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Effect of 6-Axis Robot Speed on Cycle Time and Accuracy as Pick and Place Media on Dummy CNC

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ABSTRACT

This study investigates the impact of a 6-axis robot's speed on cycle time and accuracy in pick-and-place operations integrated with CNC machines. As Industry 4.0 emphasizes automation and efficiency, optimizing robotic performance in manufacturing processes is critical. The experiment tested five speed variations (20%, 40%, 60%, 80%, and 100%) to analyze their effects on cycle time and placement accuracy. Results demonstrated a significant reduction in cycle time as speed increased: from an average of 66.45 seconds at 20% speed to 26.83 seconds at 100%. However, maximum speed (100%) introduced vibrations, causing placement errors and robot failures due to excessive force detection. In contrast, 80% speed achieved an optimal balance, maintaining high accuracy (no errors) with a cycle time of 29.07 second, only 2.24 seconds slower than 100%. The study concludes that while higher speeds enhance productivity, 80% is recommended as the default setting to ensure precision and operational reliability. The integration of sensors, grippers, and automated door control further validated the system's effectiveness in industrial CNC applications.

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1. INTRODUCTION

The current industrial development has entered Industry 4.0, where the current industry has integrated advanced technology and automation in industrial activities [1]-[2]. The development is very rapid, which can be seen from the greater need to increase productivity and require better effectiveness to maintain product quality [3]-[4]. One innovation that has received attention is the integration of pick and place systems with CNC (Computer Numerical Control) machines using robots [5].

A robot is an automation tool that combines computers, controllers, mechanical systems, electrical circuits, and sensors [6]. Robots can perform physical tasks under human control and supervision based on a set of defined programs [7]. There are many different forms of robots that can be adapted to their functions. One type of robot that is widely used is a 6-axis robot, which has 6 degrees of freedom [8]. To implement robots in industry is to make robots as media or pick and place operators [9]. Robots can perform tasks with speed, efficiency and a high degree of accuracy [10].

Pick and place is a process to move workpieces from one position to another with high precision [11]. To support the pick and place system, an end effector is needed, the type of end effector used is a mechanical gripper which is finger-shaped to clamp the workpiece [12]. Mechanical gripper type end effectors are commonly used because of several advantages, which are stronger and more stable in clamping or gripping the workpiece [13].

The use of a 6-axis robot as a medium in the pick and place process on a dummy CNC (Computer Numerical Control) machine plays an important role in production efficiency [14]. Here, the speed of the robot in performing its tasks is the main factor affecting the cycle time, which is the time required to complete a production cycle (picking up, moving and placing objects). Efficient cycle time not only increases productivity, but can also reduce overall operating costs [15]-[16].

The integration of 6-axis robots as pick and place media on CNC machines offers great potential for improving the precision and accuracy of the material handling process [17]. Sensors also play an important role in the system to support real-time decision making, enabling rapid adjustments to changing conditions in the production environment. An integrated automation system can produce higher quality and consistent output [19].

2. METHOD

For the design and assembly of this tool, it is done by adjusting to the needs of the entire system. System design is used to determine the components of the tool to be made. So that the final result of the component will be in accordance with what the tool needs, Figure 1 is a block diagram of the working system scheme, which has 3 inputs, 3 outputs connected to the actuator and a PC. Based on Figure 1 of the entire system, the function of each component is as follows:

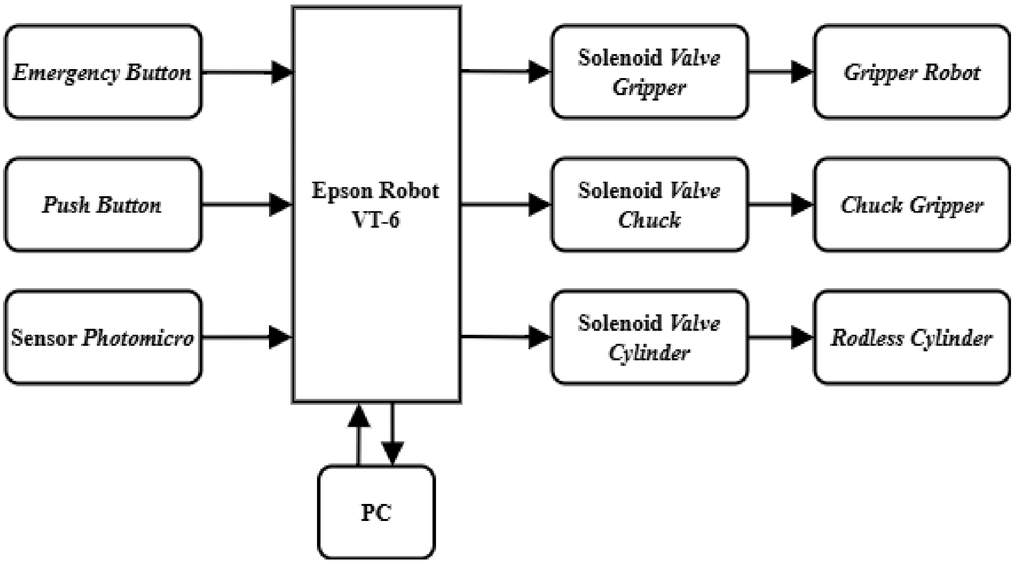

Figure 1. Block Diagram

1. Emergency button that acts as a contact breaker on the robot to prevent crashes during setup.
2. Push-button that acts as a contact to run and reset the robot.
3. Photomicro sensor that acts as a sensor that detects the state of the door on the CNC machine, whether it is open or closed.
4. Epson VT-6 robot, which is a media or operator to pick and place on a CNC machine. This robot is already equipped with a controller, so it does not need an external controller.
5. Solenoid valve that functions as an air flow controller to supply air needs to the cylinder. When a voltage is applied to the valve, the valve opens and the cylinder closes.
6. Robot gripper and chuck gripper, which functions as an end effector or actuator to pick up and clamp the workpiece.
7. Rodless cylinder functions as an actuator to automatically open and close the door on the CNC machine.
8. PC functions as a medium to program the robot..

The operating principle of the tool and robot focuses on the use of inputs and outputs as the main controllers that provide instructions to the robot, sensors, magnets, and grippers. The process begins with sensors sensing the state of the work environment and sending input signals to the robot controller. The controller then processes the signal and executes a predefined program, sending output signals to various components such as the gripper and solenoid. Once the robot moves to the specified workpiece position and grips it, the controller sends a signal to open the CNC door. Once the door is open, the robot can enter the CNC machine to place the workpiece on the automatic chuck. When the machining process is complete, the robot returns to pick up the machined part and return it to the home position, this cycle continues until the stop button is pressed.

This entire cycle can be seen in Figure 3, which is a flowchart as a description of the steps and logic of the system, where the number 1 indicates active status and 0 indicates inactive, thus providing a clear picture of the program's workflow. This flowchart is made to make it easier to understand the working principle of the tool. With the flowchart, it can be clearly shown how the stages of the process carried out by the tool when working. In addition, with the flowchart, the flow of all system movements will be clearer and more concise. Figure 2, it is a sketch diagram of the robot's position.

