To study and improve the contact pressure of MCCB contact system by analysing the spring performance used in MCCB

Submitted By

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To study and improve the contact pressure of MCCB contact system by analysing the spring performance used in MCCB

Major Project Report

Submitted in partial fulfillment of the requirements

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Master of Technology in Mechanical Engineering

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Submitted By

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CERTIFICATE

This is to certify that the Major Project Report entitled **"To study and improve the contact pressure of MCCB contact system by analysing the spring performance used in MCCB"** submitted by Mr.**Mohnish kukawalkar (16MMCC07)**, towards the partial fulfillment of the requirements for Semester-IV of Master of Technology (Mechanical Engineering) in the field of CAD/CAM of Nirma University is the record of work carried out by her under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of our knowledge have not been submitted to any other University or Institution for award of any degree or diploma.

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DECLARATION

1. The Thesis comprises my original work toward the degree of Master of Technology in Cad/Cam at Institute of Technology, Nirma University and has not been submitted elsewhere for a degree.

2. Due to acknowledgment has been made in the text to all other material used

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Undertaking for Originality of the Work

I, Mohnish G kukawalkar, Roll No.16MMCC07 , give undertaking that the Major Project entitled ”To study and improve the contact pressure of MCCB contact system by analysing the spring performance used in MCCB” submitted by me, towards the fulfillment of the requirements for the degree of Master of Technology in Cad/Cam of Nirma University, Ahmedabad, is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

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Place: Ahmedabad

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Acknowledgement

With immense pleasure, I would like to present this report on"To study and improve the contact pressure of MCCB contact system by analysing the spring performance used in MCCB".I am very thankful to all those who helped me for providing valuable guidance throughout the project work. It is a pleasant aspect that I have now the opportunity to express my gratitude towards them.

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-Mohnish Kukawalkar
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Abstract

MCCB's are widely used as protection device in industries. The main purpose of MCCB is to make, carry or break the current under normal as well as under abnormal conditions such as short circuit and Over load. During the working condition of MCCB, the contact system is closed and current flows through current carrying path which consists moving and fixed contact. Contact system includes driveshaft, contact spring, upper contact, spring cap and contact buttons.

As the current flows there is a temperature rise of the contact system and that rise in temperature gives rise to CREEP phenomenon which affects the functioning of contact system.After a period of time there is decrease in the load and free length of the contact spring which directly affects the contact pressure between the moving and fixed contact of MCCB contact system.Decrease in spring length and load is also termed as spring SET.Due to this Low contact pressure is created which makes poor contact between the contact buttons thus increase the milli-volt drop of this joint. High milli-volt drop joint always increases the temperature generation rate which affects the performance of the MCCB and also electrical life of the MCCB. The present work emphasis on the improvement of the contact system by studying existing contact system on practical basis to know the scope of improvement and limitation.

Based on the outcomes,new design,improvements is proposed and prototyping is tested to calibrate the contact pressure of the breaker.Creo software is used for 3D modelling of the proposed designs.Oven is used to conduct practical test.Prototypes of the proposed design is validated by practical test on 630A Frame MCCB.On successful completion of design validation, proposed design has been implemented to improve the contact pressure of the MCCB.

Keywords : MCCB,CREEP,Contact pressure,High temperature,Springs, Spring set.

Nomenclature

OD	Outer diameter, mm
L	Free length, mm
M_d	Mean diameter, mm
d	Wire diameter, mm
C	Spring index
N_a	Working coils
G	Modulus of rigidity,N/mm^2
F	Load value, N/mm^2
K	Wahl correction factor

Abbreviations

MCCB	**Moulded Case Circuit Breaker**
LC	**Lower contact**
UC	**Upper contact**
MV	**Milli-volt**
CP	**Contact Pressure**
OT	**Over travel**
CB	**Circuit breaker**
PTFE	**Polytetrafluoroethylene**
Cr-Si	**Chrome silicon**

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Chapter 1

Introduction to MCCB

1.1 GENERAL

Molded case circuit breaker(MCCB) is a electro-mechanical switching device capable of making,carrying and breaking current under normal condition for the case of maintenance. It also has the capability of making carrying and breaking the current under abnormal condition like short circuit condition. An MCCB provides protection by combining a Bi-metallic strip device along with a current sensitive electromagnetic(Fixed and moving magnet) device. Both these devices act in accordance with the trip mechanism.

