Final Effector's productivity simulation test based on Honduran textile and food production processes

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Abstract*– Current robotics advances allow optimization of logistics processes, in large industries, the implementation of manipulators make repetitive, and precise tasks easier to complete in a short period of time. Country's economy growth depends on how productive the production lines are. Honduras lacks industrial robotic implementation, due to the slow advance in optimization, industrial tasks are mostly carried out by operators who work together to complete these processes. Due to the uncertainty generated by these issues within the country, a productivity test of four end-effectors and industrial robots was carried out using a simulator, in which scenarios were designed for an individual test of each end-effector proving the optimal one for each industrial task. This study was completed using the spiral-type methodology, in which iterations concerned the textiles and food industrial scenarios, highlighting as a first option, the pneumatic operation end-effectors.

Keywords*— Robotics, end-effectors, productivity, industrial processes, Honduras

I. Introduction

Industrial robots are specially designed for repetitive activities and capable of performing jobs that are risky or complicated for humans to handle. Due to being reprogrammable, robots can perform multiple tasks, or the same, but in different ways. With the arrival of the fourth industrial revolution, new technologies appeared that optimized industrial processes; autonomous production methods powered by collaborative, flexible and versatile intelligent robots capable of working hand in hand with humans [1]. These technological advances are applied around the world, but in Honduras robotics has not caused the same impact as in other countries, the most prevalent robots are manipulators or articulated, in SPS for instance, there are less than a hundred industrial robots, including articulated ones that are used in logistic applications [2]. The main application where these machines are settled is in logistic areas, in palletizing tasks or handling products, mainly for food and car harness industries[3].

The terminal element of a robot known as an end effector is an actuator that is used to interact with objects in its environment, increasing the robot's capacity in industrial applications, reducing execution times, improving quality while handling delicate products, precisely completing tasks, among others. Grasping devices are tools that are useful to perform the loading of objects in systems for manipulation, handling, or transportation [4]. The grasping ability that these tools possess is what makes an end effector productive before any industrial task.

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There are different types of grasping, some of them manage objects by electromagnetic attraction, vacuums, gripping systems, or a combination of these [5]. Clamping characteristics indicates the type of product with which it is capable of working.

End effectors that work by electromagnetic attraction are known as Magnetic end effectors, and these are special in gripping ferromagnetic materials, they can hold objects with non-flat surfaces. Also there are two types of these terminal elements: permanent magnet and electromagnetic [6]. Another grasping type often used for vertical lifting, in palletizing, are vacuums. They attach to an object by a work force resulting from the vacuum pressure in the effective area of the pad and atmospheric pressure [7]. Referring to soft robotics, there are gripping systems made by soft materials that cooperate with the manipulation of complex and delicate tasks, meaning that due to its flexible, soft, adaptable characteristics this tool has the ability to grasp an heterogeneous surface, and withstand deformations while executing a task [8]. And with the combined tool, the various implementations you can run within the production lines are beneficial to productivity. The combined magnetic gripper, for instance, can work in different scenarios and materials, although their productivity is not the usual as when they are implemented with metallic materials [9].

Therefore, to a proper implementation of the different existing tools on industrial processes, a simulation study is required to show up how production time changes depending on the effector's attachment type, also for every stage in the process demonstrate the number of parts processed by minute in order to determine how successful the tools manipulation was handled in the process.

II. Methodology Implementation

This research study requires a spiral methodological analysis in which constant iterations of the process are made to achieve a convincing productivity study among the end-effectors tested. The iteration stages in this method are 4 (planning, risk analysis, development and implementation, evaluation.) each one is important since the observation of results in the face of the determined scenarios or variables is vital to demonstrate a precise percentage of productivity. The stages for each iteration are developed as the simulations of each scenario are carried out.

III. Results

In this section, both iterations were carried out and the result of each end effector in the different scenarios is demonstrated.

TABLE I. END-EFFECTORS

Vacuum	**Magnetic**	**Magnetic-Gripper**	**Soft Gripper**
			

Before simulations its necessary to briefly mention about the end effectors characteristics that were used in both scenarios.

