# AUTOMOLD CELL CONTROLLER: AUTOMATION OF MOLD MACHINES TO REDUCE QUALITY ISSUES

**Abigail SarahKatrize M. Cruz**
**Rachelle Ann H. Lavarez**
**Chrisna C. Malabanan**

Manufacturing Systems, IT and Smart Manufacturing; Assembly Production
Allegro Microsystems Philippines Inc.
Sampaguita St. Marimar Village Brgy. Sun Valley Bicutan, Parañaque
abcruz@allegromicro.com
rlavarez@allegromicro.com
cmalabanan@allegromicro.com

## *ABSTRACT*

The manufacturing industry has seen a significant increase in the application of machine automation as part of the Industry 4.0. With this trend, companies are now able to implement controls in the production line, including the mold operation. As a result, the team has developed an AutoMold Cell Controller to help mitigate the occurrence of quality issues. By reducing human movement, manual process validation, and data collection, this system has been able to significantly decrease, if not eliminate, the trend in the number of quality issues reported. This is a great example of how technology can be leveraged to improve the efficiency and effectiveness of manufacturing processes. With the implementation of automated systems, companies can reduce the risk of human error and streamline their operations, ultimately leading to better quality products and increased customer satisfaction.

## 1. 0 INTRODUCTION

Industry 4.0 is now being executed in most manufacturing companies like Dell, Cisco, and GE Industrial Communications, by using smart technologies and automated processes powered mostly by data and machine learning (Marr, 2018) [1].


Figure 1. Industry 4.0 and its Composition

One of the first steps to accomplish this is by using Cell Controllers (CC). Its main purpose is to verify if tasks are properly executed by validating the requirements such as temperature, if within specification, and schedules if done with cleaning or maintenance before proceeding to the next procedure (Kim and Choi, 1997) [2]. With that, quality controls are being put into place to avoid quality issues in semiconductor processes such as Mold.

For the past years, the mold process has encountered several quality related issues. This then is a good opportunity for Cell Controllers to be applied.

### *1.1 Problem Statement*

A total of 16 Auto Mold related quality issues were raised since 2017. Some of these quality issues related to auto mold procedure were damaged lead frames, incomplete mold, molded wrong, mixed devices, misprocessed units, protruded, depressed ejector pin, misalign package, package void, heavy flashes, chipped package, wire sway and expired mold compound.

Through brainstorming and using a fishbone diagram, the team have categorized defects based on the 4Ms (Man, Machine, Material, and Method) as seen on Figure 2 to further understand how to mitigate these.

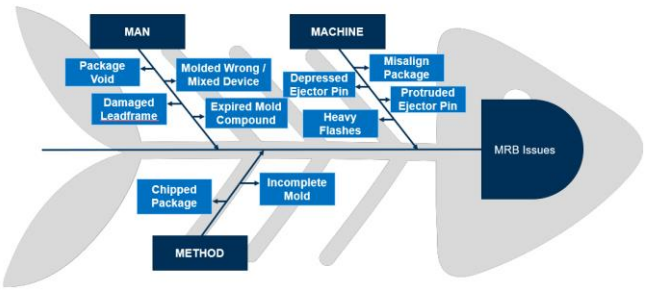


Figure 2. Ishikawa / Fishbone Diagram of Quality Issues

The quality issues that were identified as caused by Man are Package Void, Molded Wrong / Mixed Device, Damaged Lead Frame, and Expired Mold Compound.

For quality issues caused by Machine, these are Misalign Package, Depressed Ejector Pin, Protruded Ejector Pin, and Heavy Flashes.

For the remaining, which are Chipped Package and Incomplete Mold, these are caused by Method related issues.

With the root cause identified per issue, these can be classified whether it can be mitigated by AutoMoldCC or not.

