AIAA-94-1186-CP
N94-30536

INTEGRATION OF VISION AND ROBOTIC WORKCELL

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Abstract

The paper discusses the incorporation of vision into a robotic cell to obtain cell status information and use this information to influence the robot operation. It discusses both mechanical and informational solutions to the operational issues which are present.

The cell uses a machine vision system to determine information about part presence in the shipping tray, part location in the tray, and tray orientation. The vision system's edge detector algorithm is used to identify the orientation of the packing trays. In addition, different vision tools are used to determine if parts are present in the trays based on the unique configuration of the individual parts.

The mechanical solutions discuss the handling of medium weight (10 - 25 lb.) parts at an average cycle time of 3.1 seconds per part. The robot gripper must handle 33 different models, three identical parts at a time. This is accomplished by using stacks of rotary actuators and slides between the stacks.

I. Background

One of our manufacturing divisions was having an ergonomics issue with their alternator packing operation. The pack operator was required to manually handle 500 15-pound parts per hour. In addition, he was required to handle one 25-pound, 22 inch by 44 inch shipping tray for every 15 parts.

They requested assistance with the development of a robotic cell to unload their final test line, place the parts into shipping trays and handle the shipping trays. A dunnage transporting conveyor was already present, however, it was manually controlled.

There are only two different rating sizes for the alternators (95 amp - Medium Frame (MF); 130 amp - Large Frame (LF)). However, there are 33 different types of alternators with the differences being mainly in the mounting configurations. There are 18 different possible combinations of orientation moves from the test line to the shipping trays (3 positions on the test line, 3 positions on the holding fixture, 2 different tray orientations).

The alternator is assembled using three through bolts (see Fig. 1). These bolts define the three points at the bottom of the alternator. The shipping trays have the three points contained and supported for shipping.

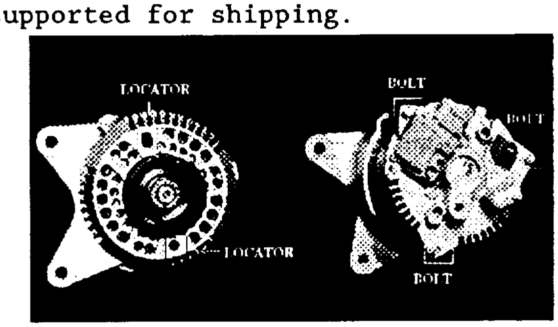

Fig. 1 Alternator

The original layout of the packing cell is shown in figure #2.

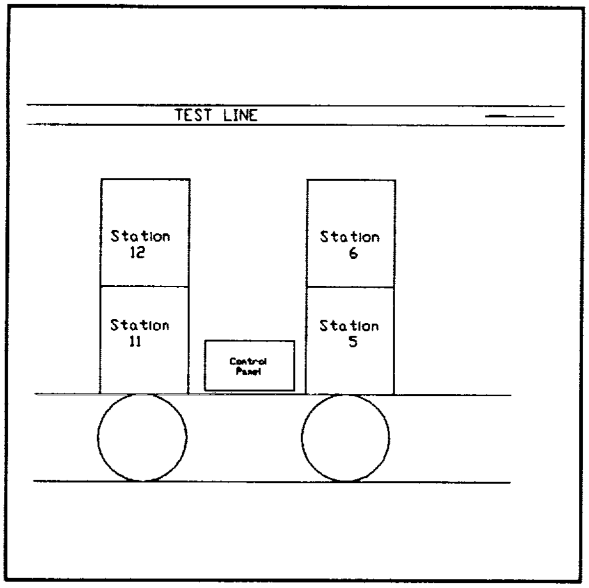

Fig. 2 Layout

II. Mechanical Issues

A. The following is a partial list of some of the major mechanical problems affecting the automation of this operation:

1. The shipping trays cannot be modified in any way. These trays were not designed for automation;
2. There are three different orientations (to the part locators - see Fig. 1) of the parts into the trays;
3. The part spacing in the tray is different for the medium size alternator (medium frame) and the large size alternator (large frame) by .030 inch (0.76mm);
4. Some of the parts have interference fits into the trays;
5. Because of the non-synchronous operation of the test line, three different parts could be waiting at the unload station at a given time.

B. Solutions to the above issues are described below :

1. Because of the number and cost of shipping trays in use, they can not be modified in any way. There are five different types of trays based on the different sizes and mounting configuration of the parts. The trays were not designed for automation and the standard grip points are 44 inches apart.

