Root Cause Analysis of Cover Assembly Line of Clutch Plate

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Abstract. The cause and effect analysis mainly aims to reduce the consumer complaints with failure mode analysis and 8D principle. This work aims to reduce the run out defect percentage in clutch cover plate and most of the defects are produced due to run out. The overall defect observed from run out was usually 60-70%. The height difference between the fingers exceeds the specified limit is named as run out defect for 18 finger diaphragm. The major parameters identified for measuring root cause analysis of clutch plate are diaphragm finger uneven, diaphragm angle, diaphragm bi-cone height and diaphragm hardness. The root cause defect was reduced by cause and effect method, 8D analysis and 5W principle. The lean principle is employed in this work to utilize the men, material and resources with maximum efficiency. The lean principle reduces the waste and allows the company to supply the product in time with maximum accuracy.

Keywords: Runout defect, Diaphragm, 8D method, 5W principle

1. Introduction
Run out is the major defect or cause for rejection of clutch plate, the contribution of run out defect in overall defect percentage is approximately 60-70 percentage for kappa clutch plate model and it is used in kappa engine for Hyundai i10, i20 model. By reducing the run out defect in clutch plate it would improve the production rate, performance output, good customer satisfaction, these objectives could be achieved by eliminating the root cause of the problem. From the identified parameters the root cause of the problem could be found by cause and effect analysis [1]. The root causes parameter’s data were collected and analyzed using 8D method and 5 why? Principle. Thus so the problem can be eliminated in the working area and it will improve the performance output [2]. The system effectiveness can be improved with 5W principle by improving quality, system performance and reducing wastage time [3].
Manual Runout Correction process are the cover plate is placed on the run out machine fixture. When the green button is pressed the cover plate gets clamped and rotates the fixture slowly to a full rotation for run out checking. The reading in digital display is checked if run out is within specification. If it is within the specification the machine will unclamp automatically and the green light will glow. If the run out is not within specification then Corrective action need to be taken. If the digital reading shows positive values, then the finger need to be push down using lever individually and if the digital reading
shows negative value, pull the finger up using lever. Once it is corrected write the reading in the cover plate.

The disadvantages of manual line are listed below:

- Low production.
- Need more man power
- Required more time to complete the process.
- Difficult to achieve the process demand on time.

Guideline for Automatic Runout Correction process are the cover plate is placed on the automatic run out correction machine (Aero Tech Machine). The machines automatically check whether if the cover plate is within the specification limit it will be passed out or it will be rejected.

The advantages of automatic line are listed below:

- High production rate.
- High accuracy in completing the work.
- No need for more man power but only to loading and unloading the jobs.
- Can complete the job very easily and with less time.
- Can achieve the process demand on time.

The disadvantages of automatic line are listed below:

- The rejected cover plates are corrected manually in an automatic line.
- This may cause rework, over time, stoppage of line, no smooth flow, delay in customer order, need workers, etc.

The following methods used are 8D Method, Cause and Effect Diagram, 5 why? Analysis, Pareto Analysis.

The Root Cause Tools and Approaches might be employed according to predominant circumstances and situations of Man, Material, Machines, Systems and Processes [4]. The lean concept is employed to reduce the wastage time, better utilization of raw materials to avoid wastages and in time delivery at low cost production are major challenges of an organization [5]. Day to day raise in demand and competitions and quality of product drives the industry to implement lean principle to betterment of product in social, economic and environmental aspects [6]. Carlos A. Riesenberger [7] et al (2009) conducted an application of the Six Sigma methodology in consumer criticisms management: a case study in the automotive industry, this is an examination was prepared to find the variables persuading the consumer criticism dealing process throughout a case study in the automotive industry. The Six Sigma methodology delivers a planned construction for problematic investigation and problem solving. Carlos A. Rosenberger [8] et al (2010) conducted an 8D methodology an actual way to reduce repetition of consumer grievances, this work explains the difficulties accompanying with the client criticism organization procedure; in a concern that practices the 8D methodology. These analyses are mainly focused to improve the quality and reducing the cost and reduction at low cost [9]. Dalgobind Mahto [10] et al (2008) conducted an application of root cause investigation in development of product quality and productivity in conventional Root Cause Analysis Tools and approaches offer about construction to the process of human affair problem solving.