### *1.1.1 Project Objective*

The project's main objective is to innovate ways to mitigate the following quality issues related to Auto Mold with automation:

i. Misalign Package
ii. Incomplete Mold
iii. Mixed Devices / Molded Wrong
iv. Protruded Ejector Pin
v. Depressed Ejector Pin
vi. Package Void
vii. Heavy Flashes
viii. Expired Mold Compound
ix. Wiresway

The project also aims to reduce the operator's movement, manual process validation usually done by operators and the use of paper materials during the process. It also as well aims to integrate the Manufacturing Execution System (MES) and machine controls and to generate a real-time process log from the equipment.

### *1.1.2 Scopes and Limitations*

The Cell Controller project was deployed on Auto Mold Machines that has SECSGEM capability between August 23, 2021, up to March 10, 2023. Only phase 1 of the project has been deployed and it does not yet accommodate the continuous loading feature between two lots.

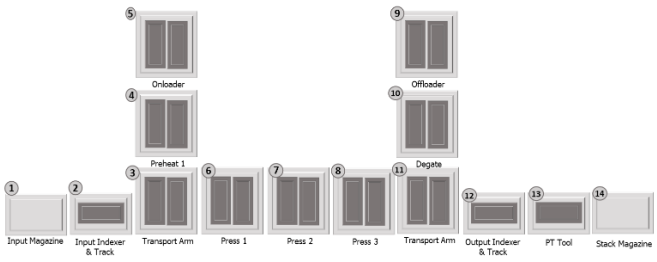


Figure 3. Block Diagram of Auto Mold Machine.

### *1.1.3 Understanding the Problem*

Molding is one of the semiconductor assembly processes where plastic materials are liquefied and solidified to encapsulate components to protect ICs and passive devices (Hackett and Loskot, 2005) [3].

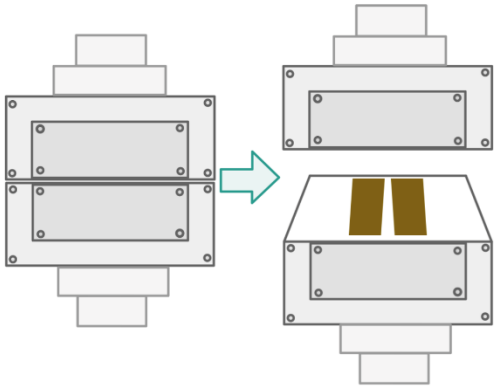

Figure 4. Block Diagram of a Mold Press which shows how one manual mold shot looks like in a mold machine.

Like in other assembly procedures, a real-time process log is vital for gathering data, especially when there are some issues that need investigation. However, the Manufacturing Execution System (MES), which is currently being used to track the operations the units went through, is not integrated into the machine which results in inaccurate data results that will affect the lot containment and machine change point where the problem originally started.

Adding to the situation, the current assembly system practices Machine Man Ratio (MMR) which allows the Operator to operate more than 1-2 machines at the same time.

## 2.0 REVIEW OF RELATED WORK

Not Applicable

## 3.0 METHODOLOGY

Before implementing Cell Controllers, a planning stage is held to ensure that all stakeholders, including Production Leads, Process Engineers, Quality Engineers, Maintenance Engineers, Trainers, etc., are consulted and their requirements are met. During this stage, the control plan and design documents are reviewed and finalized, after which the Development Stage begins. In this stage, coding and machine characterization are carried out, and Alpha Testing is conducted to ensure that everything that has already been developed is working as planned. User Acceptance Testing is then done with the users to ensure that the application meets all the requirements and expectations set during the planning

stage. After passing all the test items, the Business Analyst holds training sessions for the Trainers and Production Team, and a final decision is made on whether to push the application's deployment. Finally, with the approval of all the stakeholders' heads, the Cell Controller is deployed on the Production Server.


Figure 5. Stages of Creating a Cell Controller.

With the Cell Controller implemented, we can see in the System Architecture, as shown on Figure 6, how the operator interacts with the tablet where the AutoMoldCC Application is accessed through the Ignition Application. This table is then connected to a Wireless Network connection to communicate with the Ignition Gateway Server. Through this server, we can access the MES, the SQL CC Database, and the AutoMold machine on which we can communicate to it through SECSGEM communication.