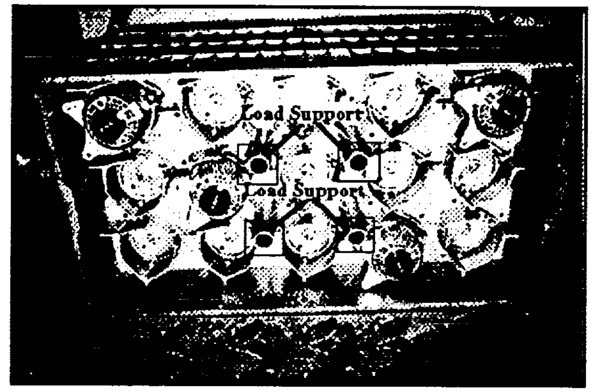

Fig. 3 Shipping Tray

As the 44 inch spread between the tray grip points would make the robotic gripper very large and heavy, another grip location was a necessity. The only common internal features to the different trays are the four load support posts which are hollow (Fig. 3).

2. Friction gripper devices utilizing urethane die strippers and individual remote center compliance devices (Fig. 4) were developed to work inside the hollow posts (Fig. 3). This friction gripper demonstrated capability of moving over 100 pounds while maintaining enough stability to directly place the tray into its next position.

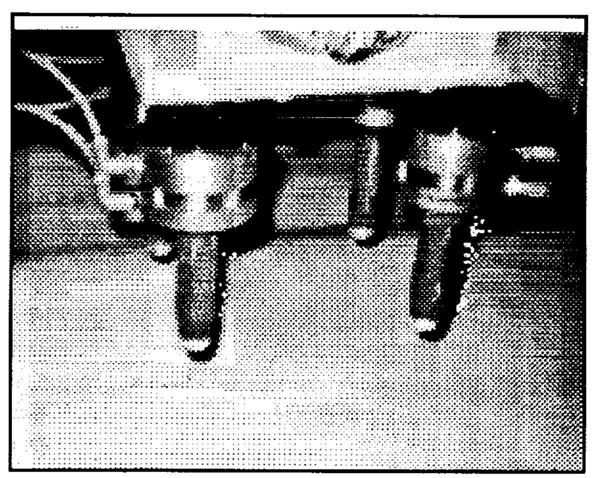
Fig. 4 Friction Gripper

3. As the parts have different mounting configurations, there are

three different possible orientations of the parts into the shipping trays. The part orientation (to the machining locator holes in the top - Fig. 1) in the test line pallets is not consistent between different part types. The part orientation in the shipping tray is also not consistent between the different part types.

The multiple orientations required would be a simple task for a robot handling a single part. However, the speed required to meet cycle time, in conjunction with handling the trays prevents this from being a single robot system. The initial solution was to have the parts removed from the test line, orientated into tray orientation and placed into a 3-part holding fixture by a robot. Then a second robot would pick up three alternators at a time and place them into the shipping trays. It would also handle the empty trays.

After a ROBCAD ™ simulation showed that this process would only achieve a cycle time of 5.0 seconds, an additional small robot was added to the system. There are now 2 small robots removing parts from the test line, orienting them and placing them into four (4) 3-part holding fixtures. (Fig. 5)

The final layout of the packing cell is shown in figure 5. The robots, vision system and escape line were added to automate the cell.

Based on this process, the third robot's gripper must handle three parts simultaneously. The gripper must also be able to handle the three different orientations for part placement into the trays. Changing orientation was accomplished by using a stack of two Robohand Ultra Thin Rotary Actuators (RR-46) capable of 180 degree rotation in each of the three individual part gripper stacks (Fig. 6).

4. The spacing between the LF parts in the trays is different than

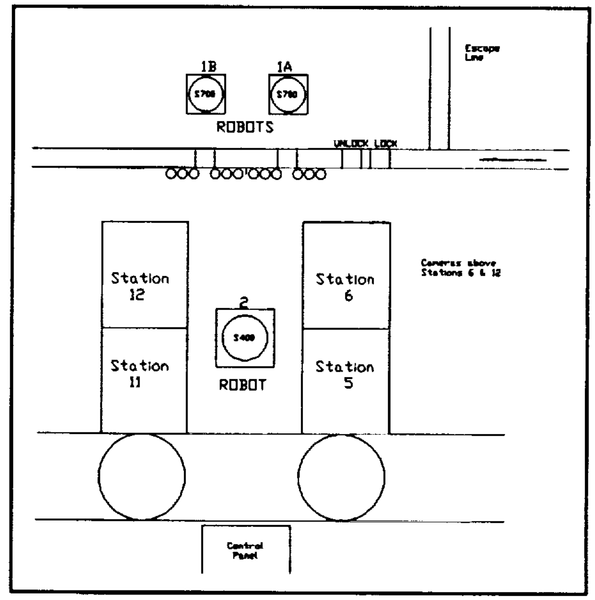

Fig. 5 Final Layout

the spacing of the MF parts by 0.030 inch (0.76 mm).

