MSOP HANDLER PARTS PER JAM (PPJ) IMPROVEMENT USING BEST TOOL MATCHING (BTM) METHODOLOGY

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ABSTRACT

Parts per jam (PPJ) is a critical metric for assessing equipment performance, indicating the number of parts processed before a jam occurs. Achieving and maintaining high PPJ is essential for optimizing manufacturing operations and minimizing costs.

Traditionally, this requires costly and time-consuming routine maintenance checks, continuous monitoring, and Design of Experiments (DOE). This paper presents a pioneering methodology, known as the Best Tool Matching (BTM), which identifies root causes of equipment downtime using historical data at zero cost. By establishing matching signals across identical tools and leveraging any deviations, the BTM methodology offers valuable insights for continuous improvement in equipment reliability and performance.

1. 0 INTRODUCTION

Best Tool Matching (BTM) serves as a highly effective methodology designed to foster continuous improvement in equipment efficiency via comparative performance analysis. Originating within Analog Devices, Inc. (ADI), BTM is actively employed across Analog Devices Manufacturing Operations sites. This methodology is tailored to assess and compare the performance of diverse tools, leveraging a comprehensive analysis of both output and input parameters. Output parameters, including yield, Mean Time Between Failure (MTBF), and Parts Per Jam (PPJ), undergo thorough evaluation in relation to a spectrum of input parameters, commonly referred to as confounding variables. These input parameters encompass crucial factors such as package type, handler type, test temperature, and more, thus providing a holistic framework for optimizing equipment performance and operational efficiency.

By systematically comparing output parameters across different combinations of input variables, the Best Tool Matching methodology enables us to identify both the worst-performing and best-performing tools within a group. This analysis provides valuable insights into tool performance and highlights opportunities for improvement.

For example, consider a scenario where the yield of semiconductor manufacturing tools across different package types and test temperatures are analyzed. By applying the Best Tool Matching methodology, the tools that are most effective under specific conditions and where there are opportunities for optimization can be pinpointed.

Ultimately, any discrepancies or deltas observed through this analysis represent potential areas for improvement in tool performance, guiding strategic decision-making and resource allocation.

1.1 Best Tool Matching Structure

The BTM methodology is structured around a comprehensive 7-step process, guiding analysts and practitioners through the journey from signal identification to documentation of actions:

Step 1: Identification – Define clear objectives and key metrics and establish the composition of the analytical team.

Step 2: Filtering – Gather relevant data based on specific confounding variables identified in Step 1.

Step 3: Generate Probability Plots – Visualize data distributions to identify patterns and trends.

Step 4: Define the Worst-performing and Best-performing Tools – Utilize analytical insights to designate tools' performance rankings.

Step 5: Validation of the Worst-performing and Best-performing Tools – Verify performance assessments through rigorous validation processes.

Step 6: Action Plan – Develop actionable strategies to address identified performance gaps and optimize tool efficiency.

Step 7: Documentation of Closed-loop Actions – Thoroughly document all implemented actions, fostering a systematic approach to continuous enhancement. This documentation should encompass detailed fan-out plans, ensuring dissemination of learnings and improvements across various products and processes within the organization.

Leveraging the 7-step Best Tool Matching methodology, valuable opportunities for continuous enhancements can be identified, shining light on areas where solutions can be made.

2. 0 REVIEW OF RELATED WORK

While design of experiments and preventive maintenance endeavors may produce comparable results to Best Tool Matching, BTM stands out for its proactive and cost-effective approach, utilizing readily available data within the manufacturing line. At ADI, handler data is consolidated using an internal hardware and software system (data collecting tool). This comprehensive system captures crucial handler metrics including status, binning data, and jams. These data are then accessible and analyzable through the Power BI dashboard (see Fig. 1).

