C. Analyze Phase

The third phase is Analyze, consists of brainstorming all possible root causes by using Ishikawa diagram and a selection of the possible root-causes through multi-voting to identify the possible root-causes of the potential causes as identified in Measure Phase. Since the Measure phase found the part not function due to stuck pin is the main defects, the brainstorming session was conducted to discuss the possible root causes of the defect and plotting into Ishikawa diagram according to the process capability study which is defined two potential processes; winding and solder component leg. Generally by using these tools the main root causes of the unrequired processes can be identified and then the processes can either be eliminated or minimized accordingly depending on the solution derived. The Ishikawa diagram is used as a guideline during a brainstorming session. The brainstorming session using Ishikawa diagram involves cross functional team members to ensure all possible root causes will be recorded based on the four factors which are man, method, material and machine. The Ishikawa diagram can also allow the possible causes or problem to be identified structurally and can also determine the relationships between potential causes of problems. Several numbers of possible root causes are identified during brainstorming session, and all the factors must be filtered out to choose the possible root causes which are really contributing to the defects. Upon completion of the brainstorming session, the team members must conduct another session, which is known as multi-voting session to select the potential root causes based on the rating score one to ten.

1. Ishikawa Diagram

The Ishikawa diagram is the brainstorming session among team members to brainstorm the possible root-causes of the defects of stuck pin. The failures of stuck pin cause for the most part not the function has been investigated the possible root-causes by using an Ishikawa diagram. The Ishikawa diagram for the stuck pin was shown in Fig. 6. Four common areas which are man, method, material and machine has been investigated for both of the potential failure processes as per defined in Measure phase which are Winding Process and Solder Component leg.

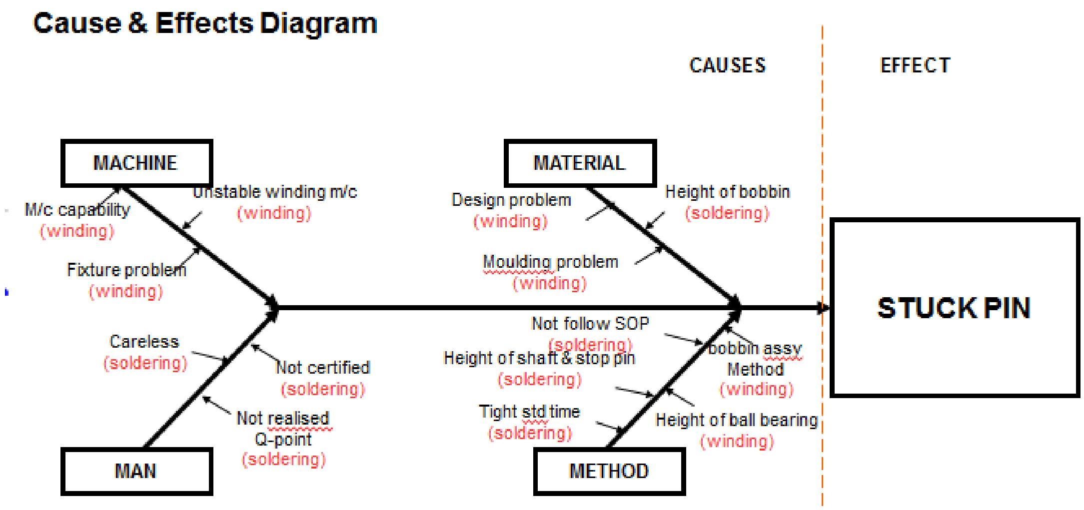

Fig. 6. Ishikawa diagram for stuck pin

2. Multi-voting Analysis

Since the possible root-causes has been brainstormed and the possible root causes were recorded, the multi-voting analysis has been adopted to select the root causes based on mutual agreement among team members. From the 14 possible root causes from the Ishikawa diagram for stuck pins, three potential root causes have been selected based on the highest number of ratings according voting from the team members and the listed potential root causes according to the ranking one to three, there result shows unstable winding machine, height of shaft and stop pin and bobbin assembly method is a processes contributing into the defects. The detail analysis of the multi-voting activity shows in Table IV.

TABLE IV. MULTI-VOTING ANALYSIS FOR STUCK PIN

MAIN	BRANCES	TEAM MEMBERS					TOTAL	PRIORITY
		HELMI	MALA	LEONG	NORDIN	IZWAN		
MAN	CARELESS	4	4	4	5	4	21	10
	NOT CERTIFIES	4	3	4	5	5	21	11
	NOT REALISED Q-POINT	5	3	3	3	2	16	12
METHOD	TIGHT STANDARD TIME	2	3	3	2	3	13	14
	HEIGHT OF SHAFT AND STOP PIN	7	6	7	7	7	34	2
	NOT FOLLOW SOP	4	4	5	4	5	22	9
	BOBBIN ASSEMBLY METHOD	6	5	7	8	6	32	3
	HEIGHT OF BALL BEARING	6	6	6	6	6	30	4
MATERIAL	HEIGHT OF BOBBIN	6	4	5	6	5	26	6
	DESIGN PROBLEM	4	3	3	3	2	15	13
	MOULD PROBLEM (INCOMING)	5	6	5	5	6	27	5
MACHINE	MACHINE CAPABILITY	5	4	5	6	4	24	8
	FIXTURE PROBLEM	5	4	5	6	5	25	7
	UNSTABLE WINDING MACHINE	7	7	7	7	7	35	1

