Design and Fabrication of an Agile Sorting and Feeding System

Akshat Gupta, Girish Singhi, Gunjan Agarwal, Natarajan Sankar, Pradeep Khanna

Abstract --- **Modern production techniques demand high degree of automation in feeding and handling of individual components. Where the amount of production equipment has allowed machining times to be reduced in many processes, at the same time, feeding operations are still manually carried out which means that the handling of components accounts for a greater proportion of overall working cycle time. Mechanized part feeding has thus become an indispensable part of today's automated assembly lines where feeding of small parts in a preferred orientation is of paramount importance.**

The conventional vibratory bowl feeder used in the industry is capable of feeding a variety of parts but is usually used for feeding one particular type of component to a particular assembly line. Situations occur where there are multiple assembly lines running in parallel carrying different components. Each line has a dedicated feeding system supplying components to the same. In case the variety of parts to be fed is large then this system of having different feeders for different parts is not feasible. The aim of our work is to design, fabricate and analyze the performance of an agile feeding system, which eliminates the need for multiple feeding systems and replaces it by a single unit.

Our system consists of a vibratory bowl part feeder and a pneumatic programmable system integrated with it for identifying the different parts, sorting them and feeding them to their desired locations. The Agile feeding system being developed will be able to successfully sort parts based on their shapes using the Area Detection algorithm.

Index Terms -- **Automation, agile, feeders, feed rate, vibratory feeder.**

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I. INTRODUCTION

The importance of assembly in an industry cannot be undermined since assembling cost may account for upto 50% of the total manufacturing cost incurred. Automation in assembly is thus essential to maximize productivity. Feeders form an integral part of a mechanized assembly as not only are they responsible for part feeding from a bulk supply but also convert the randomness of parts into a flow in a geometrical pattern. In other words, feeders transfer components at desired orientation to the desired location, which may be a conveyor or machine.

These devices, which singulate and orient parts prior to packing or insertion are a primary challenge for industrial automation. Feeders are extensively used in the industry as an integral component of the assembly line. They are used for feeding small components such as capsules, nuts and bolts at a specified feedrate and orientation to desired locations (conveyor belt or machine).

Importance Of Feeders

A.   *Need for automation*

With increasing labour cost and increasing demand for finished goods, automation has become a prime requisite in order to maximize productivity in industry.

B.   *Need for automation in assembly*

Assembly accounts for upto 50% of the total manufacturing cost so it is quite mandatory that we opt for a mechanized assembly.

C.   *Need for feeders in mechanized assembly*:

Our requirement is basically part feeding/ supplying from a random bulk supply. So for the flow of parts in a geometrical pattern on the line, we desire parts to be oriented in a particular fashion. This is where feeders come into play.

D.   *Need for agile feeding systems*

For multiple assembly lines running in parallel, separate feeders for separate lines feeding different products have to be used. This system of having separate feeders for separate

components is not very feasible. Hence an agile feeding system would have extensive application in the assembly line in industry. Also there is tremendous scope for the reduction of trial and error in a particular design by means of extensive analysis.

Agile Manufacturing

Agile manufacturing is the ability to accomplish rapid changeover between the manufacture of different assemblies. Rapid changeover is further defined as the ability to move from the assembly of one product to the assembly of a similar product with a minimum of change in tooling and software. Rapid changeover enables the production of small lot sizes, allowing for `just-in-time' production.Agility has been expressed as having four underlying principles [Goldman, Nagel, and Preiss]

- Delivering value to the customer.
- Being ready for change.
- Valuing human knowledge and skills.
- Forming virtual partnerships.

Of these, the first three can be found within the operating philosophies of companies generally thought to be "lean" as described in The Machine that Changed the World. [Womack, Jones, and Roos] The fourth principle is different. In fact, Agile and Lean take quite different attitudes toward partnerships, and here is where an important research and practical challenge may lie. In the world of agility, where such partnerships are predicted to be of dramatically shorter duration, extra attention will have to be paid to launching and maintaining supplier relations.