2. Experimental Work and Analysis

2.1. Aero-Tech Run Out Correction Machine

Run out is the height difference between finger in the diaphragm. Finger height difference is measured with help of rotating probe (play char probe) in an Aero-Tech run out correction machine and with the help of 18 levers the 18 finger are corrected by pneumatic press. If finger exceeds the given
specification limit then the cover plate is rejected. It will cause a finger breakage, rejection of part inside the assembly cell and would/will cause judder noise, idle noise, and engine vibration in the car, if the fingers are not corrected.

Specifications of Aero Tech run out machine are given below:

- Run out Specification : 0.50 mm (Max)
- Bottom bunk Diameter : Ø 44 mm
- Bending height : 31.70 mm

2.2. Pareto Analysis

The Pareto chart and table are shown in figure 1 and table 1 clearly shows all defect percentage for kappa clutch plate, where the accumulation of run out defect is about 69% and while rest of the other overall defect percentage is only 31%, if the run out been reduced then defect rate is also reduced and can increase the production performance as for the process requirement.

| S.No | Defects                     | Number of Defects | Kappa Cover Assembly |
|------|-----------------------------|-------------------|-----------------------|
| 1    | Run Out                     | 1033              | 69%                   |
| 2    | Bearing Load New More       | 170               | 11%                   |
| 3    | Bearing Height More         | 156               | 10%                   |
| 4    | Parallelism More            | 42                | 3%                    |
| 5    | Finger Broken               | 42                | 3%                    |
| 6    | Clamp Load New Less         | 33                | 2%                    |
| 7    | Fouling                     | 22                | 1%                    |
| 8    | Pp Lift Less                | 4                 | 0%                    |
| 9    | Clamp Load Wear Less        | 0                 | 0%                    |
| 10   | Bearing Load Wear Less      | 0                 | 0%                    |
| 11   | Bearing Height Less         | 0                 | 0%                    |
| 12   | Ubm                         | 0                 | 0%                    |

| Total Rejection | 1502 | 100% |

Table 1. Defects and Rejection rate for August Month
2.3. 8D Flow Chart Analysis

The figure 2 is the flow chart for 8D analysis is used for quality problem solving. Once the problem (run out more) has been identified, defined and describe it to develop a containment plan for that problem with the help of cause and effect analysis, the 4M’s-Men, Machine, Material, and Method to find the possible cause or parameter for the problem. Then identify the potential or major causes of the problem for run out defect once the major parameter have been identified. Test it one by one whether it is the root cause of the problem, if not go to next parameter and repeat the same process until root cause is found for the problem. If the root cause is been found then take corrective action to solve it, implement it. Validate the corrective action and take preventive measure for run out problem so that it will not repeat.

Figure 2. Flow chart for 8D method

2.4. Cause and Effect Analysis for Run Out

Cause and effect analysis is used to find the root cause of the problem, it is a graphical tool which helps in identify, shot, and display possible cause of run out problem and eliminate the other parameter in the 4m’s-men, machine, material, and method, to find the major parameter for the run out defect and gives clear idea to find the root cause.
The following are the major parameter which causes the run out issue in clutch plate:

- Diaphragm angle
- Diaphragm finger uneven
- Diaphragm Bi-cone height
- Diaphragm uneven seating
- Diaphragm hardness variation

**Figure 3.** Cause and effect diagram

If the finger height is not within the specification limit in diaphragm then the part is rejected, so the material dimension of the diaphragm and/or material property which might be the reason for the defect, so these are the major contribution for run out [13]. If the run out is more or exceeds the give specification limit then the part gets rejected or it will lead to the following issue in the diaphragm.

