De-stacking Mechanism in PLC

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***Abstract*—A Programmable Logic Controller (PLC) is a specialized computer system commonly used in industrial automation applications, specially designed to control and monitor machinery and processes in manufacturing plants, power generation facilities, and wide usage in various other industries.**

PLCs are used to automate tasks that were previously performed by human operators or mechanical systems since they are programmed to execute specific tasks, follow predefined logic, and respond to inputs and outputs. In this paper, we are going to discuss the relationship between PLC and the de-stacking of automated raft cleaning mechanisms.

Keywords—PLC, raft cleaning, pneumatic system

I. Introduction

The de-stacking mechanism, controlled by a PLC, is responsible for accurately and efficiently removing items from a stack. The stack can consist of items such as boxes, pallets, or other objects. The PLC-based control system coordinates the operation of various components involved in the de-stacking process, ensuring precise and reliable performance. In a de-stacking mechanism, components such as sensors, actuators, conveyors, inputs, and outputs will be discussed further.

II. SOLIDWORKS Prototype

A. Lifting cylinder part

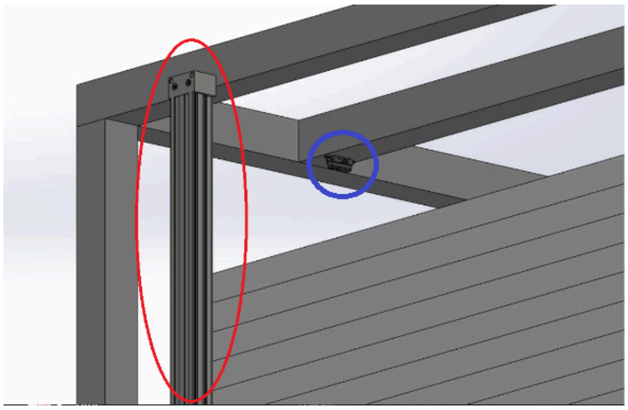

Fig. 1. Cylinder used for lifting the rafts.

Based on the red highlighted part of Fig.1, SMC MY1B20-2000 cylinder which is a double-acting cylinder is used for lifting the stacked rafts with upward and downward motions. This cylinder consists of 2 valves, namely valve 1a and valve 1b. The blue highlighted part of Fig.1 is the distance sensor used to detect when the raft reaches the top to be de-stacked onto the conveyor belt. The sensor used in this de-stacking system is GP2Y0A21YK0F.

B. Destacking cylinder part

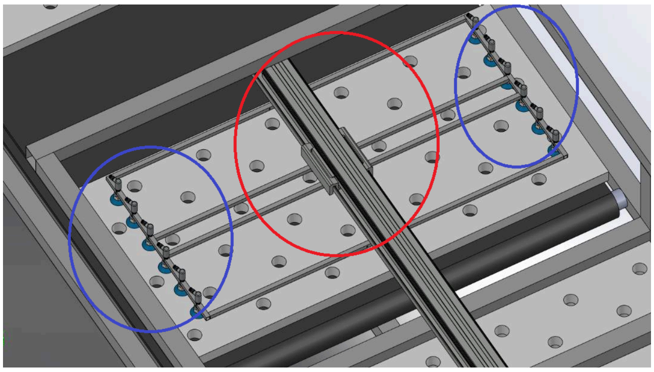

Fig. 2. Cylinder and suction grips used for the de-stacking process.

Based on the red highlighted part of Fig.2, it is the SMC MY1B20-1000 cylinder, it is also another double-acting cylinder used for forward and backward motion. This cylinder consists of 2 valves, namely valve 3a and valve 3b. Furthermore, the blue highlighted part of Fig.2 is the suction grips that consist of 1 valve, namely valve 2a.

C. Overall design of de-stacking system

Fig. 3. Complete de-stacking design

As shown in Fig.3, the complete de-stacking design with all the cylinders and suction grips assembled together. The de-stacking system can de-stack up to 55 rafts in one process. When valve 1a is on, the lifting cylinder will extend and move in an upward direction to lift up the rafts and when the rafts get detected by the distance sensor, valve 1a will be switched off and the lifting process will be stopped. At the same time, it will trigger valve 3a and valve 2a to be switched on, this process will move a raft from the stacked rafts to the conveyor belt. After the cylinder in Figure 2 extends completely, valve 2a and valve 3a will be turned off which releases the raft onto the conveyor belt. This is followed by triggering valve 3b which restores the position of the cylinder to pick up the next raft. Valve 1a will also be triggered again to lift up the next raft to be de-stacked onto the conveyor belt from the stacked rafts. This process will be repeated until all 55 rafts are completely de-stacked. After all rafts are de-stacked, valve 1b will be triggered and the lifting cylinder will restore to its original position to continue the next de-stacking process.