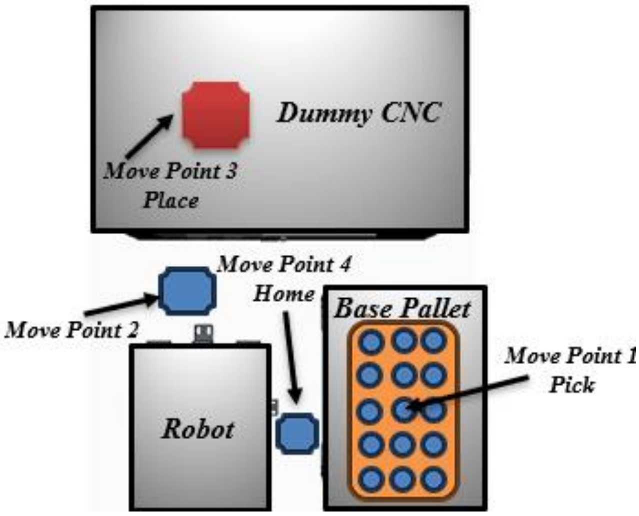

Figure 2. Sketch Diagram of the robot's position

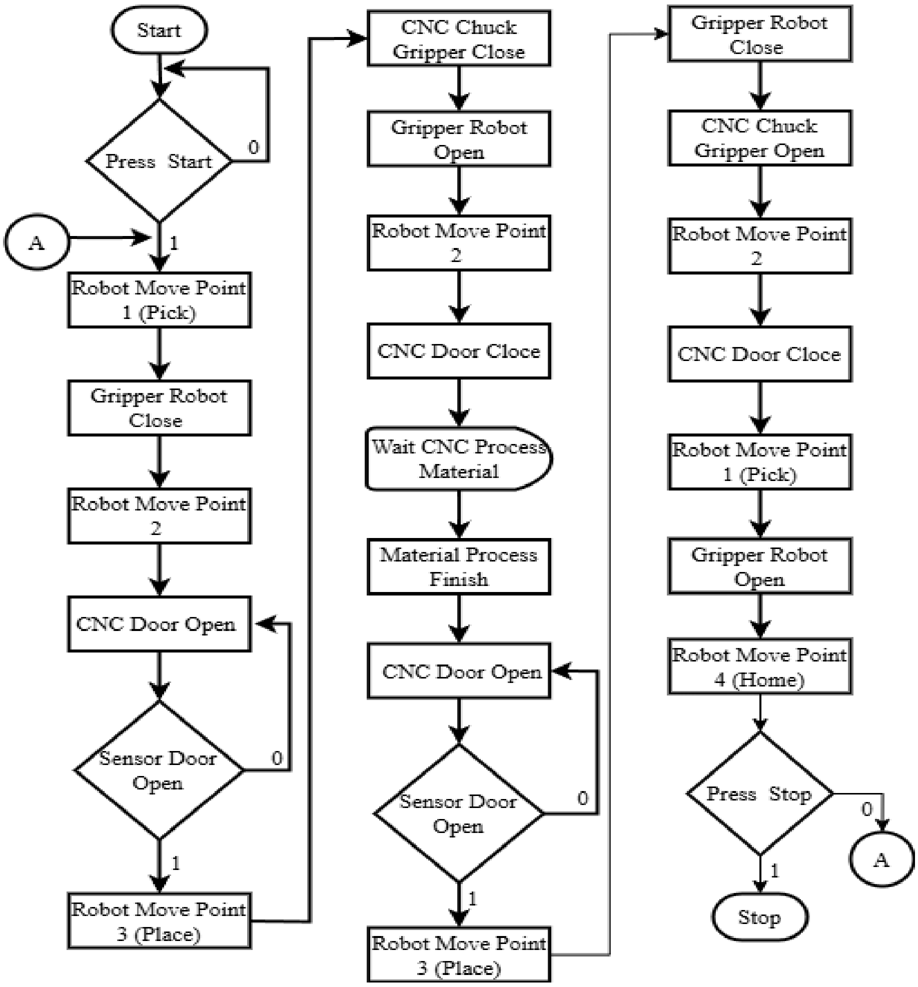

Figure 3. Flowchart System

3. RESULT AND DISCUSSION

Testing the Effect of 6-Axis Robot Speed Implemented on CNC Machines on Cycle Time and Accuracy aims to determine and compare the time and accuracy of robots in pick and place operations on CNC machines. The robot test uses 5 speed variations that can be set in the robot program, for speeds of 20%, 40%, 60%, 80% and 100%. The use of the selected speed is the result of considering the robot's space, load, and the size of the workpiece and gripper.

Table 1. Average Cycle Time Speed 20% - 80%

NO	*Speed*	Average Cycle Time	Action
1	20%	66.45 s	Good
2	40%	41.45 s	Good
3	60%	33.4 s	Good
4	80%	29.07 s	Good

Table 1 shows the average data from 20% speed to 80% speed, which at 20% speed has an average cycle time of 68.68 s. The 20% speed takes too long to complete a cycle, but it is very good for pick and place accuracy with no errors or missed placements. In addition, the robot's cycle time at 40% speed increases significantly compared to 20% speed. The average cycle time required to complete a cycle is 44.12 s. This increase in speed does not affect the robot's pick and place accuracy.