Agile feeding systems

Part feeders are very specific to the geometry of the parts. A specialized feeder only will cater to a specific part depending on its geometry. The existence of a large variety of components to be fed necessitates the development of a feeder, which can feed different types of components at a time. Though the Vibratory bowl feeder is the most versatile and widely used in Industrial automation systems but its use is limited to feeding of one particular type of component to a particular assembly line. In case more than one part is to be fed, more than one setup is used each with its integral feeder. In case the variety of parts to be fed is large then this system of having different feeders for different parts is not feasible. This has brought forth the concept of "Agile Feeding Systems".

Need for flexible systems

Feeder bowls and pneumatic pick-and-place devices are common in today's automated assembly systems.

In the next century, these devices will increasingly be replaced with flexible parts feeders and robots. Adaptable feeders and robots can be reprogrammed to feed and assemble different parts, with little or no mechanical changes. These agile systems will be able to build many product variants on the same line at the same time. Flexible feeding systems will also let assemblers implement demand-pull systems, building to order instead of forecasts. This will help assemblers reduce their dependence on costly inventory.

Systems must get smarter so that less technically skilled personnel can operate them successfully. "Smarter" means that systems must self-diagnose problems and alert the operator before the process fails. The need for smarter systems will drive the conversion from assembly systems controlled by programmable logic controllers (PLCs) to those controlled by personal computers with PLC emulators. To meet manufacturers' time to market demands, machine builders and systems integrators will have to deliver assembly systems in less time. Moreover, those systems will have to produce more assemblies per square foot of plant space, at a lower total cost per assembly.

II. PRINCIPLE OF WORKING

This setup is designed to feed 3 different types of parts to their respective desired positions. The 3 parts being fed are of different shapes namely hexagonal, square and circular. These are kept in bulk in the bowl of the vibratory bowl feeder and are fed out of feeder at a particular orientation in a random order. The vibratory bowl feeder helps in bringing these parts at a particular orientation. These parts pass onto a conveyor belt after coming out of the feeder. They are in a random order and a camera is placed at the beginning of the conveyor belt to capture the image of the part passing on the belt. The processor compares this image with a pre-stored image and using an area detection algorithm it identifies the shape of the part. On basis of this output a signal is given through a parallel port interface to a system, which sorts these 3 parts and delivers them to their desired locations.

This assembly for sorting consists of an actuator system, which comprises 3 assemblies of a 5/2 way single acting solenoid and a pneumatic cylinder each. The signal given through the parallel port interface is given to the desired solenoid, which actuates the cylinder and pushes the parts onto their respective conveyor belts, which delivers the parts to their desired positions.
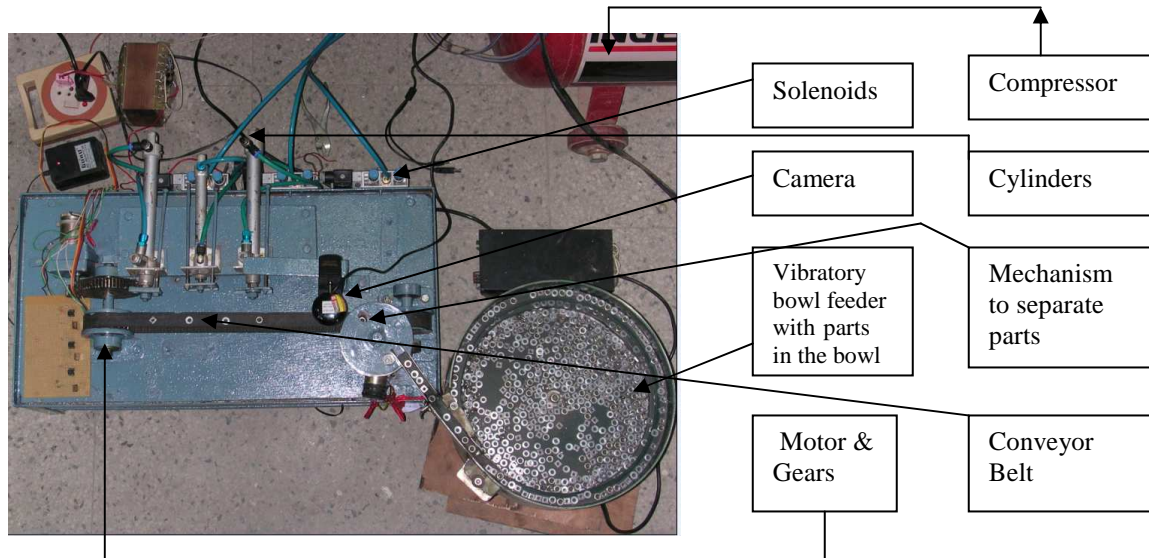
III. DESIGN AND FABRICATION OF HARDWARE

