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# Six-sigma derivatives: A case study

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A B S T R A C T

Nowadays, automobile industries are facing huge competition as the sector is expanding and ameliorating day by day. All organizations are thriving to attain top position by increasing their productivity. Productivity improvement is a function of eliminating rejection problem and improving system. To excel and improve the organizational efficiency a complete focus on finding root causes and eliminating factors responsible is needed. In industries, hurdles are associated with all operations. The existing study is about problem solving in a die-casting industry manufacturing alternator bracket. The authors explain the use of different statistical quality tools with the help of Minitab software to analyze root cause for enhancing the low productivity level. The streaming explanation of methodology can be useful for the organization of similar profile towards productivity improvement.



## 1. Introduction

Six-Sigma is a very famous tool among industrial engineers especially used for problem solving in manufacturing environment (Edgeman & Dugan, 2008; Ho, 2010; Srinivasan et al., 2016; Falcón et al., 2012; Sharma, 2012). Various case studies have been reported till date that show the successful implementation of DMAIC methodology for productivity enhancement (Kaushik et al., 2017; Kaushik et al., 2016; Kaushik & Mittal, 2015b; Kaushik, et al. 2016). Other than Six-Sigma there are various other tools available such as advance product quality planning (Mittal et al., 2010; Mittal et al., 2010; Mittal et al., 2011; Mittal et al., 2012), Business process re-engineering (Mittal et al., 2016), Quality council (Mittal & Prajapati, 2014), Total quality management (Kaushik & Mittal, 2015a; Sharma, 2013; Sharma, 2017b; Sharma, 2017a), Quality function deployment (Mittal & Kaushik, 2011), Fuzzy MADM (Mittal et al., 2017b; Mittal et al., 2016), Operations research tools (Mittal et al., 2017; Mittal et al.. 2017a) etc., but six-sigma has proven itself as the most successful tool among manufacturing environment. The present study was performed at a die-casting industry in Gurgaon, Haryana, India. The industry is a house of built in technology and developing cutting edge die-casting products for major Overall Equipment Manufacturing (OEMs) worldwide. Industry was facing continuously low productivity levels and therefore

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immediate attention was needed in form of a quality management project. The part under consideration was an alternator. Alternator is an electrical device which converts mechanical energy into electrical energy. These are used in various places, but industry produces the alternators to be used in automobiles only. Various components used in assembly of the alternator are: Front bracket, back bracket, stator, rotor, rectifier diode, voltage regulator, fan, pulley, bearing etc.

Of the various components listed above, the present study focuses on bracket. There are two brackets used in the alternator. One is placed at front side and another one is on the back side of the alternator. The main purpose of the bracket in alternator is holding all the components of an alternator. The brackets of the alternator are manufactured with the help of the casting process. The size of the brackets depends on the alternator size and design as per as requirement of the customers. In present case, the alternator bracket in consideration is manufactured using aluminum alloy ADC-12. The organization was facing continuous quality related complaints from one of its elite customer which was due to mounting lug broken. In a recent complaint, seven pieces of M10 mounting lug broken were found in one lot of alternators. Therefore, a Six-Sigma project was initiated for improving the quality and achieve customer satisfaction.

## 2. Implementation of Six-Sigma DMAIC Methodology

Sigma is a measure of standard deviation and Six-Sigma corresponds to deviation of the order of 3.4 Defective Parts per Million Opportunities (DPMO). It follows a simple Define-Measure-Analyze-Improve-Control (DMAIC) methodology. A cross functional team was formed which consist 8 members from various functional areas within the organization. Various phases followed during the project are as follows:

### *2.1 Define*

The first phase of DMAIC methodology is define phase. It consists of pre planning, team formation and mainly the complete description of problem. Problem definition means the voice of customer (Sharma, 2013a; Sharma & Kadyan, 2016a; Sharma & Kadyan, 2016b) i.e. What exactly the consumer wants and what are the deficiencies which we have to shift our focus on? The industry was running at 20644 DPMO, which after calculating the Cost of Poor Quality (COPQ) comes out to be INR 2.5 lakh per annum in monetary value. In the recent customer complaint (Table 1) a total of seven pieces were found Not Good (NG) due to mounting lug broken (Fig. 1).