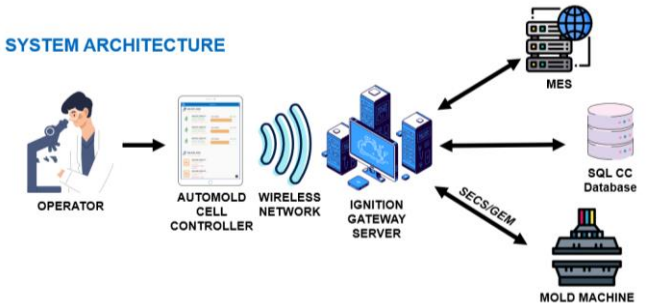


Figure 6. System Architecture of AutoMoldCC.

GEM (or SECS/GEM) is a set of connectivity standards designed by the Semiconductor Equipment Materials Initiative (SEMI) to establish communication between automated equipment and the host's factory network, allowing for Smart Factory Manufacturing. SECS stands for Semiconductor Equipment Communication Standard, while GEM refers to the SEMI connectivity standard E30, which specifies the Generic Model for Communications and Control of Manufacturing Equipment.

Further within the AutoMold Cell Controller as it is connected through the Ignition Gateway Server, it retrieves and sends data from the MES Database/ Server which helps on the validation and controls needed for monitoring Machine Cleaning, Lot Processing, SPC Results, etc. as shown on Figure 7.

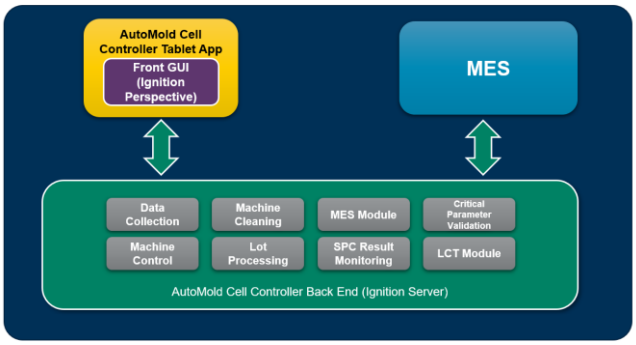


Figure 7. System Architecture of Modules being transacted between AutoMoldCC and MES

Retrofitted sensors inside the Auto Mold machine for AutoMoldCC were necessary due to the limitations in the commands given to us by the vendor. The AutoMoldCC now has retrofitted sensors at specific locations in the machine, as shown in Figure 8. The locations of these sensors are as follows:

A. Barcode Scanner Sensor - It is used to validate the magazine included from the lot number. To prevent the magazine from falling and ensure accurate scanning, a barcode scanner jig has been added to hold the magazine in place.
B. Strip In Sensor – Its function is to count the number of strips loaded for molding.
C. Strip Out Sensor – Its function is to count the number of molded strips.
D. Cassette Sensor – Its function is to detect the presence or absence of the cassette in the machine.
E. Lead Frame Output Sensor – Used to notify if there are remaining strips from the other previous process lot to avoid mixing.

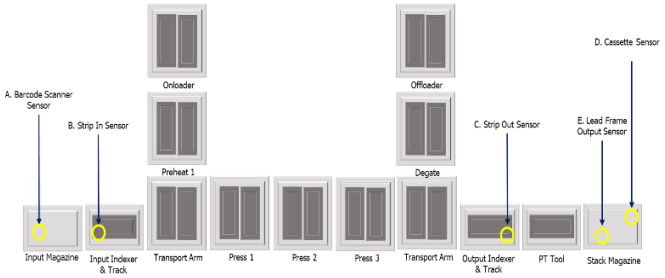


Figure 8. All Retrofitted Omron Sensors in an Auto Mold Machine

## 4.0 RESULTS AND DISCUSSION

The high-level flowchart shown in figure 9 provides a clear understanding of the process of a mold operator. The chart shows the various steps involved in the process, starting from the receipt of the mold to the final inspection of the product. The process includes preparing the mold for production, setting up the machine, selecting and preparing the correct materials, and running the production process. Once the production is complete, the product is removed from the mold and undergoes a final inspection to ensure that it meets the required specifications. The chart also shows the various quality checks that are performed at different stages of the process to ensure that quality standards are maintained. Overall, this flowchart provides a comprehensive overview of the process followed by mold operators and helps to identify areas for improvement to increase efficiency and quality.

