An Intelligent Part Sensing and Manipulation System for Productivity Enhancement

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Abstract **- This paper presents an autonomous part handling system design to provide better material handling and process improvement in hydraulic press- shop floor. The proposed system integrates the two successive machines with mechatronics elements such as programmable logic controller, light dependent resistor and Vacuum grippers. The conveyance and handling of semi-finished automotive part such as Horn Housing is done with reference to the geometrical entity. The parts ejected from the pre-forming process hydraulic press machine is identified by LDR based orientation locator and further these parts are exactly loaded into the fixtures of the successive hydraulic press in an efficient way with the assistance of vacuum gripper. On the ground the designed system is more adaptive and eliminates the manual feeding of parts (horn housings), enhance the flawless production strategy. In addition to that appropriate productivity enhancement, slash out the cycle time and also ensure safety aspects.**

Index terms — Part handling, Manual feeding, Geometrical entity, Adaptive mechanism, Orientation locator.

I. INTRODUCTION

Especially the system designed to cope up with the rapid flow of automotive spares ejected from hydraulic press. Basically the horn housing part provides the mechanical support to the electrical assembly of the automobile horn. Horn housings are formed with two hydraulic press, the processes are categorized into two stages like pre-forming and profiling operations. The existing process design is ineffective with manual part storage and conveyance to successive operations. The pre-formed horn housing are conventionally collected with bins and moved to profiling machine with manual strategy, further the loading of semi-finished parts into the fixtures of stage two operations are accomplished by a semi-skilled labour. The cycle time of the process is increased by manual handling and loading activities.

The Horn housing manufacturing process involves

- Stage I (Pre-forming operations)
  - Raw material feeding (Steel plate)
  - Blanking
  - Drawing I & II
  - Re-striking
  - Piercing
  - Notching
  - Flattering/ planishing
- Stage II (Profiling operations)
  - Manual feeding of semi-finished goods
  - Riveting
  - Bending and lancing
  - Lettering

II. FIELD STUDY ON EXISTING SYSTEM

Detailed observation results that the horn housing production process carried out by employing a human resource to conveying and loading the horn housing at production line. Practically it is very hectic and fatigue process tends to slow down the production efficiency as well as deteriorate the quality of the product.

The goods are made to fall into nylon bin with trolley arrangement, after the completion of stage I process; the successive machine is located few meters far away from the stage I. The labour moves the trolley manually to the stage II operational machine setup. The worker will get himself seated near the machine for the whole shift and load the components into auto indexing fixtures at regular intervals.

Fig 2.1 Semi-finished part collection with bin

The loaded parts are further handled by vacuum operated pick and place end effector to perform Stage II operations. The pre-loading is sensitive activity, the operator's full attention and accuracy decides process efficiency and minimization of scrap rate.

The observed difficulties and drawbacks are:

- The manual feeding of the housing components onto the Auto Indexing fixture is found to be physically more difficult for the workers.

- The loading of these components when done conventionally, is time consuming which leads to increase in the cycle time of production. Thus affecting the production rate.
- The movement of the semi-finished parts from one machine to another increase the idle time.

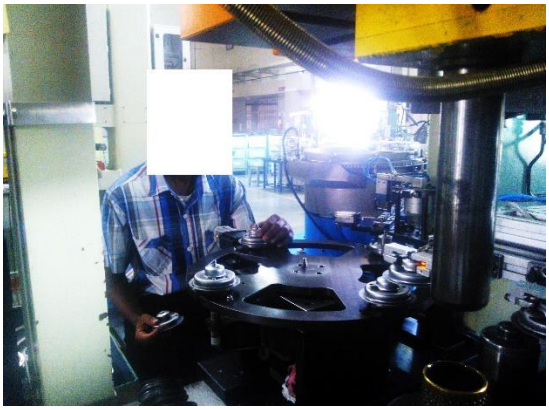

Fig 2.2. Manual feeding by semi-skilled personal

- The mishandling of the horn housing may also take place depending upon the labour conscious and endurance.
- The unnecessary utilization of human source is found in this process which is considered as an excessivelabour cost.
- Chance of Erratic loading and irregularities due to the fatigue of human resource.