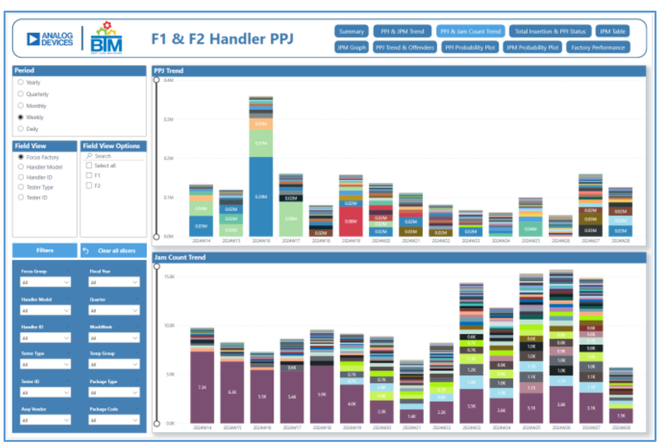


Fig 1. Handler PPJ Power BI Dashboard

3.0 METHODOLOGY

Several teams comprised of Quality Assurance, Process, Test Product, and Equipment engineers participated in a rigorous 3-day workshop focused on Best Tool Matching to gain a comprehensive understanding of its principles and processes. This workshop involved classroom training, demonstrations, and personalized coaching sessions led by BTM Subject Matter Experts (SMEs). Subsequently, the trainees collaborated in teams to apply the BTM methodology to their respective signals or improvement opportunities. The tangible outcome of this workshop was the implementation of actual improvements in both Test Manufacturing and Back-end processes.

Teams engaged in Gemba activities and conducted thorough analyses of their systems. At the conclusion of the training, each team presented their projects along with a timeline outlining planned actions. To ensure continued progress, SMEs facilitated weekly meetings to review project advancements and monitored results until completion.

This paper discusses a sample project as an illustrative application of the BTM methodology.

4.0 RESULTS AND DISCUSSION

4.1 Identification and Filtering

During the evaluation of gravity-fed handlers, a thorough examination was conducted across various confounding variables, encompassing evaluation time frame, package type, and test temperature. With a keen focus on optimizing efficiency, the improvement efforts were concentrated on the volume-runner, specifically targeting enhancement opportunities within the MSOP package type and at ambient temperature group (refer to Fig. 2).

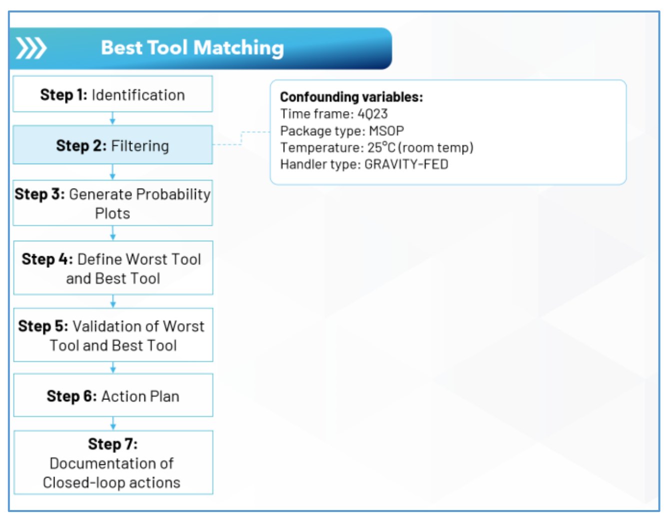


Fig. 2. Step 2 of the 7-step BTM approach showing the confounding variables of the project.

4.2 Generating Probability Plots

The BTM methodology places particular emphasis on probability plots as the preferred method for data presentation and analysis over alternative formats like trend charts and box plots. Their ability to provide a clear visualization of data distribution makes probability plots a highly effective tool for analysis within the BTM framework.

By leveraging PPJ data collected from the data collecting tool and employing the advanced analytics capabilities of Tableau (Handler PPJ Power BI dashboard is not yet available at the time, FY2023), an in-depth analysis was conducted to identify both the best-performing and worst-performing tools (refer to Fig. 3). The analysis indicated that the top-performing tool (Handler A) demonstrated a significantly higher median throughput compared to the least effective tool (Handler B). This striking discrepancy presents a 1.6K PPJ matching opportunity (MO) between the best and worst tools (see Fig. 4).

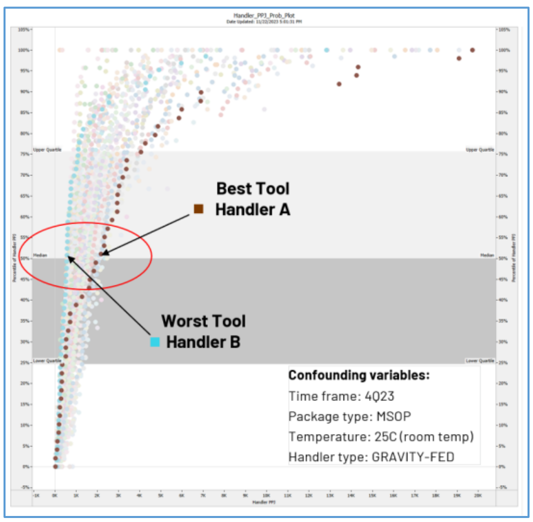


Fig. 3. PPJ probability plots showing all MSOP handlers, 4Q23 data.