- Magnetic end-effector: It is an effector that has an electromagnetic magnet, this means that as soon as the electric current is deactivated, the iron core loses its magnetization. Regarding the clamping time, it performs the grip in 0.17s and 0.2s of release it [10].
- Magnetic-gripper end-effector: They also have an electromagnet and clamps; the electromagnet is actuated by a servomotor and then the clamps ensure the grip. the minimum time in which the terminal element makes its grip is 0.1s and 0.3s to release the object [9].
- Pneumatic end-effector: The pneumatic effector used contains two bellows suction cups with shock absorbing pleats for handling more delicate products, these pleats may vary depending on the functionality requested. The type of vacuum generating source is Venturi valves, they are lightweight and compact in design, useful for any common vacuum gripping application. The grip and release time of the pneumatic end effector takes 0.4s to grip and 0.6 to release [11].
- Soft grippers: The two-finger soft grippers are used for handling food, tasks or products that are more delicate. It is made with soft and flexible materials, so that it is adaptable and appropriate to the product with which it comes into contact. It has a handling time of 0.2s and 0.4s to release the grasp [12].

TABLE II. GRIP/RELEASE TIME

Magnetic	**Magnetic gripper**	**Pneumatic**	**Soft grippers**
0.17 (sec)/0.2(sec)	0.1(sec)/0.3(sec)	0.4(sec)/0.6(sec)	0.2(sec) /0.4(sec)

A. *Textile Sector Scenario Iteration*

1) *Design*

In figure 1 is presented the design of the stage, in which two robots, the Viper1700 and Hornett565, were implemented.

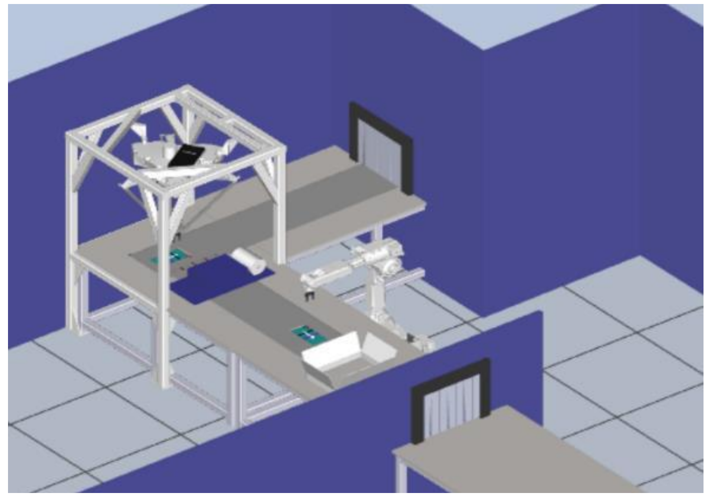

Figure 1. Textiles Scenario Design

The parallel robot grips the shirts on the first belt that moves with a speed of 75mm/s and a belt dimension of 2500mm x 500mm. The displacement range that one shirt has from another is 250mm. The robot stacks 3 shirts and these are subsequently sealed and the Viper performs the final palletizing taking the packages from the second band that moves with the same speed of 75mm / s and a dimension of 2000mm x 500mm. The range of movement between packages is 500mm.

TABLE III. TEXTILES CONVEYORS BELT INFORMATION

Conveyor 1: Hornett565	**Conveyor 2: Viper1700**
Dimension: 2500mm x 500mm V: 75mm/s Range between products: 250mm	Dimension: 2000mm x 500mm V: 75mm/s Range between products: 500mm

The grip and release time of the effectors was obtained from previous experiments, these values will be constant for all cases. Look TABLE II.

2) *Simulation*

In every simulation test, data of processed pieces and pieces lost per minute were taken, also the simulations lasted 10 minutes with each effector.

a) soft grippers: Starting with the soft grippers, in the first minute no part had yet started to be made at 10 min, 7.75 processed parts were reached. The end effector was suitable for this type of task, the material of the product and the seal did not affect the grip.

b) Magnetic-gripper end-effector: Due to the design of the electromagnet combined with grippers, the effector generates more possible applications in industrial processes, this made it possible to manipulate the sleeves, processing 7.90 pieces per minute.

c) Magnetic end-effector: The third textile simulation was carried out with the magnetic end effectors, when using this type of terminal elements, the material with which it will be worked must be considered mainly because, if this observation is not made in a textile process with materials of cotton or yield, there is no magnetic attraction therefore the effector is completely useless.

d) Pneumatic end-effector: Based on the comparative graphics, figure 2, data of the same scenario and final element are presented, the only distinction is that one performs multipick and the other Singlepick. Due to its double suction cup design and reduced volume, it easily performs double picking, speeds up the process without product accumulation. This also gives you an advantage over cycling, making it easier to cycle. This effector managed to process 7.76 pieces in the Singlepick and 7.79 with the multipick.

