ADAS MULTI-FUNCTION LIDAR SCRAP ELIMINATION

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ABSTRACT

This paper focuses on the study to reduce scrap related ADAS Multi-Function LiDAR products. There was a peak scrap cost of 0.62% for the month of July 2022, wherein 30% was contributed by MTF60 Test failures.

The objective of this project is to eliminate the Modular Transfer Function at 60 **(**MTF60) failures the fastest way possible as this has a huge impact in MFL overall scrap.

Initially, the failures were correlated to suppliers' MTF0 test parameter. However, Plant Ingolstadt's scrap is not as high as Plant Calamba considering that they have same suppliers. This led the team to further check on the environmental factors such as staging time and temperature effect on the Optic Modules Performance. This hypothesis led to several simulations and later a conclusion that thermal stress induced by changing temperatures can cause changes to gluing property which has high impact on MTF60 Test results.

Controllable countermeasures were implemented which resulted to significant reduction of failures. Through this project, scrap rate related to MTF60 was eliminated which has an equivalent Scrap Cost Avoidance of 10.3 million pesos for year 2022.

The plant's dedication in setting the standard for good scrap performance was clearly demonstrated. Through organized problem-solving and solid network collaboration, the team exhibited scientific and systematic techniques to identify technical and systemic root causes, resulting in sustainable solutions.

1.0 INTRODUCTION

Autonomous mobility is one of the most important future markets in the automotive industry. Continental Plant Calamba as one of the leading automotive suppliers in the region, commits to improve manufacturing processes to contribute to this growing market.

Advanced Driver Assistance Systems (ADAS) is a business unit that develops and produces sensors, driving features, and a central unit for assisted and automated driving. The goal is to make "Vision Zero" a reality, which is our vision of accident-free driving. As part of ADAS worldwide operations, ADAS Calamba actively supports worldwide serial production of Short-Range Radar (SRR) and Multi-Function LiDAR (MFL) and support industrialization and drive standardization of our processes and as a benchmark in our performance.

To ensure that Vision Zero is achieved, Plant Calamba guarantees to maintain the outstanding quality of its products. Dealing with production-related flaws is another aspect of this. With this, the Scrap is one of the main Key Performance Indexes (KPI) being tracked. This project aims to reduce scrap costs while maintaining a high level of product quality in line with Hoshin Kanri at Continental Plant Calamba.

2.0 REVIEW OF RELATED WORK

2.1 Multi-Function Camera with Lidar (MFL)

Multi-Function LiDAR (MFL) is a sensor unit which is a combination of a Complementary Metal-Oxide-Semiconductor (CMOS) camera and an infrared Light Detection and Ranging (LiDAR). The combination of these two sensor technologies can detect objects ahead of the vehicle and can determine whether collision is imminent by calculating the distance from that object.

When there is a possibility of collision, the MFL can signal the Assisted Driving Control Unit (ADCU) to alert the driver either via visual and/or audio alarm, or it can directly trigger the Automatic Emergency Braking (AEB) System to prevent the collision.

2.2 Camera/Image Quality Assessment

Image quality from cameras can be assessed by either of the two methods:

- Subjective method – make use of humans to observe the quality of the captured image and grade these images accordingly. Human subjects consider several standards in assessing the image quality.

- Objective method – use parameters and mathematical models to estimate the quality of the image in qualitative and quantitative terms.

Examples of objective parameters used are:

- contrast, resolution, sharpness, distortion, noise
- optomechanical properties such as: tilt, pitch, yaw
- color characteristics: chromatic aberrations.
- other optical parameters: relative illumination, focal length
- modulation transfer function

In assembly lines or during manufacturing of cameras, wherein hundreds or thousands of units are being manufactured every single day, it is obviously more practical to use the objective method over subjective method in the assessment of image quality from cameras.

2.3 Modulation Transfer Function (MTF)

The Modulation Transfer Function (MTF) tells how much contrast in the original object is maintained by the image sensor. In other words, it characterizes how faithfully the spatial frequency content of the object gets transferred to the image.

MTF can also be viewed as the ratio of the output modulation (contrast of the image) produced by the system to the input modulation (actual contrast of the object) of different spatial frequencies. Below is the typical graph of an MTF.