III. PROPOSED SYSTEM

An automated way of approach could able to tackle the maneuverability issues observed with the existing processing methods. The conventional process method is upgraded with the mechatronic elements such as Programmable logic controller and sensors arrangements. The feed forward element of the proposed system is light dependent resistor; it will act as key sensing unit of the system.

The system design is well equipped with automation strategies. When the stage I process is done, the parts are ejected through a taper steel plate and directed to the belt conveyor. At the end of the belt conveyor, a proximity sensor is placed to activate the vacuum operated end effector. The transfer of the part is carried out by the belt conveyor unlike manual movement in existing process.

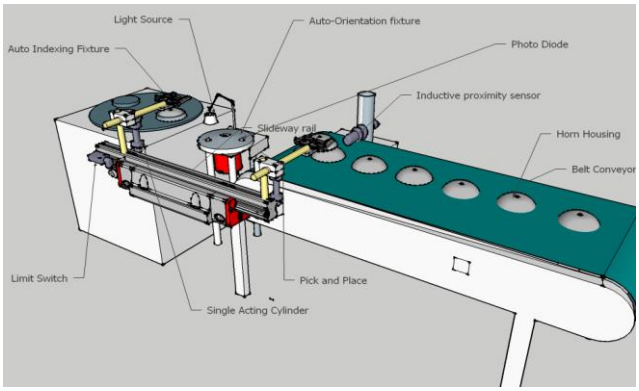

Fig3.1 Pictorial representation of proposed system

The vacuum end effector will place the horn housing onto the orientation locator, immediately the optical sensing unit triggers the stepper motor of the orientation finder and light source is switched ON. After some angular movement the Light dependent resistor will get an exact orientation in reference to the fixture arrangement. This orientation is obtained by the photo sensing principle; hence the part is picked up by vacuum end effector and placed over the auto-indexing fixtures for the stage II process operations.

IV. BRIEFING ABOUT AUTOMATED PROCESS

The process enhancement is obtained by employment of sensors and actuators instead of human source.

The sequence of process

- Acquisition and conveyance of housings
- Placing of housings into auto orient fixture
- Obtaining of required orientation
- Location of housings into auto indexing fixture

A. Acquisition and Conveyance of Housings

The proposed system has a conveyor belt which operates in variable speed and convenient to haul items from one point to another. It is a mechanical loop, usually made of rubber that goes around its mechanism for a continuous cycle.

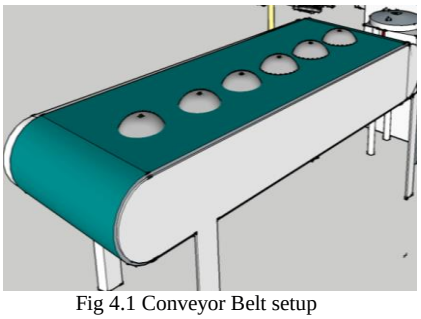

Fig 4.1 Conveyor Belt setup

The conveyor belts are motorized, which connects the two machines and holds the semi-finished horn housings. Basically it is operated by compact Brushless DC gear motor.

B. Placing of housings into auto orient fixture

There is a manipulator placed at the end of this lengthy conveyor belt. The semi-finished part is picked up by the

automated-pneumatic controlled end effector. The gripper has an optical proximity sensor head that senses the arrival or presence of component in the conveyor belt.

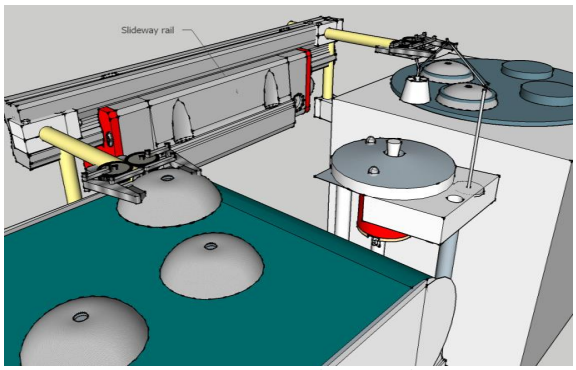

Fig 4.2 Picking up of Housing from conveyor

The gripper end has a vacuum cup for holding up the part, so that if the component arrives even upside down, it can be easily handled without any distractions. Further the end effector displaces the housing with the help of motor operated slide-way projection. Finally the housing is being located at the exact span and height of the auto-orient fixture.