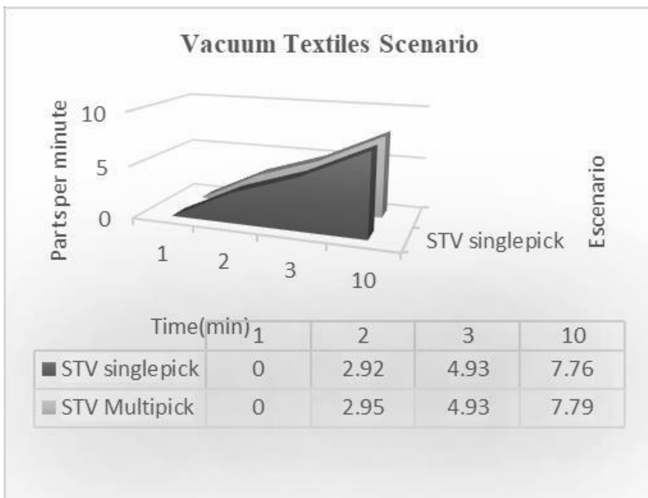

Figure 2. Graphic Demonstration of Vacuums Multipick

Results on figure 2, show not a big difference between the multipick and single pick function. Single pick means just one of the final effectors vacuums was grasping and in multipick they were both grasping material, two at a time. The speed of the conveyor belt was not adequate to take advantage of the vacuums handling speed, look TABLE III. The distance between each product could be another factor to consider, since by reducing this, you can lighten the movement of more shirts without the need to vary the speed of the belt.

3) *Schema Analysis*

Based on the productivity of parts processed per minute, vacuum is optimal in the textile scene due to the multipick applicability shown in TABLE IV. And it is a better option due to the type of suction cups that do not generate damage by gripping the packaging material.

TABLE IV. TEXTILES SCENARIO ANALYSIS

Textiles Scenario			
End-Effectors	Parts per minute(10min)	Parts not processed	Grip/release Time
Soft Grippers	7.75	0.00	0.2s/0.4s
Magnetic Gripper	7.90	0.00	0.1s/0.3s
Magnetic	0.00	248.00	0.17s/0.2s
Vacuum	7.76	0.00	0.4s/0.6s
Multipick Vacuum	7.79	0.00	0.4s/0.6s

B. *Food Sector Scenario Iteration*

1) *Design*

This scenario on Figure 3, was integrated with two robots as well, the Viper1700 and Hornett565fixed.

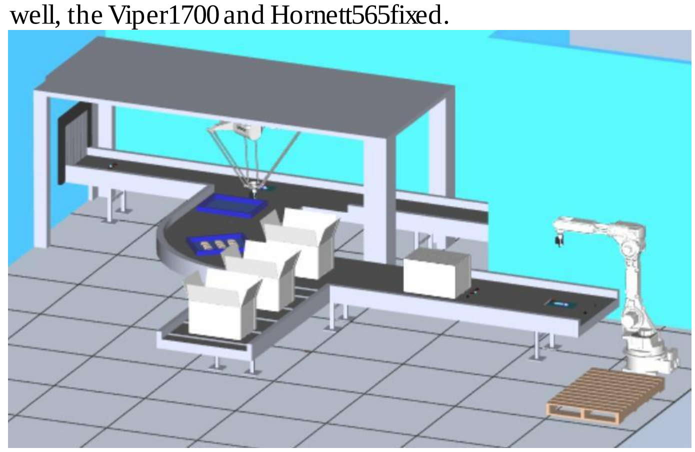

Figure 3. Food Scenario Design

The parallel robot begins to sort 12 loaves on a tray after taking the product from the first belt that moves with a speed of 75mm / s and a belt dimension of 3000mm x 250mm.
The range between loaves is 100mm. The second belt in which the Viper works, it operates with the same speed of 75mm / s, but its dimension differs with 1300mm x 250mm and a range of 1550mm.

