Design improvement for laser jig cavity depth to reduce pad stain

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ABSTRACT

In the manufacturing industry, ensuring product quality and consistency is paramount to maintaining competitive advantage and meeting customer expectations. This project aims to investigate the root causes low utilization rate of laser cutting process and develop innovative solutions to minimize its occurrence.

4M approach was used to determine the root cause of the low utilization rate of laser cutting machines. Laser cutting machine downtime due to pad discoloration occurrence was identified the main contributor of low utilization rate. Evaluations on man, machine, method and material was conducted to identify the main contributor of pad discoloration. Results indicated that laser tooling cavity depth causes the occurrence of pad discoloration.

Modification of the laser jig tooling cavity depth was conducted, and upon validation showed decreased defect level and improved utilization rate.

1. 0 INTRODUCTION

In the manufacturing industry, ensuring product quality and consistency is paramount to maintaining competitive advantage and meeting customer expectations. Pad discoloration presents a significant challenge that directly affects both product aesthetics and operational efficiency. This project is strategically aligned with business objectives to mitigate these challenges and enhance overall performance through several key avenues.

This project aims to investigate the root causes of low utilization rate of laser cutting process and develop innovative solutions to minimize its occurrence. By conducting detailed analysis of material properties and manufacturing processes. The project seeks to identify critical factors contributing to pad discoloration. Understanding these factors is essential for optimizing manufacturing processes and enhancing the durability and aesthetic consistency of pads used in production.

1.1 Root cause analysis for low utilization rate of laser cutting machines

1.1.1 Machine Utilization

Due to the tighten criteria of customer, utilization rate of laser cutting machine decrease from above target of 90% to below target of 75% due to machine downtime.

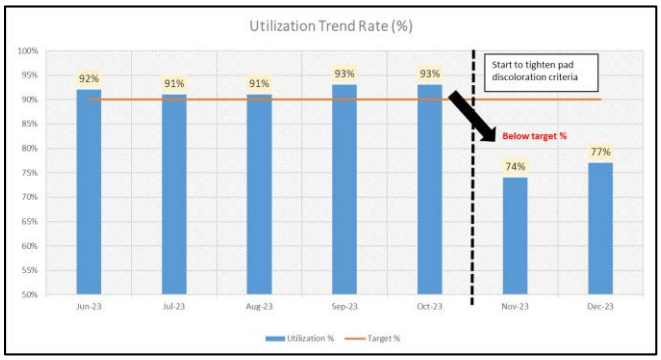
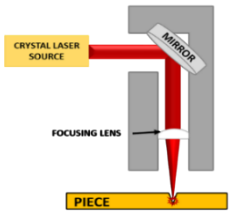


Fig.1 Utilization Trend Rate. shows the machine utilization trend rate due to pad discoloration indicating a significant decrease after the tightening of the customer criteria of pad discoloration.

1.1.2 What is Laser Cutting Process

Laser Cutting is a process of singulating units through utilization of crystal medium, optics, machine setting and parameters such as power, pulse rate, velocity and repetition count, and a cutting sequence program such as BAS files.



Parameter	UOM
Power	Watts (W)
Pulse rate	Frequency (KHz)
Velocity	mm/s
Repetition count	Count

Fig 2. Laser Cutting Mechanism and Machine Setting. The laser optics hits a mirror and passes through a focusing lens then strikes outline of the unit based on the set parameters.

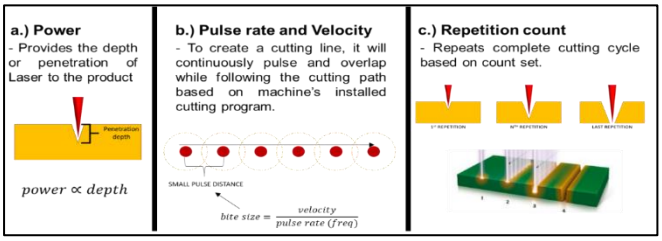


Fig 3. Laser Parameters. The intensity and strength of the laser machine varies depending on the parameters set.

1.1.3 Root Cause Analysis of Downtime Occurrence

Analyzing the contributing factors on the significant decrease in machine utilization, the group came up with five potential downtime sources which were dislodge, contamination, burn, uncut and pad discoloration.

