# RCCB Manufacturing Process Improvement through Latch Assembly Design Changes

**Miss V.C.Tambe[1] Prof. S.B.Belkar[2]**
[1]PG Student [2]Associate Professor
[1,2]Department of Mechanical Engineering
[1,2]P.R.E.C. Loni, S.P.P.U. Pune, India

*Abstract*— A Residual Current Circuit Breaker (RCCB) is a current sensing device used to protect a low voltage circuit in case of fault. A residual-current circuit breaker (RCCB), is a device which is used for quickly disconnecting the current to prevent serious harm from an ongoing electric shock. Two major challenges that industries are facing, are continuous improvement in productivity and quality of the product. RCCB also requires some design changes for its effective working and to decrease the defects per million which is one of the biggest problem faced in industry. These manufacturers in RCCB has been successfully employing Design changes , the strong statistical tool 'Shainin' for Design of Experiments (DOE) and the root cause identification techniques for analysis and optimization of the quality related issues.

***Key words:*** RCCB, Shainin Methodology, NAF (Neutral Advance Failure) Root Cause Analysis (RCA), Component Search

## I. Introduction

Residual Current Circuit Breakers are used for protecting an individual from the risks of electrical shocks, and fires that are caused due to faulty wiring or earth faults. Latch assembly is the device mounted on the RCCB for ON-OFF control of knob with respect to the residual current. Latch assembly consists of number of mechanical components like release lever, lock lever, there resp. springs, top and bottom plate, knob etc. The ON-OFF process of the latch assembly is depends on the components and there mechanism which used in latch assembly. The continuous slipping of the lever results to the failure of assembly called as de-latching process.

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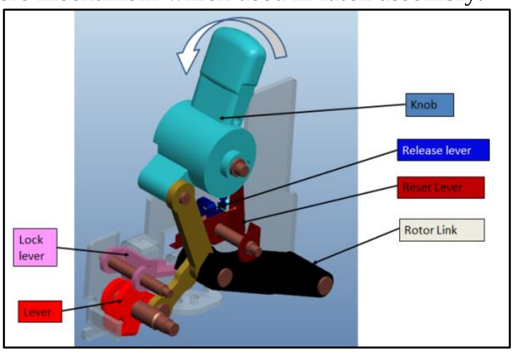



Fig. 1: Latch Assembly

The Shainin based approach is a severe discipline for performance improvement in engineering and manufacturing. Increasing reliability of products demands that the problems that arise during functioning of parts and products need to be identified, the root cause has to established, and finally, the problem needs to be solved. Defect in any part of a component results in manufacturing of the entire component by itself causing a serious problem.

In this regard Loss Cause action Mode and RCA methods such as Fishbone diagram, Shainin, Why-Why analysis, Failure tree analysis etc. have been very effectively used in the industries. . The present work deals with one of the quality issues will be resolved by doing some design manufacturing process changes at LARSEN AND TOUBRO, Ahmednagar.

## II. Literature Review

The Shainin method starts with assumption that there may be one single root cause for the problem or that this root cause has the largest contribution to the problem [1] .Residual Current Circuit Breaker (RCCB) is a current sensing device used to protect a low voltage circuit in case of a fault. RCCB contains a switch device that switches off whenever a fault occurs in the connected circuit. [2]. After design of experiments (DOE) and Taguchi DOE, the third approach is Shainin DOE, which is a collection of simple and powerful techniques invented by Dorian Shainin of the United States[3].

Likert's method of scoring his categories can be justified by Rasch Rating-Scale model if the categories produce unidimensional responses. Tests involving eight items from American Panel Study suggest that unidimensionality often is not achieved with the Likert categories strongly agree, disagree, and strongly disagree.The Likert method is commonly used as a standard psychometric scale to measure responses. Likert measurement scale has a procedure that facilitates survey construction and administration, and data coding and analysis [4]. In a Cause Effect Chain Analysis, the Problem which is to be solved is taken as the starting point and written into a box [5].

A Cause-and-Effect Diagram is a tool that helps identify, sort, and display possible causes of a specific problem or quality characteristic. Ishikawa diagrams (also called fishbone diagrams, herringbone diagrams, cause-and-effect diagrams, or Fishikawa) are causal diagrams created by Kaoru Ishikawa (1968) that show the causes of a specific event[6].