2) *Simulation*

a) Soft grippers: The soft gripper is ideal for this type of industrial process because its flexible material allows the handling of fragile products with greater safety, therefore, the handling of the product was successful without affecting the bread. In this scenario, the viper1700 robot could not perform its palletizing task due to the difference in dimensions between the tool and the box. The parallel robot made 22.70 parts processed and 244 lost, the viper1700 lost 28 of those parts over the course of 10 minutes. In canned food the process was easily finished with the same number of parts per minute, but using higher force, 15.4N max to lift a can.

b) Magnetic gripper end-effector: The bread stage is not suitable for this type of effector, firstly, because the bread does not generate magnetic attraction, but the fact of containing clamps, theoretically put to the test if they manage to grip the bread as a soft clamp. Either way, the contact of the magnet with the food is inappropriate, being a corrosive material, the oxide would contaminate the quality of the product. The simulation was run anyway and 24.97 pieces per minute and 210 pieces lost were processed, 28 of those pieces were lost by the viper because it could not palletize either due to the difference in dimensions. As for canned food results were the same but cans were precisely manipulated due to the grippers fitting the cans top.

c) Magnetic end-effector: It was useless to bread manipulation; it lost all the pieces. Previously it was analyzed the characteristics, behavior, and possible scenarios in which these grip effectors with magnetic attraction are more profitable, in this way with the study of said effector it could be intuited the negative performance it would have. The simulation was carried out in the same way that it was carried out with the others and in the first 60 seconds it was found that the magnetics cannot handle products that are not made of ferromagnetic material. Although the robot used is programmed to perform a specific movement with the actuator, it will move, but it will not perform the grip anyway. Meanwhile, canned food manipulation was easily carried out it did a total of 24.56 parts per minute and lost 210 pieces in 10 min.

d) Pneumatic end-effector: For the last simulation, the multipick function was performed only with the parallel robot, because the viper1700 performs a palletizing with a larger object, the difference in sizes requires to do just a single pick.

With the multipick function, the suction cup processes a total of 14.37 ppm, 0.87 parts are processed by the viper1700 and 13.45 by the Hornett.
Then it is simulated again, but with both effectors performing the single pick and this processes 14.29 pieces in 10 minutes and 0.90 of those pieces are processed by the Viper and 13.39 pieces by the hornet. To mention both canned food and bread did the same number of parts per minute but differ in the force required to do the gripping, for canned food a max force of 23.2N and for each loave just 1.1N

3) Schema Analysis

For the bread scenario based on the productivity of processed pieces, the magnetic grippers appear to be the one that manages the most pieces to process due to its holding time, look TABLE II, this gives it an advantage over the other effectors, but it is not the most suitable for handling food, for making the soft gripper the best option.

TABLE V. LOAVES AND CANNED FOOD SCENARIO ANALYSIS

Loaves Scenario			
End-Effectors	Parts per minute(10min)	Parts not processed	Grip/release Time (Sec)
Soft Grippers	22.70	242.00	0.2s/0.4s
Magnetic Gripper	24.97	210.00	0.1s/0.3s
Magnetic	0.00	455.00	0.17s/0.2s
Vacuum	14.29	0.00	0.4s/0.6s
Multipick Vacuum	14.37	0.00	0.4s/0.6s
Canned Food			
End-Effectors	Parts per minute(10min)	Parts not processed	Grip/release Time (Sec)
Soft Grippers	22.70	242.00	0.2s/0.4s
Magnetic Gripper	24.97	210.00	0.1s/0.3s
Magnetic	24. 56	729.00	0.17s/0.2s
Vacuum	14.29	0.00	0.4s/0.6s
Multipick Vacuum	14.37	0.00	0.4s/0.6s

Overall, the first scenario figure 1, concerned by textile industry and the simulation was carried on, getting 7.79 shirts processed per minute in a 10-minute simulation by the pneumatic end-effector see TABLE IV and TABLE VI, using the multipick. The vacuums suction cups are specially designed for heterogeneous surfaces, giving them the ability to grip the film with a vertical lifting force of 2.5N.
Meanwhile magnetic grippers task required lifting a mass of 0.125kg. It performed 7.90 pieces processed per minute in a total of 10 min.
Grippers did a total of 7.79 pieces per minute in a total of 10 min, and the normal force with which the griper acts, considering 0.6 of coefficient friction, was 1.025N.
The magnetic end-effector couldn’t process any due to its physical characteristics, in terms of productivity the second scenario was appropriate to its functionality.

The food industry scenario figure 2, includes the processing of bread and canned food, it was the second iteration of this study.