**Table 1**
Latest Customer Complaint Report

Problem: M10 Mounting Lug Broken
Product: Alternator
Part No: 7006

| Sr. No. | Description | Quantity/Place |
|---|---|---|
| 1. | Record Date | 12/08/2015 |
| 2. | Rejection Quantity | Total 7 |
| 3. | Found Area | Alternator Production Line |
| 4. | Return Reason | M10 Mounting Lug Broken |
| 5. | Stock: Raw Material and Assembly | Store Stock + Finished Goods = 0/103 NG |
| 6. | Repair or Not | Not Repaired |

### *2.2 Measure*

In this phase the extent of the problem is measured. Apart from it, a temporary corrective action was taken at the customer end which includes segregation of parts at their end and placing an extra inspection facility till the permanent action is taken. Table 2 shows the interim corrective action data for 3 consecutive months. A Pareto chart (Fig. 2) was prepared for finding the major causes of the rejection. The chart clearly shows the major cause of the rejection to be Fitment broken contributing approximately 53% of the total rejection. A measurement system analysis (MSA) (Fig. 3) was also run which shows the measuring instruments were ok and in rightful condition. MSA is essential part of analysis phase as it tells about the state of measuring instrument and process followed within the organization. False measurement system can cause the good parts to get reject and NG parts to reach customer end resulting customer complaint.

**Fig. 1.** NG/Good Parts and their Corresponding Grain Images

**Table 2**
Interim Corrective Action

| Total Quantity | Quantity OK | Quantity Not OK | When | %Effective |
|---|---|---|---|---|
| 110 | 110 | 0 | February | 100% |
| 120 | 120 | 0 | March | 100% |
| 100 | 93 | 7 | April | 100% |

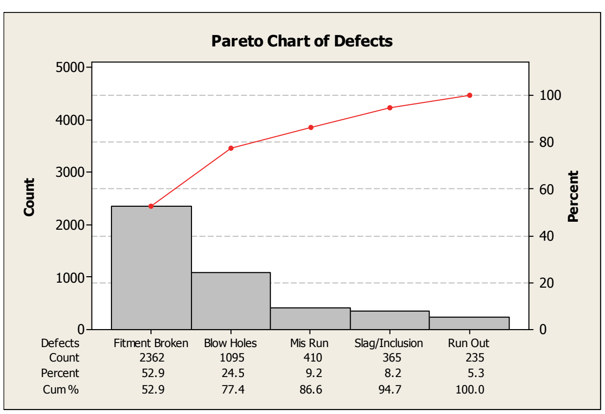


**Fig. 2.** Pareto Chart for Rejection

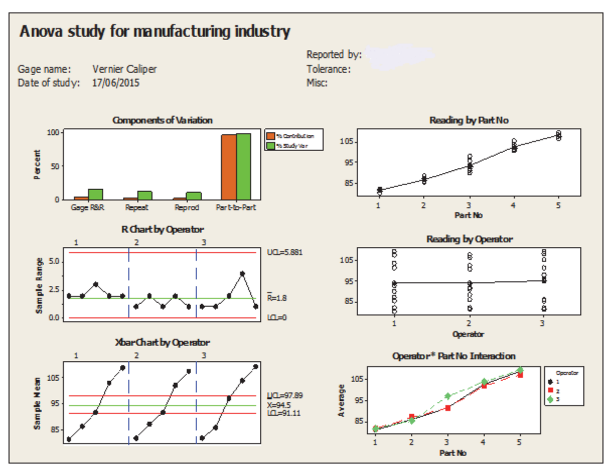


**Fig. 3.** Measurement System Analysis

## 2.3 *Analyze*

This phase is mainly concerned with in-depth analysis of manufacturing process for finding the ultimate cause of problem defined in define phase. For achieving it, first of all, a process map (Fig. 4) was generated which showed the various processes followed in manufacturing the product, highlighting the process generating (die-casting) the defect (Fig. 5). Then various statistical, for instance, fishbone diagram (Fig. 6), brainstorming (Sharma & Kadyan, 2015a; Sharma & Kadyan, 2015b), 5-M analysis (Table 3), why-

why analysis and simulation were used to find the ultimate cause of mounting lug broken. Various activities that can be performed during this phase are as follows:

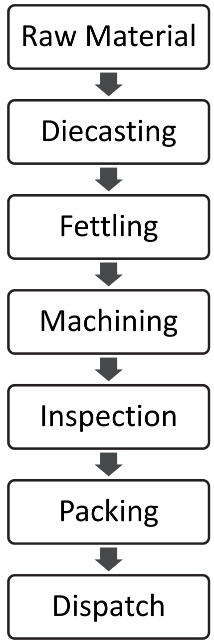


**Fig. 4.** Process Flow Chart

**Fig. 5.** Image of Die-Casting Operation

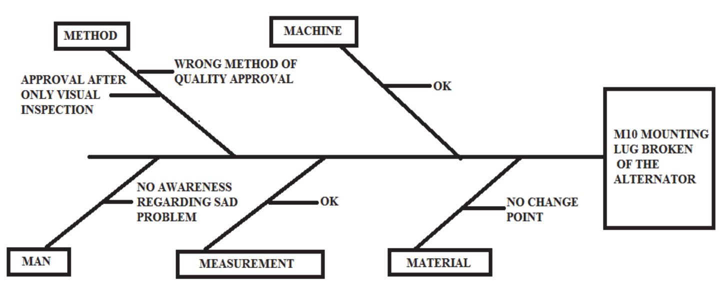


**Fig. 6.** Fishbone Diagram

**Table 3**
5-M Analysis

| 5M | SPECIFICATION | ACTUAL | JUDGEMENT |
|---|---|---|---|
| MAN | QUALITY APPROVAL | NO AWARENESS REGARDING APPROVAL | × |
| MEASURMENT | AS PER STANDARD | OK | ✓ |
| METHOD | APPROVAL METHOD | ONLY VISUAL INSPECTION | × |
| MATERIAL | MATERIAL AS PER | NO CHANGE POINT | ✓ |
| MACHINE | AS PER STANDARD | OK | ✓ |

**Table 4**
Why-Why Analysis

| STEPS | STEP 1 | STEP 2 | STEP 3 | STEP 4 |
|---|---|---|---|---|
| **OCCURRENCE CAUSE** | FITMENT NOT POSSIBLE AT CUSTOMER END | M10 MUNTING LUG BROKEN | COLD SHUT OBSERVED AT THAT PORTION | SETTING PIECE OF DIE CASTING MIX WITH OK SUPPLY |
| **FLOW OUT CAUSE** | WRONG METHOD OF QUALITY APPROVAL | APPROVAL GIVEN ONLY AFTER VISUAL INSPECTION | | |

Simulation was performed to produce same defective part so that real cause of rejection can be found out. It was carried out in three phases as follows:

**Simulation 1:** Low material temperature (Fig 7)

OK Condition:

1. Material Temperature: 620~660°C
2. Die Temperature: 300~320°C
3. Injection Pressure: 100~120MPa

Simulation Condition:

1. Material Temperature: 600~620°C
2. Die Temperature: 300~320°C
3. Injection Pressure: 100~120MPa

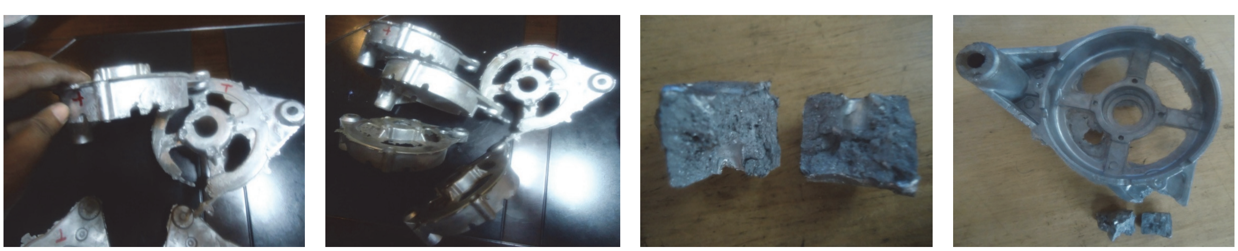

**Fig. 7.** Simulation 1

Conclusion:

1. Even after 25$^{th}$ shots, short filling observed in pieces.
2. Not same as customer return piece.

Therefore, the machine setting used in this simulation did not specify the real cause and hence can be neglected.

**Simulation 2:** Low injection pressure (Fig. 8)

Ok Condition:

1. Material Temperature: 620~660°C
2. Die Temperature: 300~320°C
3. Injection Pressure: 100~120MPa

Simulation Condition:

1. Material Temperature: 620~660°C
2. Die Temperature: 300~320°C
3. Injection Pressure: 80~100MPa

**Fig. 8.** Simulation 2

Conclusion:

1. Even after 25th shots, heavy below holes and fine grain size observed.
2. Not same as customer return piece.

Therefore, the machine setting used in this simulation too did not specify the real cause and hence can be neglected.

**Simulation 2:** Low die temperature/initial shots (Fig. 9)

Ok Condition:

1. Material Temperature: 620~660°C
2. Die Temperature: 300~320°C
3. Injection Pressure: 100~120MPa

Simulation Condition:

1. Material Temperature: 620~660°C
2. Die Temperature: Normal Process
3. Injection Pressure: 100~120MPa

20th No. of Piece | 25th No. of Piece | 20th No. of Piece | 25th No. of Piece

**Fig. 9.** Simulation 3

Conclusion:

1. After 20th& 25th Shots, Disputed grain size observed.
2. Same as customer return piece.

Therefore, the machine setting used in this simulation matches with the real cause and hence needs correction.

