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Reduction in Diversity for Sash Tape Application Using Poka-Yoke Methods

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***Abstract*—Correct selection of sash tape in high-mix automotive manufacturing is essential for first-time-right quality, consistency, and takt compliance. When multiple car models pass through the same line, operators may select the wrong sash tape SKU. This paper presents a method to reduce sash tape diversity using combined information and physical poka-yoke systems. A passive UHF RFID tag on the vehicle dolly is read at the station to enable correct bin unlocking, HMI guidance, and traceability. The system minimizes operator decisions and prevents errors while ensuring all actions occur within takt time. This approach demonstrates a cost-effective automation solution for automotive assembly.**

***Index Terms*—Automotive manufacturing, poka-yoke, RFID, sash tape, selective access, takt time, traceability.**

I. INTRODUCTION

Modern automotive manufacturing plants are characterized by a growing trend towards mixed-model assembly lines in which several types of vehicles can be produced within a continuous flow of products. —Fig.1 While this provides more flexibility, it makes it harder for operators to select parts because the number of options for every component increases. The operation of installing the sash tape is among the activities in which a simple mistake can lead to aesthetic imperfections, poor quality fitment, dissatisfied customers, and additional costs due to reworking. The goal of this project is to minimize confusion among operators and ensure that only the right stock keeping unit of sash tape is used for the current model of the vehicle.

Fig 1: RNAIPL Plant

The project was designed based on the principle of poka-yoke. Rather than relying on operator training and memorization, or manually verifying the vehicle type, the new system guarantees that an operator always selects the right option by controlling the selection process. The system incorporates radio frequency identification, digital verification of the recipe, human-machine interface, and selective access to bins. In other words, the diversity of manual selection tasks is replaced with a single valid choice.

II. PROBLEM STATEMENT

Under the existing system, the operator might have to determine the right sash tape according to variant data, model information, job card, or other visual cues. With many tapes of similar appearance —Fig.2 stocked nearby, there will be a greater likelihood of misinterpreting the information. Even if the operator adheres strictly to the instructions, fatigue, takt pressures, low visibility, or similarities in the materials can still result in the wrong choice.

Choosing the wrong type of sash tape can lead to defects, which are discovered either at the point of application or during subsequent inspection. The resulting consequences include removal, reapplication, —Fig.3 labor costs, production downtime, and potential damage to the surface. It should be noted that this is not just a material issue; it is also a process reliability problem. The proposed solution must ensure that any wrong selection is prevented before the application stage.

Fig 2: sash Tape

Fig 3: Damaged Tape

III. OBJECTIVES

The primary objective is to develop a mistake-proofing concept that reduces sash tape selection diversity to one valid option per vehicle. The system must identify the vehicle automatically, validate the required sash tape recipe, and allow access only to the correct bin. It should also provide clear visual guidance to the operator and generate a traceable record of each transaction.

The secondary objectives are to maintain takt-neutral operation, improve right-first-time output, reduce rework, support operator confidence, and create a scalable framework that can be extended to other trim, paint shop, or assembly-line material selection activities.

IV. LITERATURE BACKGROUND

Poka-yoke techniques are widely adopted in the manufacturing industry to reduce error rates by designing processes that make erroneous actions difficult or impossible [1]. Poka-yoke techniques are frequently employed in automotive assembly lines for the detection of the presence of parts, fixture alignment, torque verification, and sequence control. The advantage of the use of poka-yokes is that it changes the paradigm of quality control from end-of-line inspections to proactive controls [9].

Radio Frequency Identification (RFID) is often employed in manufacturing for automatic identification of objects, tracking along production lines, inventory management, and recipe-based automation [6]. Passive RFID tags using ultra-high-frequency waves can be embedded with electronic product codes for individual carriers, dollies, or workpieces. Connected with a manufacturing execution system, RFID tags can provide information about workpieces that can then be used for triggering process actions and variant-specific controls.

V. PROPOSED METHODOLOGY

As per the methodology, a passive UHF RFID tag should be affixed to or linked with the vehicle dolly. Upon entering the station for sash tape application, the RFID reader located in the fixed station reads the electronic product code of the UHF RFID tag and uses the product code as a digital identity of the vehicle. The system then forwards the identity to the recipe validation logic which matches it with the particular vehicle model, variant, and its sash tape requirements. Once the identity of the vehicle has been validated, the controller unlocks only the appropriate bin associated with the sash tape requirement and locks all other bins. The human-machine interface will display the identity of the vehicle, required description of the material, the number of the bin, and status of the process. In this case, the operator receives digital instructions and physical restriction to proceed. After picking the material, it should be logged in the system along with time, ID of the operator if available, recipe version and the station information.