Larsen and Toubro manufacture a wide range of MCCBs ranging from 16 A to 1250 A with breaking capacity up to 70 kA. The different variants of MCCBs are named as Frame0, Frame1, Frame2, Frame3 and Frame4 on the basis of frame size.

1.2 Introduction to MCCB - 630A

Larsen and Toubro manufacture a wide range of MCCBs ranging from 16 A to 1250. Frame 3 630A comes with breaking capacity of 100kA.It provides protection with two variants Thermal-magnetic and microprocessor release.Thermal-magnetic provides protection by bi-metal strip and electro-magnet device in abnormal condition while microprocessor gives protection by release circuit.It is used for load of 630A.

	Frame0	
Rated Current	20, 25, 32, 40, 50, 63, 80, 100A	
Release	Thermal-Magnetic	
	Frame1	
Rated Current	100, 125, 160, 200, 250A	
Release	Thermal-Magnetic	
	Frame2	
Rated Current	63, 80, 100, 125, 160, 200, 250A	40, 63, 100, 160, 250A
Release	Thermal-Magnetic	Microprocessor
	Frame3	
Rated Current	320, 400, 500, 630A	400, 630A
Release	Thermal-Magnetic	Microprocessor
	Frame4	
Rated Current	800, 1000, 1250A	
Release	Microprocessor	

Figure 1.1: Range of MCCB

The main parts of MCCB are:

Frame: It is a protected covering to put CB and its parts which are produced using thermo-set plastic, for example, Glass polymer. The protecting material is settled on the rating of CB. Casing appraisals reveal a few evaluations and data, for example, greatest voltage, ampere rating, intruding on rating, and physical size.

