Automation at a Stamping Industry

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Abstract: - We present an improved model of a robotic manipulator proposed earlier by our group for the local stamping industry. The new design which is an outcome of an undergraduate student project is more efficient and cost effective and is easier to construct and control due to the use of special mechanisms. We present measurements done on a "life-size" model constructed to test and prove the feasibility of the idea.

Key words: - Manufacturing, Two armed robot, engineering design.

1. Introduction

A large number of repetitive processes in the Mexican industrial sector are currently being performed using human labor. This makes it difficult to maintain standards, optimize the use of machines and boost the competitive advantage. Rapid advances in this sector together with an increasing international pressure to enhance product quality and time of manufacture at lower costs require automation of these processes. Stamping or printing machines are very common in the plastic injection market. Every little plastic piece in the need of a stamp (markings) must go through a stamping machine. Given the low manufacturing costs in Mexico and other developing countries it is not always convenient to change to new more efficient mechanical machines. Automated machines through external (low cost) robots may be one of the best solutions due to the low costs and feasibility of external installation in the machine. In an earlier paper [1] we solved this problem with a local industry making control knobs for the kitchen stoves. The industry currently utilizes manual techniques for the stamping of these knobs (the stamping machine itself is automatic). The manual labor is needed to feed the machine with unprinted knobs. We have now improved the earlier design and have made the robot even easier to construct and operate.

When the stamping problem was brought to us we started evaluating various "ready made" solutions, specifically robotic arms to perform the job. However, we faced two problems: the high cost of commercial systems, and unavailability of a robot which "optimally" solves this problem. Most of the robots were overkill for the type of problem and the user was supposed to pay the price of these extra, but useless degrees of freedom. We thus developed a new and unique robotic solution for the industry. Our initial solution has been arrived at after a long process of evaluating alternatives and the main idea was the utilization of two arms fixed at 90°. This separation helped the robot work twice as fast and to improve the printing and stamping of the plastic pieces while reducing the robot control and error detection work. The new model has a different mechanical structure and control system. The whole robot can be assembled quickly with many off-the-shelf parts and hence the cost per robot is much lower than the commercial competition. The design of the original system was inspired by TRIZ [2-4] though we have not used it for the new model. This is essentially because the students were not yet trained to handle this methodology.

The plan of the paper is as follows. In section 2 we review the state of the stamping industry and the problem as it exists today. Section 3 describes the new design. We give our conclusions in section 4.

2. The stamping industry

Stamping or printing machines are very common in the plastic injection market. Every little plastic piece in the needs of a stamp must go through a stamping machine. Most of these systems suffer from the variations from the work of human operators and fail to produce quality products and end up wasting a lot of resources (being time one of the most important resources). Given the low manufacturing costs in Mexico and developing countries it is not always convenient to change to new more efficient stamping machines. Automated machines through external robots may be one of the best solutions due to the reduced costs and feasibility of external installation in the machine.

In order to understand the problem we prepared a list of steps the machine and human operator takes to arrive at the final product. The plant consists of injection molding machines stamp printing in one and two colors. Figure 1 shows a photograph of the real industrial system as it exists today.

The steps taken at this plant are:

- The knobs arrive at the stamping station, disordered and in boxes of 100 pieces each.
- An operator brings the boxes close to the stamping machine.
- The operator takes one knob and puts it in the position for stamping (exactly in the center and the correct direction).
- In case the human operator drops the knob on the floor, a dummy knob has to be placed on the machine while the machine keeps stamping (wastage of ink). This may also create need for an adjustment of the machine before starting again.
- Once stamped it has to be taken out manually and replaced by another piece.
    - The process of changing knobs must be done very quickly and creates accidents and faults due to the working speed of the operator(s).
    - On the average, one operator can have one accident per day. Though these accidents do not harm the operator, they do slow down the manufacturing process.
    - Accidents may also require the readjustment of the machine, requiring further maintenance time.
- The outgoing knobs are collected in trays for later baking.
    - The trays of 25 knobs enter the oven every 15 minutes.

- This work has to be done by another operator.
- Once baked, they are left for cooling for 10 minutes after which they can be packed.

In the complete process there are two steps requiring automation, each performing a sub task.

1. The task of putting the knobs on the stamping machine, in the correct position and direction, and
2. The task of removing them from there and taking them to the baking section.

However we observed that the two steps are closely located (in space) and can be coordinated. In its original format it requires two three degrees-of-freedom (translational) robots. However, with some additional moving belt mechanisms, the work can be coordinated at one point using one robot with two manipulators. In the next section we discuss the proposed solution.