Here, we are using these techniques in solving the following problems occurring in the our product like, The continuous slipping of the lever results to the failure of assembly called as de-latching process. Company received internal customer complaint of 'Neutral Advance Failure' in RCCBs which result into the rejection of RCCBs at final Quality inspection stage. This failure can lead to intended function failure of Earth Leakage Products. While making RCCB ON, N-pole should make contact first with respect to remaining poles, if it does not happen then it comes under NAF (Neutral Advance Fail) defect. These are major problems resulting in to the 1.5 lakh dpm.

### A. Objectives

In this research work, we are dealing with RCCB product and problems during manufacturing, reasons behind the failure of the product. So main objectives are

- To study the working of product and different causes of failure.
- To improve the First Time Yield of the RCCB
- 'Tool rectification' for some CTQ dimensions

### B. Scope of the Research

Provide some manufacturing process and design changes so that the slipping of lever can be avoided.

Make the components with specified tolerances so that the Neutral advance provided in the N-pole can be maintained. Modification in Assembly & Testing Fixture at vendor's end. Removal of Test Bench Variability in house.

## III. PRODUCT DEFECTS

### A. De-Latching

Latch assembly used in RCCB product is combination of different mechanical parts. The ON-OFF process of the latch assembly depends on the components and there mechanism used in latch assembly, the continuous slipping of the lever results in to the failure of assembly called as de-latching process.

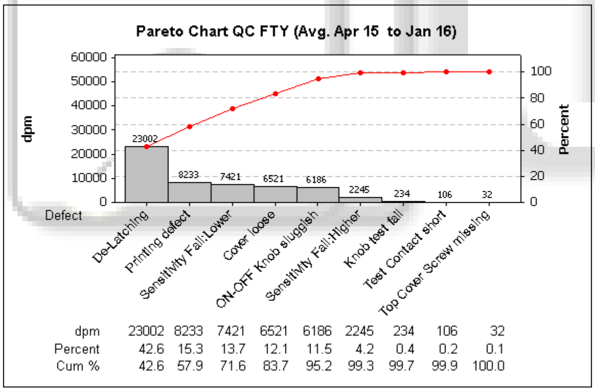



Fig. 2: Pareto chart

### B. ON-OFF Knob Sluggish

In most of the RCCB, during working condition on off knob becomes more sluggish because of uneven riveting process. Manual riveting has been used for Knob Link assembly riveting. So there may be chances of uneven force over the assembly. This results in to loose of sluggish behavior of ON OFF knob which is severe problem in the RCCB manufacturing process.

### C. Sensitivity Fail: Higher, Sensitivity Fail: Lower

While making RCCB ON, N-pole should make contact first with respect to remaining poles, if it does not happen then it comes under NAF (Neutral Advance Fail) defect.

- Knob test Fail Test
- Printing defects
- Contact short
- Cover loose

## IV. EXPERIMENTAL METHODS

### A. RCCB De-latching

#### 1) Cause Effect Diagram and Analysis

When you have a serious problem, it's important to explore all of the things that could cause it, before you start to think about a solution.