C. *Obtaining the required orientation*

The Housing placed after the Auto Orientation fixture, the setup will rotated by DC motor.

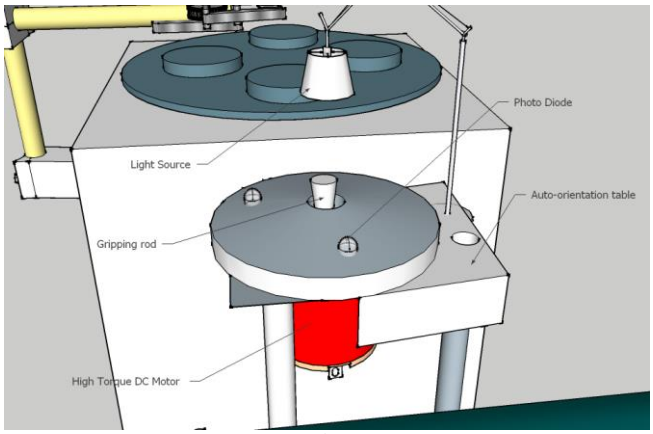

Fig 4.3 Typical sketch of Auto positioning system

Simultaneously the light source get switched ON which is located above this fixture. There are two reference holes in housing which helps to make the exact positioning. The Light Dependent Resistor (LDR) is placed under the Auto Orientation fixture below those reference holes.

Those photo diodes will make the motor of the fixture table to rotate until both the photo diodes receive the illumination through the reference holes from light source. Thus the motor will stopped immediately, this control action performed by a Programmable Logic Controller (PLC).

D. *Location of housings into auto indexing fixture*

There is an Auto Indexing fixture basically found to be attached to this machine have capacity to hold four components. The fixtures profile off-set to 90˚ angle to one another and the table is circular in shape.

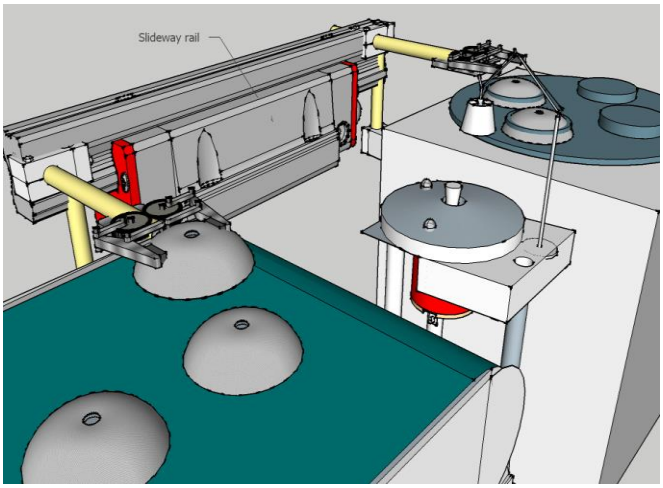

Fig 4.4 Picking Operation

At the end of exact orientation process both the manipulators are actuated by at same time, End effector II grasps the oriented housing and placed over the auto indexing fixture. Mean time end effector I picks up the new component from the conveyor and placed on the Auto-orientation fixture, further the process repeated as cyclic manner.

V. SYSTEM INTEGRATION AND FUNCTIONALITY

The block diagram Figs the integral components involved in the proposed system.

E. *Mechanical elements*

The part conveyance and handling will be carried out by the mechanical systems with corresponding drive signals.

a) Conveyor

A Belt type conveyor used to collect all semi-finished parts from the stage I machine.

b) Pneumatic Cylinder with piston rod

The reach of vacuum operated end effector is established by the linear motion offered by pneumatic cylinder.