- Finger uneven
- Finger breakage

**Figure 4.** Uneven height in diaphragm

**Figure 5.** Finger breakage in diaphragm

If bending height is maximum and/or low hardening then it might lead to finger breakage, so bending height must be reduced to avoid finger breakage. Hardening the diaphragm spring will avoid/reduce wear and to increase hardness or strength of the fingers and also avoid finger breakage. Due to continuous load acting in the clutch plate i.e., on the diaphragm spring [11], while changing gear or shifting gear, to slow down the speed of the car, or to increase the speed of the car, or to have smooth drive in uneven road or while driving the car in traffic condition etc. It is essential to continuously press the pedal; therefore, diaphragm spring may get wear out at the edge of the finger by induction hardening. It will improve the strength and life of spring [12].
3. Data Collection and Analysis

3.1. Monthly Production and Rejection
Table 2 contains the information about the monthly production and rejection of kappa model and the percentage of rejection. To reduce this high percentage of rejection rework has been done manually in automatic line as shown in figure 6.

| Month   | Total Production Of Clutch Plate(Qty) | Rejection due to run out (Qty) | Percentage of rejection due run out (%) |
|---------|--------------------------------------|--------------------------------|----------------------------------------|
| July    | 4903                                 | 899                            | 18.33                                  |
| August  | 6253                                 | 1033                           | 16.52                                  |
| September | 5004                               | 935                            | 18.68                                  |
| October | 1567                                 | 165                            | 10.52                                  |
| December | 9051                                | 1316                           | 14.53                                  |

Figure 6. Manual rework

3.2. Root Cause Problem Identification
From the given Table 3 the root cause problem can be clearly singled out from the other parameters, so it is clear that Bi-cone height, free condition height is out of the specification limit but DSP angle, DSP hardness are within the specification limit. Max to Min Difference Testing: Table 4 and Table 5 shows the free condition height (maximum and minimum) difference between the 18 fingers of the diaphragm spring. The specification for free condition height is maximum 1 of about mm, but it is about 1.23 and 1.57 mm which exceeds the given limit.
Table 3. Data Collected on Different Parameter

| SI. NO | DSP CHARACTERISTIC | SPEC | UNIT | OBSERVATIONS | REMARK |
|--------|--------------------|------|------|--------------|--------|
|        |                    |      |      | Hot Forming Stage | Shot Peening Stage | Ok Part | Not Ok Part |
| 1      | Free cond. ht      | 1 Max | mm   | 22.51 | 22.22 | 22.77 | 23.74 | 24.07 | 23.47 | 24.31 | Not Ok Part |
| 2      | Bi cone ht         | 7.5±0.2 | mm   | 7.22 | 7.08 | 7.55 | 8.36 | 8.37 | 8.22 | 8.16 | Not Ok Part |
| 3      | Angle              | 10°±3.0° - 11°±0° | deg | 11°01 | 10°56 | 10°58 | 10°58 | 10°49 | 10°59 | 10°55 | 11°02 | 11°01 | 11°00 | Ok Part |
| 4      | Hardness           | 44.50 | HRC  | 46 | 47 | 48 | 47 | 48 | 49 | 46 | Ok Part |

Table 4. Diaphragm Finger Height after Hot Forming Stage

| Finger Numbers | Finger Height(mm) | Finger Numbers | Finger Height(mm) |
|----------------|-------------------|----------------|-------------------|
| 1              | 23.34             | 10             | 22.91             |
| 2              | 23.29             | 11             | 23.61             |
| 3              | 23.42             | 12             | 23.45             |
| 4              | 22.75             | 13             | 23.30             |
| 5              | 23.65             | 14             | 23.27             |
| 6              | 23.55             | 15             | 22.51             |
| 7              | 23.61             | 16             | 23.17             |
| 8              | 23.74             | 17             | 23.13             |
| 9              | 23.39             | 18             | 23.51             |