III. Operational Flow and Pseudocode

After we had done the mechanism prototype in SOLIDWORKS, we converted the operation flow into pseudocode for better understanding and more simplicity for PLC.

A. *Operation flow*

Assume there are 10 rafts that need to be de-stacked for an automated raft cleaner. The 10 rafts are stacked together in their original position. When the start button is pressed, the vertical pneumatic cylinder extends and pushes upward. This action activates the up counter, which begins counting up from 0 to 10, and denotes 10 as the maximum number of the raft. Sensor detector 1 (sensor) and base sensor constantly remain on, but when the vertical pneumatic cylinder reaches a certain level, sensor turns off and the cylinder stops its motion. At the same time, the horizontal pneumatic system initiates (extends) and pushes the raft onto the conveyor. This extension process takes 8 seconds, while the retraction takes 6 seconds. Then, a vertical extension happens to push the raft upwards. The counter increases by 1. The process repeats again from the vertical pneumatic cylinder extends and pushes upwards until the counter reaches 10. Finally, the vertical pneumatic cylinder retracts until the base sensor is triggered.

B. *Pseudocode*

Procedure: De-stacking mechanism
Input: start button, 1 stack of 10 rafts (represented by count), 2 sensors (sensor and base sensor)
Output: 10 separated rafts

```
begin
    Start == 1 // start button pressed
    Conveyor == 1 // activated
    sensor == 1 // sensor on
    base sensor == 1 // sensor on
    count = 0 // up counter & no raft is loaded
        while count ≤ 10 // assume 10 raft only
            vertical pneumatic cylinder extends
            if      sensor = 0 // sensor triggered
            vertical pneumatic = 0 //  stop
            horizontal pneumatic cylinder extends
            8 seconds
            horizontal pneumatic cylinder retracts 6
            seconds and vertically extends for 2
            seconds
        count +=1
        end while // 10 rafts are loaded
    vertical pneumatic cylinder retracts // restore position
        if      base sensor = 0// sensor triggered
        vertical pneumatic cylinder = 0 //stop motion
        end if
end
```

From the pseudocode, noted that the conveyor is activated for the consecutive process, for instance, cleaning, drying, and stacking.

IV. Programmable Logic Controller (PLC)

After the operational flow and pseudocode is successfully created, we start to design PLC by using plcfiddle.com and Mitsubishi FX-TRN-BEG-E.2.