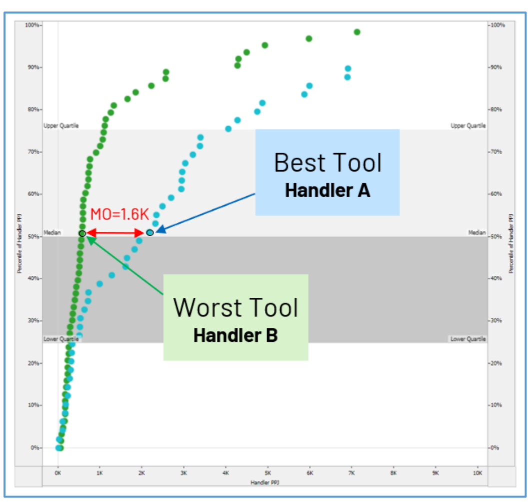


Fig. 4. Median PPJ probability plots showing 1.6K matching opportunity between the best-performing and worst-performing tools.

4.3 Defining the Worst-Performing and Best-Performing Tools

Upon further analysis of the worst-performing tool (Handler B), it became evident that the root cause of the problem lies within its loader module. More specifically, the highest contributor of loader jams was identified as jam code L01ERR04, signifying a failure of the tube singulator to reach the horizontal position (refer to Fig. 5).

Fig. 5. Top jam contributor is the loader module.

4.4 Validation of the Worst-Performing and Best-Performing Tools

A Gemba walk was conducted to scrutinize the performance of the worst tool, revealing critical insights into the functionality of the tube singulator. It became evident that the effective operation of the singulator function relies heavily on precise mechanical alignment and turning speed settings.

4.4.1 Mechanical alignment

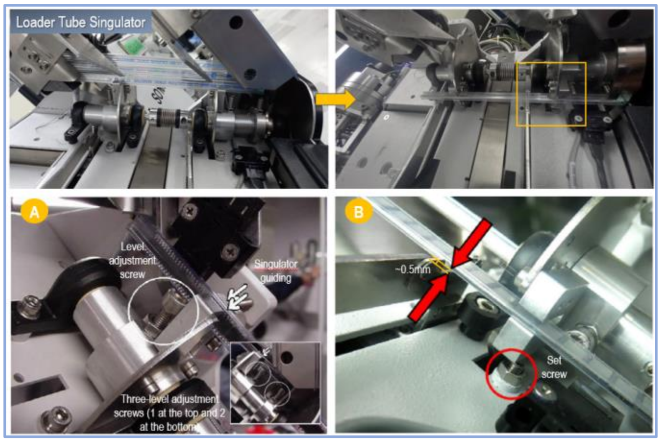
A. It is essential to ensure alignment consistency between the tube and the singulator guide. This alignment can be fine-tuned using the three-level screws, as depicted in Fig. 6A.

B. Maintaining an approximate 0.5mm clearance between the lower edge of the tube and the guide, as shown on Fig. 6B, is crucial for optimal performance.

4.4.2 Turning speed [1]

Turning speed should adhere to the 800ms-1200ms specification (OEM standards) to ensure seamless operation (see Fig. 7). Additionally, several other factors have the potential to influence turning speed, including CDA pressure, cylinder condition, and the tuning of pneumatic valve restrictor.

After thorough Gemba observations, several discrepancies were noted between the worst and best tools. In terms of factors impacting mechanical alignment, findings revealed misalignments in screws 2 and 3 of the three-level adjustment screw. Furthermore, deviations from specifications were noted in the turning speed settings, with discrepancies of 430ms and 590ms observed respectively in the transition from singulator to vertical position and singulator to horizontal position.



Figs. 6A and 6B. Loader tube singulator – mechanical alignment settings.

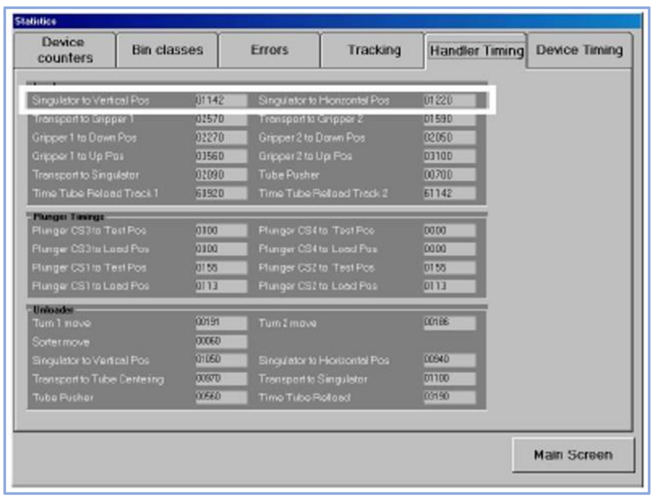


Fig. 7. Handler user interface (UI) showing the turning speed settings.