At 60% speed, the average cycle time for the robot to complete a cycle is 35.27 s, which is better than at 40% speed. At this speed, the robot's pick and place accuracy is still very good, with no errors that cause the robot to miss a placement. The 60% speed can be used as a default speed on the robot as a medium for performing pick and place on the CNC. Furthermore, at 80% speed, the accuracy of the robot in performing pick and place is still very good without any miss placement or error. The average cycle time required to perform a cycle is 30.59 s.

Table 2. Speed 100%

NO	*Cycle Time* (s)	*Error*	Action
1	27	No Error	Good
2	27.05	No Error	Not Good
3	26.82	No Error	Not Good
4	26.67	No Error	Good
5	26.72	No Error	Not Good
6	26.75	No Error	Good
7	26.78	No Error	Good
8	-	Error	Not Good
9	27	No Error	Good
10	26.89	No Error	Good

Table 2 shows data from 100% speed. At this speed, the cycle time required for the robot to complete 1 cycle is about 26.83 s. The time difference between 100% and 80% speed is not too far, only 2.24 s. However, at this speed, the accuracy of the robot in performing pick and place is very poor due to the vibration generated by the robot as it moves, resulting in errors due to missed workpiece placement, which causes the robot to fail, or force stop because the robot detects excessive force when placing the workpiece, it is shown in figure 4.

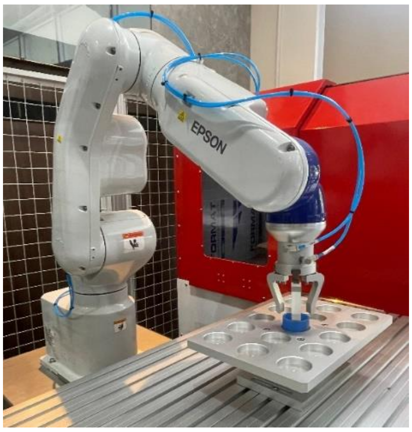

Figure 4. Robot Error and Was Force Stop

In the 2nd and 3rd cycle, there was an error in placing the workpiece on the pallet, which caused the workpiece to rub against the pallet. On the 5th cycle, when the robot was about to pick up the part on the chuck dummy CNC, the robot gripper rubbed against the part due to the vibration generated by the robot. In the 8th cycle, an error occurred when the robot was about to place the workpiece on the pallet, this happened because the vibration generated by the robot worsened the position of the placement point on the pallet, so the placement point shifted and was not precise, resulting in an error and the robot died due to excessive force caused by the imprecise placement of the workpiece. Therefore, 100% speed cannot be applied to the robot as the speed for pick and place on the dummy CNC.

When the robot is operating at 80% speed, it can complete the task of placing the workpiece accurately and without making any mistakes. The robot's accuracy in picking and placing tasks did not decline throughout the course of the ten tests, and it remained well-maintained. As previously said, the 100% pace is insufficient for completing the select and place assignment. Therefore, the best speed to use when the robot is doing pick and place is 80% at the maximum speed and 60% at the lowest speed.

Figure 5 is a graph of the average cycle time test results from 20% to 100% speed that was tested, and Figure 6 is a graph of the accuracy test results from 20% to 100% speed. The graph is obtained from the author's test data. This test was conducted at the Teaching Factory of Industrial Robotics and Automation, Universitas Negeri Padang.