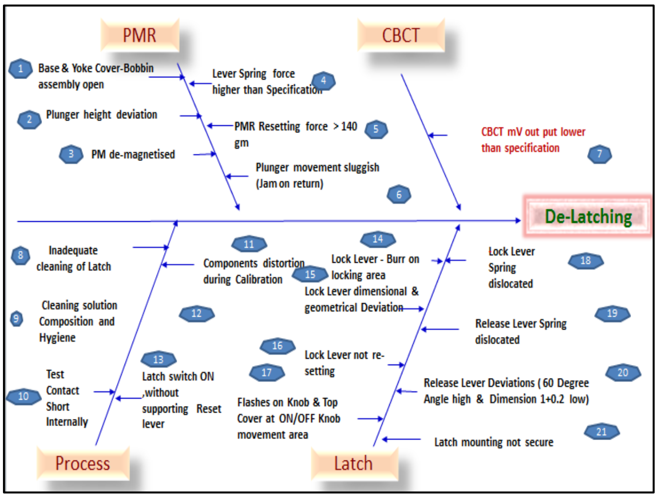



Fig. 3: Cause effect diagram of RCCB

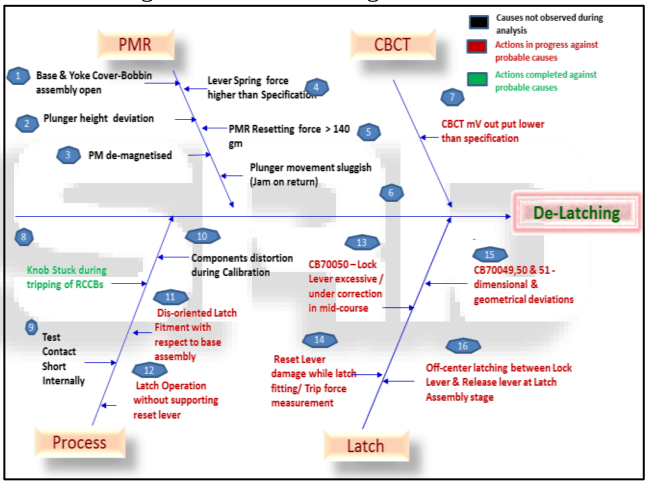



Fig. 4: Cause effect diagram conclusion of RCCB

Cause and Effect Analysis gives you a useful way of doing this. This diagram-based technique, which combines Brainstorming with a type of Mind-Map, pushes you to consider all possible causes of a problem, rather than just the ones that are most obvious.

Fig. 2 shows the causes of de-latching in the RCCB. These all are the probable causes. The surety of the causes can be given by observing all the failed components for a period of 2 weeks. After observation, Fig. 3 shows the analysis of the cause effect diagram

#### 2) Cause Validation – Using DOE (Shainin Approach)

Cause of De-latching is found by using Modified Component search method (Shainin Technique). Since Latch Assembly being riveted assembly, while dismantling components, 8 out of 21 components got damaged. We replaced them with new components while re-assembly.

Hence, we used Modified Component search method (Shainin Technique).

Grading as per Likert scale are taken as reference for BOB & WOW RCCBs

| Sr. No | Process | BOB | WOW |
|---|---|---|---|
| | | X | X |

| | | | |
|---|---|---|---|
| 1 | Initial Reading | 1 | 9 |
| 2 | 1st re -assembly | 2 | 2 |
| 3 | 2nd re-assembly | 2 | 9 |
| Difference bet Median (D) | | 7 | |
| Avg of the ranges (d) | | 4 | |
| D/d | | 1.75 | |

Table 1: Measurement of parameters 'X' of BOB & WOW RCCB

Since 'D/d' ratio is < 3, Assembly process or components replaced during re-assembly can contribute to defect.

*3) Assembly Process & Replaced components*

Following are the operations that may cause assembly error which can lead to De-latch Failure:

- Latch Mounting – Latch Dimensions, Tightening torque, Latching stages
- Mid-Course Correction – Lock Lever damage, Release Lever damage
- Trip Force Measurement – Reset Lever damage
- Calibration

From above analysis, a list of replaced components, prioritized based on possible contribution to De-latch is as below:

- XB02021 - Release Lever Spring – Spring Tension at loaded position
- CB70051 - Release Lever – Concentricity, Burr
- CB70046 - Riveted Bottom Plate – Lock Lever Rivet ,Release Lever Rivet
- CB70045 – Top Plate
- XB02020 – Lock Lever Spring – Spring Tension

The above trial shows that, Load value measurement at particular angle is must in this case as this spring decides release lever position while latching. But this value is not defined in the design.

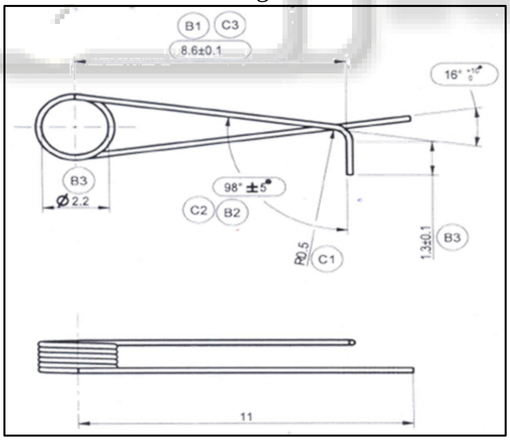



Fig. 5: Release Lever Spring – Spring Tension at loaded position

## V. DESIGN OF RELEASE LEVER SPRING

### *A. Selection of Spring Material*

SS 302 is an austenitic Chromium-Nickel stainless steel offering the optimum combination of corrosion resistance, strength and ductility. These attributes make it a favorite for many mechanical switch components.