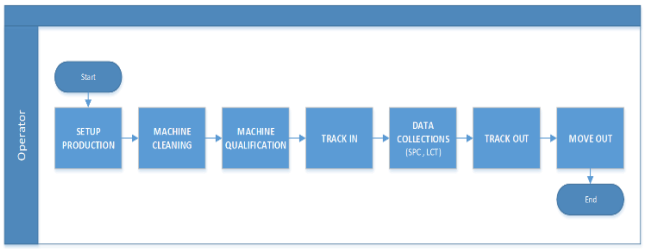


Figure 9. High level process flow chart of a mold operator

The table below shows the comparison between the manual Mold process and the process when using a cell controller. Based on the data, the cell controller added restrictions to ensure that the process precedence is followed and to reduce activities performed by the Operators.

Table 1. Machine Response on a Manual Mold Process

| PROCESS ACTIVITIES | MACHINE RESPONSE (Manual Process) |
|---|---|
| FULL/ REGULAR CLEANING | • HMI will notify the activity.<br>• **Can still track in/ process lots even if cleaning not yet performed.** |
| CONDITIONAL/ SPECIAL CLEANING | |
| TRACK IN/ LOT VALIDATION | • **Separate Transaction** in CAMSTAR |
| COMPUTATION OF NUMBER OF UNITS PER PRESS | • Mold Operators need to **manually compute the number of units** to be tracked in per equipment press |
| NO SPC DIMENSIONAL QUALIFICATION/ WIRESWAY MONITORING | • Notified by A2 Operators<br>• **Can still track in/ process lots** |
| FAILED SPC DIMENSIONAL QUALIFICATION/ WIRESWAY MONITORING | |

Table 2. Machine Response with AutoMoldCC Implemented

| PROCESS ACTIVITIES | MACHINE RESPONSE (With AutomoldCC) |
|---|---|
| FULL/ REGULAR CLEANING | • CC will **notify and require the activity if scheduled.**<br>• Not allowed to track in/ process lot unless cleaning has been performed or waived. |
| CONDITIONAL/ SPECIAL CLEANING | |
| TRACK IN/ LOT VALIDATION | • **One time/ joined transaction** through CC |
| COMPUTATION OF NUMBER OF UNITS PER PRESS | • CC will **automatically compute the expected number of units** to be processed for each equipment press |
| NO SPC DIMENSIONAL QUALIFICATION/ WIRESWAY MONITORING | • **CC will send an auto stop/ offline command to the machine**<br>• A2 Operator needs to submit needed data to continue lot processing. |
| FAILED SPC DIMENSIONAL QUALIFICATION/ WIRESWAY MONITORING | • **CC will send an auto stop/ offline command to the machine**<br>• A2 Operator needs to submit a PASSED result to continue lot processing. |

## *4.1 Data Collection Process and Analysis*

As shown in figure 10, all quality issues related to Auto Mold have been collected from 2017 to 2022. Top of the list is the misalign package. The grayed-out bars are defects that are beyond the cell controller's control.

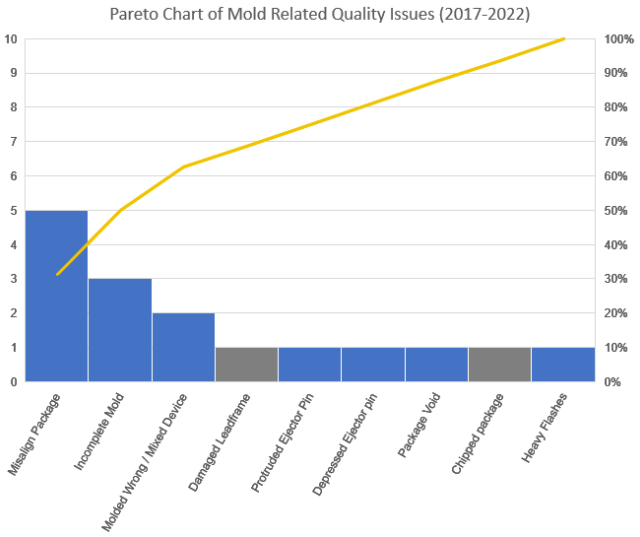


Figure 10. Pareto Chart of Auto Mold Related Quality Issues from 2017 to 2022.