Solenoids	Compressor
Camera	Cylinders
Vibratory bowl feeder with parts in the bowl	Mechanism to separate parts
Motor & Gears	Conveyor Belt

Figure 1: Fabricated Set-up of agile Feeder

Hardware

(1) Vibratory bowl feeder is fabricated for feeding parts from bulk and supply them in   particular orientation to the conveyor through a chute.

(2) A high resolution Camera is used for detection of parts and capturing image for the same.

(3) An algorithm in VB language is used for identification of parts and comparison of part images with the pre- defined images stored in memory of computer.

(4) Data signals are sent from the processor to the required actuator by means of a suitable interface device comprising parallel port and relay circuit.

(5) The Pneumatic circuit actuator comprises of a compressor, cylinders, solenoid valves and manifold.

(6) Rejected/ Corresponding pneumatic cylinder piston sends the part to the desired location (conveyor) where it is required.

(7) Unidentified/ incorrect parts can be recirculated and sent back to vibratory bowl feeder.

Software

(1) Algorithm for image identification - Area detection is the main principle being utilized.

(2) Software required to capture and refresh images continuously.

(3) Interface software to operate parallel port of processor.
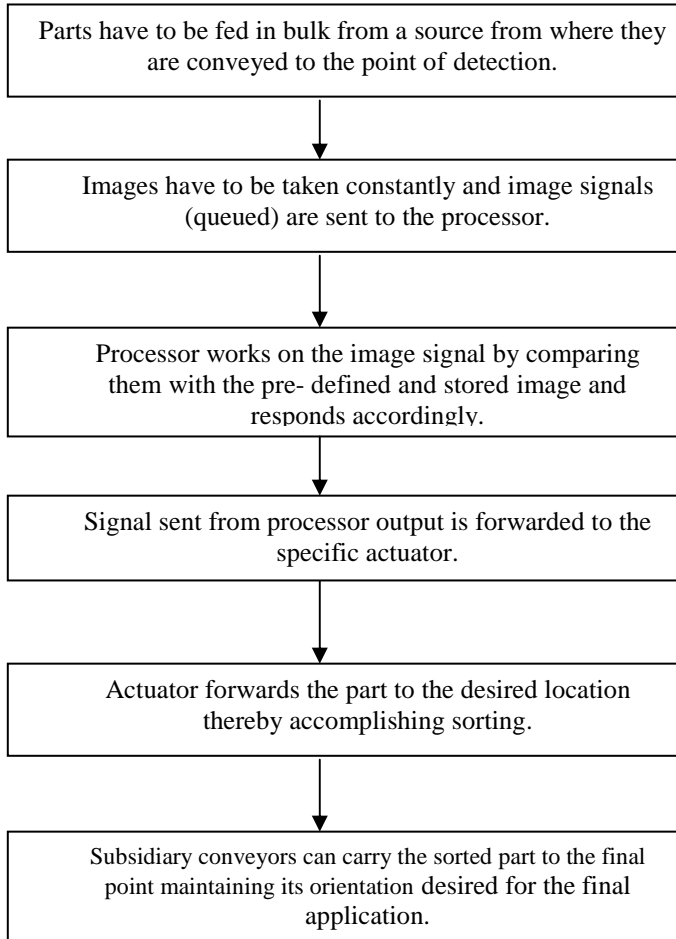
Pneumatic Circuit