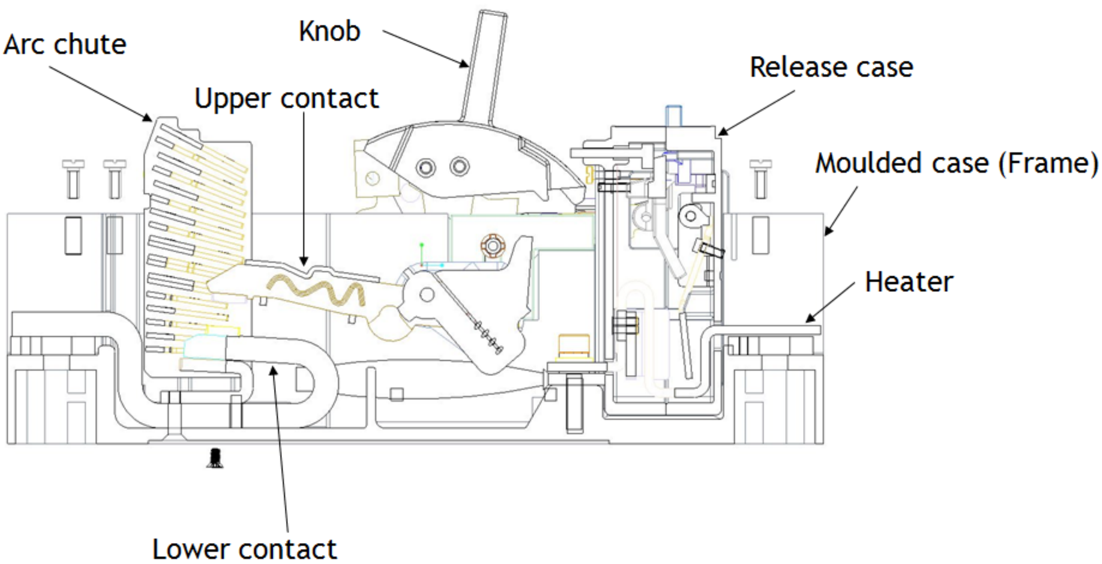


Figure 1.2: Cross-sectional View of MCCB

Contacts: Moving contact and fixed contact both are called as the contacts of the MCCB.Making,carrying,and breaking of the current are done with the help of those contacts. During any abnormal condition, the contacts break the circuit and limit the current to zero value.
Arc Chute Assembly: when the moving contacts and fixed contact are opens in the circuit,There is a current flows for a small duration of time which is called as arc. This arc is cease by arc-chute which is assembled just after the moving contact and fixed contacts. They are an array of several U shaped plates called de-ion plates.
Mechanism: The mechanism get together comprises of the side plates (two numbers),latch assembly (latch the latch links), latch bracket, latch bracket spring pins. The side plates are put left and right of the latch. The latch get together i.e. the hook and the lower joins are bolted. The material of the side plates is of gentle steel, which is then zinc plated. The material of the hook section and the lock is stainless steel. The hook section is held immovably by a stick against a torsion spring..
Trip unit: Over current is sense by Trip unit and tripping command is given to CB. During the overload,Bending of the bi-metallic occurs and which activates the trip plate by its force which opens the contacts. During short circuit fault, the magnetic arrangement trips the breaker.

Figure 1.3: Frame 3 MCCB

1.3 Thesis outline

The thesis outline of each chapter are specified as follows.
Chapter 1 Expresses the introduction about MCCB's,range of MCCB and functioning of MCCB.Various parts of MCCB are shown and there working is mentioned in it.
Chapter 2 reviews historical development of MCCB,Creep,Stress relaxation in springs,with the principle of working of contact system in MCCB,Contact pressure,Existing problem,ways to overcome the problem and objective of present study.
Chapter 3 reviews about the experimental investigation of springs,manufacturing process springs,specification,calculation and analysis of stresses,drawbacks of existing springs,proposed springs and experimental work carried on proposed spring.
Chapter 4 reviews about contact pressure improvement by designing new upper contact.
Chapter 5 Conclusion and future work.

Chapter 2

Literature Survey

This chapter reviews in historical development of springs set problems,stress relaxation,PTFE development,creep.Authors have research on high temperature effects on springs,changes in the micro structure,creep rate and how to control the effects high temperature.

2.1 Historical development

Geinitz et al.[3] In this paper For relaxation which properties of the material are important and, then various steps processes to manufacture spring. which conditions have what effect on the load lost by relaxation of the spring.Various experiments like tempering, shot peening, pre-setting are done on the spring wire before manufacture and their results are studied.Paper gives us the data of various results of conducted results at different temperature and a different time.
HENRY et al.[4] In this paper, the main purpose is to remove the stress from the spring and also remove the residual stress from it which are caused at the manufacturing of the spring. The coiling operation increase elastic properties of spring. Stress eliminating operation will carry in 400-900 F temperature for 30 minutes.

Llano-Vizcaya et al.[5] In this paper springs are manufacture at that time ,tensile, internal stress are generated which are responsible for low life of spring. Elimination of stress can be done by heat treatment. spring is below the material transformation temperature are heated. Suitable condition of heat experiment was obtained, this gives rise to high fatigue resistance with minimum spring relaxation.

SIMON et al.[6] In this paper, Stress mitigating tests were directed at 600 to 700 Celsius and found that, under steady displacement, the degrading of the spring power is one to three order of magnitude than would be anticipated from creep information from samples under tensile loading.

Perevertov et al.[7] In this paper loops of a ferromagnetic material containing stresses due to heat treatment are investigated. At 300-740° Celsius range 54SiCr6 spring steel was quenched and tempered . Changes in hysteresis curves At temperatures from 300-500 ° Celsius occured. the effective field changes linearly with the tempering temperature In the range of 300 to 500 degree Celsius. The temperature range the internal stress.

Roselita et al.[8] In this paper the increase in number of cycles to failure by Heat and surface treatments of spring steels which can greatly affect fatigue life. In this paper study deals with the parameters of the manufacturing process to transforming the initial micro structure of 56SiCr7 steel to tempered marten site, and increasing the surface hardness and fatigue resistance. This study shows significant hardness increase on the surface of the steel, and verifies how heat- treatment and shot-peening affect surface hardness.

Digpalsinh parmar et al.[9] In this paper author have discussed about the forces acting on the contact system.two forces acts holms and lorentz which are repulsive by nature, repulsive forces decreases the contact pressure of the system. various experiments carried on JMAG and FE tool to overcome problem.