As a first test, a pneumatic effector was implemented, both in the handling of canned food and bread, this pneumatic tool processed 14.29 pieces per minute and worked with a retention force of 23N for the cans and 1.10N to manipulate each bread see TABLE V and TABLE VI. Due to rough surfaces, the bread had a coefficient of friction of 0.6 and the cans 0.5 because they had a smoother surface.

On the other hand, the magnetic grippers end- effectors processed 24.97 parts processed per minute. The manipulation of the cans was more precise due to the structure of the effector, the work carried out by lifting the cans was 1.73J and 0.03J for each bread, the manipulation with the parallel robot was carried out without interruptions, but the Viper did not I managed to palletize with this type of tool due to the difference in dimensions between the box and the effector. Now with the magnetic final effector, this was not useful for the bread scenario, but with the canned food it processed 24.56 cans per minute.

TABLE VI. THEORETICAL HOLDING FORCE OF A SUCTION CUP

Safety Factor S:	1.5	Smooth and non-porous parts
	2,0	non-homogeneous critical parts
Friction Coefficient μ:	0,2 - 0,3	Wet surfaces
	0,5	wood, metal, glass, ston
	0,6	Superficies rugosas
Horizontal suction cup vertical force		
	FTH	Theoretical retention force [N]
	m	Mass[kg]
	g	ground acceleration [9,81 m/s2]
	a	Installation acceleration [m/s2]
	S	Safety Factor

The theoretical holding force of a suction cup and other material friction coefficient was shown by author [13].

IV. DISCUSSION

The implementation of robotics issue brings with it the use of adequate tools in the performance of industrial tasks, the optimization of these processes would help the demand that each manufacturing company presents. Optimizing the productivity of different Honduran industrial processes through the application of robots is one way in which robotics would help the Honduran industry grow. As previously demonstrated, the robots and the use of the appropriate final tools in the manufacturing processes, streamlined the production tasks and the handling of products was precise while maintaining their quality.

Also, end effector designs have been made by university graduates, each implementing a specific task, with applications that contribute to the productivity of industrial processes, such as the magnetic end effector that can control energy saving energy consumption and grasping force. The design of soft clamps based on an elastomer especially for the handling of vegetables, this design contributes to the optimization of the agricultural industry, due to the material it was adapted to the different sizes of the vegetables. There were some end effectors that manipulate tomatoes and had a combined design of a vacuum and a 4-fingered tool [14]. The author [15] also implemented a soft robotic gripper for the manipulating nonrigid material like in bakery industry, because traditional rigid grippers were too rigid for handling bread, affecting its quality. The bellows suction cups especially designed for heterogeneous surfaces [3].

Another author was found who performed an increased soft-rigid clamp with an electromagnet to handle clothes precisely [9]. The applications of these tools facilitate industrial processes, and some could be used in different industrial sectors. Therefore, a productivity study of different terminal tools is needed and to demonstrate the applicability of each one.

Magnetic end effectors were given the task of handling canned food because this effector matches the energy consumption to each type of weight, it is beneficial because different sizes of canned food can be processed. This effector was mounted on the cobra 350 robot and made a total of 22.16 parts per minute. Compared to the current test the result was 24.56 pieces per minute, with a difference of 2.4 pieces.

The magnetic gripper end-effector, for the manipulation of the shirts, this added a magnet in the fabric so that the effector could easily grip the piece, 5/5 attempts were successful, there were no failures in the grip, a result that resembles the current test. The effector made a total of 7.90 pieces per minute without losing any. The implementation of the magnet is advantageous for gripping due to the precision that the effector would have when gripping a specific point on the fabric.

The soft gripper for handling cupcakes did approximately 12 parts per minute, the difference in the distribution of each bread gave this result, while in the current one it was distributed in order, therefore it achieves the manipulation of 23 parts per minute. The test carried out with the suction cups resulted in an average of 18.31 pieces processed per minute.

V. CONCLUSION

Through the designs carried out, it was possible to simulate both industrial scenarios, allowing the productivity analysis of each end-effector. Soft grippers stood out as those indicated for the bread scenario, their elastic material allowed an adequate handling of the bread, with a total of 22.70 pieces per minute. For the processing of cans, the magnetic gripper was indicated by the precision of its grip, and for textiles, the suction cup with its multi-grip function. More simulations can be done using softwares like MATLAB and solidworks to validate energy consumption and mathematical models [16].

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