Table 1: Proposed subsystems

Subsystem	Item	Typical Spec	Approx. Unit Price (INR)
Fixed RFID	Impinj R700 fixed reader (ETSI)	4 antenna ports, PoE/PoE+, REST/MQTT, -92/-93 dBm, up to ~1100 tags/s	₹1,07,500–₹1,15,000
Antenna	ETSI UHF panel (e.g., Zebra AN440/AN510/AN520)	865–868 MHz, 6–12 dBi, circular/linear	₹10,000–₹18,000
HMI	Siemens KTP700 Basic 7"	800×480, Ethernet/PROFINET, 24 VDC	₹30,000–₹35,000
Tags	UHF on-metal tags	IP67+, 865–868 MHz, 0–512 bit User Mem	₹50–₹250 (basic models from ₹25)
Handheld encoder	Chainway C72 / C5 / C71	Android 11/13, UHF module	₹48,999–₹59,499
OPC UA bridge (optional)	STS OPC-UA Gateway	LAN, 12–24 V, web config	₹85,000
Mounts/cables	RF coax (LMR-400), brackets	N/RP-TNC	₹3,000–₹6,000 set

The project can be developed using Impinj R700 or any other type of fixed UHF RFID reader, circularly polarized antennas installed close to the station entrance, programmable controller, a servo-based or solenoid-based locking mechanism, and a compact HMI —Table 1. The bin compartment may be fabricated as a transparent covered rack so that the operator can visually identify the material while still being prevented from accessing non-approved bins —Fig.4 & Fig.5.

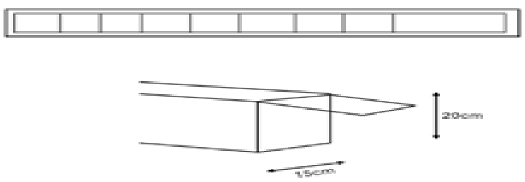

Fig 4: 9-compartment bin

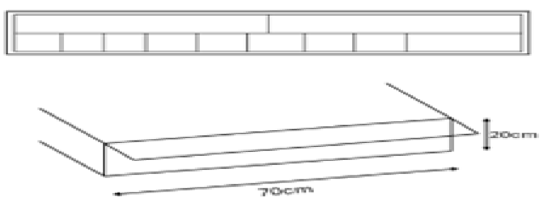

Fig 5: 11-compartment bin

VI. SYSTEM ARCHITECTURE

There will be five distinct layers in the architecture: identification, validation, control, actuation, and traceability. The identification layer will read the RFID tag —Fig.6. The validation layer will check the tag identity against the database of digital recipes. The control layer will select the appropriate bin to unlock. The actuation layer will unlock the right bin/lid. The traceability layer will log the information for auditing.

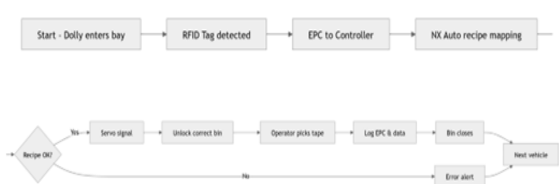

Fig 6: System Model

The overall flow will be vehicle dolly arrival, RFID tag reading, electronic product code reading, recipe search, bin assignment, selective bin unlock, operator select, application complete, and logging. With this flow, the need for an operator to manually interpret the variants becomes unnecessary. There will be a go/no-go decision based on the recipe before selecting the materials.

VII. HARDWARE AND SOFTWARE REQUIREMENTS

Hardware components will include UHF passive tag, RFID reader, RFID antenna —Fig.6, controller, HMI screen —Fig.7, power source, access bin, servomotor or locking mechanism, optional proximity sensor, and work station mounting. The RFID reader is supposed to allow communication via industrial means such as Ethernet, REST, MQTT, and LLRP as per plant integration needs.

Fig 6: RFID

Fig 7: HMI Panel

Software components will include reading algorithm for tags, product code filter, recipe map, HMI screen design, access bin operation algorithm, error handling, and data logging. Validation algorithm for software needs to cater to duplicate reads, missed reads, read at incorrect station, communication delays, etc. There will be provision for supervisor manual override as well which shall be logged.