E. Dhanumalayan Girish M. Joshi et al.[10] In this paper authors have discussed about the properties of PTFE and its performance.PTFE is used in various application like coating,Thermos sealing,insulation etc.Various feelers are added in it advantage of those are described in it.

Ronald Rowand et al.[11]In this patent inventor have described about various methods of coating on metals.

Evans,R.W;Wilshire B. et al.[12] In this paper authors have explain about the subject of creep in metals and alternatives to approach creep creep fracture.New approach like theta projection concept,offers coherent explanation.It also allow data derived from test lasting from 3 month to up to 10 yeas to predict creep strain and creep life.

Mclean,D et al.[13] In this paper authors is explaining about different several creep regimes depending mainly on temperature.Rate of creep is very dependent on temperate,stress applied,composition of material.

Michael E kassner et al.[14] In this book author have explained about the fundamentals of creep plasticity and analysis of investigation i variety of arise relevant to creep.Various power laws creep dislocation,fracture is explained in this paper.

Jean-paul Porier et al.[15] In this paper authors have explained about high temperature plastic deformation,lattice dislocation,lattice defects,vacancies,grain boundaries,also creep control is being explain.

Chen Y,Lu,X,Blawert C,el al.[16] In this paper authors have explained about coating of plasma electrolytic oxidation fabricated on magnesium allow via PTFE particles.To improve dispersion stability of particle surfactate are used.

Xig-dond yuan,Xiao-jie Yang et al.[17] in this paper authors have explained about friction properties of PTFE coating on disc, tested under vacuum condition.It shows that frictional coefficient of PTFE coat first increased with increased in sliding velocity and ten decrease with increase of slide when slide is higher than1.2 m/s.Wear of PTFE coating was first decreased with increased in load and then increased with load when load is higher than 6N.

Jasminka tarcavic,Roman pohrt, valentin L,Papav et al.[18] in this paper plastic properties of PTFE under condition of high pressure and shear,experimental behaviour sheet indenter under combine action of shear and normal stress.yield stress is found proportional to normal stress.

Richard K kirby et al.[19] In this paper author experimented 4 samples of PTFE were taken,results shows that annealed Teflon are indicated in plot of expansion vs temperate, in table listing average coefficient of linear expansion from -190 to 300° Celsius.The effect of residual stresses on expansion of Teflon was studied found to be considerable.

Low-voltage switchgear and controlgear[20]IEC 60947-1,standard for MCCB

Circuit Breaker "Low-voltage switchgear and control-gear.[21]IEC 60947-2 standard for tests requirements.