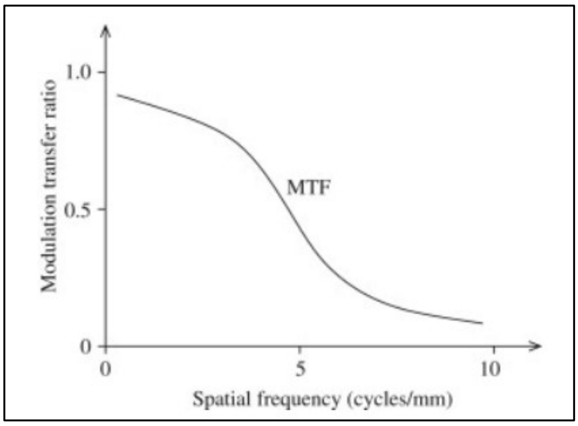

Fig 2.3-1 – Typical resulting graph of MTF

The graph shows that it becomes more difficult for a camera to reproduce the same contrast of the object as the spatial frequency increases or as the distance from the object increases.
MTF values range from 0 to 1, where 1 is the ideal value.

3.0 METHODOLOGY

3.1 Define

The ADAS Multi-function LiDAR (MFL) Product constantly failed to achieve scrap rate from January to July 2022. The objective of 0.27% has already been missed by 43% for the year to date during the first half of the year.

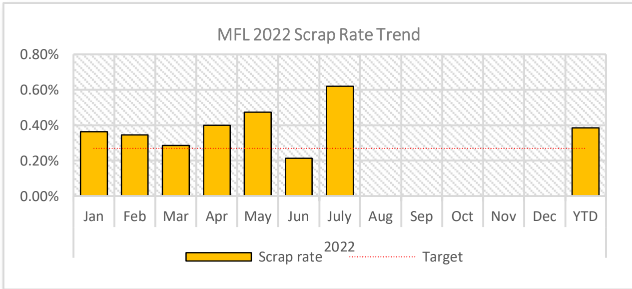

Figure 3.1-1. 2022 MFL Scrap Rate Trend

3.2 Measure

The Pareto figure below shows that the "Green Right MTF60" Test Failures at End-of-Line Camera Station was the major scrap contributor for the first half of Y2022. It contributed to 30% of the scrap rate.

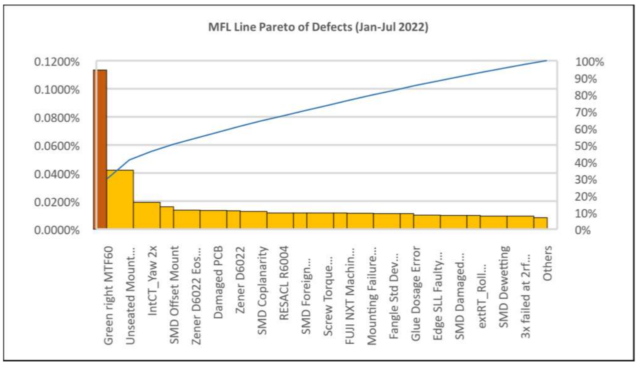

Figure 3.2-1. 2022 Pareto of Scrap Contributors

3.2.1 What is MTF60?

"MTF60" stands for Modular Transfer Function at 60-line pairs per millimeter resolution. It is a standard measure of a camera performance to capture image with better contrast and fine details.

3.2.2 End-of-Line (EOL) Camera Test Station

In EOL Camera station, sharpness test is evaluated by MTF60 and is performed using an optical collimator imaging a cross hair target to a distinctive distance. The sharpness test is calculated inside the camera with the help of the production software.

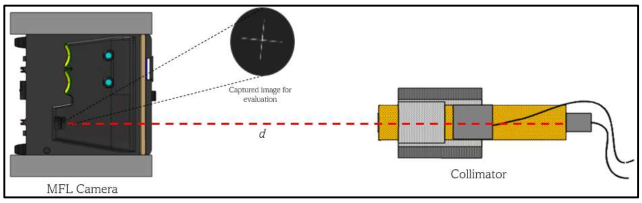

Figure 3.2.2-1. Station Set-Up for Sharpness Test

3.3 Analyze

3.3.1 Fishbone

To simplify the problem and identify the root cause, all potential causes under Man, Method, Measurement, Material, Machine and Environment (5M1E) were listed using a cause-and-effect diagram called Ishikawa diagram as shown in Figure 3.3.1-1.