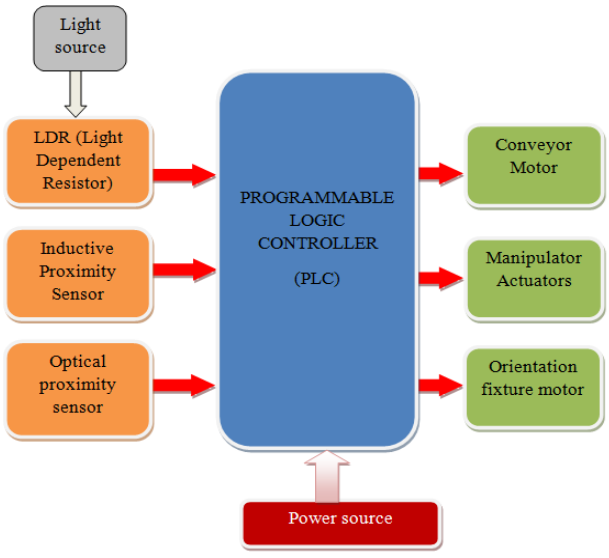

Fig 5.1 Block diagram of proposed system

c) Pneumatic actuators (Vacuum grippers)

The exclusive setup which suck the parts from the fixture of the machine and spontaneously transfer into the stage II machine fixture, which plays the proactive element of the system.

F. Electrical and Electronic elements

The main propulsion signals are arrived from the electronics devices as a feedback pulses and corresponding control signals also fed into the system to operate it.

d) Motors

With this system three kinds of motors have been deployed. They are

- Brushless DC Motor – To operate conveyor
- DC Gear Motor – Operates Auto orientation motor
- DC Servo Motor – Drive the end effectors.

e) Sensors

It is a feed forward element of the system, which provides the field device status information to master control system.

The following Sensors are employed,

- Inductive proximity sensor – To ensure the presence of horn housing in the conveyor.
- Optical proximity sensor – To operate the orientation locator, when parts are being placed.

f) Light dependent resistor

It is the major element part; it works on the principle of photo sensing mechanism. This coordinates the orientation locator according to the fixture setup arrangement.

VI. PROGRAMMING CONCEPTS AND LADDER LOGIC

The Ladder Builder is software which allows creating sequence of programs. It offers excellent functionality and advanced programming processing ability. The Ladder logic is widely used to program PLCs, where sequential control of a process or manufacturing operation is required.

Ladder logic can be thought of as a rule-based language rather than a procedural language. A "rung" in the ladder represents a rule. When implemented with relays and other electromechanical devices, the various rules "execute" simultaneously and immediately. When implemented in a programmable logic controller, the rules are typically executed sequentially by software, in a continuous loop (scan).

KV Ladder builder is the software used to implement the process control logics in PLC.

The KV Builder can simulate program execution even without a PLC connected. Providing a single step execution (forward and reverse) in addition to a regular scan execution function increases debugging efficiency.

G .Ladder Builder functions

- Editor function - Allows to create logic
- Simulator function – Execution and debugging
- Monitor function – Display of ON/OFF status.

H. Ladder Diagram

Ladder logic has “contacts” that make or break circuits to control coils each coil or contact corresponds to the status of a single bit in the programmable controller's memory. The “coil” (output of a rung) may represent a physical output which operates some device connected to the programmable controller, or may represent an internal storage bit for use elsewhere in the program.

Ladder logic is formed for following mode of operations:

- **Relay ladder logic – Auto operation program**
- **Relay ladder logic – Manual operation program**
- **Relay ladder logic – Emergency Stop program**

g) Ladder logic – Auto operation

The automatic operation ladder logic program has created for the entire functionality of the system, which operates the field devices in an independent manner and free from human interventions.