Table 5. Diaphragm Finger Heights after Shot Peening Stage

| Finger Numbers | Finger Height(mm) | Finger Numbers | Finger Height(mm) |
|----------------|-------------------|----------------|-------------------|
| 1              | 23.69             | 10             | 23.76             |
| 2              | 23.51             | 11             | 23.64             |
| 3              | 23.78             | 12             | 22.61             |
| 4              | 24.07             | 13             | 23.55             |
| 5              | 23.89             | 14             | 22.50             |
| 6              | 23.94             | 15             | 23.48             |
| 7              | 23.74             | 16             | 23.85             |
| 8              | 23.30             | 17             | 23.59             |
| 9              | 22.68             | 18             | 23.82             |

3.3. Finger's Bi Cone Height Reading
Once the max and min difference is found in the diaphragm fingers, it is cut with the help of abrasive cutter to measure the bi-cone height, where the specification for bi cone height is (7.5±0.2) mm. So the bi-cone height have to be changed to obtain the standard and to reduce the defect in the cover plate, number of trail have been conducted to change the specification limit and finally it is changed to 6.4±.2

Table 6. Value for Bi-Cone Height

| Sl no | DSP Bi-cone ht | Ok or Not Ok | Sl no | DSP Bi-cone ht | Ok or Not Ok |
|-------|---------------|-------------|-------|---------------|-------------|
| 1     | 7.67          | OK          | 13    | 8.17          | Not Ok      |
| 2     | 7.84          | OK          | 14    | 8.25          | Not Ok      |
| 3     | 7.93          | Not Ok      | 15    | 7.69          | OK          |
| 4     | 7.47          | OK          | 16    | 7.63          | OK          |
| 5     | 7.53          | OK          | 17    | 7.70          | OK          |
| 6     | 8.22          | Not Ok      | 18    | 8.05          | Not Ok      |
| 7     | 8.12          | Not Ok      | 19    | 7.45          | OK          |
| 8     | 8.05          | Not Ok      | 20    | 7.62          | OK          |
| 9     | 7.98          | Not Ok      | 21    | 7.99          | Not Ok      |
| 10    | 7.53          | OK          | 22    | 8.06          | Not Ok      |
| 11    | 7.62          | OK          | 23    | 7.60          | OK          |
| 12    | 7.97          | Not Ok      | 24    | 7.72          | OK          |

Table 7. Diaphragm Finger Height after Hot Forming Stage

| Finger no | Free condition height | Finger no | Free condition height |
|-----------|-----------------------|-----------|-----------------------|
| 1         | 23.28                 | 10        | 23.54                 |
| 2         | 23.21                 | 11        | 23.51                 |
| 3         | 23.33                 | 12        | 23.57                 |
| 4         | 23.49                 | 13        | 23.41                 |
| 5         | 23.46                 | 14        | 23.27                 |
| 6         | 23.65                 | 15        | 23.38                 |
| 7         | 23.57                 | 16        | 23.37                 |
| 8         | 23.63                 | 17        | 23.39                 |
| 9         | 23.47                 | 18        | 23.33                 |

Table 8. Diaphragm Finger Heights after Shot Peening Stage

| Finger no | Free condition height | Finger no | Free condition height |
|-----------|-----------------------|-----------|-----------------------|
| 1         | 23.43                 | 10        | 23.66                 |
| 2         | 23.42                 | 11        | 23.89                 |
| 3         | 23.61                 | 12        | 24.02                 |
| 4         | 23.74                 | 13        | 24.06                 |
| 5         | 23.55                 | 14        | 23.81                 |
| 6         | 23.55                 | 15        | 23.70                 |
| 7         | 23.68                 | 16        | 23.45                 |
| 8         | 23.77                 | 17        | 23.55                 |
| 9         | 23.66                 | 18        | 23.65                 |
Table 9. New Design Diaphragm