*1) Nominal Composition*

| | | | |
|---|---|---|---|
| Chromium | 18.2% | Silicon | 5% |
| Nickel | 8.5% | Carbon | 06% |
| Manganese | 1.6% | Iron | Balance |

Table 2: Nominal Composition of SS 302

*2) Typical Mechanical Properties:*

| Properties | Metric | Imperial |
|---|---|---|
| Tensile Strength | 620MPa | 89900 psi |
| Yield Strength (.2% Offset) | 275MPa | 39900 psi |
| Elongation | 55% | 55% |
| Elastic modulus | 193GPa | 28000ksi |
| Poisson's Ratio | 0.27-0.30 | 0.27-0.30 |

Table 3: Mechanical Properties of SS 302

### *B. Design of Torsional Spring*

Helical springs used to apply a torque or store rotational energy are commonly referred to as torsion springs. The two most common types are single and double-bodied springs. Torsion springs are found in clothes pins, window shades, counterbalance mechanisms and various types of machine components. They are also used as couplings between concentric Shafts such as in a motor and pump assembly.

Torsion springs are generally mounted around a shaft or arbor and must be supported at three or more points.

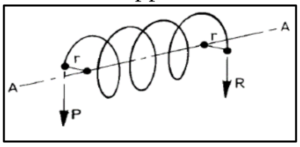



Fig. 6: Helical torsion spring

Various kinds of ends are available to facilitate mounting. Torsion springs are stressed in bending. Rectangular wire is more efficient in bending than round wire, but due to the premium cost of rectangular wire, round wire is preferred. If possible, a torsion spring should always be loaded in a direction that causes its body diameter to decrease. The residual forming stresses are favorable in this direction, but unfavorable when the spring is loaded in a direction which increases body diameter. Unless there are unfavorable residual stresses in the end bends, spring makers normally heat-treat these springs at a low temperature to stabilize the end positions rather than to full stress relieve them. If the direction of loading tends to increase body diameter, the spring maker should be advised to stress relieve the springs. The Associated Spring SPEC line contains many torsion spring designs using stainless steel and music wire, either left or right-hand wound. These springs have tangent ends and are available for immediate delivery.

Let P is the force acting on the torsional spring and R is the radius of coil diameter then torque applied over the spring will be P * R.

$$T = P * R \quad [1]$$

In torsion, spring will be subjected to bending stresses and small amount of tensile stresses due to applied tensile force P. But magnitude of tensile stress will be very small so we can neglect it in the design consideration.

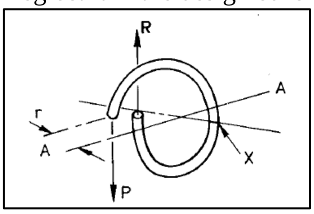



Fig. 7: loading condition of torsion loading

Bending stresses is given by,

For round wire,

$$f_b = 32P*R/\ \pi d^3 \qquad [2]$$

Where, $f_b$ =Bending stress

P = Force

R = D/2 (D= Coil Diameter)

d = wire diameter

By comparing equation [1] and [2]

$$T = f_b * \pi d^3 /32 \qquad [3]$$

As AISI SS 302 Material having tensile strength 620 MPa and by spring design standards, bending stress is 60 % of tensile strength.