**Simulation 3:** Low die temperature/final shots (Fig. 10)

In this case we have the following

1. Material Temperature: 620~660°C
2. Die Temperature: 300~320°C
3. Injection Pressure: 100~120MPa

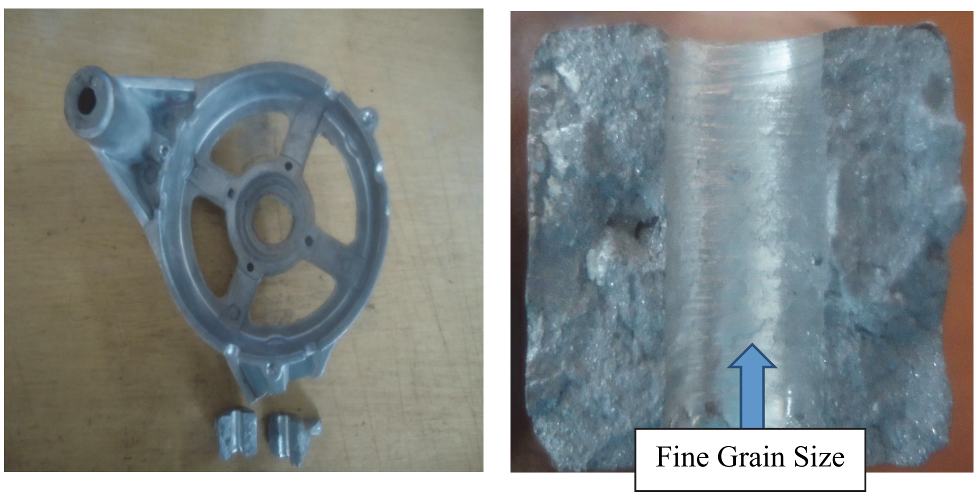


**Fig. 10.** Ok Condition Part

Therefore:

1. After 26th Shots fine grain size observed.
2. Same as Ok condition.

Now the machine setting was freeze as mentioned above in Ok conditioned part and also documented in the control plan of the part to eliminate any future ambiguity.

*2.4 Improve*

In this phase, in accordance to the root causes found out in analysis phase, corrective action was planned and implemented (Sharma, 2017b; Sharma, 2013c). First of all, a training for all concerned employees was arranged to detail them about the problem and remedial actions. Then a risk assessment and Failure Mode Effect Analysis (FMEA) was performed. Machines settings were changed in all concerned documents. New bracket has been changed in alternator assembly. The all casting process should be changed permanently according to root cause analysis. All temperature and pressure parameter will be fixed according to root cause to prevent the further problems and remove problems permanently. Quality department was made responsible for implementing and validating the permanent corrective action and Research & Development (R & D) department removed the containment action plan for permanent changes.

Table 5 shows the various measures and their corresponding status. Table 6 depicts the documentation change measures and corresponding status.

**Table 5**
Status of Various Measures

| **OCCURE ACTION** | **WHO** | **STAUTS** |
|---|---|---|
| Change the material temperature | Furnace operator | OK |
| Change the injection pressure | Injection molding machine operator | OK |
| Change quality approval method | Quality department | OK |
| Aware the worker about problem | Cross functional team (CFT) | OK |

**Table 6**
Documentation Change Status

| **IMPEMENTATION** | **ACTION** | **RESPONSIBILITY** |
|---|---|---|
| DFMEA | No changed | R&D |
| Drawing | No changed | R&D |
| Part Inspection Standard | Changed | CFT |
| PFMEA | No changed | Process Engineer |
| Control Plan | Changed | CFT |
| Process Instruction | Given | Process Engineer |
| Training Matrix | Given | Process Engineer |

After successful implantation of corrective actions, the PPM levels was drastically reduced to 2.68 ppm which was a huge achievement for the industry of this level. PPM improvement also brought financial gains which in turn motivated the industry to implement similar projects in various other sections.

**Table 7**
Review Status

| **Review & update system/procedures** | **Action** | **Responsibility** |
|---|---|---|
| All Document | All the related documents have already been changed | CFT |

### *2.5 Control*

In this phase, steps are taken to prevent the recurrence of the cause of rejection (Kaushik et al., 2008). The changes made in the process were assessed and monitor. Also, an opportunity was given to team for preserving the status and share the knowledge acquired during project to management and colleagues. In present study, the process is still under monitoring. Although a review of the status change has been performed (Table 7). After the completion of this phase, similar processes and products will be reviewed and if needed corrections will be made. Further, special procedures and work instructions will be developed. A special training program will be executed for all operators. All in all, it will be try out to make it as an organizational culture.

## 3. Conclusion

The prime motive of this case study was dissecting problem and solving it in industrial environment by implementing six-sigma DMAIC methodology and acquiring desired results working in a team. Adequate persuasion of corrective actions brought down the rejection levels from 20664 ppm to 2.68 ppm. This undoubtedly was a great accomplishment. The case study also brought financial gains. A cost benefits of 2.5 lakhs per annum were achieved. Talking about intangible benefits organization was able to achieve employee motivation, personal development, competitiveness, sense of team work and much similar project initiations. Authors encourage similar implementations to enhance the productivity levels of small scale industries.

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