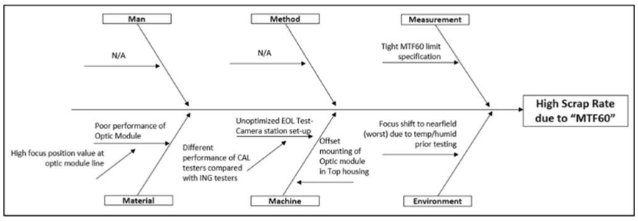

Figure 3.3.1-1. Fishbone/Ishikawa diagram for root cause analysis on MTF60 Failures at EOL-Test Camera Station

3.3.2 Factor Analysis

Series of evaluations, testing and data gathering were performed to check if each possible factor on the Ishikawa diagram is a valid factor or not a valid factor through a systematic problem-solving approach by using factor analysis method. The following are considered the valid factors.

1. **Material – Poor Optic Module Performance at Supplier Side**

Using fitted line plot in Minitab to check the correlation with supplier's test parameters, MTF60 is strongly correlated with "40,6 MTF0" from Optic Module line at supplier side. The MTF60 measurement is inversely proportional with Best Focus measurement. Thus, all failed parts in MTF60 have values near the upper limit of supplier.

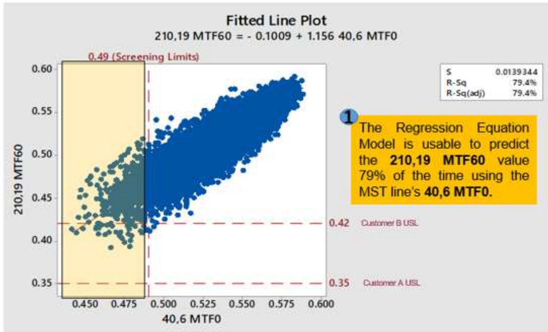

Figure 3.3.2-1. Fitted Line Plot showing the relationship of "MTF60" and supplier parameter.

2. **Measurement – Tight Specification of "MTF60" Test Parameter**

"MTF60" specifications were compared between customers. As there was already an approval of limits relaxation for customer A, high scrap rate was encountered for customer B with still tight limits.

Table 3.3.2-1 MTF60 Specification Table

Customer	Lower Limit	Upper Limit
A	0.35	1.00
B	0.42	1.00

3. **Environment – Effect of Temperature on "MTF60" Performance**

Other production line in Plant Ingolstadt was also encountering "MTF60" failures. However, their scrap rate is not significant unlike Plant Calamba.

In comparison, Plant Ingolstadt, aside from MFL, has its own optic module production line; Plant Calamba on the other hand, its optic module parts undergo shipment from Ingolstadt to Calamba.

This observation led to hypothesis that the camera performance could be impacted by two variables during shipment:

a) Staging time

Staging time in this study is defined as the gap (number of days) between the time Optic module is being manufactured and the time Optic module is being assembled and tested in MFL line EOL Camera station.

Based on yield data of plant Ingolstadt, 91% of their failed parts that were passed on second test only had an average of 5 days staging time whereas Optic module used by Plant Calamba had an average of 27 days. To examine the relationship of staging time and MTF60 performance, fitted line plot is used below:

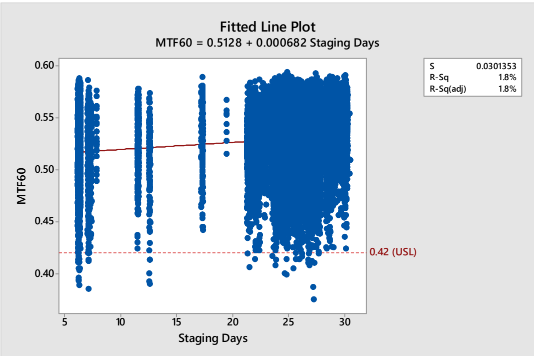

Figure 3.3.2-2. Fitted Line Plot showing the relationship of "MTF60" and Staging time.

There was, however, no significant correlation between MTF60 and Staging time, according to the results of the fitted line plot. Consequently, this is not the cause of the factory in Ingolstadt's low scrap rate and Calamba's high scrap rate.

b) Temperature

Gluing of lens and PCB is one of the processes to manufacture an Optic Module. Thermal stress can cause changes on these materials due to shift of temperature from hot to cold or vice versa during delivery or shipment. To simulate the effect of temperature on material, Optic modules were subjected to variety of conditions involving temperature as presented below:

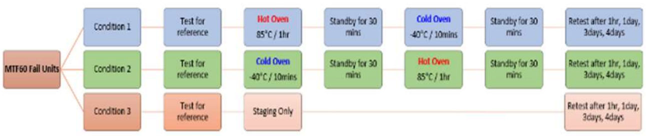

Figure 3.3.2-3. Evaluation on the effect of temperature on MTF60 performance

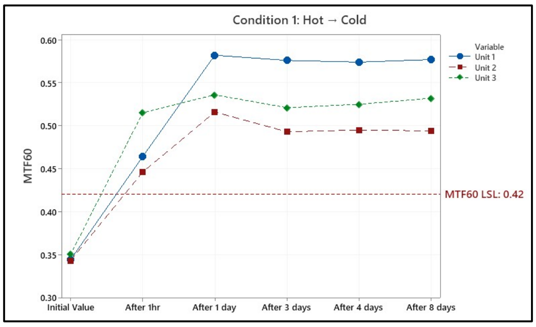

Figure 3.3.2-4. Improvement in MTF60 readings after condition 1

Evaluation showed that "Hot → Cold" condition gave the best result among the 3 conditions, and MTF60 values remained stable even after several days.

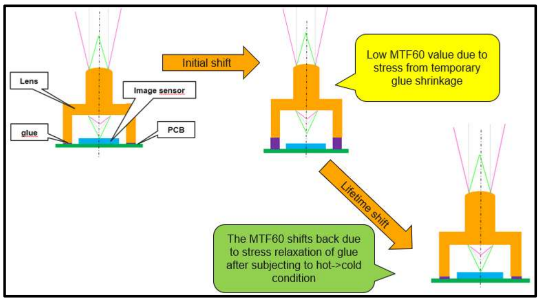

Figure 3.3.2-5 Illustration of glue relaxation after subjecting to hot-cold condition and accelerating lifetime shift.

3.4 Improve

The team listed all the possible countermeasures that can address the valid factors that were identified during the factor analysis. Using the benefit-effort chart, the best countermeasures were selected as follows:

- Item 1-c: To allocate optic module according to customer requirement based on its raw material level test results.
- Item 3-b: To accelerate the "lifetime" shift of optic module by subjecting the sensors to allowable temperature as shown in figure below.

No.	Factor	Countermeasure	Risk
1	Poor performance of optic module raw material	1-a: Request Cpk Improvement on Supplier Side	Low Risk. If Cpk will be improved, no failures will be encountered.
		1-b: Limit tightening for Optic Module "110,2 Best Focus" Test at supplier side	Medium Risk. Yield drop of will be encountered at Optic Module Line
		1-c: Allocate optic module according to customer requirement based on its raw material level test results	**Low Risk. Automated application will be used to sort which optic module will be allocated for each customer**
2	Tight Specification at "Green Right MTF60" Test Parameter	2-a: Limit change approval by Customer A *Note: Customer B has wider limits for Green Right MTF60 Test Parameter*	High Risk. Customer A is requesting for several tests during the discussion. This will took 6-12 months and 18mio Euro costs for Field of Test.
3	Uncontrolled temperature during shipment of Optic Module raw material	3-a: Transfer the optic module line to Plant Calamba *This will avoid variations during transport of raw material*	High Risk: No guarantee that no failures will be encountered
		3-b: Accelerate the "lifetime" shift of optic module by subjecting the sensors to allowable temperature	**Low Risk: Risk assessment will be conducted and will be reviewed by R&D and HQ**

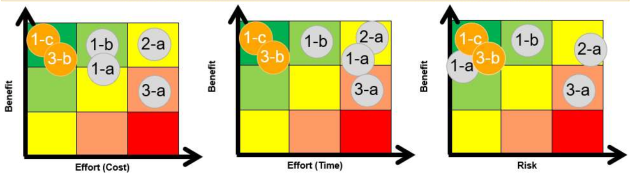

Figure 3.4-1: Benefit-Effort Chart

The team focused on controllable countermeasures that can be implemented immediately to reduce the scrap rate. One of the countermeasures was to allocate optic module according to customer requirement based on its raw material level "MTF 0" test results. This checking will be done by production operators using an automated application that will provide the decision which optic module is for which customer as shown in Figure 3.4-2.

This improvement item has drastically reduced the scrap by 80% as predicted on the correlation as shown in Figure 3.3.2-1.

Figure 3.4-2: Automated Application

The work instructions as shown in figure 3.4-3 during this process were oriented to the production team to ensure that no other issues will arise during this process.