REMARKS:

RATING SCALE	1	5	10
	LESS	MODERATE	HIGH

D. Improve Phase

Once the project teams are satisfied with their data and determined that additional analysis will not add to their understanding of the problem, it's time to move on to solution development and known as an Improve phase. The team is most likely collecting improvement ideas throughout the overall activities, but a structure improvement effort can lead to innovative and elegant solutions. In order to ensure the right decision is made, the potential countermeasures will be identified through the observation and discussion, the hypothesis test should be conducted to ensure the counter measure really solve the quality issue. Once the process of improvement was validated by hypothesis test, the improvement activity will be implemented as per project planning.

1. Hypothesis Test

The improve phase was conducted once the potential causes of the failure was identified. This phase consists of three steps which are suggestion of the solutions, hypothesis test and implementation. All the three potential root causes of failure for stuck pin was proposed the solution to solve the problem and validate the propose solution by using the hypothesis test. The possible solution was developed through discussion among team members based on the current practice in production processes. The solutions of these three main root causes has been agreed by team members and the solution for the problem of unstable winding machine is setting of the height of shaft into opposite direction of the current setting to avoid from the over or under winding. The second problem is the height of shaft of stop pin in soldering process by additional process of checking the stop pin before soldering the leg to ensure the stop pin in the right track instead of soldering without proper checking. While, the problem of the bobbin assembly method is seggration of the upper bobbin and lower bobbin avoiding from the mixing which is will cause the stuck pin because of the different height of the both bobbins.

From these three possible solutions, hypothesis test was conducted to comparing the result of defects between current practices and proposed solution. The hypothesis has been applied to compared the result of the experiment (P value) with percentage of error (alpha, α) as per simulated by Minitab software. The rule of the hypothesis test is, if the P value < alpha, α; means have a significant factor contributing to the failure of the part. Based on the hypothesis test result, found the bobbin assembly method is not significant factor contribute to the failure because of not found any different between current practice and proposed solution but unstable winding machine and height of shaft was found significant factor and both of the factor have been improved based on proposed solutions. The results hypothesis test for both factors shows in Fig. 7 and Fig. 8.

Hypothesis Test: Chi-Square

Data collection:

	Situation A	Situation B
Accept :	236	240
Reject :	4	0
Total :	240	240

**Remarks:

Situation A : No checking the stop pin condition before winding (if machine down during winding)

Situation B : Check the stop pin condition before winding (if machine down during winding)

Hypothesis Test: Chi-Square

STEP 1:

Ho : Result from Situation A **equal to** Situation B

Ha : Result from Situation A **NOT equal** to Situation B

STEP 2:

Alpha, α = 0.05

STEP 3:

P_{value} = 0.044

Alpha, α = 0.05

P_{value} < alpha, α ; Reject H_o, Accept H_a

If: Pvalue > α; accept Ho, reject Ha
Pvalue < α; Reject Ho, accept Ha

Conclusion:

Result from Situation A is NOT equal to Situation B.

- **Situation B does not contribute to Stuck pins**

Fig. 7. Hypothesis test for unstable winding machine

Hypothesis Test: Chi-Square

Data collection:

	Setting A	Setting B
Accept :	473	479
Reject :	7	1
Total :	480	480

**Remarks:

Setting A : 7.1 + 0.15mm (UPPER SIDE)

Setting B : 7.1 - 0.15mm (LOWER SIDE)

Hypothesis Test: Chi-Square

STEP 1:

Ho : Result from Setting A **equal to** Setting B

Ha : Result from Setting A **NOT equal** to Setting B

STEP 2:

Alpha, α = 0.05

STEP 3:

P_{value} = 0.033

Alpha, α = 0.05

P_{value} < alpha, α ; Reject H_o, Accept H_a

If: Pvalue > α; accept Ho, reject Ha
Pvalue < α; Reject Ho, accept Ha

Conclusion:

Result from Setting A NOT equal to Setting B.

- **Setting B is better than setting A**

Fig. 8. Hypothesis test for unstable height of shaft

E. Control Phase

The Control phase is the conclusion of the team's journey. The control phase completes an improvement activity ensures day-to-day processes stay in the meeting quality specification and become standard. This phase includes establishing a scatter plot, monitoring the process capability to ensure always meeting the specification, and provide the proper training into workers to ensure the problem will not appear again in the future and highlighted the lesson learned in production floor to ensure workers not make the mistake. Scatter plot is the technique to monitor any abnormality of the data based on trend of the graph. Instability of the data can be recognized and process capability will be applied to monitor the consistency of the assembly processes. At the end of the improvements, visual of the lesson learned of defects will publish in production work station to alert the workers and ensure the defects will not happen again in future.