| SI No | CHARACTERISTIC | SPEC | UNIT | OBSERVATIONS | REMARK |
|-------|----------------|------|------|--------------|--------|
|       |                |      |      | Hot Forming Stage | Shot Peening Stage | OK Part | Not OK Part |
| 1     | Free cond. ht  | Max  | mm   | 23.39 | 22.33 | 22.21 | 23.35 | OK       |
|       |                |      |      | 24.06 | 23.66 | 23.65 | 23.66 |          |
| 2     | Bi cone ht     | 6.4±0.2 | mm   | 6.22 | 6.08 | 6.85 | 5.58 | OK       |
|       |                |      |      | 6.36 | 6.46 | 6.50 | 6.46 |          |
| 3     | Angle          | 10°30' - 11°00' | deg | 10°26 | 11°00 | 11°00 | 10°53 | OK       |
|       |                |      |      | 10°21 | 10°51 | 10°59 | 10°57 |          |
|       |                |      |      | 10°52 | 10°45 | 11°01 | 11°01 |          |
| 4     | Hardness       | 44-50 | HRc | 46 | 46 | 47 | 46 | OK       |
|       |                |      |      | 46 | 47 | 48 | 46 |          |

4. Result and Discussion

From the table 2 the rejection amount is more and the average rejection is approximately 15.938% for all month and where in few days the rejection rate goes above 25%. The reason for this increase in percentage of rejection is due to run out, the rejected cover plates are corrected manually in an automatic line; which might cause rework, over time, stoppage of line, no smooth flow, delay in customer order, need workers, etc. [17]. The defect can be identified by data collection and analysis. The root causes has been identified from the major parameter and step to reduce and/or eliminate the defect were conducted and the defect percentage have been reduced.

From the table 4 and table 5 it’s clear that the finger height difference which exceeds the specification value. To have a clear idea whether the value are changing in heat treatment process too shot peening process, an analysis been conducted in both the process but the result have been the same in the both process and no change between them, where maximum and minimum height difference in diaphragm after hot forming stage are 23.74 and 22.51, there difference is about 1.23 which exceed the given specification limit and similarly after shot peening stage the value is 24.07 and 22.5 it difference is 1.57 which also exceeds the give specification limit. From Table -6 it’s clear that the bi-cone value is exceeding the given specification limits which in turn be the root cause of the problem for run out issue [16].

The existing tool free condition height, bi-cone height, angle and hardness are modified for new tool to reduce the rejection for hot forming process and shot peening process. The measurement and analysis have been done to increase the productivity and in time delivery of product with root cause problem which reduced the rejection rate of inline cover plate [14]. The 8-D analysis was implemented to improve the quality and problem solving methods. The 5-W principle reduces the same kind of problem will not be repeated again and again.

From table 7 and table 8 gives the maximum and minimum height difference have been measured after changing the design specification for Bi-Cone height from (7.5±0.2) mm to (6.4±0.2) mm and the value is 23.65 and 23.21 after hot forming stage and difference is about 0.44 and while for shot peening stage the value is 23.42 and 24.06 and difference is about 0.64 which is within the specified limit and the rejection has been reduced [15]. From table 9 it is clear that all the specification values are within the limit for the new designed tool.
5. Conclusion
This work discussed to reduce the rejection percentage by employing root cause analysis, 8-D method and 5W principle. This work was carried out in a company to make survey of various failures and rejection of clutch plate during production and the study was carried out to eliminate wastage of time and material at low cost production. The hot forming process and shot peening process were considered to measure the bi-cone height, angle and hardness at various operating conditions. The designed new tool with hot forming process gave better result in all identified parameters and summarized here. The rejection rates for diaphragm Bi cone height have been reduced from 20% to 6% when the new tool was replaced instead of old one. The deviation for hot forming stage was 0.44 and for shot peening process was about 0.64. From the above observations, the rejection was reduced with new designed tool. So the rejection percentage is been reduce from 22% to 6% for cover assembly line of clutch plate.

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