$$f_b = 0.6 * 620 = 372\text{MPa}$$

Put value of $f_b$ in Equ.[3],

$$T = f_b * \pi d^3 /32$$

Spring wire diameter is 0.2 mm

$$T = 372 * \pi * 0.2^3 /32$$

$$T = 0.292 \text{ N.mm}$$

But, we have to increase the torque up to 0.4-0.5 N.mm So,

For T = 0.4 N.mm we will calculate wire diameter,

$$0.4 = 372 * \pi * d^3 /32$$

$$d = 0.22 \text{ mm}$$

We have to check the torsional shear stress of spring for the same diameter,

$$\tau = 8\ P\ D\ /\ \pi * d^3$$

$$\tau = (8 * 40 * 10^{-3} * 9.81 * 2.2)\ /\ \pi * 0.22^3$$

$$\tau = 202.77 \text{ MPa}$$

Allowable Torsional shear stress for stainless steel is,

$$\tau_{all} = 0.35 * \text{tensile strength}$$

$$\tau_{all} = 0.35 * 620$$

$$\tau_{all} = 217 \text{ MPa}$$

As $\tau$ is less than $\tau_{all}$, so design of torsion spring is safe

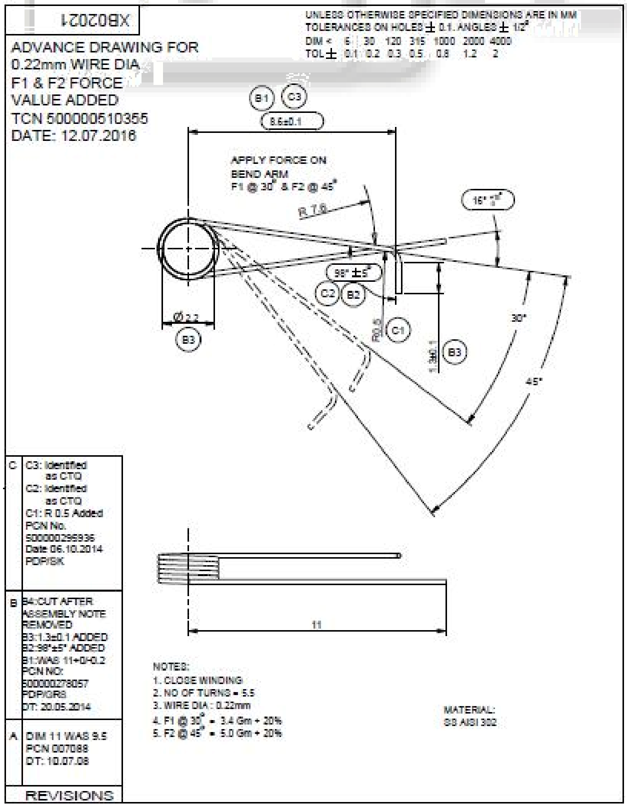
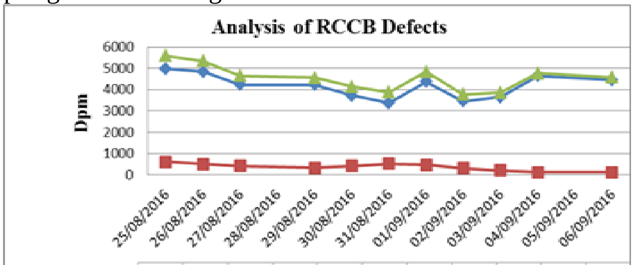



Fig. 8: Design of torsion spring with new wire diameter

### *C. Results and Discussion*

Load values at loaded condition of spring against bottom plate were not given on drawing. Load value measurement at particular angle is must in this case as this spring decides release lever position while latching. So Load values given and samples are measured and accordingly release lever spring has been designed.




| | 25/08/2016 | 26/08/2016 | 27/08/2016 | 29/08/2016 | 30/08/2016 | 31/08/2016 | 01/09/2016 | 02/09/2016 | 03/09/2016 | 04/09/2016 | 06/09/2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| De-latch defect | 4987 | 4834 | 4225 | 4235 | 3728 | 3365 | 4365 | 3456 | 3645 | 4652 | 4453 |
| Knob stuck | 612 | 514 | 421 | 328 | 417 | 517 | 473 | 324 | 216 | 125 | 120 |
| FTY | 5599 | 5348 | 4646 | 4563 | 4145 | 3882 | 4838 | 3780 | 3861 | 4777 | 4573 |

Fig. 9: Defects per day

- Due to developed release lever spring, there is Significant drop in de-latch defect.
- Modification is required in existing gauges of moving contacts to arrest defective moving contacts at its source.
- Fixture design is required for latch sub assembly spin riveting.

## ACKNOWLEDGMENT

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## REFERENCES

[1] Jeroen de Mast et.al., “Discussion on Shainin System”, Quality Engineering, Jan 2008, 20–22.

[2] A. Albardar et.al., “Diesel Engine Fuel Injection Monitoring using Acoustic Measurements and Independent Component Analysis”, Measurement, 43, 2010, 1376–1386.

[3] Dennis K. J. Lin, "Making full use of Taguchi's orthogonal arrays", Quality and Reliability Engineering International, pp. 117-121, 1994

[4] Qing Li "A novel Likert scale based on fuzzy sets theory",Expert Systems with Applications Volume 40, Issue 5, April 2013, Pages 1609–1618

[5] Cameron G., TRIZICS, Create Space, 2010; ISBN 1456319892; p 49

[6] Ishikawa, Kaoru (1990); (Translator: J. H. Loftus); Introduction to Quality Control; 448 p