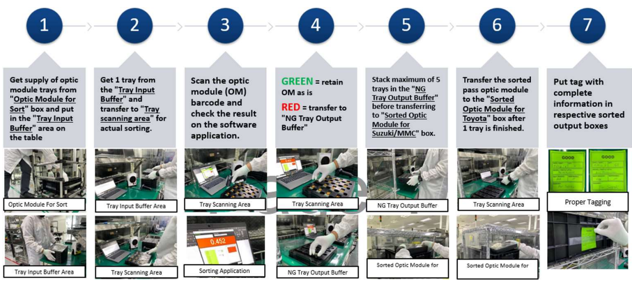

Figure 3.4-3: Work Instruction

Another countermeasure that was implemented was to accelerate the "lifetime" shift of optic module by subjecting the sensors to allowable temperature as shown in figure 3.4-4. "Green Right MTF60" values increase by subjecting the sensors to Cold and Hot Chamber as shown in figure 3.4-5. With this, scrap related to MTF60 was eliminated. This flow was reviewed by cross-functional team involved at Plant Calamba as well as Ingolstadt Test Engineering and Lindau R&D.

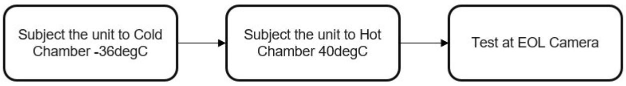

Figure 3.4-4: Process Flow

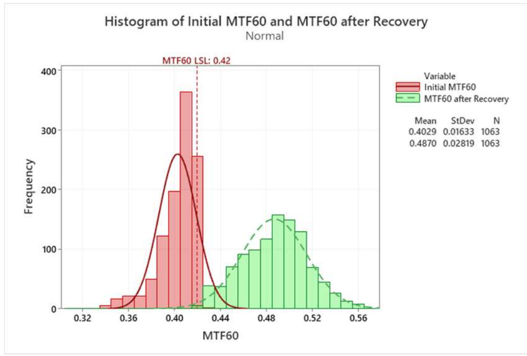

Figure 3.4-5: 1K+ pcs initial batch of units that undergone recovery

3.5 Control

Implemented actions were aligned with other departments such as the Quality Assurance, Failure Analysis, and Production team. Training and reinforcement were incorporated into the production staff (e.g., Operators, Material handlers, and Supervisors) to perform the standard procedure as shown in Figure 3.4-3. The allocation of optic modules according to customer requirements was communicated with and approved by Quality Engineers. Presently, the improved performance has been maintained by these control measures.

4.0 RESULTS AND DISCUSSION

After complete implementation of corrective actions, scrap related to "Green Right MTF60" was eliminated.

Counter measure	Factor	Action Item	Resp.	Target Date	Status
Preventive Action	Poor performance of optic module raw material	Allocate optic module according to customer requirement based on its raw material level test results	J. Pangan	20-Jul-22	Done
	Uncontrolled temperature during shipment of Optic Module raw material	Accelerate the "lifetime" shift of optic module by subjecting the sensors to allowable temperature	J. Pagala	30-Sep-22	Done

Figure 4-1 Summary of Countermeasures

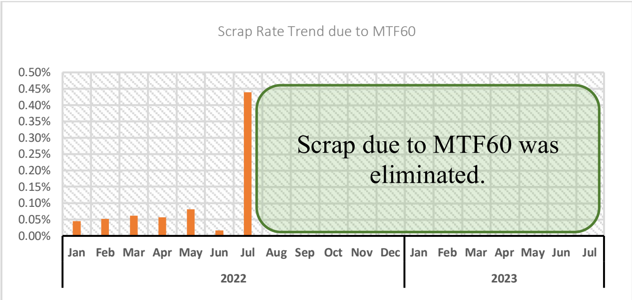

Figure 4-2 Result of scrap after implementation of corrective actions

After the implementation of all the corrective actions, the reduction of scrap resulted to 10.3 million scrap cost avoidance for year 2022.

5.0 CONCLUSION

"MTF0" has a strong positive correlation to "Green Right MTF60". MTF60 performance was predicted almost 79% of the time using the supplier's MTF0 result, so yield has significantly improved. The failed sensors were subjected to hot and cold chamber since the performance of optic module was greatly affected by the temperature. This process has significantly reduced the MFL line scrap rate up to present.

6.0 RECOMMENDATIONS

1. Temperature should be part of factor analysis if dealing with camera sharpness performance.
2. The regression analysis is a good statistical method to check the impact of a variable to another. It helps with predicting and controlling the outcome to the affected variable.
3. Benefit-Effort chart is also a good measure to identify corrective action/s that is/are best to work on to achieve a main goal.

7.0 ACKNOWLEDGMENT

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9.0 ABOUT THE AUTHORS

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