4.5 Action Plan

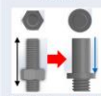
Based on the Gemba findings, the following corrective actions were taken:

4.5.1 Mechanical alignment was addressed by manually fine-tuning level screws 2 & 3. During this process, the potential benefits of implementing fixed level screws to streamline future adjustments were considered.

4.5.2 Turning speed settings were adjusted by fine-tuning the sensor screws to achieve the nominal turning speed setting of 800ms.

As part of due diligence, other factors that could impact the loader singulator function were also examined, such as ensuring proper insertion of end plugs on tubes and maintaining stability in CDA pressure. Thorough examination revealed no issues in these critical areas. Refer to Table 1.

Table 1. Action Plan

Items	Description of Problem	Worst Tool	Best Tool	Gap	Action	When	Who	Status
Mechanical alignment	Alignment of tube and singulator guide	Mis-aligned	Properly aligned	Level adjustment screws 2 & 3	Fine tune alignment	w403	Maintenance team	Done
					Implement fixed level screws  Existing screw / New screw	To complete by w427	Maintenance team	Ongoing
Turning speed settings	Turning speed - singulator to vertical position	370ms	800ms	430ms	Fine tuned sensor screw to achieve ~800ms turning speed	w403	Maintenance team	Done
	Turning speed - singulator to horizontal position	220ms	810ms	590ms				
Other items /variables checked	Proper insertion of end plugs on tubes	No issue	No issue	None	No action			
	Stability of CDA pressure	No issue	No issue	None	No action			

4.6 Documentation of Closed-loop Actions

In light of these findings, two main actions were derived:

4.6.1 To address the mechanical alignment issue more comprehensively, the use of fixed level screws was implemented (as shown in Table 1). This proactive step will eliminate the need for manual adjustment, thus minimizing variation in mechanical alignment.

4.6.2 The critical importance of consistently maintaining specified parameter settings was recognized. To ensure this, turning speed was integrated into the settings to be checked during preventive maintenance procedures. Refer to Fig. 8.

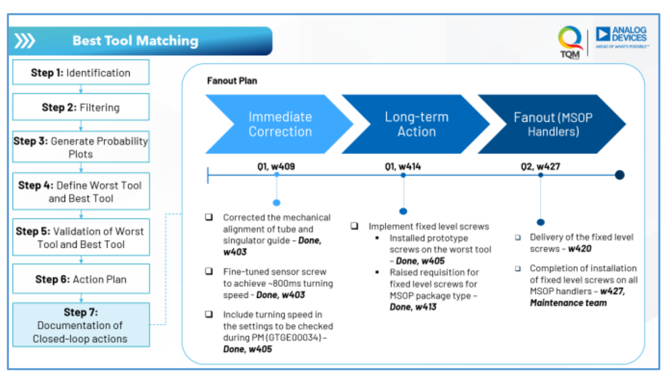


Fig. 8. Documentation of corrective actions

4.7 Results, Learnings, and Key Take-aways

Following the implementation of corrective measures, a significant improvement was observed in the performance of the worst tool, increasing its PPJ by 200%. Additionally, there was a significant reduction in loader jams, dropping from 395 jams per million (JPM) down to only 56 JPM. Furthermore, the occurrences of the specific jam error code L01ERR04 decreased from 283 to only 26 instances. Refer to Fig. 9.

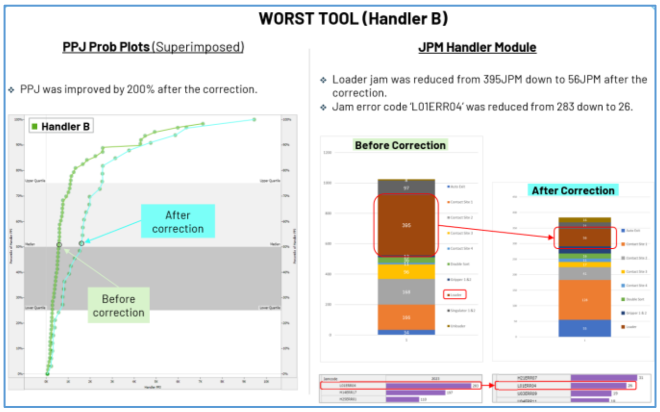


Fig. 9. Worst tool (Handler B) performance – Before and After implementation of corrective measures.