VIII. RESULTS AND DISCUSSION

The anticipated outcome will be a significant decrease in wrong picks due to the limitation that the picker must only have access to the one validated bin. The information poka-yokes ensure no confusion in picking the recipe, whereas the physical poka-yoke ensures that the picker does not have access to any other bin.

The entire procedure should be completed in less than 1.5 seconds to allow the process to remain independent of takt time. By verifying first and then picking, the picker can proceed with the rest of his/her job without stopping to verify each time. The data logger will be useful in conducting quality audits, tracking process delays, and identifying areas that require training.

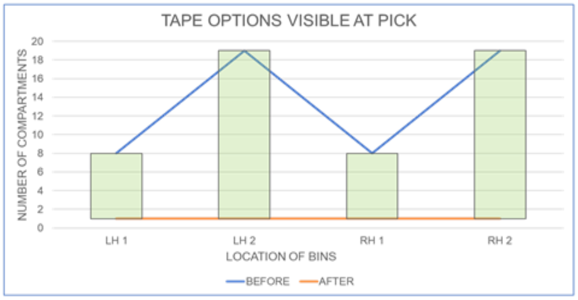

Fig 8: Visible Tape option at pick

This process improvement method will help increase right-first-time efficiency —Fig.8, minimize rework, and prevent material waste due to wrong picks. In addition, the proposed method will improve customer satisfaction with the quality of their products.

IX. ADVANTAGES

The first benefit that comes from implementing the system is error prevention. An operator will not be able to make an error while selecting the incorrect sash tape as the opening of the compartment will only happen when it has been validated. The second benefit is that there is decreased cognitive load —Fig.9 since the system translates various options into just one choice. The third benefit is the possibility of tracking operations since all read/pick operations are logged along with timestamps and station identification data.

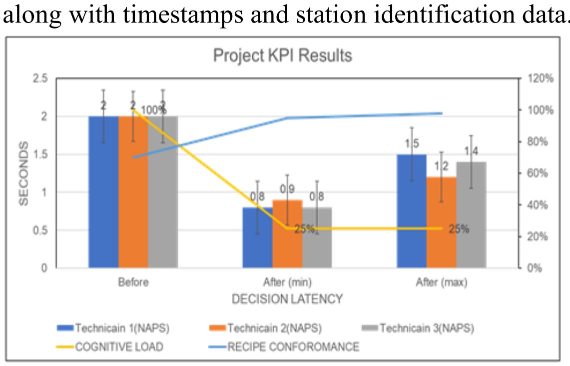

Fig 9: Project KPI results

Another benefit of using the system is scalability. Other variant-sensitive parts, such as clips, seals, labels, badges, trims, fasteners, or wiring accessories, can also utilize it.

X. LIMITATIONS

This principle relies on the reliable readout of the tag, the accurate mapping of the recipe, and maintenance of the bin locking mechanism. Various environmental factors like metal surfaces, orientation of the tags, location of antennas, and radio frequency interference can influence RFID functionality. This is why pilot testing is needed before implementation. Bin design should also be user-friendly to avoid slowing down the process due to mistake-proofing.

One more constraint is the accuracy of the database. In case the master data of the recipe is inaccurate, the system could accurately perform the wrong command.

XI. FUTURE SCOPE

Further development could include an interface with the plant manufacturing execution system, automated recipe matching, operator sign-in using RFID or biometric scanning, dashboard analysis, Andon notification, and preventive maintenance for bin actuators. Computer vision technology can also be incorporated to ensure that the proper tape is being dispensed.

This system can be scaled up from a single station to a line-wide poka-yoke solution. A unified architecture can enable several part families to be supported and establish a traceable quality control process for diverse automotive assembly.

XII. CONCLUSION

A poka-yoke method was discussed above for minimizing diversity of sash tape applications. This methodology employs such components as vehicle RFID tagging, recipe checking, controlled bin opening, HMI assistance, and events logging, making sure that an incorrect part will never be taken out at its source. Such a solution allows for first-time-right manufacturing while still working in a takt-neutral manner.

From the case study above, one can conclude that the process of automation does not mean getting rid of the operator but rather showing him or her how things should be done and eliminating any possibilities of errors that could have been prevented.

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