According to the data collected between 2017 and 2022, the AutoMoldCC can mitigate mold related issues by an impressive 88%. As shown in Figure 11, there's a significant decrease in mold related issues after implementing the AutoMoldCC.

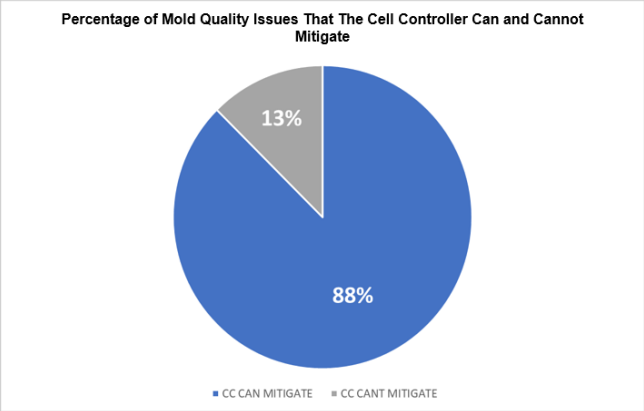


Figure 11. Pie Chart of Mold Related Quality Issues that AutoMoldCC can Mitigate from 2017 to 2022. The pie chart shows the percentage of Quality issues that our AutoMoldCC can and can't prevent.

In Table 4, we can see the added validations and controls that were added for each quality issue when the AutoMoldCC was implemented on the mold operation.

Table 4. Top 5 Quality Issues and the Specific Controls Done by AutoMoldCC to Mitigate It

| Quality Issue | Without AutoMoldCC | With AutoMoldCC |
|---|---|---|
| **Misalign Package** (MS2009)<br><br>*Other Related Issues:*<br>- Wiresway | ➢ Possible to process lots without submitting SPC Dimensional/ Wiresway result for the whole shift<br>➢ A2 Operators needs to physically tell the mold operator that there was a FAILED result | ➢ For SPC Dimensional/ Wiresway Monitoring, AutoMoldCC immediately sends an auto stop / offline command when none was submitted by middle of the shift or when a FAILED result was submitted |
| **Mixed Devices / Molded Wrong** (WO2007) | ➢ Operators can load the magazine on the machine and run it without validating first if the carrier is attached to the lot to be processed.<br>➢ Operators may also load lots with a device that is not allowed on the machine. | ➢ AutoMoldCC validates if scanned magazine is attached on the current lot and is allowed to be processed in the machine by checking its package.<br>➢ Lot number is retrieved by scanning the magazine. |
| **Package Void** (MS2005) | ➢ Operators may process lots even if mold cleaning was not performed as scheduled or due to prolonged downtime that may cause sticking on the mold chase. | **For Regular Cleaning (Full) and Special Cleaning (Conditional):**<br>➢ AutoMoldCC validates if the machine has already undergone cleaning on the specified schedule.<br>➢ AutoMoldCC validates the idle time of the equipment presses.<br>➢ AutoMoldCC captures the machine cleaning procedures and shots done.<br>➢ AutoMoldCC automatically reflects the current cleaning status in the equipment history |
| **Heavy Flashes**<br><br>*Other Related Issues:*<br>- Incomplete Mold<br>- Protruded Ejector Pin<br>- Depressed Ejector Pin | ➢ Operators may disregard the out of spec parameter and continue to track in and process the lot. | ➢ AutoMoldCC will send an auto offline or stop command to the machine if an **Out of Spec Parameter has been detected**.<br>➢ AutoMoldCC will also not allow operators to proceed in processing lots if an Out of Spec parameter has been detected before Track In transactions. |
| **Expired Mold Compound** | ➢ Operator may not notice or forget the expiration of the mold compound and continue the lot processing. | ➢ AutoMoldCC validates if the mold compound currently tracked in CAMSTAR is **not yet expired** before processing the lot.<br>➢ AutoMoldCC sends an auto stop command to the machine if the mold compound **has expired** during lot processing. |