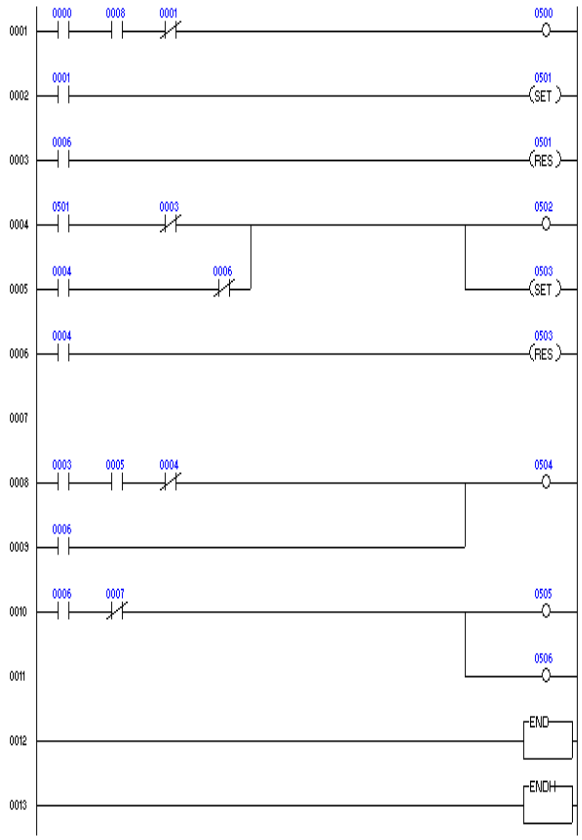

Fig6.1 Relay ladder logic – Auto operation

An auto operation program is the major ladder diagram of the designed system.

h) Ladder logic – Manual operation

Whenever the manual sequence operation is necessary instead of auto mode, the manual ladder diagram is been used. The field devices such as motors, conveyors, vacuum end effectors operations has been done individually.

Fig6.2 Relay ladder logic – Manual operation

i) Ladder logic – Emergency stop

In case of emergency conditions like malfunction of hydraulic press, improper loading, defective product flow, abnormalities observed while production the emergency stop program is being executed.

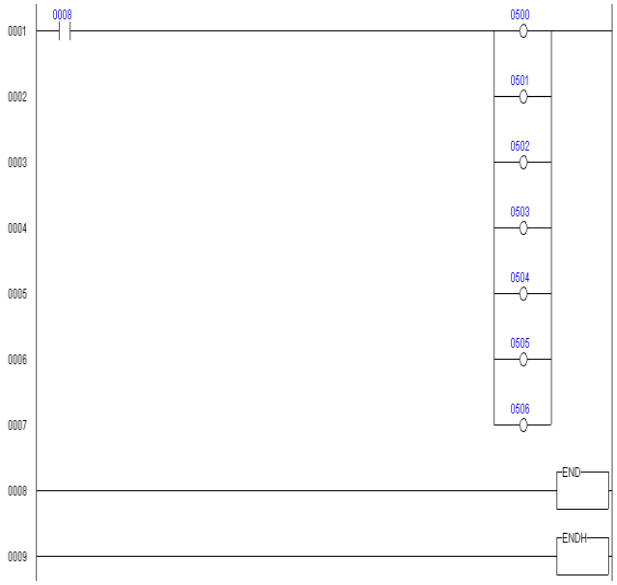

Fig 6.3 Relay ladder logic – Emergency Stop

I. I/O Descriptions

The input/output module address and their respective memory functionalities are listed below.

Table 6.1 Input Descriptions

Sl.No	Address	Description
1	0000	Main power ON/OFF
2	0001	Inductive proximity sensor-1
3	0002	Servo motor on
4	0003	Optical proximity sensor
5	0004	Limit switch
6	0005	Reed switch
7	0006	Inductive proximity sensor-2
8	0007	Light dependent resistor
9	0008	Emergency stop

Table 6.2 Output Descriptions

Sl.No	Address	Description
1	0500	Conveyor motor on/off
2	0501	Sensor signal set coil
3	0502	Solenoid valve excitation
4	0503	Vacuum source on/off
5	0504	Servo motor forward/reverse
6	0505	DC motor on/off
7	0506	Light source on/off

VII. FUTURE SCOPE AND DEVELOPMENTS

The proposed approach can be improved or modified based on the volume of production per shift by the following methods

- Deploying two sensing setups will enhance the production rate and the material conveyance speed also gets increased.
- In advanced trend of automation the Humanoid Hand can replace the entire orientation system with excellent functioning capabilities.
- Implementation of IR based photo diode can improve the positioning accuracy of the system.
- Servo motors can be employed instead of using ordinary prime movers for the better motion control operations.

VIII. CONCLUSION

Finally this innovative approach of part handling will make revolutionary changes in material conveyance, handling, loading and unloading the semi-finished part in the press shop. The system eliminates the human resources as well as improves the production efficiency, quality of parts being produced in shop floor. It will minimize the mishandling, loading rejections and unjustified scraps and rework. Thus turning up of the conventional process into an automatic way in economic manner will slashed down the expenses afford by the firm.

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