The three-part gripper was designed to change the distances between the individual grippers by using two THK slides with actuator cylinders on each side (Fig. 6). Identification of part type is discussed in Informational Issues.

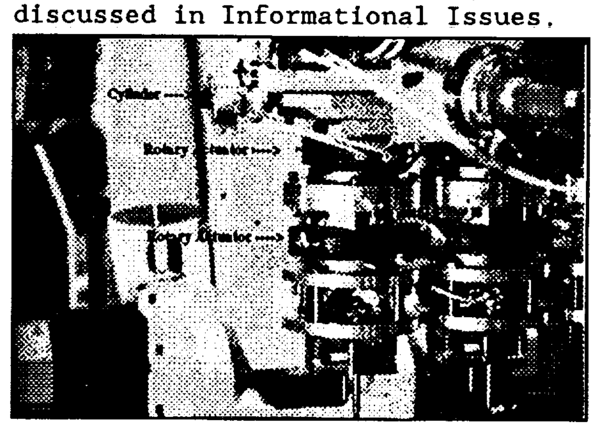

Fig. 6 Gripper

5. Some of the parts have interference fits into the trays. Because of this, individual stack compliance devices were added. A simple machined cone and spring tension were used for the required compliance (Fig. 7).

6. Because of the non-synchronous operation of the test

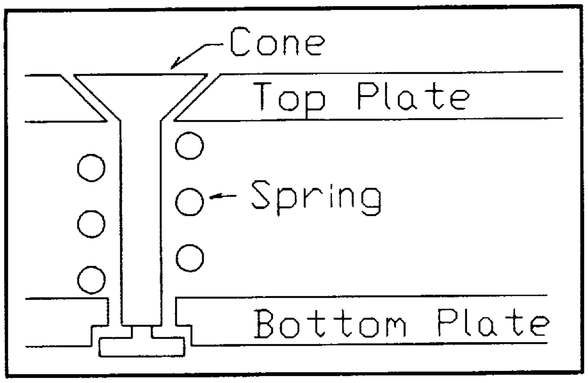

Fig. 7 Compliance Device

line, three different parts could be waiting at the unload station at any given time.

An escape line will be added to the test line to hold the third part type when needed. The other two parts will be handled by loading one into trays at Station 6 and the other at Station 12 (Fig. 8). This is the maximum number of different parts which would be at the unload station under normal operating conditions.

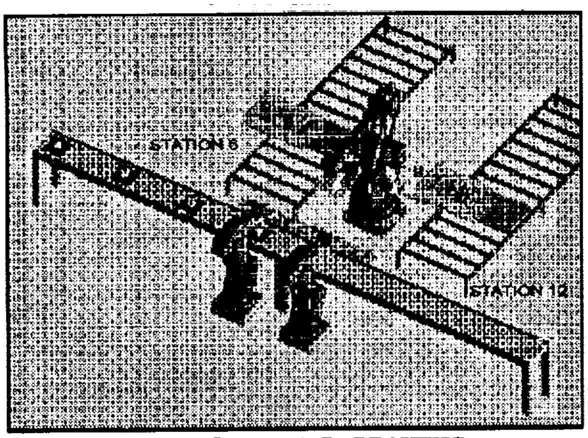

Fig. 8 ROBCAD DRAWING

III. Informational Issues

A. The following is a partial list of some of the major informational problems affecting the automation of this operation:

1. There are no features on the trays to insure they come to the pack station in the same orientation;
2. Because of changeovers and system fallout, a tray may return to the pack cell partially full;
3. Part type identification is required as the parts enter the unload cell to insure proper handling;
4. Each tray must be confirmed as full prior to leaving the cell.

B. Solutions to the above issues are described below :

1. There are no orientation features on the tray to insure that they are stacked in a consistent orientation. Therefore, they can arrive at the cell rotated 180 degrees to each other. As the parts can only be correctly placed into the trays in one direction, the robot must know the orientation of the tray.