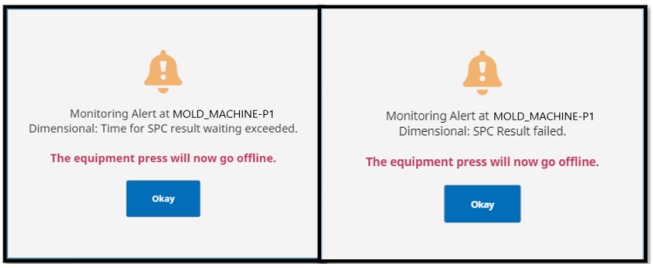


Figure 12. SPC Dimensional Monitoring Related Error Messages for the Mitigation of Misalign Package Issues. Right pop up is shown whenever no SPC result was submitted for the equipment press with required submission on the current shift. For the left pop up, this is shown when a failed SPC result was submitted.

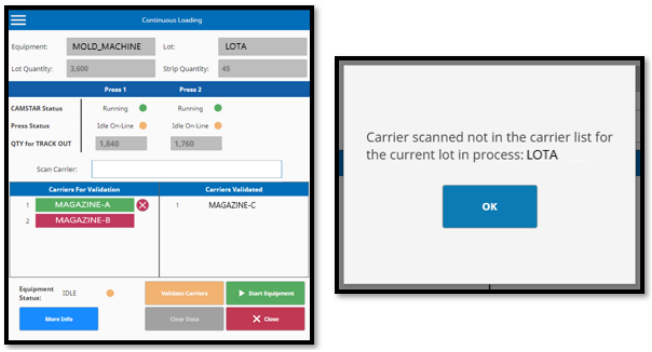


Figure 13. Track In Module of AutoMoldCC Integrated with Lot Carrier Tool (LCT) – Carrier Validation Feature for the Mitigation of Mixed Devices / Molded Wrong Issues. Operators are required to scan and validate magazines before Track In to check whether these are attached to the lot.

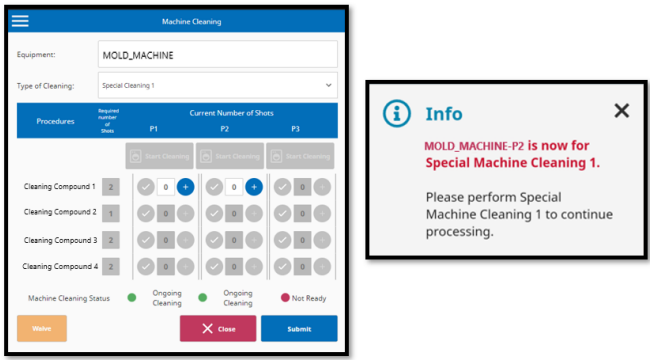


Figure 14. Machine Cleaning Module of AutoMoldCC for the Mitigation of Package Void Issues. Operators are required to perform machine cleaning when scheduled for the shift before proceeding/ resuming to other processes.

