INTEGRATED SYSTEM FOR MECHANIC BAND CONVEYORS WITH HYBRID MOTOR, TV CAMERA AND ROBOT

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Abstract: The aim of the paper is to present a system used for the unloading of the mechanic band with low speed and carrying heavy materials. The movement is assured by an hybrid electrical induction motor able to develop a sufficient force according to the speed of the band and the mass of the transported blocks. The blocks are uncharged and pushed into a stack by a robot, in fact a manipulator with 6 liberty degrees controlled by a computer. Two TV cameras are connected to the computer. Based on the image analysis the computers synthesises the commands for the robot.

Keywords: hybrid electrical induction motor, digital image processing, robot, automation

INTRODUCTION

The mechanic conveyor bands are widely used in constructions and in the industry of construction materials.

Constructions band conveyors can work in the environment, in a tuff climate activating against the electric and mechanic elements. The sand, the dust, the frost and the humidity have a negative influence on the equipment's working and affects especially the function of the reduction gears of revolution.

The main inconvenient of the low speed mechanic band conveyors, trained up with electric motors, usually asynchronous, is that the mechanic reduction gears of revolution, coupled with the activating engines, present a high incidence of the defects by reducing the period of working of the technological equipment because of the frequent interventions for reparations.

This paper describes some main aspects of an integrated system for unloading a conveyor band (see figure 3), presenting the control of this operation by a robot guided by computers processing the images captured by two cameras and scanning the outputs of an automate controlling the hybrid electrical induction motors that trains up the conveyor band.

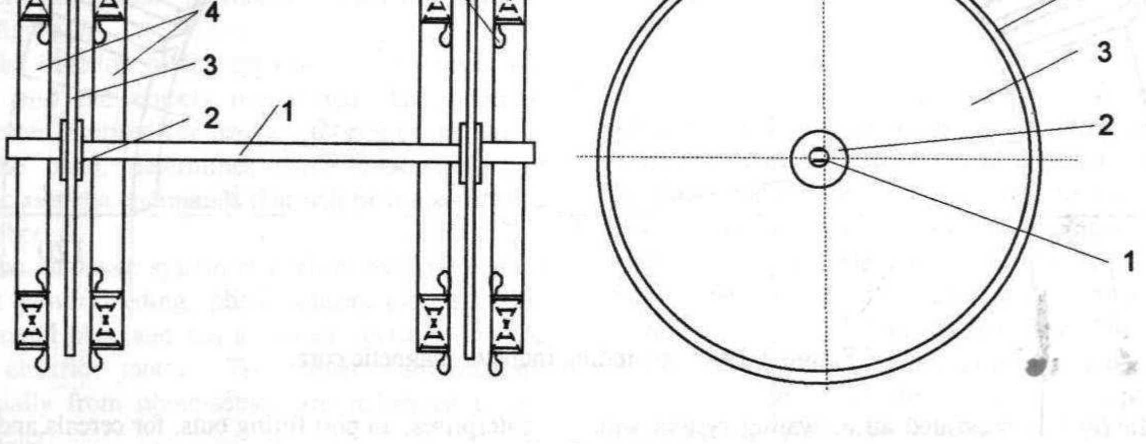

Figure1. Activating system at low speed with EIHM for mechanic band conveyors.

1. ELECTRIC ACTIVATING SYSTEM AT LOW SPEED WITH HYBRID MOTOR FOR MECHANIC BAND CONVEYORS

It is introduced a new modern activating system at low speed, equipped with an electric induction hybrid asynchronous motor (EIHM) [3] for the mechanic band conveyors used in constructions.

1.1. Particularities of an activating system with EIHM

The technical problem that is resolved by our installation consists of the expulsion of the reduction gear of revolution from the action system by directly training the band conveyor with low speed EIHM, this way resulting the reducing of the off-times for the repairing of the defects of the reduction gears, reducing the costs of the conveyor equipment, the weight of the equipment, diminishing extra expenses for maintaining, when the movement from the motor to the band is done directly, without using a reduction gear, the power on the installation goes higher, the transporting installation can be also built in a modulate way with doubled groups of EIHM, at every drum made in order to activate the band. The conveying band trained directly by the EIHM, in the new proposed variant moves away the up mentioned disadvantages because the activating system is realised with EIHM, which develop a low speed revolution motion [5]; this fact permits the exclusion of the cinematic chain of the mechanic reduction gear of revolution.

An EIHM is recommended to be built with $p \geq 4$ poles number. After the radius R dependent, pole pitch τ, the tangential synchronous velocity v_1 is computed using the primary suply tension frequency f_1:

$$v_{1(R)} = 2 f_1 \tau_{(R)} \qquad (1)$$

where $v_{1(R)}$ and $\tau_{(R)}$ are values dependent segment circle inductor radium.