2.2 Existing design of contact system

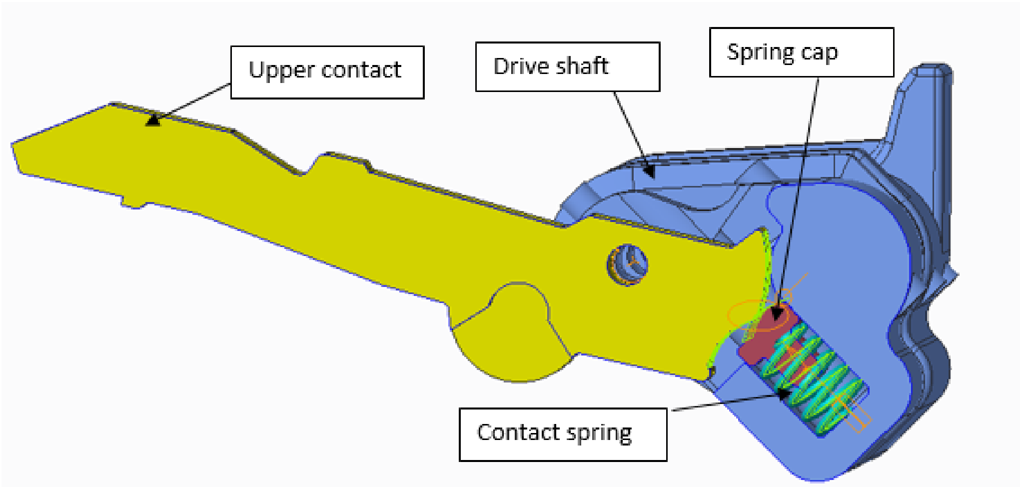


Figure 2.1: Contact system

1)Upper contact:As shown in fig 2.2,During making and breaking of the circuit,the upper contacts play an important role in the breaker.The main function of the moving contact is to break the contact during the abnormal condition.The moving contact is assembled to drive shaft which is linked with the mechanism.Upper contact is made from the copper material as it is good conductor of electricity and the manufacturing process used to make upper contact is extrusion wire cut process.Later the machining is done and made up of proper dimensions.MCCB comes with 3 pole and 4 pole. Size of upper contact varies with rating of the breaking capacity.Given fig.2.2 shows the existing profile dimension of the Upper contact.This dimension is also plays to achieve Contact pressure (CP abbreviation) to the contact system.

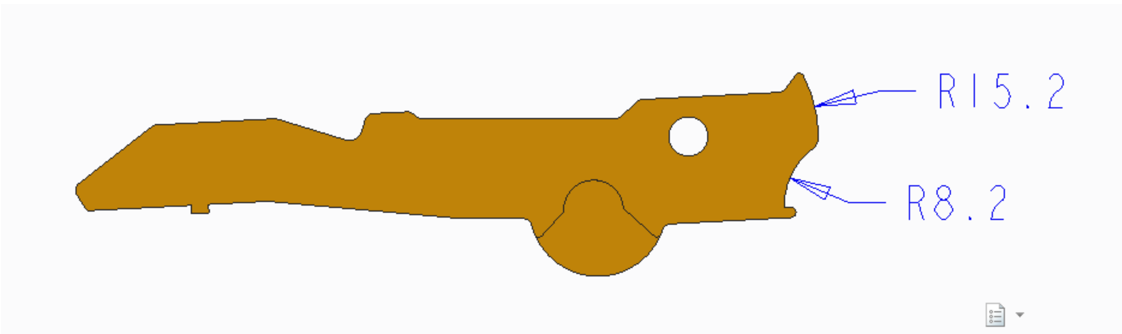


Figure 2.2: Existing Upper contact

2) Contact Spring:As shown in fig 2.3,Contact spring is compression spring made up from IS 4454 part 1 grade 3 steel material.During the working condition of the breaker, the spring is assembled in driveshaft which gives back force to the upper contact.This results in the achieving contact pressure between upper and lower contact.Steel springs are less heat resistant and hence temperature affect is seen during a period of time under working condition.Decrease in load value is seen in this spring after some working period.The spring is made up of ground ends to transmit proper force to the upper contact.

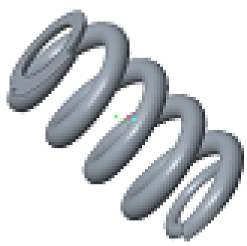


Figure 2.3: Contact spring

3) Spring cap:As shown in fig.2.4, The spring cap is the intermediate part between the upper contact and spring in which the springs are mounted on them. The arrangement of two springs is given to mount on the cap. The spring back force is held on the cap which it pushes the moving contact. It is made up of brass and with chromium plating to improve its strength and shiny appearance.

Figure 2.4: Spring cap

4) Drive shaft:As shown in fig.2.5, Drive shaft is used to make and break the contact with the moving contact. it can be 3-pole or 4-pole R,Y,B as per the requirement. The material used for making driveshaft is unsaturated polymer and moulding process is used to manufacture.The making process of driveshaft also faces some problems like warpage.This is also one of the reason for the reduction in over travel (OT abbreviation).The material warp and the marking is deviated and drilling made on it gets deviated.