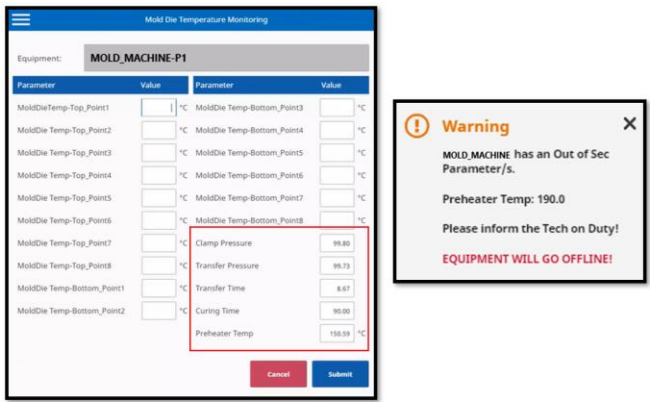


Figure 15. Mold Die Temperature Monitoring Module of AutoMoldCC for the Mitigation of Heavy Flashes Issues. Operators are required to submit critical parameter values within specifications. Proceeding to the next procedure is not allowed if there is at least one out of spec parameter. Pop ups will also be shown, and offline / stop command will be sent if there is an ongoing lot processing.

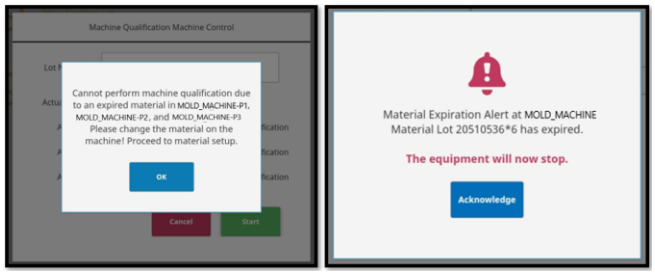


Figure 16. Expired Material Related Error Messages. Lot Processing will not be allowed if material is expired before Track In. A stop command will also be sent if the material became expired during lot processing.

Other validations done in AutoMoldCC are the following: (1) checks if the Lot is at the right operation / step, (2) checks if the MES Status is ready for Track In, (3) checks if the actual Press Status is ready for Lot Processing, (4) computes the Total Material Qty needed to process the Total Lot Qty, (5) retrieves the Lot Quantity, (6) retrieves the Strip Qty from Previous Operation, (7) validates if Machine Qualification is done, and (8) validates if Plunger/Mold Chase Replacement is done/waived.

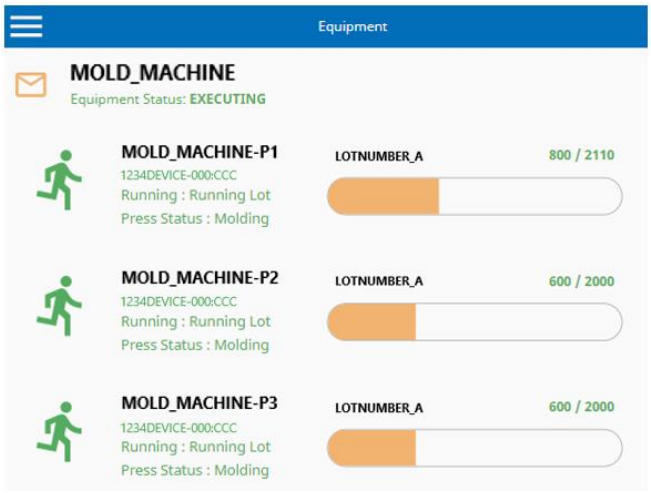


Figure 17. AutoMoldCC Equipment List Module

## 5.0 CONCLUSION

AutoMoldCC is a good start wherein the organization can be further involved with the implementation of Industry 4.0 in manufacturing companies where automation and data analysis prevail. As more real-time process logs and data have been validated and gathered by using Cell Controllers, this will enable the application of Diagnostic and Preventive Analytics in the future to pursue the organization's goals in exceeding the customer's expectations with good quality products. With the implementation of AutoMoldCC on August 23, 2021, no Auto Mold related quality issue has been raised as of FY24Q1 (June 30, 2023) on the deployed machines. The following quality issues are so far mitigated by using AutoMoldCC; Misalign Package, Incomplete mold, Mixed Devices, Molded Wrong, Protruded Ejector Pin, Depressed Ejector Pin, Package Void, Heavy Flashes, Expired Mold Compound, Wiresway. Improvements in the mold process using AutoMoldCC are still expected to be deployed this FY23.