In the base of the maximum radius of inductor R_{max} and the angular speed ω, the tangential synchronous velocity $v_{1(Rmax)}$ is calculated.

1.2. Compounds parts of an EIHM with bilateral toroidal inductors

The EIHM has its primary winding on the toroidal inductors placed bilateral from the disc - made of conductive material - together with the activating drummer of the conveying band, this disk is also the inducted with the secondary winding of the hybrid motor..

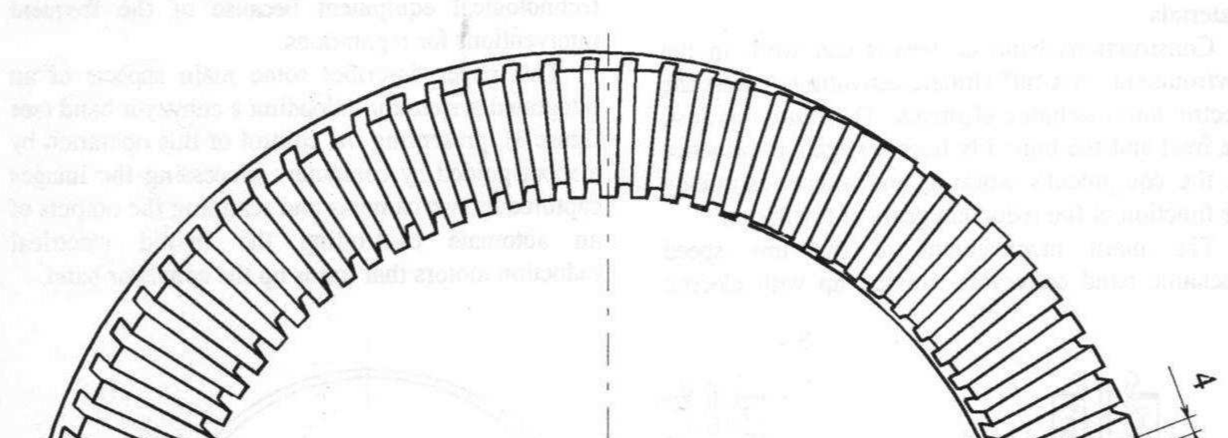

Figure 2. Built unwinding inductor magnetic core.

In fig.1 is presented an activating system with EIHM for conveying bands used in constructions, mining exploitations, in quarries, in the metallurgical enterprises, in port fitting outs, for cereals and food business, for rolling stairs or other systems of transport a 1 drummer on which the rolling band of the conveyer is held, by using the elastic couple 2, there are linked on the lateral sides two disks made of electric secondary winding of the hybrid motors. On both sides of every disk 3, there are two fixed toroidal inductors 4, on which is placed the distributed primary winding 5, or in the form of a ring.

In order to improve the performances of this electric machine, the disk of conductive material can be played of the middle, a sandwich-like structure, by using super magnetic material (silicosis sheet iron or other iron -magnetically material).

The toroidal inductor of the EIHM may have an opening segment as a semi-toroidal (semicircle), the construction of the primary magnetic core without winding being represented by fig.2, or as a complete semicircle opened at 360^0, case in which the engine becomes an asynchronous one with a rolling disc.

The core in fig 2 has been projected, built and tested by the author in lab by using a testing.