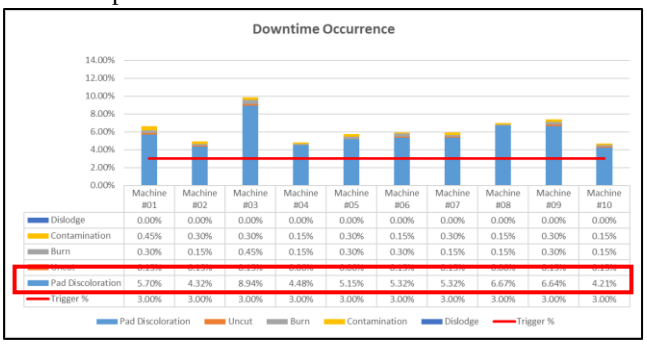


Fig 4. Downtime Occurrence Trend. Based on checking of the downtime occurrence of laser cutting machine, top contributor is due to the issue of pad discoloration with 5.68% average downtime occurrence.

1.1.3 How Pad Discoloration Occurs

During processing, laser cutting will produce fumes and made contact to pad that resulted to pad discoloration. As shown in Fig 5.

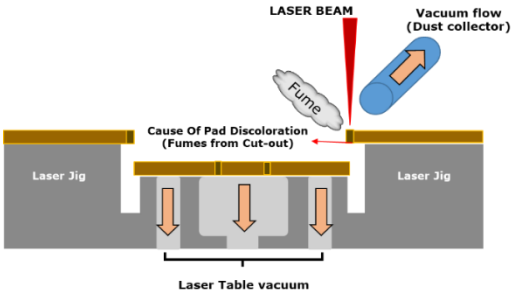


Fig 5. Pad Discoloration Occurrence. As laser beam hits the unit, fumes from cut outs produces the stain or discoloration on the pad.

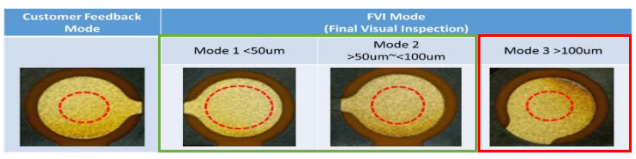


Fig 5. Pad discoloration defect mode

2. 0 REVIEW OF RELATED WORK

This section discusses previous studies that relate to the problem that the author is solving. It explains the theoretical considerations if applicable. As an option, this section can be combined with "1.0 INTRODUCTION". When this is done, write here the entry "Refer to 1.0 Introduction.". Else, write "Not Applicable.".

When citing a previous related work done by another person or group, proper referencing should be observed and followed.

3.0 METHODOLOGY

3.1 Root Cause Analysis of Pad Discoloration Occurence

The root cause analysis is conducted using 4M (Man, Method, Material, and Machine) analysis. Hypotheses were formulated and evaluations were conducted specifically for each contributors specified in 4M.

Table 1. Pad Discoloration 4M Matrix

Manpower	Machine	Method	Material	Toolings
Evaluate with 5 MPs to process lots	Same	Same	Same	Same
Same	Process using 10 different machines	Same	Same	Same
Same	Same	Validate actual procedure vs work instruction.	Same	Same
Same	Same	Same	Compare pad discoloration levels of 10 different lots.	Same
Same	Same	Same	Same	Use laser jig of different cavity depth.

This table shows the activities conducted to analyze the potential contribution of each factor in the occurrence of pad discoloration.

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4.0 RESULTS AND DISCUSSION

4.1 Root Cause Analysis of Pad Discoloration Occurrence

4.1.1 Man

The evaluation of different MP indicated that there is no significant difference between each MP which manifests low probability of man-related cause of occurrence.

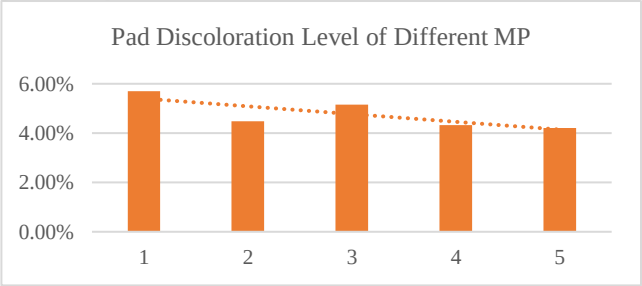


Fig 6. Pad Discoloration Level of Different MP. This figure shows the pad discoloration contribution of different MP.

4.1.1 Material

Based on the pad discoloration level of ten different lots, results showed that defect levels does not significantly vary indicating low probability of material-related cause of pad discoloration occurrence.