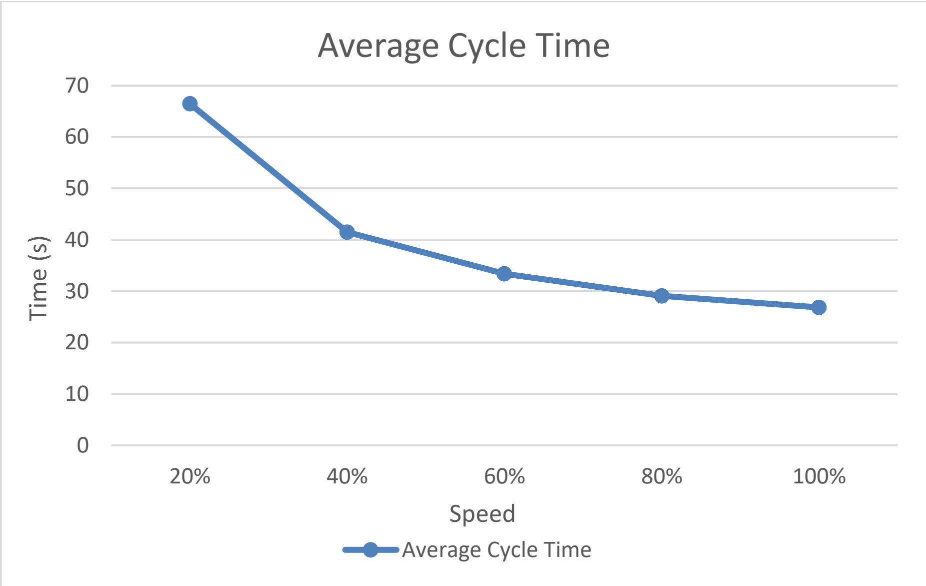

Figure 5. Cycle Time Testing Graph

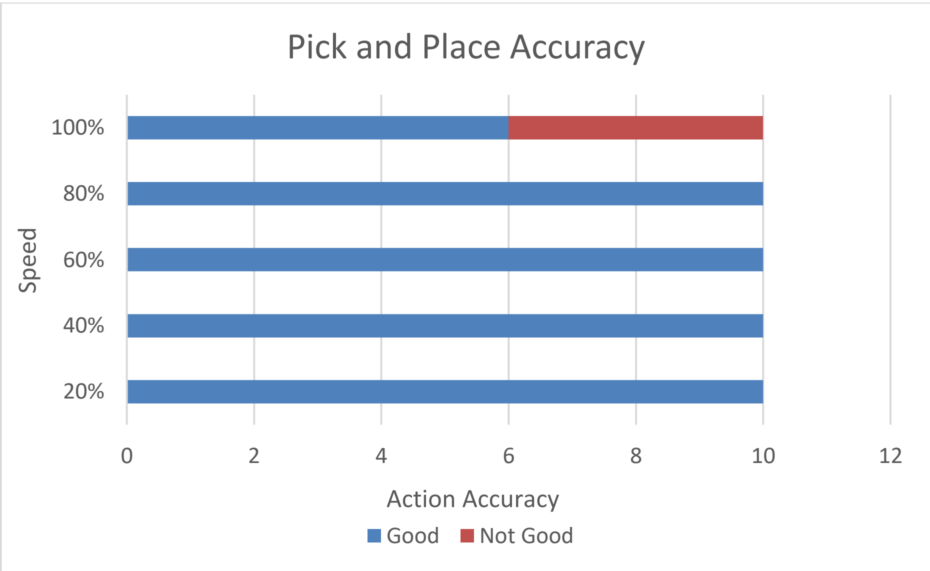

Figure 6. Accuracy Testing Graph

4. CONCLUSION

From the tests carried out, namely testing the speed of the 6-axis robot against cycle time and accuracy as a pick and place media on CNC, the data obtained that the speed of the robot is very influential on the cycle time. Where the higher the speed of the robot, the shorter the cycle time of the robot to do 1 cycle. However, high speed can affect the quality of the robot's accuracy in picking and placing, as evidenced at 100% speed there is a miss placement because the position of the workpiece shifts due to the vibrations produced by the robot, which causes the robot to fail and die because the robot detects excessive force (exceeding the 6Kg limit). Therefore, the maximum speed that can be recommended to be used as the default speed on the robot is 80%, because the quality of the robot's accuracy in picking and placing is quite good without any miss placement and the time needed to complete 1 cycle is not much different from 100% speed.

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