3. The Proposed Design

We started working on the improvement of the earlier robot with the main objective of decreasing the complexity of the control system and the corresponding circuitry needed. With four servo motors working in the robot, it was difficult to coordinate things. Hence we started thinking in two different directions.

a. Reducing or combining the control of two grippers into one, and
b. Reducing the two degrees of freedom of the manipulator (up and down in z direction and rotation along the same axis)

As an additional variable, we also sought to make the robot suitable for heavy duty task without using excessively large servomotors or gear mechanisms.

Using cylindrical coordinates, we see that the variables to be controlled are (r, ϕ, z). Since the arm length is fixed, r is a constant, we are left with two variables. Out of these two, one can be eliminated through the use of constraint on the movement in the form of a plane curve. In our case, the manipulator is forced to move on a circular path (see Figure 2 below). This gives rise to dynamic singularities at some points but can be eliminated in the mechanism through the use of cut-off points. A detailed analysis of these systems will appear elsewhere [5].

A working model (shown in Figure 3) has been built and tested to verify the feasibility of the proposal. In this model the angle between the two arms has been reduced to 54^o to make it just sufficient for the task. The triangle with two arms at two ends and the servo at the other has the following dimensions: 29 cm between the two arms, 32 cm between arm and the servo. One servo motor opens and closes the two actuators that hold the pieces and the other servo motor rotates the two arms from the initial to final position. It takes about 2 seconds to complete one cycle, though this could be improved through a better calibration. Including time for grippers, we get something like 10 seconds.

4. Conclusions

There are many robots designed for automatic production in the stamping sector. None has reached the needs to satisfy the efficiency of the industry at an affordable cost. We have shown above the development of a low cost robot which solves the problem in an efficient way. One of the key ideas of this robot is the utilization of two fixed arms working in parallel, on the time delayed part of the same process. This separation of work in two manipulators helps the robot work twice as fast to improve the printing and stamping of the plastic pieces. The economic analysis of the system reveals clear advantages over the manual system and has been published earlier [1]. We reproduce here the results for ready reference:

Operator	Pieces produced	Hours worked	Pieces produced per hour	Production (at 100%)	Utilization %
1	25,280	144	176	46,800	54.02%
2	2,334	24	97	9,750	23.94%
3	46,150	160	288	52,000	88.75%
4	10,134	56	181	21,680	46.74%
5	47,390	112	423	49,400	95.93%
6	41,805	200	209	46,800	89.33%
Sum of operators	173,093	696	248.7	---	---
1 Robot	51,840	160	360	57,600	90.00%
6 Robots	225,504	696	2160	---	---

The data shown above for the six (human) operators had been collected at the actual industry. The robot data is based on simulation and actual speed of the prototype. A quick look at the last three rows shows a clear advantage provided by the robots.

5. Acknowledgements

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Figures

Figure 1: The stamping machine with the kitchen knobs on the right hand side.

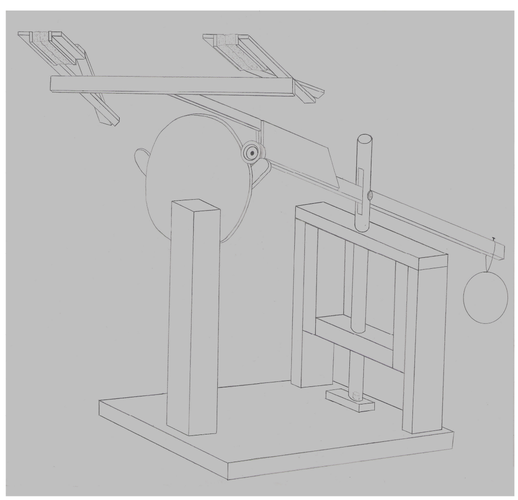

Figure 2: A pencil drawing of the system showing the schematics

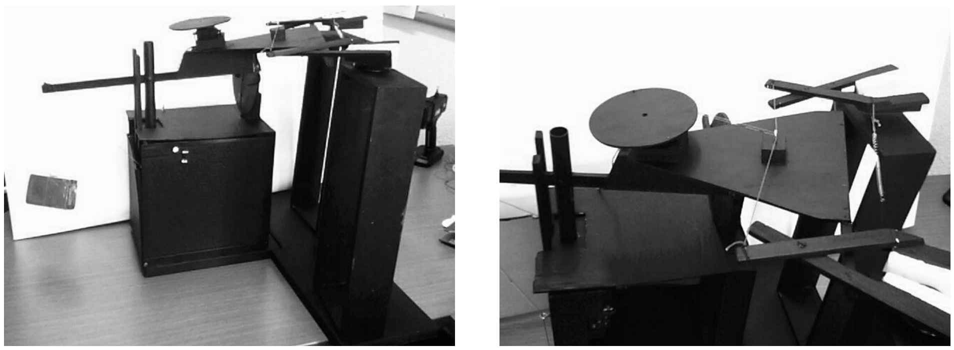

Figure 3: Four different views of the completed (wooden) prototype.