The pneumatic circuit is required to send the sorted parts to their respective locations after the camera has detected the image on the basis of area detection algorithm and sent the corresponding signal to the actuator via the parallel port. Our pneumatic circuit comprises the following components:

1) Three double acting cylinders
2) Three 5/2 way double solenoid valves
3) Six flow control valves
4) Compressor – 8 bar
5) Manifold
6) Tubing

Figure 2: Pneumatic set-up

Schematic Diagram Of The Process

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┌─────────────────────────────────────────┐
│ Parts have to be fed in bulk from a      │
│ source from where they are conveyed to   │
│ the point of detection.                  │
└─────────────────────────────────────────┘
                   │
                   ▼
┌─────────────────────────────────────────┐
│ Images have to be taken constantly and   │
│ image signals (queued) are sent to the   │
│ processor.                               │
└─────────────────────────────────────────┘
                   │
                   ▼
┌─────────────────────────────────────────┐
│ Processor works on the image signal by   │
│ comparing them with the pre- defined and │
│ stored image and responds accordingly.   │
└─────────────────────────────────────────┘
                   │
                   ▼
┌─────────────────────────────────────────┐
│ Signal sent from processor output is     │
│ forwarded to the specific actuator.      │
└─────────────────────────────────────────┘
                   │
                   ▼
┌─────────────────────────────────────────┐
│ Actuator forwards the part to the        │
│ desired location thereby accomplishing   │
│ sorting.                                 │
└─────────────────────────────────────────┘
                   │
                   ▼
┌─────────────────────────────────────────┐
│ Subsidiary conveyors can carry the       │
│ sorted part to the final point           │
│ maintaining its orientation desired for  │
│ the final application.                   │
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Troubleshooting By Additional Component Addition

Problem: In a vibratory bowl feeder each part is being pushed by the part preceding it, thereby resulting in the feeding of the succeeding part .In this manner a queue of parts is formed which exerts a force on every part in the forward direction. This inherent feeding mechanism of the vibratory bowl feeder posed a serious problem in the working of the concerned agile feeder since it employs a camera, which requires sufficient time to capture the photos and identify the different parts. Once the images are taken by the camera, they are sent to the image recognition software which works on the area detection algorithm. The part is identified by this software and the signal is sent to the electronic circuit with the help of a parallel port which in turn actuates the cylinder corresponding to the concerned part. It was observed that this exercise required a minimum of 5 seconds to execute. So it was desired that the parts maintain this sufficient time gap between one and another. Also, when a queue of parts is fed, the images taken by the camera covered more than one part in a single image. Since the software that has been designed works on the area

detection algorithm, so it was unable to identify the parts correctly in such a situation.

