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An Approach towards Process FMEA of Structured Light Scanning (SLS) Measurement Process

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ABSTRACT: Structured light scanner systems are comprehensive three dimensional measurement solutions which deliver high-accuracy data captured at high-speed for small-to-medium sized parts. It is a critical measurement process utilized in the inspection of various parts. The current paper describes about the Process-FMEA which aims to identify and assess potential failure modes in the SLS measurement process and implement effective controls to mitigate risks. Here a participative method using a cross-functional team for brainstorming was employed to gather the information about the failure modes that can occur in the measurement process with their causes their effects and devising the control plan.

NOMENCLATURE

PFMEA	Process Failure Mode and Effects Analysis
RPN	Risk Priority Number
SLS	Structured Light System
CP	Control Plan
STL	Standard Tessellation Language
FOV	Field of View

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I. INTRODUCTION

Structured Light Scanner is a 3D device that analyzes a real-world object or environment to collect data on its shape and possibly its appearance (i.e. colour). It consists of light source, laser pointer, cameras and computer system with scanning and analysis software.

Fig. 1 Structured Light Scanner under study

The collected data can then be used to construct digital, three dimensional models useful for a wide variety of applications [1]. SLS involves various steps to get the measurements on various parts. It involves scanning of the part to get the point cloud and then converting the same into the Standard Tessellation Language (STL) model for evaluation. The structured light scanning measurement process consists of the following key steps given in the Fig.2 process flow. The failure modes of the SLS measurement process are related to these steps.

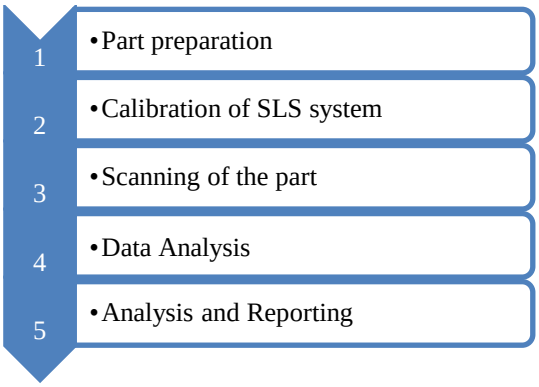

Fig.2 SLS measurement process flow

Part preparation is a crucial step that ensures part is ready for the structured light scanning. This process involves cleaning and preparing the surfaces to ensure accurate and reliable scan results. After cleaning, developer is applied on the specular surfaces to ensure better scanning results.

Calibration is a critical step to ensure the SLS provides accurate and reliable measurements. This process involves adjusting and verifying the system's parameters to match the expected values. It is carried out with the help of calibration artifact provided for a particular field of view (FOV).

Structured light scanning involves projecting a pattern of light (fringes) on to the part's surface and capturing the deformation of the pattern to create a point cloud and STL model of the part for comparison against the part CAD model and inspection of the features. This step requires careful attention to avoid issues with light source and system alignment [2].

Data processing involves converting and processing the raw data in the form of point cloud obtained from structured light scanning into a usable 3D model. Software glitches during this step can compromise the integrity of the model.

In the last step of analysis and reporting, the 3D model generated from structured light scanning is analysed, and a report is generated. Misinterpretation of the results can lead to incorrect conclusions.

Process FMEA focuses on the potential process–related failures and their causes. Here main drive is to understand the process through the identification of as many potential failures as possible. It typically assumes that the design is sound. It also involves avoiding potential non-conformities by ranking the risk of them occurring [3]. Here aim is to try to eliminate process deficiencies which can result in errors and faulty results. During PFMEA development recommended actions are targeted at eliminating the root cause of the potential failures. PFMEA involves development of process flow diagram, carrying out the process FMEA and then developing the control plan as depicted in Fig. 3.

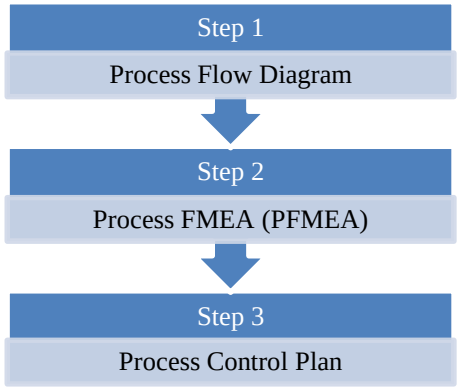

Fig.3 PFMEA development process

Process FMEA procedure

Process FMEA involves various steps as follows:

- identification of process step in the measurement process
- identification of the failure modes of the measurement process
- evaluating the potential effects of the failures/errors
- establishing the possible causes of the failures/errors
- taking account of the existing control of the processes

- establishing the Severity (S), Occurrence (O) and Detection (D) numbers for the failure modes
- evaluating the Risk Priority Number (RPN)
- defining the actions required
- establishing the control plan

The standard tables for the severity, occurrence and detection are devised as follows:

Severity

Severity is the assessment of the seriousness of the effect of the potential failure mode. In this we have to determine all failure modes based on the functional requirements and their effects [4]. A reduction in severity ranking index can be effected through a design change to system, subsystem or component, or a redesign of the process. Severity table considered for the current study is given in table1 as follows:

Table (1). Severity table

Severity (S)	Definition
1	No impact on measurement accuracy
2	Minor impact, easily correctable with minimal impact on results
3	Minor impact, correctable with moderate effort.
4	Moderate impact, correctable with significant effort, minimal impact on measurement accuracy.
5	Moderate impact, may require recalibration, slight distortion in measurement results.
6	Significant impact, may lead to inaccurate measurements over time.
7	Major impact, likely to cause immediate deviation in measurements.
8	Critical impact, may lead to critical inaccuracies in critical dimensions.
9	Dangerous impact, poses a safety risk due to incorrect measurements.
10	Extremely dangerous impact, poses severe safety risk, critical engine failures possible.

Occurrence

Occurrence is the likelihood that a specific cause/mechanism of failure / error will occur. Preventing or controlling the causes/mechanisms of failure through a design or process change is the only way a reduction in the occurrence. Occurrence table used for the current study is as follows:

Table (2). Occurrence table

Occurrence (O)	Definition
1	Highly unlikely, almost impossible to occur.
2	Very unlikely, occasional occurrences with minimal impact.
3	Unlikely, may occur occasionally with moderate impact.
4	Possible, could occur under certain conditions, moderate impact.
5	Occasional, likely to occur in specific situations, noticeable impact.
6	Occurs frequently, likely to happen in normal operations, impact on results.
7	Frequent occurrences, likely to happen in typical operations, significant impact.
8	Very frequent, almost certain to occur in normal operations, critical impact.
9	Extremely frequent, expected to occur continuously, dangerous impact.
10	Certain to occur in almost all situations, extremely dangerous impact, critical engine failures possible.

Detection (D)

Detection is the rank related to the best detection control listed in the process control area. It is a relative ranking, under the ambit of the individual FMEA. Generally, the planned process control has to be improved to lower the detection rating. Detection table followed is as shown in table3 below.

Table (3). Detection table

Detection (D)	Definition
1	Very effective, virtually certain to detect any deviations in measurements.
2	Highly effective, very likely to detect any discrepancies in measurements.
3	Effective, likely to detect discrepancies during routine checks.
4	Moderately effective, may detect discrepancies with additional effort.
5	Moderate, 50-50 chance of detecting discrepancies, may require specialized checks.

6	Ineffective, unlikely to detect discrepancies during routine checks.
7	Highly ineffective, very unlikely to detect discrepancies with routine checks.
8	Almost certain to not detect discrepancies even with specialized checks.
9	Virtually impossible to detect discrepancies, even with advanced methods.
10	Impossible to detect discrepancies, significant risk of inaccurate measurements.

II. FAILURE MODES, EFFECTS AND CAUSES

The SLS measurement process can have numerous failure modes depending upon the process step. Various failures with potential effects and causes brainstormed by a cross functional team are given in the following table (4).

Table (4). Failure modes, effects and causes in SLS measurement process

Sl No.	Process Step	Failure Mode	Potential Effects	Causes
1.	Part preparation	Contamination	Reduced scan accuracy	• Improper cleaning procedure • Foreign material presence
2.	Calibration	Calibration error	Inaccurate measurements	• Equipment drift • Incorrect calibration setup
3.	Structured light scanning / Hardware Malfunction	• Light source failure • System Alignment Issues	• Incomplete scan data/data loss • Distorted 3D model	• Bulb failure • Power fluctuations • Mechanical misalignment
4.	Data Processing	Software Glitch	Data corruption	• Programming errors • Compatibility issues
5.	Analysis and Reporting	Misinterpretation	Incorrect analysis results	• Lack of user training • Ambiguous reporting format
6.	Environmental Conditions	Fluctuations in temperature or humidity.	Distorted scans, measurement inaccuracies	• Air condition failure • Power failures • Extreme weather conditions

III. RESULTS AND DISCUSSION

In the study under taken the cross functional team debated on the severity (S), occurrence (O) and detection (D) ratings and various values were accorded to these failure modes. Based on these values Risk Priority Number (S x O x D) was arrived at for the failure modes. The following Table (5) gives the details:

Table (5). Risk priority matrix

Sl No.	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN = S x O x D
1.	Contamination	4	3	4	48
2.	Calibration error	3	2	4	24
3.	Light source failure	4	3	3	36
4.	System Alignment Issues	4	2	3	24
5.	Software Glitch	3	2	4	24
6.	Misinterpretation	3	3	3	27
7.	Environmental Conditions	3	4	2	24

Based on the above risk results a control plan was devised to carry out a comprehensive study of the process steps and developing the control strategies for each failure mode. The control plan so developed is shown in the Table (6) as below:

Table(6). Control strategies for the detected failure modes

Sl No.	Failure Mode	RPN	Control Plan
1.	Contamination	48	a) Developed a standardized cleaning protocol for parts, specifying approved cleaning agents and methods. b) Provided comprehensive training to operators on the proper cleaning procedures to minimize the risk of contamination. c) Implemented regular audits and inspections to ensure adherence to cleaning protocols. d) Maintained a record of cleaning activities, including the type of cleaning agent used and the date of the last cleaning.
2.	Calibration error	24	a) Established a regular calibration schedule, with frequency determined by system specifications and usage. b) Documented calibration settings and adjustments made during each calibration session. c) Implemented a calibration verification process to confirm the accuracy of the calibration before scanning critical parts. d) Trained operators on proper calibration procedures and provided guidelines for troubleshooting calibration errors.
3.	Light source failure	36	a) Installed backup light sources to ensure continuous operation in case of primary light source failure. b) Implemented a routine inspection schedule for the structured light scanning system to identify and address alignment issues promptly. c) Performed regular checks on power sources and implement surge protection measures to prevent power fluctuations.
4.	System Alignment Issues	24	a) Established a maintenance schedule for the entire structured light scanning system, including mechanical components, to ensure proper alignment.
5.	Software Glitch	24	a) Regularly updating scanning software to the latest version to benefit from bug fixes and improvements. b) Maintained a backup of previous software versions to quickly revert in case of issues with updates. c) Provided training to operators on software usage and troubleshooting techniques. d) Established a protocol for reporting and addressing software-related issues promptly.
6.	Misinterpretation	27	a) Providing comprehensive training to users on the interpretation of 3D models and analysis reports. b) Developing standardized reporting formats with clear guidelines for interpretation. c) Establishing a peer review process for complex or critical analyses to ensure accuracy. d) Regularly conducting proficiency tests for users to assess their interpretation skills.
7.	Environmental Conditions	24	a) Maintain controlled environmental conditions. b) Periodic checks and adjustments during extreme weather.

After applying the control plan strategies the Risk Priority Number (RPN) is reassessed to see the positive effect of the recommended actions. The revised RPNs are shown in the Fig. 3 as follows:

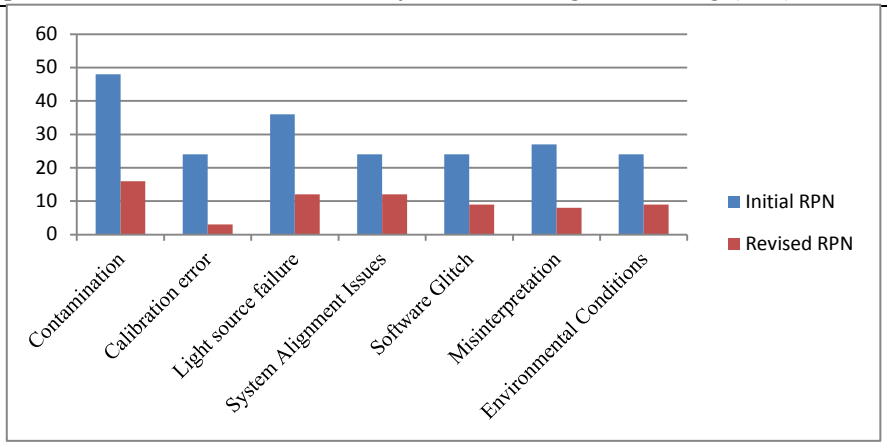

Fig. 3 Revised Risk Priority Numbers

IV. CONCLUSION

The structured light scanning measurement process for parts is complex and involves multiple steps. Implementing a robust control plan at each stage is crucial to mitigate potential failure modes and ensure the reliability and accuracy of the measurement process. This Process FMEA aims to enhance the reliability and accuracy of the structured light scanning measurement process by identifying potential failure modes, assessing their severity, occurrence, and detectability, and implementing effective control measures. Regular reviews and updates to this FMEA will ensure continued improvement in the measurement process. Regular monitoring, training, and updates will contribute to continuous improvement in the overall quality of the scanning and measurement process.

REFRENCES

[1]. A. Georgopoulos, Ch. Ioannidis, A. Valanis, "Assessing the performance of a Structured Light Scanner, International Archives of Photogrammetry", Remote Sensing and Spatial Information Sciences, Vol. XXXVIII, Part 5 Commission V Symposium, Newcastle upon Tyne, UK. 2010

[2]. Prem Rachakonda, Bala Muralikrishnan, Daniel Sawyer, "Sources of Errors in Structured Light 3D Scanners", Dimensional Metrology Group, Sensor Science Division, National Institute of Standards and Technology, Gaithersburg, MD

[3]. Fulea L, Bulgaru M, Borzan M, Bocanet V, "Contributions regarding the application of FMEA analysis to measuring with a CMM", https://www.reserach gate.net/publication/298026542, January 2013

[4]. Riddhish Thakore, Rajat Dave, Tejas Parsana, "A Case Study: A Process FMEA Tool to Enhance Quality and Efficiency of Bearing Manufacturing Industry", Scholars Journal of Engineering and Technology (SJET), Sch. J. Eng. Tech., 2015; 3(4B):413-418, ISSN 2321-435X (Online), ISSN 2347-9523 (Print)