A. *PLC ladder diagram in plcfiddle.com*

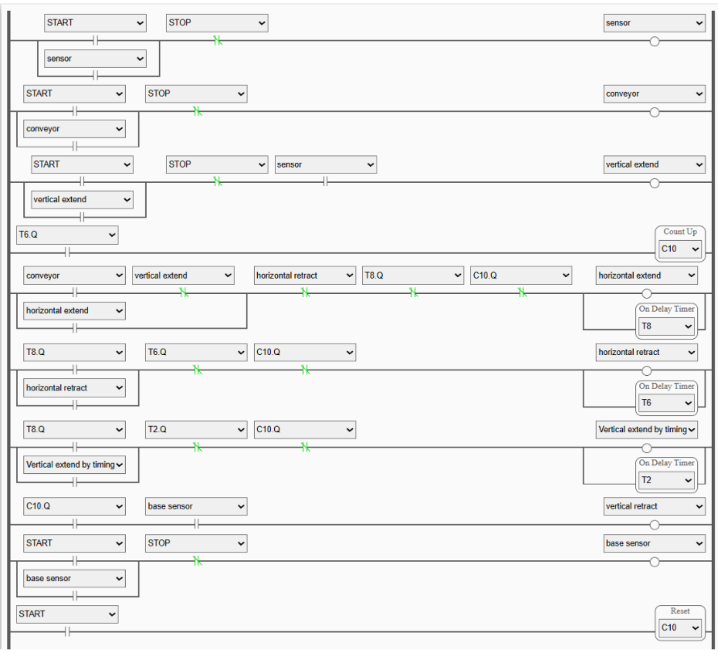

Fig. 4. Overview of PLC ladder diagram on plcfiddle.com

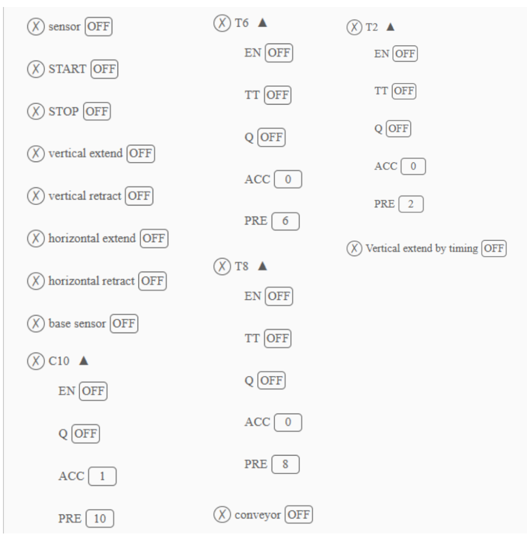

Fig. 5. plcfiddle.com tag list

In this PLC design, we have 2 sensors, namely sensor and base sensor, 5 types of actuation, 1 up counter with preset of 10, 3 on delay timer for 8, 6 and 2 seconds respectively, and 2 push button for start and stop signal. The 5 types of actuation include 'vertical extend', 'vertical retract', 'vertical retract by timing', 'horizontal extend' and 'horizontal retract'. In its initial state, all signals will be off and no actuation happens. We can divide its operation into 3 stages based on 3 important signals, which are the start, sensor, and a done signal from the counter C10.

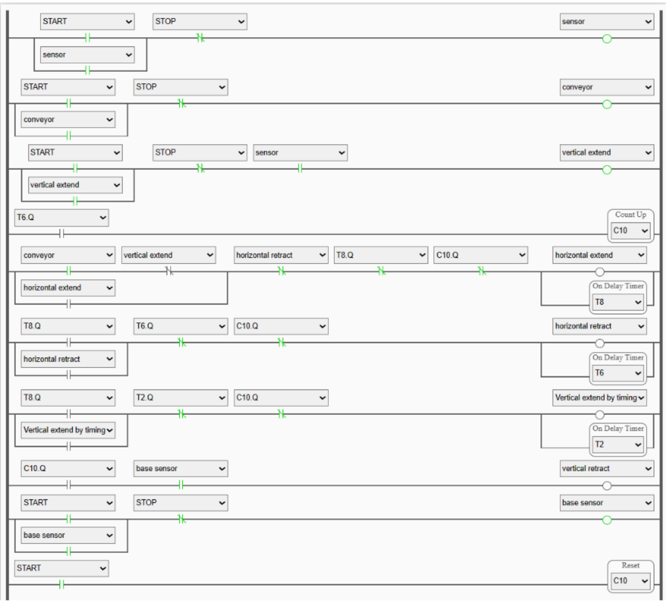

Fig. 6. The start signal is available to the PLC circuit.

When the start signal is provided, the conveyor, sensor, base sensor, and the reset for the counter will be triggered to change from 'OFF' to 'ON' state while the counter will be reset to 0. Since the START is representing a push button, it will bounce back from 'ON' to 'OFF' when it's not pressed. Meanwhile, the conveyor, sensor, and base sensor still activate due to a latching connection, unless a stop signal is given. Note that when the start signal is provided, the 'vertical extend' will activate simultaneously.

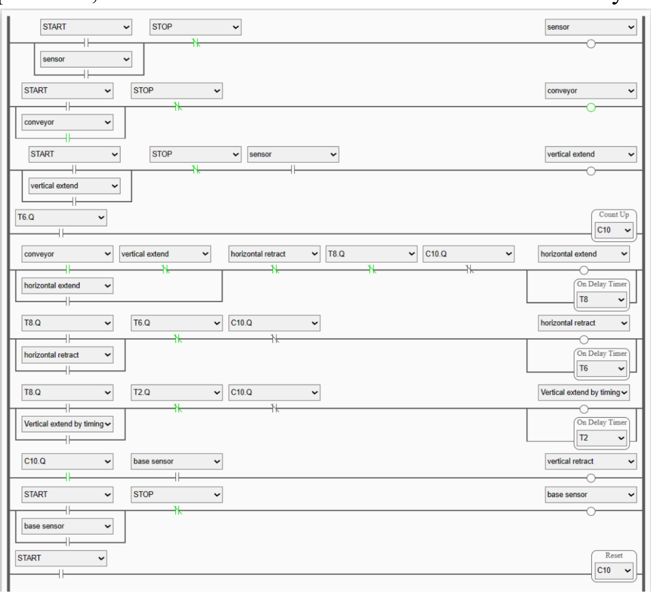

Fig. 7. The sensor is 'OFF' and the vertical extension stops.