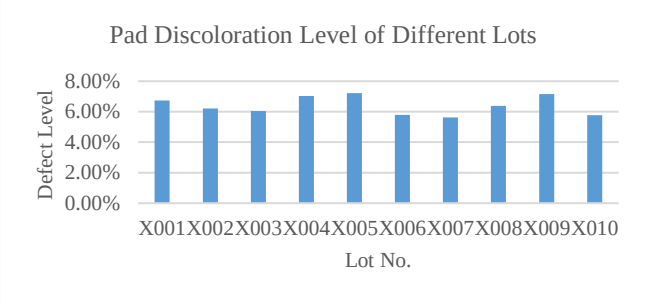


Fig. 7. Pad Discoloration level of different lots. This figure shows the occurrence level of pad discoloration measured in different 10 lots.

4.1.1 Machine

4.1.1.1 Machine Input Variable Setting Condition

The machine parameters were check to determine if within specified conditions such as the pulse rate, power, velocity and repetition rate.

Table 2 Laser Machine Parameters

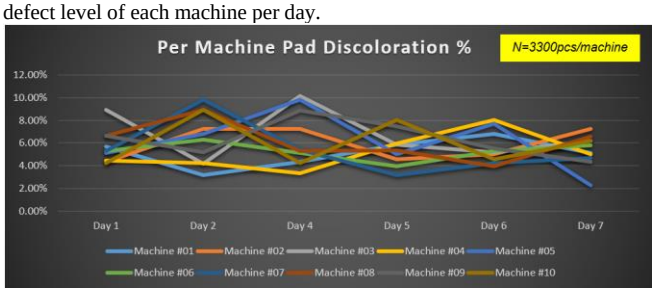
Item	Input Variables & Setting Validation	Specification	Actual reading	Result
1	Laser power condition	Exact	Within specification	Passed
2	Vacuum setting	Exact	Within specification	Passed
3	Repetition	Exact	Within specification	Passed
4	Pulse rate	Exact	Within specification	Passed
5	Velocity	Exact	Within specification	Passed

Table 2 presents the machine specifications condition. Based on validation, all machine specifications are within limit.

4.1.1.2 Machine Performance Comparison

This data presents the pad discoloration occurrence evaluation using 10 different machines observed for seven days. Based on evaluation, there was random and inconsistent occurrence of pad discoloration in different machines, indicating low probability of machine related cause of occurrence.

Fig 8. Comparison of Machine Performance. This figure shows varying defect level of each machine per day.



4.2 Evaluation of laser cutting tooling with different cavity depth

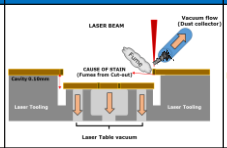
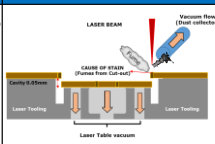
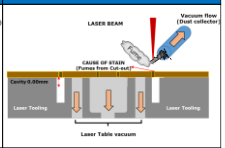
Check Items	Current Tool	Jig Design #1	Jig Design #2
Design			
Cavity depth	0.10mm	0.05mm	0.00mm (Flat)

Fig 9. Cavity Depth Modification. This figure shows the modification of the laser tooling design from 0.1mm cavity depth (default), to 0.05mm (improved).

Comparing the results of the laser tooling of different cavity depth, it is observed that tooling with larger cavity depth has higher pad discoloration level. Best condition upon the evaluation is the Jig Design #2 with 0.00mm cavity depth for pad discoloration, however upon checking it also induce additional dislodge defect that affect the next process. Recommendation to use is Jig Design #1 with 0.05mm cavity depth with lowest over-all laser defect.

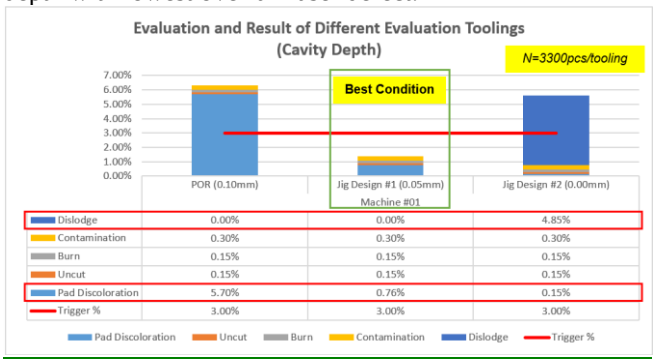


Fig 9. Cavity Depth Defect Level Comparison. This figure shows the results of the evaluation conducted using 3 laser jig design with different cavity depth.

4.2.1 Regression analysis between laser tooling cavity depth vs pad discoloration

The figure below shows the regression analysis of cavity depth and pad discoloration. With a p-value of 0.001 and correlation of 85.00% it can be inferred that the pad discoloration occurrence is caused by the cavity depth of laser jig tooling.