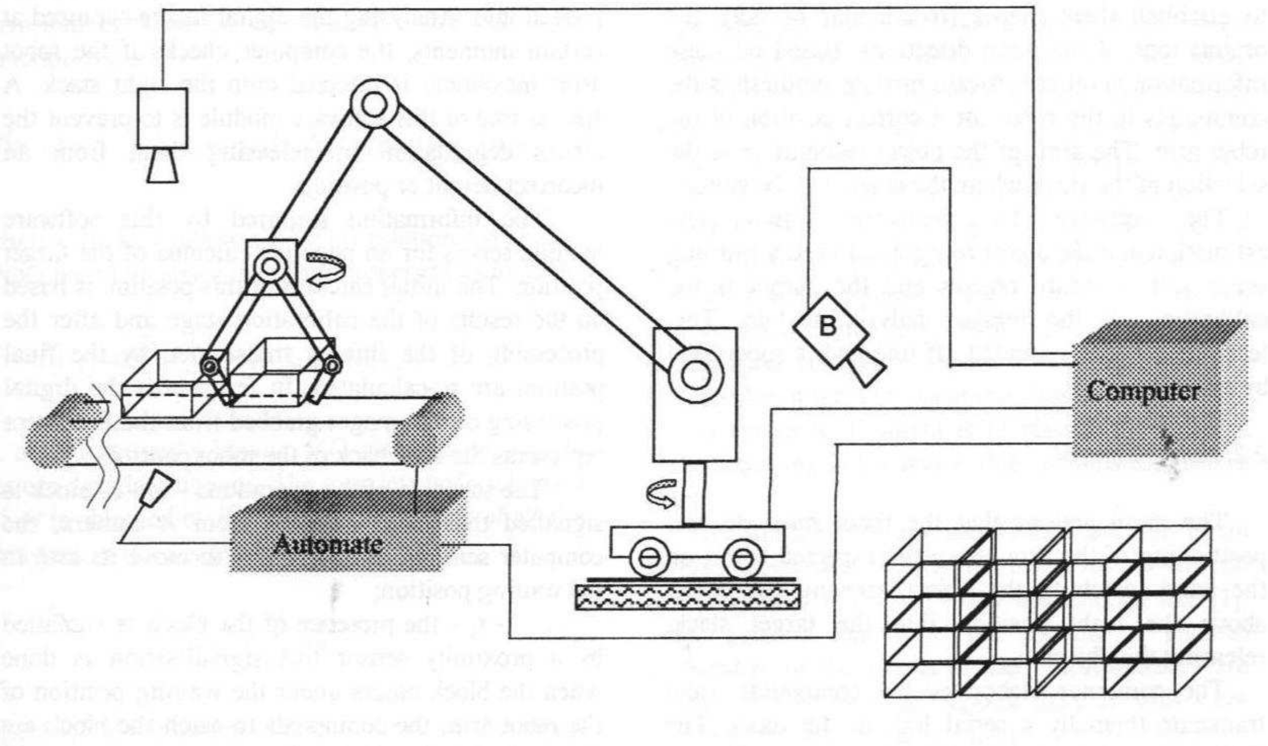

Figure 3. Integrated system for conveyor band unloading.

2. ROBOT CONTROL SYSTEM

The robot system is composed by one robot with 6 liberty degrees, two monochrome TV camera and an automate system, all linked to a computer system (see figure 3).

The function of the camera A is to survey the band and the objects transported. The program computer digitised the image and locates the blocks on the band, determines their orientations and synthesises the commands that will be transmitted to the robot.

The automate system centralises the information about power feeding, photo sensors placed in the horizontal plan and has a special device to control the electric motor. The binary information, especially from photo-sensor are redirected to the computer.

The B camera surveys the stack made by the robots. The monochrome image is grabbed and digitised by the computers. The results of the image analysis are used in the elaboration of the commands for the robot in order to build a right stack of blocks.

2.1. Acquisition and analysis of the band surface images

The surface of the band is surveyed by the monochrome TV camera named A in the figure 3. It is assumed that exists a sufficient contrast between the blocks and the surface of the band. In most cases this contrast is assured by the black colour of the band and the grey colour of the blocks (BCA). The area surveyed by the camera is artificially illuminated with constant parameters. For these reasons, the use of a monochrome camera is perfectly justified, but this is not an imperative requirement. The main stages of the image processing are: digital image acquisition, binarisation, object labelling, filtering, object analysis (shape, orientation, geometrical parameters estimation).

In order to have a certain robustness face to the variations of band colours or blocks, illumination conditions, the binarisation is made with an algorithm based on pattern recognition technique [2]. The binarysed image permits the execution of a quickly procedure for labelling objects and detecting a number of ROIs (Region of interest) containing a single object. These ROI's may be analysed one by one, leading to a high speed of processing. Some ROI that are not eliminated in the filtering process contain relevant object which are analysed in order to establish their shapes (rectangular or not), the orientations of the main directions. Based on these information another software module synthesises the commands to the robot for a correct position of the robot arm. The aim of the object recognition is the selection of the stack where the object will be stored.

The software for geometrical parameters estimation and the object recognition need a learning stage with standard objects and the output is the calibration of the image analysis module. This learning stage is executed off-line and is supervised by an operator.

2.2. Robot Control

The main actions that the robot must do are: positioning of the arm above the expected object on the band, catching the object, moving the object above the right position into the target stack, releasing the object.