When 'vertical extent' reaches a certain level, the sensor will be blocked and turned 'OFF' and this stops the motion of 'vertical extent'. At this stage, the 'horizontal extension' will be activated, pushing the raft towards the conveyor in 8 seconds. This was followed by a 'horizontal retraction' in 6 seconds, as well as a 'vertical extend by timing' in 2 seconds to push the raft vertically upwards again. When 'horizontal extend' is 'ON', 'horizontal retract' and 'vertical extend by timing' is 'OFF', and vice versa, except the 'vertical extend by timing' just activated for 2 seconds when the 'horizontal retract' is 'ON'. When the timer is done for 'horizontal retract', this will be counted as a complete cycle by counter 'C10'. The cycle starts again from the actuation 'horizontal extension' for 8 seconds, until the counter sends a done signal, 'C10.Q'.

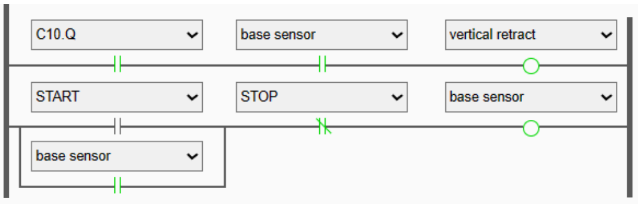

Fig. 7. The base sensor is always 'ON' and the vertical retraction happens when the counter sends out a done signal. Base sensor 'OFF' when vertical retraction blocks it.

'C10.Q' will activate the 'vertical retract' until the 'base sensor' is blocked, or turned 'OFF'.

B. *PLC ladder diagram in Mitsubishi FX-TRN-BEG-E.2*

The PLC ladder diagram in Mitsubishi FX-TRN-BEG-E.2 is similar to plcfiddle.com. The labels are shown in Table 1 below.

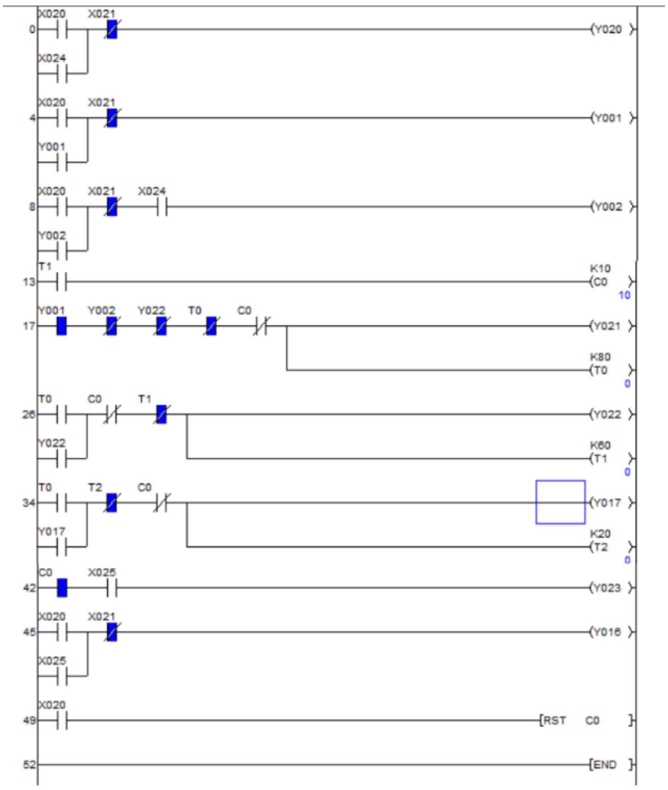

Fig. 8. PLC ladder diagram in Mitsubishi FX-TRN-BEG-E.2.

In Mitsubishi, the start button is X020 (PB1), while the stop button is X021 (PB2). In the Mitsubishi ladder design, the sensor is Y20 and X24. For Y20 is the output variable (receiver) to receive any reaction from the input. While X24 is the input variable (sender) to send the data to the output variable. Actually, the conveyor is labeled as Y001 and the vertical extend is Y002. Timer T6 is labeled as T1 while Timer T8 is labeled as T0 and also T2 remains T2. The CoK10 is counter for 10, while Y21 and Y22 are horizontal extend and horizontal retract. Y017 is the timing for vertical extending. Then the base sensor is Y016 and X25. In addition, Y23 is vertical retract and RST C0 is reset counter.