Vision has been used for inspection and location determination for many years. In this application, vision is used mainly to gather cell status information.

As in most production situations where vision is used, lighting is critical. The selected system uses an intensity meter and stops operation if the lighting falls outside acceptable ranges.

In order to determine the orientation of a tray the vision system's edge detector is used in two opposite locations. This tray has webbing which is missing at one of the corners. Tray orientation is determined based on where the webbing is found and, as a safety for broken trays, where it is not found (Fig. 9).

2. Because of changeovers and system fall out, a tray may return to the loading cell partially full. The system must be able to identify the position of parts in the tray to prevent the refilling of those positions.

In order to identify where parts are in the trays, the vision edge detector was tried first. Because of the large number of air holes in the

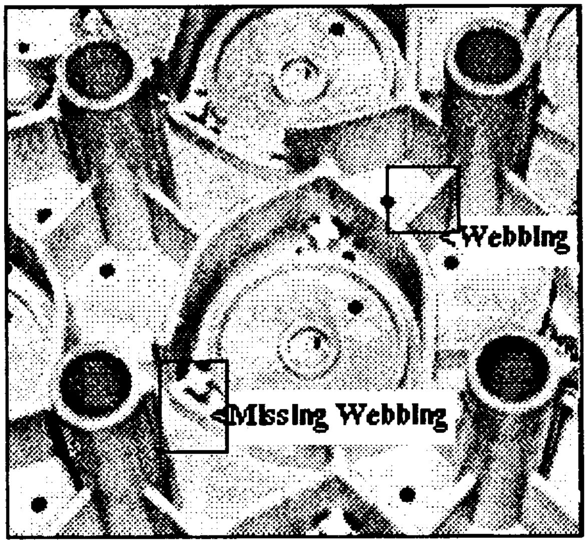

Fig. 9 Tray Webbing

top of the alternator, a find/not find limit was very robust. However, because of a concern for debris in the tray, this method is not usable (a crumpled 8.5" x 11" piece of paper had approximately the same number of edges). The system was changed to identify a specific feature, such as the diameter of the alternator pulley, to insure correct identification of part present.

In order to communicate with the robot, a method for identifying the specific location in the tray was developed and is shown below (Fig. 10).

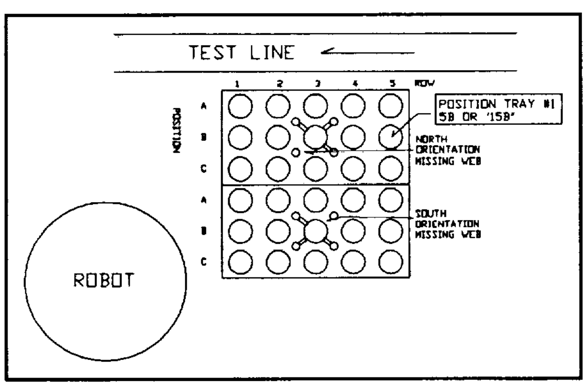

Fig.10 Part Location Identification

The large robot needs to know where parts are present in the next tray row prior to removing parts from the holding fixture. This was handled by using digital I/O with one vision system output for each of the three positions in a row and by having the robot request information for the next row immediately after releasing parts in the previous row. The robot used five outputs to request information from rows 1 to 5.

3. The first robot must know what part is presented by the test line so the robot can properly orient it for insertion into the holding fixtures, or to diverted it to the escape line, or to a specific robot if the cell is unloading more than one part. This is accomplished by using the test line pallet magnetic information card and a reader at the unload cell.

4. The customer requested that each tray be confirmed as full prior to being released for shipping.

At the completion of loading row five of a tray, the large robot will request that the vision system reconfirm that all 3 tray positions contain a part for all five rows. If a position is missing a part then the system will stop operation and notify the tender.

IV. Conclusions

The final system will use three robots and one 4-camera machine vision system to handle 15,000 parts per day.

The use of a multi-purpose gripper to handle both multiple parts and the shipping trays will allow the cell to achieve a average cycle time of 3.1 seconds.

This process development shows the benefit of using machine vision to solve cell informational issues. The use of machine vision easily solved complex informational issues which would have required many elaborate and costly sensors to accomplish.

Note: ROBCAD is a Trademark of Technomatix Technologies, Inc., Novi, Michigan.