The computer elaborates the commands and transmits them by a serial link to the robot. The fields of a robot command must contain polar co-ordinates in the robot's own co-ordinating system. In the frame of the whole control system of the robot, including TV camera, there may be distinguished 7 co-ordinates systems:

- object surveying system (S1) - measuring units: cm
- graphic system for the A TV camera (SA) - measuring units: pixels
- object catching area system (S2) - measuring units: cm
- robot co-ordinates system - polar co-ordinate for each arm (S3), measuring units CAN
- stacks systems (S4) and (S5) - measuring units: cm (one for the stack with standard objects and one for the non-standard ones)
- graphic system for the B TV camera (SB) - measuring units: pixels

These systems assure the flexibility of the operation. The co-ordinates transformation relations is based on coefficients computed during the learning stages (calibration). For example, in order to have a correct transformation between the co-ordinates in S2 and S3, the arm of the robot is moved, by a manual command of the operator, in the origin of the S2 and in a point placed on the Ox axis of the S2. As answer to a special command emitted by the computer the robot transmits the co-ordinates (in S3) of its arms.

2.3. Stack building

The arrangement of the blocks into the stacks is supervised by the computers. The B TV camera surveys the stack where the standard objects are pushed into. Analysing the digital image captured at certain moments, the computer checks if the robot arms movement is directed onto the right stack. A special role of this software module is to prevent the blocks degradation by releasing them from an incorrect height or position.

The information acquired by this software module serves for an adaptive calculus of the target position. The initial calculus of this position is based on the results of the calibration stage and after the processing of the images transmitted by the final position are re-calculated. In few words the digital processing of the images grabbed from the B camera represents the feed-back of the robot control.

The schedule of the operations - to - a. block is signalled the image analyses from A camera; the computer send an order to robot to move its arm in the waiting position;

- t_1 - the presence of the block is signalled by a proximity sensor this signallisation is done when the block enters under the waiting position of the robot arm; the commands to catch the block are transmitted to the robot

- t_2 - the robot begins to the block to the target stack.

- t_3 - another series of commands based on the image analysed the B camera is launched to the robot

- t_4 - the robot release the block on the stack.

At this final point a new block enters in the area surveyed by the A camera and a new cycle begins. The computer control the speed of the band by estimating the frequency of the objects on the band.

3. IMAGE PROCESSING AND RECOGNITION

3.1. Image processing related aspects

During the acquisition of monochrome images different noise sources may diminish the quality of digitised image. It may be distinguished two main types of noise sources: deterministic (e.g. optical system imperfections) and stochastic. The restoration of a monochrome digitised image is based on the following model of the image degradation and image restoration processes.

The original image is represented by the function $o(x, y)$ giving the brightness value in the point of co-ordinates x and y. We assume that the degradation was done by a filter with the transfer function $H(u, v)$ and an additive noise $z(x, y)$. For the restoration is responsible a filter with the transfer function $R(u, v)$. The restored image function, $f(x, y)$, must approximate the function $o(x, y)$ representing the original image. The degraded image function $d(x, y)$ is assumed that is a sum of the result of a space invariant convolution operator $h(\ )$ and the noise function $z(x, y)$:

$$d(x,y) = \int_{-c}^{c} \int_{-c}^{c} h(x,y;\alpha,\beta)\, o(\alpha,\beta)\, d\alpha d\beta + z(x,y) \quad (1)$$

where c is the window size. This relation may be re-wrote based on space invariant properties as follows

$$d(i,j) = \sum_{k=-c}^{c} \sum_{l=-c}^{c} o(i-k, j-l)\, h(k,l) + z(i,j) \quad (2)$$

A neural networks having $N.G$ neurones is used to restore dgradate images. The grey level of each pixel $r(i, j)$ is obtained by the sum of the outputs of all the neurones in the assigned group.

$$r(i,j) = \sum_{k=1}^{G} v_{ij}^{k} \quad (3)$$

where v_{ij}^{k} is the output of k-th neurone in the group of G neurones assigned to the pixel (i, j). This output is obtained by applying a threshold function $g(u)$ to the total input of the neurone. All the neurones are assumed to be interconnected by symmetric links.

We consider a monochrome image digitised in G grey levels and $N = x_{max} \cdot y_{max}$ pixels. After the binarisation follows the phase of objects isolation that is based on a convex compounds labelling method. It must be underlined that every connecting area of pixel is interpreted as an object marked by the same label.

After the identification of the object representing a block it must be determined its orientation. The main axes of the object are computed using an analogy to the samples points in an stochastic process, and were approximate by a regression line

$$y = a x + b \quad (4)$$

where the coefficients a and b are determined by the least square method using the pixels points in the object waiting area image. Their values minimize the function F(a,b), computed with the formula:

$$F(a,b) = \sum_{(xi,yi)\in Object} (y_i - ax_i - b)^2 \quad (5)$$

where the *Object* stands for the set of the pixels in the object image representing the carried block.

Having the coefficients a and b the main orientation of the block is determined.

