Design & development of an automated (robotic) snapping, banding & sorting system

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Abstract: - The paper summarizes the details of the design & development of an automated (robotic) snapping/cutting, banding & sorting system for mixed size, shape and pattern labels used for various applications. The project was a University/Industry collaboration to automate an aspect of a production line to increase the production efficiency. The specific problem to solve was to identify and remove bottlenecks in a semi-automated manufacturing process. Areas of particular concern were block cracking/snapping mechanism, handling of loose stacks of labels, banding & sorting systems, linkages between machine stages, timing & speed of the system and finally the layouts of the sheets. The project also involved a detailed investigation of the current machinery and production processes at the specific bottleneck stage to identify all sorts of problems in production whether they are related to the complexity of the designs of layouts or speed and timing of the system.

Key-Words: Robotic System, Automation, Snapping, Banding, Sorting, Labels

1 Introduction

Automation, robotics and control play an important role in manufacturing in different industries. The art of robotics and intelligent control has been transferred into the development of automated systems. The most important field in controls & robotics is the working of a system with maximum accuracy and minimum errors and if an error occurs the system should be capable of taking a significant action against it [1].

In manufacturing lines there are usually a number of inter-related processes which should coherently work efficiently to result in an efficient production. However, if there is a bottleneck at any stage the whole production line should run at a lower efficiency/capacity. Improvements may be made using lean manufacturing regarding some of the aspects of manufacturing but these are small incremental changes and do not play any vital role to enhance the production efficiency/capacity.

The paper describes a University/Industry collaborative project to investigate a manufacturing production line and identify the bottlenecks. The aim was to design and develop a robotic (automated) system to overcome the bottleneck process problems in order to increase the manufacturing efficiency to reach the desired production capacity (due to confidentiality agreement the project is described in more general terms). Based on the investigation carried out by the company involved, available automated systems do not cover the whole production line and the custom made ones are extremely expensive. Therefore the idea was to come up with a solution which was within a reasonable budget for the company.

An automated transportation and manipulation flexible robotic system for handling, snapping, banding and sorting of general purpose labels (of any shape and size) would substantially improve overall production efficiency of the concerned company where a large scale investment in new equipment could not be made. The goal was to almost double the production by automating a serious bottleneck in the manufacturing line.

A typical range of different shape and size labels, to demonstrate the handling complexity of the required robotic system, is shown in Fig. 1.

Fig.1 Example of different shape and size labels
Automation of production facility is seen as the only viable solution to substantially enhance performance and improve both capacity and reaction time during the peak production. This opportunity would offer significant business returns to the company by enabling them run double shifts and to satisfy customers they sometimes have to put in a queue or turn away during peak production times.

2 Problem Formulation
After carrying out the investigation on the production line the serious bottlenecks were identified. To overcome the bottlenecks in the production of mixed size and shape labels a robotic (automated) cracking/snapping, banding and sorting (pick & place) system was required which in turn, being successful, would increase the production capacity by double the current production.

In the existing layout the labels are printed on large sheets and after being separated from the residue are transferred to a conveyer belt by means of an automated transfer system which acts as fingers mechanism and transfers the labels from the blank separator to the conveyer belt. After being transferred to the conveyer belt, the stacks of labels are banded manually by means of cotton thread banding machines or rubber bands and then placed in their respective boxes (manually). This whole process takes a considerable amount of time and makes the process slow.

In order to make the process more efficient and fast in such situations, it is required to automate the whole process of cutting (cracking), banding and sorting (pick & place) using suitable robotic systems.

To summaries the requirements: based on the manual process, stacks of loose labels after being transferred to the conveyer belt are required to be passed through the banding machines and then the banded stacks of labels should be sorted, picked and placed in their respective boxes for final packing.

The problem was a complex one since it required a flexible mechanism to deal with loose stack of labels. Robotic handling solutions usually lend themselves to well defined objects and repetitive tasks. In order to solve this complex problem a number of solutions had to be proposed.

3 Research Phase
A detailed investigation of the existing factory machines was carried out. Banding machines and blank separator are usually used in a semi-automated fashion. A brief description of both is given below.

3.1 Overview of a Blank Separator system
A Blank Separator system is a pneumatically operated press that operates on 6 bar pressure. Usually a stack of 50-100 sheets, depending on the thickness of the sheets, are fed into the system at a time [2].