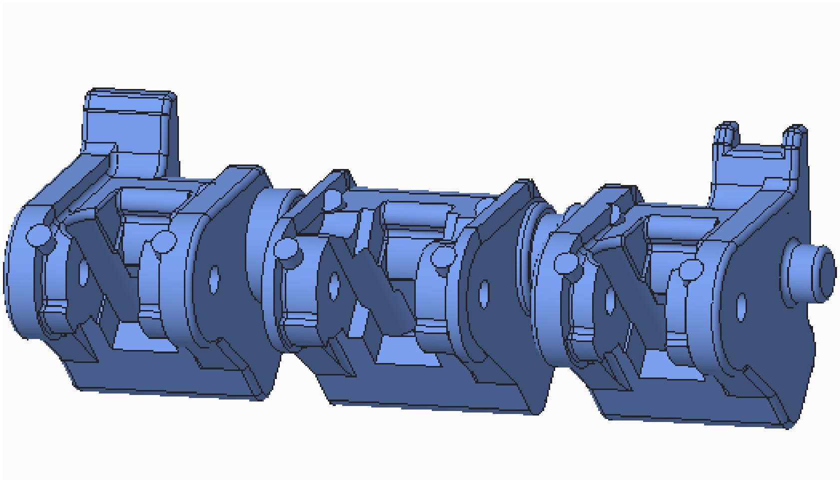


Figure 2.5: Drive shaft

5) Contact button:As shown in fig.2.6, Contact buttons are placed at the tip of moving and fixed contact.They are the intermediate point of contact between the moving and fixed contact act, the point of contact pressure is acts on the buttons only The moving contact button are made up of 98% silver and 2% of graphite to give it strength,lower contact button made from 60% silver and 40% nickel. Increasing size of contact buttons will increase CP but also increase in the cost as silver is costly.

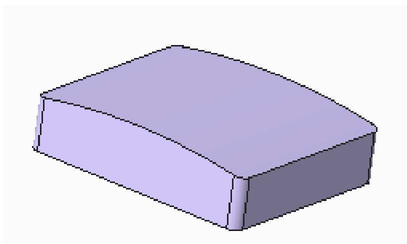


Figure 2.6: Contact button

2.3 Contact Pressure

In the ON state of the breaker there is a force acts in between upper and lower contact which is called as contact pressure. Generally the CP to be kept in between 3-6 kgs for 630A Frame 3. Change in CP affects the working of the MCCB at high extent. As there is maintained CP and after a duration of time CP decreases there is a rise in temperature affecting the contact buttons to erode. At high current supply in the contact system path way the less CP can lead to sparkling in the moving and fixed contact and this can erode the contact button. For the dependability of breaker, the CP to be kept up higher inside the band, this will prompt decreased contact button erosion.

Factors causing low Contact Pressure are listed below and discribed in details in following section

1. Low Over Travel
2. Repulsion of the contact system
3. Lower spring force

2.3.1 Low Over travel

OT is the difference in between distance of moving contact and fixed contact when the breaker in ON condition.In the present case, the OT must be kept more than around 3.5 mm.OT results in proper contact between moving and fixed contacts.Lower OT may results in loose contact and may generate sparks during on condition.This will lead to temperature rise, galling effect and erosion of contact buttons.

2.3.2 Repulsive Forces

There are two types of forces which are electromagnet forces by nature[22].Specially repulsion and attractive forces due to current carrying path produces electromagnet field which the current is flowing in opposite direction will rise to repulsion.Current distribution of present system contacts[9].Basically,two types of forces act on the upper contact due to repulsion action.