3.2 Recognition of standard objects

The significant objects identified on the conveyor band may be standard object (whole blocks), pieces of a fragmented block etc. the standard objects recognition is necessary to send to the robot the order that will move the objects in the standard objects stack, and the other objects in the other stack. The recognition process is based on a the concept of parallel separated patterns [4]. A pattern is described by an array of features or a pattern may be viewed as a point in a n-dimensional space. The similar patterns can be grouped into a finite number of sets. We suppose that these sets are disjoints and we name them classes; their representation in the pattern space consists in a number of regions that may be separable or not. For example a class contains

To recognize a pattern is to classify them into a class, according to the region that contains the pattern point.

The similarity measure used in this case may be an inverse dependence from a distance measure between two patterns x, $y \in E$. In many applications like [1], arises patterns that have not all the n features measurable, or the results of their measurements are strongly affected by noise. Suppose there are only k out of n features measurable for all the patterns. Then we will work in a projection of pattern space. More difficult is the situation that the patterns have not the same features incomplete measured. In this situation the usual solutions can be:

a) isolating incomplete patterns by:

- elimination from the set E;
- classification of the incomplete patterns in a special class [1].

b) restoring the missing values by:

- substitution of the missing features by the means of the known values of the features of the other ones patterns;
- computation of missing features by the aid of a regression function determined from complete patterns.

A major disadvantage of these methods is the requirement of a large mount of data to make possible the elimination or restoring the missing data. But in many cases it is not necessarily to compute the missing features. More important is to gain the final objective of the pattern recognition problem. In the supervised learning context the system receives as inputs data a set composed of prototypes with known classification composed of prototypes with known classification:

$$T = \{ (x, C_x) / C_x \subseteq E \text{ and } x \in C_x \} \quad (1)$$

where T is called training set, with C_x a class in the partition P over E. Considering T, the recognition system must assign a class of P to any new pattern y. This assignment may be done directly by a search in T, (pattern matching) or by a classifier that functions as follows:

- for K classes are K functions g_i;
- it classifies the new pattern y in C_i class iff

$$g_i(y) \geq g_j(y) \quad (\forall)\ i,j \leq K \quad (2)$$

The functions $g_i(x)$ may be linearly or non-linearly.

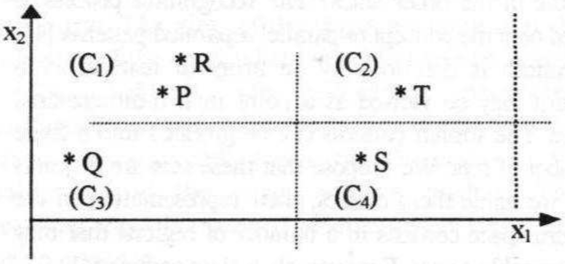

Figure 4. Case of four patterns classes inseparable in an one dimensional feature space (x_1 or x_2).

The quickly classifier is a "third order classifier" type. Clearly, a classifier obtained for complete patterns is inapplicable for patterns with missing features. An expansive solution is to obtain several classifier g_{ij}. For n features it needs a number of N_c classifiers

$$N_c = C_n^1 + C_n^2 + \ldots + C_n^n \quad (3)$$

It is important to observe that the separability of the classes may be not maintained in the projection space (figure 4).

Here we had supposed that the pattern space is a bi-dimensional one and we have four classes labelled by $C_1, \ldots, C_4$. In this case if a feature is missed, it is not possible to separate the pattern in four classes, but only in two (e.g. if x_2 is missing, it may observe a class containing the patterns from $C_1 \cup C_3$ and a class corresponding to $C_2 \cup C_4$). The separabillity analysis is accomplished during the determination of classifiers, when the cases of uncertain separability are rejected for automate recognition. The corresponding objects may be falses or non-standard objects.

The classifiers determined in the learning phase are algorithms with polynomial time complexity very appropriate to the decision making process running in the time that the object is moved from the A TV camera visual area to the area where it will be picked up by the robot arm.

CONCLUSIONS

The installation presents the following advantages:

- the direct transmission of the movement between bilateral toroidal inductors which represent the main fitting of the action motor and the inducting solidary disk by mechanically coupling with the action motor and the inducting solidary disc by mechanically coupling with the activating drummer of the conveying band;
- the expulsion of the reduction gears of revolution which diminishes the global efficiency of the equipment;
- easy and cheaper maintenance;
- protection against shock and trepidations of the mechanic reduction gears of revolution;

The system assured also the increase of the reliability and liability.

The correctness of the robot movements are depenedent of the calibration stages. These stages must be done only if one component of the system (conveyor, robot, cameras, stacks) changed its position.

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