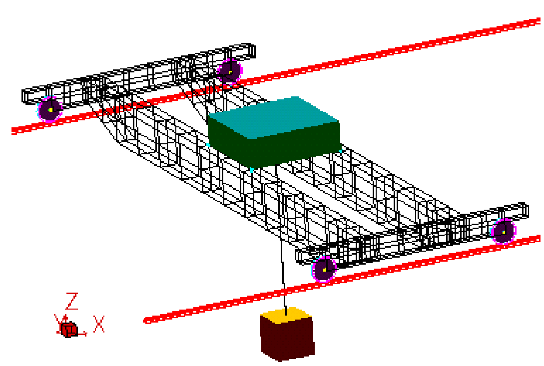

Figure 3. Virtual prototype of overhead travelling crane

Table 1. Technical data of investigated overhead crane

Parameter	**Value**	**Unit**
Lifting capacity Q	125	kN
Bridge wheel spacing L	16	m
End sill wheel spacing B	5	m
Velocity of bridge driving mechanism v_{jm}	80	m/min

Tests have been done for different control variant of device movement mechanisms: with use of resistors for asynchronous ring-shaped engine (classical control approach), with use of joystick, with use of sets with inverter and controller STK type.

Results of the control by means of switching resistors allow comparing it with results obtained from simulations with *fuzzy* control system. The improper selection control strategy causes considerable changing of torque (Figure 4) and undesirable sways a load (Figure 5). The conventional control with resistors is unfavourable for smooth changing the velocity of the mechanisms

At the same crane the investigations with use of inverters in crane movement mechanisms have been done. The selected exploitation parameters of crane were monitored under operation at the same road (distance) and were compared for different type of controls: with use of joystick and fuzzy controller. Tests have been done for different load capacity Q and rope length H (the trolley was at the middle of crane bridge). The example investigation results at load capacity Q = 5 [t] and rope length H = 5 [m] are presented at figures: position of the bridge (Figure 6), swing angle of the load suspend on rope (Figure 7).

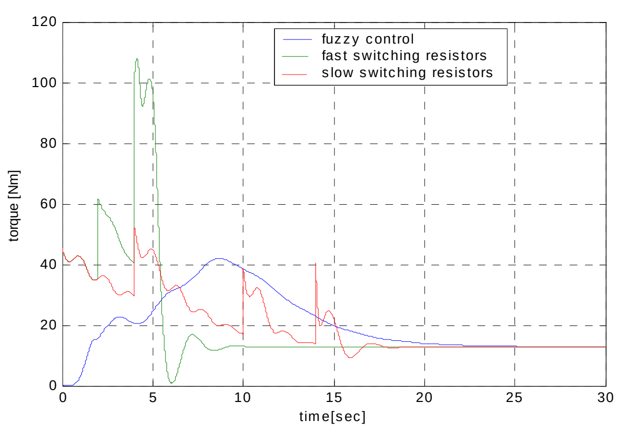

Figure 4. Torque of the trolley during control by means of resistors and fuzzy system

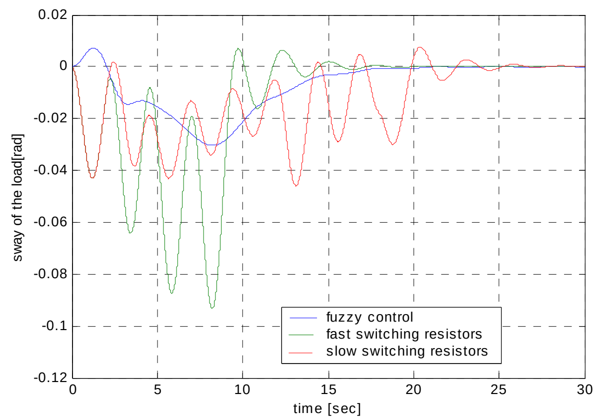

Figure 5. Sway of the load φ during control by means of resistors and fuzzy system

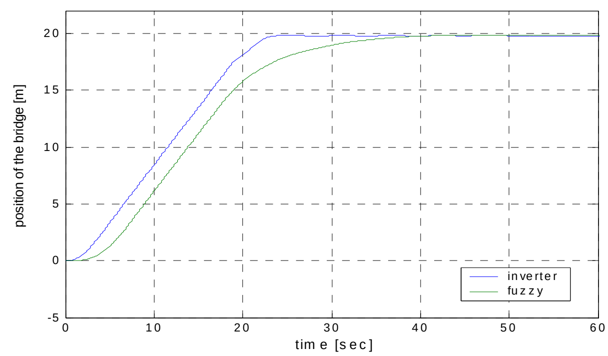

Figure 6. Position of the bridge

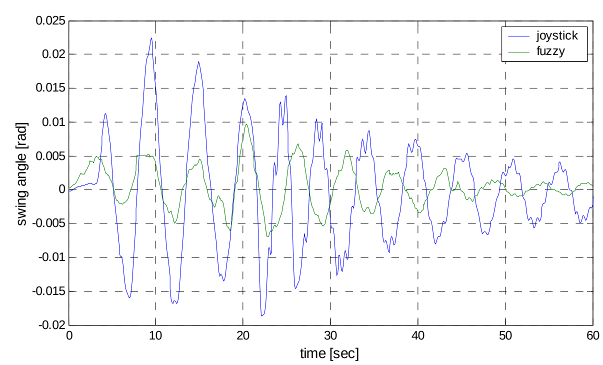

Figure 7. Swing angle of the load

The obtained exploitation investigation has been confirmed the influence of crane loading condition and used controlling techniques at selected device exploitation parameters (significant from attention of quality exploitation needs). With use of fuzzy controller the minimization of unfavourable effects accompany crane operation is more effective.

V. FINAL REMARKS

Leaded investigations conducted on cranes allow to state that using fuzzy logic in the overhead crane's control system can be profitable for its exploitation. It is confirmed by results achieved in the field of minimising load's swinging, bridge's twisting, load positioning with the assumed movement trajectory. Suggested control system enables characteristics shaping of the driving torque, minimising overload in transient states and achieving smooth characteristics of the motor's angular velocities.

As the result of conducted measurements, it have been certified that the fuzzy based controller is able to improve the properties of overhead crane movements. The accepted target of the controlling is the minimization of load deflection and positioning in the operation space.

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