Solution: Mechanical arrangement was designed as shown in the figure below. The arrangement employs two discs, placed one above the other. The lower or the stationary disc has one hole in the centre through which the shaft of the motor passes and the other hole closer to the periphery. The lower disc is mounted such that it always remains stationary with its peripheral hole placed right above the conveyer belt and the upper disc rotates above the lower one. The upper disc has one hole in the centre, which fastens the shaft of the motor with the disc using a bolt arrangement. It also has two holes placed close to the periphery such that these holes align with that of the lower disc, when the disc rotates. The parts are fed from the vibratory feeder through a chute, such that they fall into the upper disc and get entrapped in the holes of the same. When this hole of the upper disc containing the part, aligns with that of the lower disc, the part falls onto the conveyer belt. The size of the holes is such that only one part can enter at a time. The conveyer, which is moving at a definite speed, takes the part to the location where they are sorted and fed. Since the upper disc has only two holes, so only two parts can be fed in one revolution of the disc. Also, by controlling the speed of the upper disc, one can obtain different time gaps between the two parts. This mechanism ensures a sufficient time gap between the two fed parts, thereby giving the camera and the electronic circuit appropriate leverage in their reaction times.
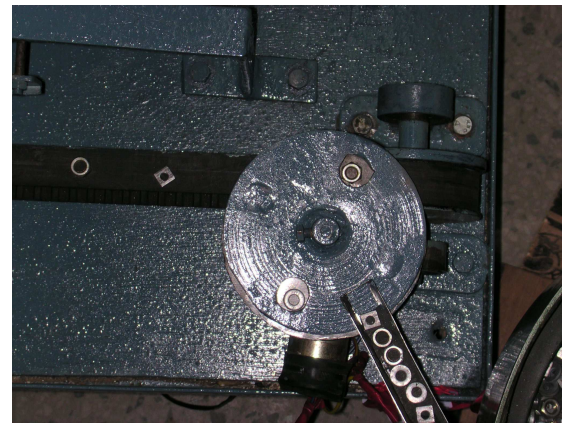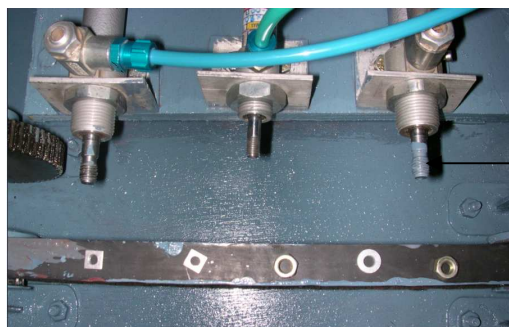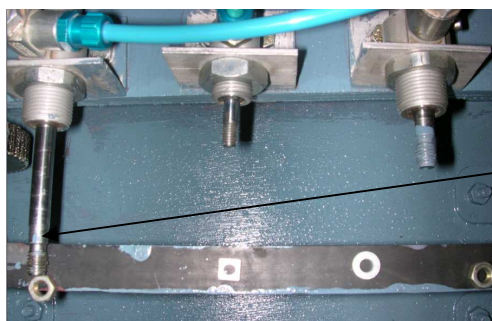

Figure 3: Gap being created between two parts by additional component addition.
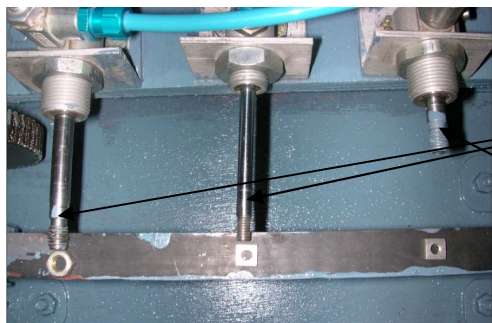
IV.   WORKING OF THE SYSTEM

This depicts the 3 cylinders at their rest positions with parts moving on the conveyor belt. (The sorting system is not in operation)

This depicts the 3rd cylinder being actuated by the presence of a hexagonal part in front of it.

This depicts the 3rd and 2nd cylinder being actuated by their respective parts in front of them but the 1st cylinder in its rest position due to the absence of the corresponding part.

Figure 4: System sorting the different types of parts

V. EXPERIMENTAL ANALYSIS

The behavior of the feeding system for the three parts was studied. The purpose was to investigate the effect of population, amplitude of vibration and part ratio on the feed rate of the selected parts. A known population of the three parts in a specific ratio was put in the vibratory bowl feeder and the output rate was observed at various amplitudes. This was done for different part populations. Population was varied from 0 to 3000 parts, based on which part population range for which the experiments to be conducted was selected. The appropriate range was selected to be from 1000 to 3000 parts. In above experiments, the vibration amplitude was varied from 0 to 90 units. Based on the result, an appropriate range was chosen to be from 30 to 40 units. After this, the parts in different ratios were taken and similar experiments were conducted. For each experiment, readings were taken for 4 minutes and the feed rate was calculated in each case in terms of parts fed per minute. Graphs (feed rate vs. amplitude at different populations and part lengths) were drawn to illustrate the results obtained from experiments.

VI. CONCLUSION

The proposed agile feeding system has been designed and fabricated. The system developed can successfully sort parts based on their shapes using the Area Detection algorithm. This eliminates the need of using different feeders for feeding parts, which differ in their shapes.

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