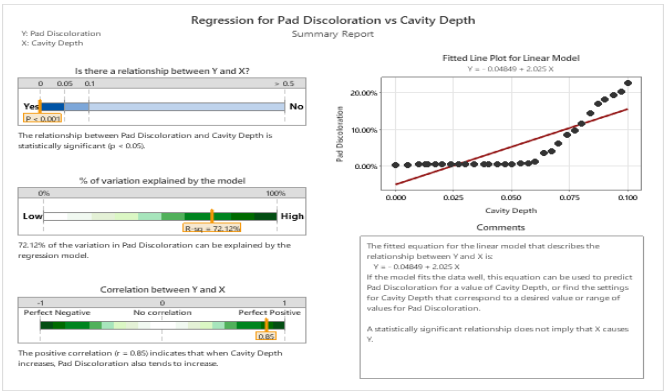


Fig.10 Laser tooling cavity depth validation. This figure shows correlation and regression analysis of pad discoloration and pad depth.

4.2.2 How cavity depth induces pad discoloration

Units are partially cut and do not descend to the cavity on the 5th repetition of the good condition, resulting in a single fume direction. On the 5th repetition of the NG condition, the material is already beginning to cut and descend into the cavity, creating two fume directions—one away from the nozzle vacuum and potentially discoloring the gold pad.

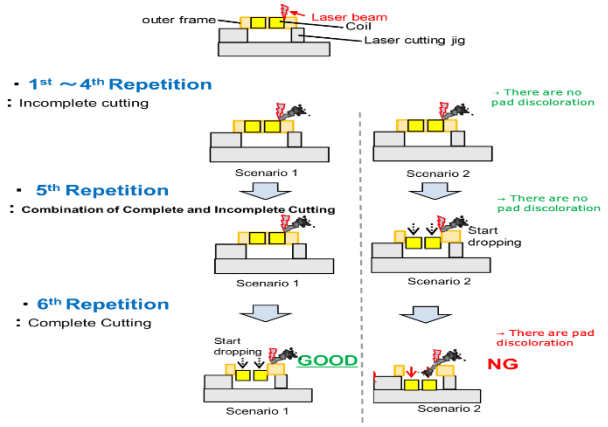


Figure 11. Laser Cutting process simulation. To fully suction the fume that result to pad discoloration, the product unit needs to be dropped as close to the vacuum nozzle as possible.

4.4 Impact of laser tooling modification

Upon application of improved laser tooling pad discoloration defect level decrease from 6.39% to 0.59%; utilization rate improve from before average of 75% to 90% utilization; this translates to the improvement of utilization impact to cost savings up to $20k per month.

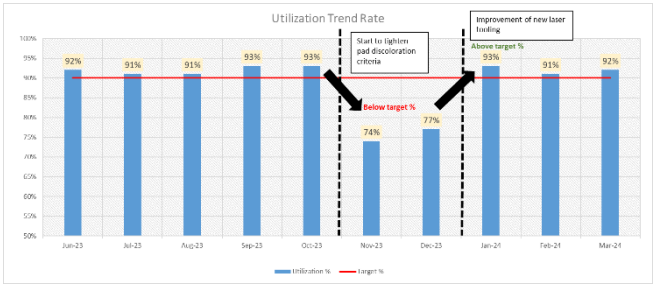


Fig 11. Cost Savings and Defect level reduction. This figure presents the impact of the improvement of laser tooling cavity depth to the company's yield performance and utilization rate.

5.0 CONCLUSION

In conclusion, the low utilization rate roots from the occurrence of pad discoloration during laser cutting process. This pad discoloration is induced by the cavity depth of the laser tooling. Based on analysis, the cavity depth of the laser tooling is a direct impact on the pad discoloration occurrence. Thus, after modifying the laser tooling cavity depth from 0.1 to 0.05, the pad discoloration level gradually decreased. This improvement translates to 90% utilization rate and up to $20k cost savings per month.

6.0 RECOMMENDATIONS

Standardization and fan out strategies play a crucial role in effectively addressing pad discoloration in manufacturing processes. Here is an overview of how these approaches can be applied; fan out of laser tooling improvement to three products with laser cutting process, automate the monitoring system for laser cutting process, and include cavity depth measurement on incoming quality assurance inspection check sheet.

7.0 ACKNOWLEDGMENT

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8.0 REFERENCES

1. W.M. Steen and J.N. Kamalu, Laser Cutting in Laser Materials Processing, North-Holland Publishing Company. 1983, pp 15-113.

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10.0 APPENDIX