TABLE I. COMPARISON OF TAG LABELS IN 2 PLATFORMS

Label In plcfiddle.com	**Label in Mitsubishi**
START	X020 (PB1)
STOP	X021 (PB2)
sensor	Y020 (output indicator), X024 (input control)
conveyor	Y001
vertical extend	Y002
T6	T1
T8	T0
T2	T2
C10	C0 K10
horizontal extend	Y021
horizontal retract	Y022
vertical extend by timing	Y017
base sensor	Y016 (output indicator), X025 (input control)
vertical retract	Y023
RST counter	RST C0

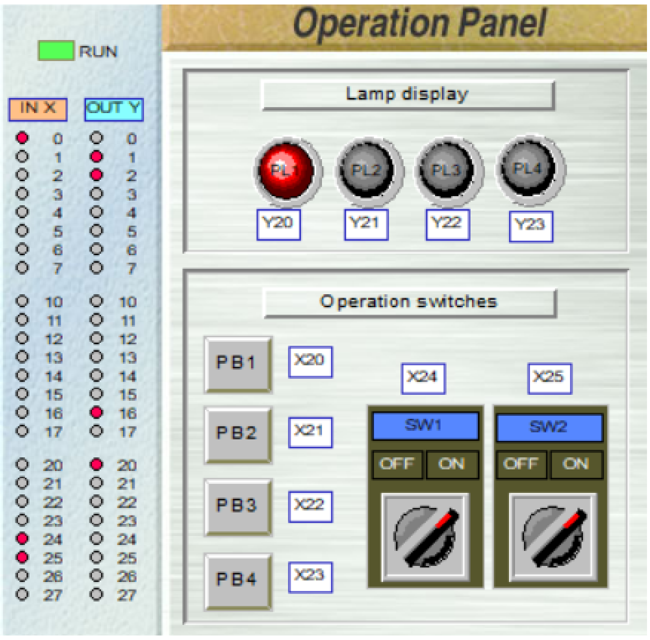

Fig. 9 . The PB1 X20 is pressed and X24 and X25 are available

When the X20 (PB1) is pressed, the Y01 (conveyor), the Y20 (sensor), the Y02 (vertical extend) and Y016 (base sensor)are triggered and showing the red light as Fig.9. The lamp displays Y20 is lit up due to a latching connection. The Y20 light up represents the sensor being triggered while the Y02 represents the vertical extend. From the design aspect, when the Start button is pressed the conveyor and sensor are triggered. The rafts are pushed by the vertical extend when the vertical extend reaches the maximum level.

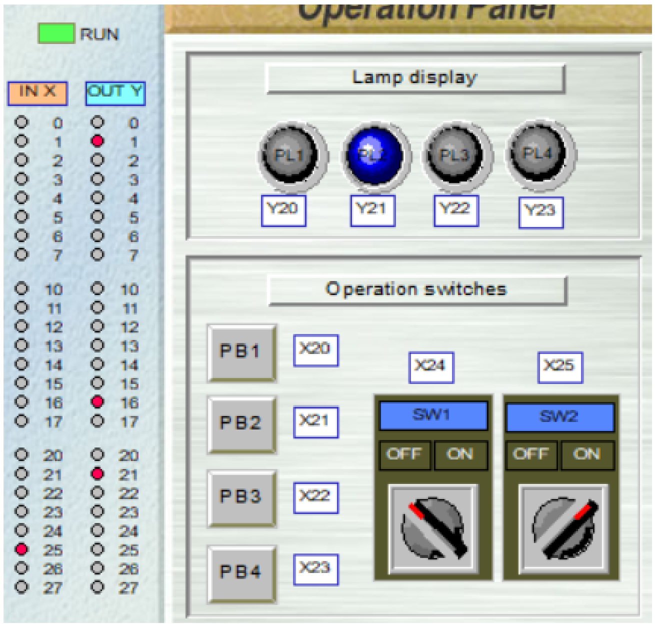

Fig. 10. X024 is turned off

When X024 is turned off, the Y001(conveyor), Y016 (base sensor) and Y021(horizontal extend) are triggered. The light is lit up as in the figure above. The X021 representing the horizontal extend means that the sucker will move to the right and the raft is sucked to the conveyor.