## 6.0 RECOMMENDATIONS

Cell Controller is a recommended tool for all semiconductor procedures to promote paperless transactions and employ real-time data gathering. This tool automates the data collection process, allowing the organization to capture real-time data, which can be used to improve the production process. Additionally, the tool provides a centralized database to store all the data, making it readily accessible for analysis and reporting. Cell Controller eliminates the need for paper transactions, saving time, resources, and reducing the risk of errors. It also promotes environmental sustainability by reducing paper usage. By implementing this digital

solution, organizations can improve their product quality, meet, and exceed customer satisfaction, and stay competitive in the market.

## 7.0 ACKNOWLEDGMENT

The successful implementation of any project requires a collaborative effort, and the Manufacturing Systems, IT and Smart Manufacturing (ITS) project is no exception. The Computer Integrated Manufacturing (CIM) and Project Management (PM) Team has done an exceptional job in leading this project to fruition. Their dedication and hard work have undoubtedly contributed to the project's success.

We would also like to express our gratitude to the Assembly Production, Maintenance Team, and Process Engineering Department for their valuable contributions. Their expertise and insights have been invaluable in ensuring that the project meets the highest standards of quality and efficiency.

The team would also like to acknowledge that the success of this project would not have been possible without the collective effort of all those involved. We are grateful for the contributions of everyone who has worked tirelessly to make this project a reality. We look forward to continued collaboration and success in the future.

## 8.0 REFERENCES

1. Marr, B., 2018. **What is Industry 4.0? Here's A Super Easy Explanation For Anyone**. [online] Forbes. Available at: <https://www.forbes.com/sites/bernardmarr/2018/09/02/what-is-industry-4-0-heres-a-super-easy-explanation-for-anyone/?sh=7165750b9788.

2. Kim, S. and Choi, K., 1997. **Open Cell Control System for Computer-Integrated Manufacturing**. IFAC Proceedings Volumes, [online] 30(14), pp.381-385. Available at: <https://www.sciencedirect.com/science/article/pii/S1474667017427510>.

3. HACKETT, N. and LOSKOT, D., 2005. **Encapsulation and Modern Molding | Semiconductor Digest**. [online] Sst.semiconductor-digest.com. Available at: <https://sst.semiconductor-digest.com/2005/10/encapsulation-and-modern-molding/>.

## 9.0 ABOUT THE AUTHORS

**Abigail SarahKatrize Cruz** has been working as a CIM Automation Engineer 2 at Allegro MicroSystems Philippines Inc for 3 years and was previously an Acoustic Fiber Optics (AFO) Data Analyst for almost 3 years in her previous company. She graduated from the University of the Philippines Los Baños with a Bachelor of Science Degree in Applied Physics Major in Instrumentation Physics. In addition to her academic background, she has also completed the Project SPARTA Data Science program which has given her a strong foundation in data analysis, machine learning and statistical modeling.

**Rachelle Ann Lavarez** is a highly skilled engineer with over a decade of experience in the semiconductor industry. She has been serving Allegro MicroSystems Philippines Inc in various roles for the past 13 years, including as CIM Automation Engineer for 1 year, Reliability Planner for 1.5 years and Assembly Maintenance Lead Technician for 10.5 years. She has an educational background that includes a degree in BS Electronics Engineering Technology from TUP-Visayas and a degree in Bachelor of Engineering Major in Manufacturing and Production from TUP-Taguig. She has also recently completed a Project SPARTA Data Science program which has further enhanced her technical skills and knowledge. Her dedication to her work and her commitment to continuous learning and improvement make her a standout professional in her field.

**Chrisna Malabanan** has been working as a Senior Production Supervisor at Allegro MicroSystems Philippines Inc for 3 years. She has a Bachelor of Science in Electrical Engineering from Mapua Institute of Technology, which has equipped her with the knowledge and skills necessary to excel in her position. As a Senior Production Supervisor, she is responsible for overseeing the production process, ensuring that products meet quality standards and managing the production team to ensure that deadlines are met. She is a natural leader, with excellent communication skills and a keen eye for detail.