3.1.1 Working of Blank Separator systems
When the sheets are fed into the press a top plate with a combination of pre inserted pattern of pins apply pressure on the sheets. Thus the residue separates from the labels which are already crease-cut by cutting machine to make it easier for the press. In this way the stack of labels are left behind on the bottom plate supported by pre inserted pattern of pins. The residue is then thrown into the waste material basket to be recycled. Figure 2 shows the configuration of a typical system [3].

Fig. 2 A typical blank separator system [3]

Stacks of labels are then taken from the separator. The whole process is repeated by the operator until the batch of sheets is finished.

3.2 Banding Machines
Cotton thread or ribbon banding machines are semi automatic systems in which the operator has to pass a stack of labels or a product to be banded through the machine lever and a relay operated switch then allows the machine to band the product. Figure 3 shows a typical ribbon banding machine [4].
In order to make the whole system more efficient and less time consuming an automated banding system is required. Different types of automated banding machines are available in the market, but in this particular case the banding machine has to operate on for example 50 different types of stacks and speed of the operation is critical to fulfill the overall robotic system requirements. Normally a person takes 4 to 5 seconds to pick up a stack of labels from the conveyer, band it using cotton thread banding machine and then place it in its respective box. Labour fatigue could increase this time. The operating time needs to be minimized for the robotic system to achieve the desired production rate.

4 Design Phase
After preliminary research and study of factory machines and different manufacturing processes a series of design proposals were prepared based on the given requirements and viable solutions.

4.1 Design 1
Every project has its teething troubles. This system also had its complications and the most important of them was the handling of labels. First it was decided to use a pneumatic two fingers gripper robot to lift individual stacks of labels directly from the separator but the problem was that there was not enough space between two stacks of labels for the gripper to pick the stacks up from the separator and place them in their respective boxes as the labels are normally designed less then 3mm apart from each other to increase yield and reduce waste. So there was not a possibility to increase space between the labels.

Another idea to sort out the spacing problem was to use a V shaped conveyer with individual rotating belts to keep stacks apart from each other. That was not feasible as a slight moment could scatter the loose labels all over the separator. Also this process was too slow to achieve the required speed and production rate.

In order to speed up the process an idea of using distributor robots on either sides of a conveyer was presented so that once the labels are on a conveyer they distribute half of the labels which are maximum of 45 (in a typical case of 90 labels on a sheet) on either sides and place them on satellite tables from where the pick & place robots would pick them up, band them using cotton thread/ribbon banding machines and place them in their respective boxes. This plan could sort out the speed issues but lifting of stacks of un-banded labels directly from the conveyer was still an issue as a slight moment of conveyer could scatter the labels all over the place and also there was not sufficient gap between stacks of labels for the robot to lift them up easily as lab experiments showed that a two-finger robot always left the last few labels on the conveyer and position detection was another major problem. Figure 4 illustrates an overview of the design.

4.2 Design 2
In order to sort out the gripping and space constraint problems, the following design was presented. Consider the system in figure 5 (only a small set of pins are shown to explain the mechanism).
In this design there are two beds (A and B) similar to the beds used in a blank separator system (see Fig. 2). A very steady electrical mechanism to lift the bed B up and down is required. A template sheet with the same number of holes used in the blank separator bed and having the same pattern for a particular batch of labels should be used in this design. The purpose of this design is to separate the stack of label by lifting every other stack to a separate height.

Now consider loose stacks on these pins, when bed B is lifted upwards, the pins which are blocked by the template sheet will lift upwards and the others will pass through it. In this way there would be sufficient gap between stack of labels that are lifted upwards for the robotic arm to recognize them and pick them up one by one and pass them through the banding machine.

Although these two designs were workable and were proved theoretically, but there were still speed and timing issues when these were further investigated and also the cost of the equipment was over the budget.

### 4.3 Final prototype design & development

Instead of catering for individual stacks of labels a further design was presented and implemented, after the required investigation and some lab testing, to deal with a full block of labels. A ‘block’ refers to a set of 16 or 18 stacks of labels, creased cut and attached to each other from two or three points and are more stable than individual stacks and hence easier to handle. The proposal for the third and final design of the prototype consists of the following processes to fulfill the robotic system requirements:

- a. Transfer/Push Mechanism
- b. Holding Mechanism
- c. Cracking Mechanism
- d. Banding machine transfer Mechanism
- e. Pick & Place Mechanism

#### 4.3.1 Transfer/Push Mechanism

A transfer mechanism or push mechanism is a plane rectangular slab supported by a typical XZ Cartesian robot having detachable lobes according to the shape of the labels and would push the blocks to the end of the table for cracking mechanism once they are on the conveyer. Figure 6 shows the design of the push mechanism.