As part of the fan-out plan, fixed level screws will be installed on the rest of the MSOP handlers. This activity is anticipated to be completed by w427, following the delivery of screws scheduled for w420.

The expansion of the implementation of fixed level screws to other package types is currently under thorough evaluation. To preempt any potential mixing of screws, the following proactive measures are being deliberated:

4.7.1 Inclusion of fixed level screws within conversion kits: Integrating fixed level screws as integral components of conversion kits will ensure seamless transition and prevent inadvertent mixing.

4.7.2 Labeling of screws (refer to Fig. 10): Employing clear and concise labeling mechanisms, as depicted in Fig. 10, will act as Poka-Yoke, ensuring only the correct screws will be used for specific package types.

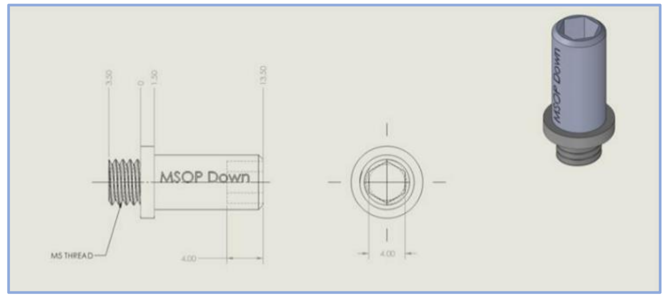


Fig. 10. Labeling of screws

5.0 CONCLUSION

By leveraging the 7-step Best Tool Matching approach, significant opportunities for PPJ improvement in the MSOP handlers were uncovered:

- Mechanical alignment variability was addressed by introducing fixed level screws. This proactive measure eliminates variations, which are often the root cause of discrepancies and errors.
- Additionally, the preventive maintenance procedure was enhanced by incorporating tube singulator speed into the checklist for verification.

After the implementation of corrective actions, the PPJ performance of the previously worst-performing tool was improved by 200%. Additionally, upon completion of fan-out activities, a positive trajectory in PPJ performance is anticipated across all MSOP handlers. These targeted measures were meticulously developed through the cost-effective BTM approach, obviating the need for time-consuming and expensive DOEs.

The success of this project continues to set the path for effectively resolving numerous other BTM signals across ADI Manufacturing Operations sites. Such initiatives play a pivotal role in advancing ADI's BMP goals, fostering continuous improvement in yield, quality, and equipment performance.

While the effectiveness of the BTM methodology has been demonstrated within ADI, its applicability extends far beyond, positioning it as a benchmark for the semiconductor manufacturing industry. This practical approach not only incurs zero cost but is also readily applicable to real-world scenarios, offering valuable insights and opportunities for improvement across various manufacturing environments.

6.0 RECOMMENDATIONS

The successful application of the BTM methodology hinges on precise data collection and thorough analysis. With the advancements in Machine Learning and Artificial Intelligence (ML/AI), data analysis has become increasingly accessible across all manufacturing operations. However, in cases where data collection remains manual, BTM can still be effectively applied by manually generating probability plots in Excel or utilizing other available tools.

While BTM has proven its effectiveness in enhancing equipment reliability and performance, its versatility extends far beyond these domains. It can be seamlessly adapted to various other topics and industries where comparative performance analysis serves as a fundamental driver for continuous improvement initiatives.

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Process Development Engineering: Mon Aranes
Equipment Engineering: Emil Capule and Jaime Paguiligan

8.0 REFERENCE

1. 01.2019 Rasco SO1000 Customer Documentation (Original instructions), CDoc en-US Version: E, “Turning speed”, pp 8-10.

9.0 ABOUT THE AUTHORS

Mary Grace C. Raborar earned her Bachelor of Science degree in Electronics and Communications Engineering from the University of Santo Tomas, Manila in 2012. Commencing her career journey with Analog Devices, Inc. in 2006 as a Failure Analysis Technician, she progressed to the role of Failure Analysis Engineer in 2012. In 2021, she transitioned to Process Development Engineering and is currently working on Data Analytics to support Analog Devices Philippines Manufacturing Operations.

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