1. Scatter Plot

Control phase is the stage to ensure the defects will not appears in future based on DMAI phases. The Scatter plot was applied as main tools to monitor the performance of the production process. The scatter plot has been selected because the data collection based on proportion of reject rate and also under category of attribute data. The scatter plot shows in Fig. 9 for the proportion of the reject rate. The result of the chart, shows the reject proportion was drastically reduced by implementaion in the DMAIC and meeting the target of the improvement activity which is 4% of the reject rate

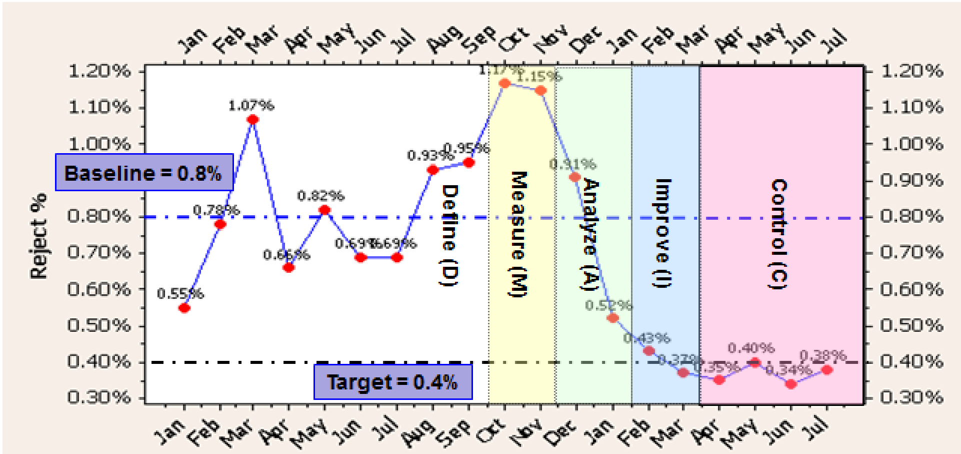

Fig. 9. Scatter plot of the WWG product

2. Process Capability Study

Since the winding process is one of the improvement area, the proccess capability has been re-calculated to ensure the process is capable and the shows in Table V. Based on the the spesificication of the winding wire is 7.1±0.15 mm and improvement has been implementing during improvement stage, the results shows the value of Cp and Cpk drastically improved and the process is capable and meeting customer expectation because the value of Cp and Cpk is > 1.0. The workers will be keep monitoring under On-Job-Training (OJT) system and lesson learned about the previous failure has been published in production floor to ensure the workers are aware about the failure part.

TABLE V. RE-CALCULATING THE PROCESS CAPABILITY STUDY FROM SAMPLE DATA OF THE THICKNESS OF THE WINDING WIRE (IN MM)

7.11	7.11	7.15	7.10
7.15	7.11	7.10	7.12
7.11	7.15	7.18	7.10
7.11	7.10	7.11	7.15
7.10	7.11	7.11	7.15
Mean, µ			7.12
Standard deviation, σ			0.02
Cp			**2.14**
Cpk			**1.84**

IV. Discussion

Defects rate of product plays a very important role for the improvement of yield and financial conditions of any company. Actually defects rate causes a direct effect on the profit margin of the product and decrease the quality cost during the manufacturing of product. Companies strive to decrease the defects rate of the product during the manufacturing processes as much as possible. By checking and inspection of defects of product at different point in a production cycle and management implement some changes specifically at those points in production where more defects are likely to happen. DMAIC model is one of the best emerging approaches for quality assurance and management in automobile parts manufacturing. This paper discussed the implementation of DMAIC methodology in reducing defectives in a car audio manufacturing industry. The DMAIC approach has been used to achieve this result. This paper explains the step-by-step approach of DMAIC implementation in this manufacturing process for improving quality level. Using the suggested DMAIC methodology, the rejection percentage is reduced by 50% from current reject rate. Further improvement in the rejection is expected in the long run after the continuous implementation of all the solutions. With such encouraging result, the team decides to continue doing more improvement project for other products in the future. It also changes the mind set of people to do “fire-fighting method” of tackling the problem.

V. CONCLUSION

In this paper, Six Sigma DMAIC with quality tools has successfully implemented in automotive components manufacturing industry. The DMAIC methodology is one of the method has been adopted in various types of industries because systematic approach to analyze the background of the defects and solving the quality issue step by step. The DMAIC method is defined as project goals and existing processes, measuring of the existing processes, analyze the data to determine the cause-and-effect relationships, improve the current process based on the data control any deviations before product defects occurs. DMAIC methodology helps companies realize that it is a company-wide approach to reducing defects and eliminating product variations. But, the DMAIC methodology is only the platform of the continuous improvement activity with several versions of identification the application tools for every phase. Different type of industry will be using different tools for each phase depending on the type of data collection, data availability, the processes involved and experiences and knowledge of the team members. This paper presents the development of the DMAIC model by identifying the suitable effects tools for each phase with minimized the analysis, but the result shows the high impact into improvement activity. Based on the investigation and implementation of the case study industry, the result shows an adaptation of DMAIC with suitable tools for each phase complements with the quality improvement program

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