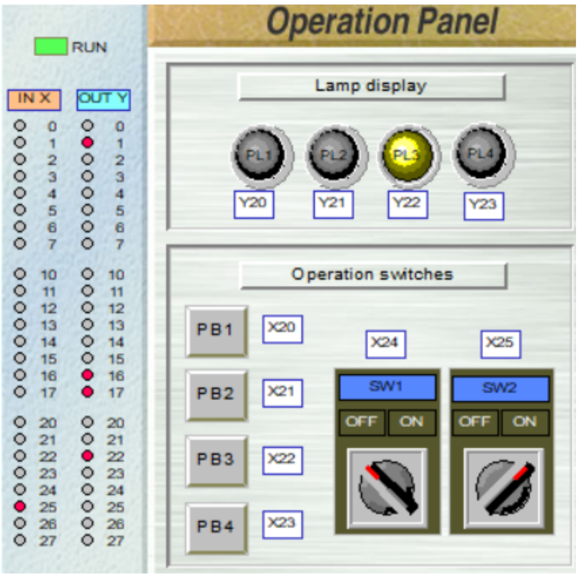

Fig. 11. The situation after Fig. 10.

After horizontal extend, the Y022 (horizontal retract) and Y017 (vertical extend by timing) are lighted up. This means that the sucker will move in the direction of the raft and the rafts will be pushed higher by the vertical extend by timing in 2 seconds. The counter will increase by 1 when this process is done one time.

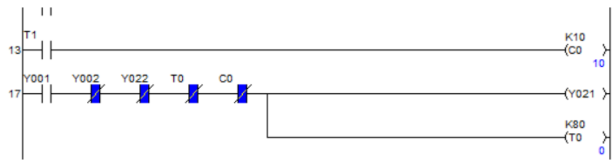

Fig. 12. The counter reaches 10

The counter (K10 C0) will increase when the counter reaches 10. The figure above shows the counter has finished its limit.

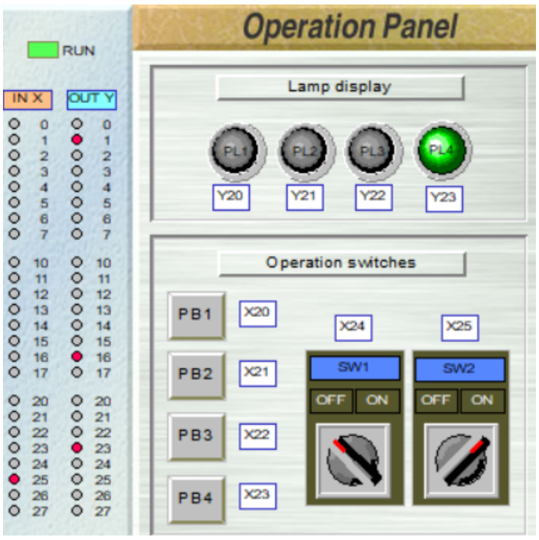

Fig. 13. Situation when counter = 10.

When the counter is reached 10 the Y023 is triggered. Y023 is triggered means that vertical retract is happening.

V. Conclusion

In conclusion, the implementation of a destacking mechanism using SolidWorks and PLC for design and simulation offers numerous benefits. SolidWorks enables efficient 3D modeling, analysis, and visualization of the destacking mechanism, aiding in the identification and resolution of potential design flaws. By integrating a PLC and Mitsubishi simulation, the mechanism's functionality can be simulated and tested virtually, allowing for optimization and refinement before physical implementation. This combined approach enhances the overall design process and allows us to better understand the destacking system process. Ultimately, the use of SolidWorks and PLC in destacking mechanism design and simulation can be seen to offer an effective and reliable solution such as streamlining operations and improving productivity in various industries.

VI. Acknowledgment

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VII. References

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VIII. Appendix

A. *Animated Video link*

https://drive.google.com/drive/folders/1OqMeqSIpPo2izDgVgAzOY2-zJ9OKxqM3?usp=sharing

B. *Solidworks design, PLC fiddle and Mitsubishi link*

Solidworks design & Mitsubishi file link:
https://drive.google.com/file/d/1Zet4xX5np2qFynY-0bgmLEi-aFpZBVfZ/view?usp=sharing
PLC fiddle link:
https://www.plcfiddle.com/fiddles/6156ca1a-3bad-446a-8318-27380f2f31e2