#### 4.3.2 Holding Mechanism

Once the blocks are transferred to the end of the table and are detected by sensors, the push mechanism will now keep the blocks in appropriate position. Here before cracking, a holding mechanism is required to hold the blocks firmly with sufficient force while cracking takes place and furthermore this ensures that the holding mechanism will not damage the top layers of labels in the block.

This holding mechanism would be a sort of rectangular slab mounted on two pneumatically operated actuators on either sides. The actuators provide the up and down movement to the slab. Once the block is in appropriate position the computer would send a signal to the holding mechanism and the slab will drop down on the blocks to hold the rest of the block in such a way that the cracking mechanism would easily crack a stack of labels from the block without making rest of the labels loose. After cracking the holding mechanism will let loose the block for the push system to move it forward.
for the next cracking of stack of labels. This process will be repeated for all the stacks in a block.

4.3.3 Cracking/ Snapping Mechanism

The most important and crucial part in the whole process is the cracking mechanism.

Once the holding mechanism holds the block firmly the cracking mechanism which is mounted on a linear drive belt will come into action. The cracking mechanism is more like an elbow and wrist mechanism. The actuator at wrist allows the pneumatic gripper to hold the stack of labels firmly with sufficient force and twist 90° to crack the stack of labels from the main block. Another actuator which operates like an elbow then lifts up the stack and transfers it to the banding mechanism (section 4.3.4). The same process repeats itself but now in the opposite direction depending on labels position. A 3D model of the cracking mechanism is shown in figure 7.

4.3.4 Banding Mechanism

After separation from the block, the stack of labels is then transferred from the cracking gripper to the banding gripper. Banding gripper is a sort of pneumatic clamer mounted on a drive belt that passes the stack of labels through the banding machine and after banding operation, the banded stack of labels is placed on a small table for a pick & place robot to pick it up and place it in its respective box. Figure 8 shows the prototype developed for the banding mechanism.

4.4.5 Sorting System

After banding the stacks of labels are then transferred to their respective boxes through two large pick & place robots on either side of the conveyer. This robot is a three-axes Cartesian robot with a rotational suction gripper. The Cartesian robot would directly lift the banded stack of labels from a platform between banding axis and pick & place robot. The rotational gripper is required to orientate the stacks at the exact position for placing in the boxes.

A 2D drawing of the full system is shown in figure 9.

4.4.6 Vision System

A vision system is required to read the identity code of stack of sheets and then compare that code with a computer database. After comparison the system will automatically upload a specific program to run for the
particular pattern and labels on the sheet. As the patterns of the sheets are the same as those stored in the software so it is easy to define the movement of the blocks on the conveyor for automatic cracking system? Using this method, the vision system required will be a simple system but details of the simultaneous movements of pushing system and block cracking robot must be well defined.

4.4.7 Software
The software of the prototype was written in PLC programming. It has been made very user friendly so that a new operator can easily understand the code and could reprogram it according to the new batch requirements.

5 Results
Timing and speed of the system were the main issues right from the start. After the development of the prototype system, many tests were carried out off-line by using different thickness labels. The results showed that the developed prototype could fulfill the requirements. Hence the next stage is to consider the development of the full system.

6 Conclusions
The collaboration of University/Industry in solving specific problems which may have a wider range of applications is the way forward to enhance manufacturing capabilities. The paper described a complex robotic problem where a number of solutions had to be considered to fulfill the requirements of which one of the outcomes was expected to be a double production speed.

Although there are a number of cutting, banding and sorting systems available in the market, an integrated robotic system to be used in a production line is not readily available for handling of different shape and size stack of loose labels. A number of solutions were proposed for a system to deal with a typical application where a combination of an automated snapping/cutting, banding and sorting system should be integrated in a production line.

A prototype was designed, developed and tested based on the best design, to verify that the proposed solution for a robotic system could fulfill the requirements.

Based on the results obtained from the prototype, the full system, once implemented, is envisaged not only to reduce the labour cost significantly but also to allow the concerned company to meet the required target of double production in a day and work with all of their commonly produced labels as specified in their requirements.

References:
[4] URL: http://www.jentonbandingsystems.co.uk/