1) Lorentz force

2) Holms force

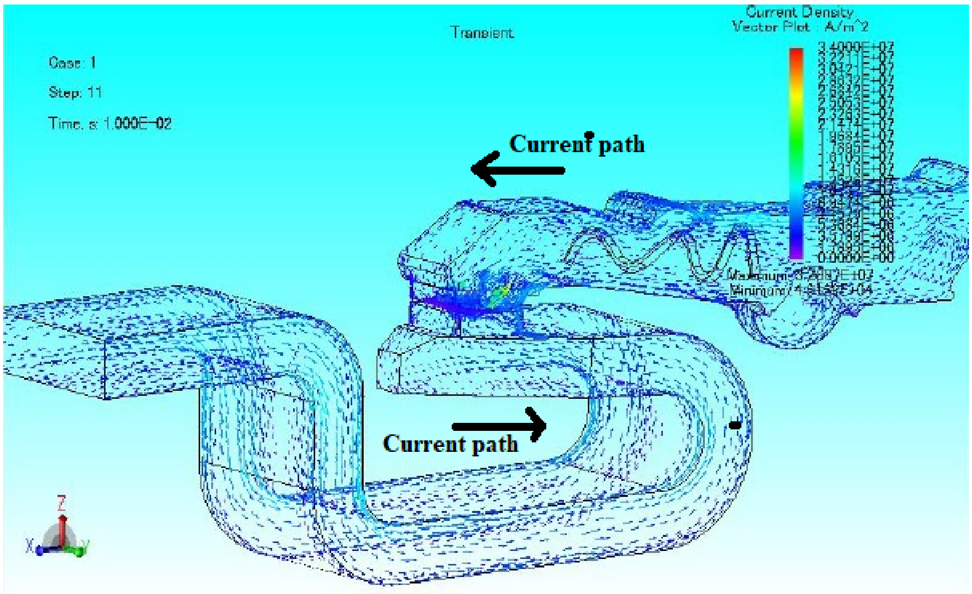


Figure 2.7: Forces acting on the UC and LC of contact system

As shown in fig.2.7 current carrying path is shown from upper contact to fixed contact. As the current travels, the direction of the current is opposite in direction between the upper contact and lower contact.This creates repulsive forces in between the upper contact and fixed contact which tends to repel each other.This repulsive forces can be one of reason to decrease the contact pressure[23][24].

So there is a necessity to maintain the contact force in the contact system to avoid the problem of abnormal tripping and improve breaker life.

2.3.3 Lower Spring Force

The load value of contact spring plays a vital part in CP. With the spring with low load value will gives a low CP as the over lapping of moving contact onto the fixed contact will be reduced this will give rise to high temperature genration between the upper contact and fixed contact,high temperature can tend to contact button erosion and MCCB may get a nuisance tripping action.With high load value of spring,there may be more contact pressure which will not perform tripping action during abnormal condition.Thus the spring force to be well in the predefined band.

The forces developed by the compression spring[25] is given by equation (2.1)

$$F = \frac{G * d^4 * D}{8 * M_d^3 * N_a} \tag{2.1}$$

Where

G - Modulus of rigidity

d - Wire diameter

D - Deflection

M_d- mean diameter

N_a- Number of active turns

Due to the temperature rise in the contact system,springs faces high temperature environment,the residual stresses is relieved and hence spring action is reduced.The material of the spring and deflection/compression spring plays a dominant role in spring force for the given spring.Hence spring plays important role in achieving contact pressure in the contact system.

With the course of time the spring action found to be impaired.An attempt has been made to resolve this problem.The problem description is given below.

2.4 Problem description

MCCB has the capacity of making, carrying and breaking the current under typical and anomalous conditions.MCCB frame 3 630A is capable of working under load of 630 amperes.The contact system is an arrangement for making and breaking a circuit.Contact system contains components which includes drive shaft,upper contact,contact spring,cap,contact buttons. During working condition, there is a apparently decrease in contact pressure of contact system which is present in between the moving and fixed contact.Low contact pressure will create poor contact between the contact buttons and thus increase the milli-volt drop of this joint. High milli-volt drop joint will always increases the temperature generation rate.This causes abnormal tripping of the contact system which affects the performance of the MCCB. Study of contact system shows that contact spring and upper contact plays major part to achieve contact pressure.High temperature in the contact system, affects spring performance due to which there is a loss of load and free length of the spring is decrease(Spring setting) during a period of time.The plastic deformation occurs in the spring at constant temperature is termed as CREEP[13]. This results in decrease of contact pressure of the MCCB.

2.5 Objectives of present study

1. **Analysis of the spring action and contact pressure.**
2. **Effect of temperature on setting of spring.**
3. **Redesign of spring with alternate material.**
4. **Redesign of upper contact to improve contact pressure.**
5. **Prototyping development and validation.**

Chapter 3

Experimental investigation on Contact Springs

Contact spring plays an important role in achieving contact pressure in contact system.The compression springs are assembled in drive shaft and compressed by upper contact,the compression of spring gives contact pressure between upper and fixed contact.Total 6 nos.of spring are assembled in drive shaft 2 springs in each R,Y,B pole.Spring cap is assembled on 2 springs which push upper contact on to the fixed contact to maintain contact pressure.In this way contact pressure is achieved in contact system of MCCB.

Figure 3.1: Grade 3 Steel spring

3.1 Manufacturing Process

In the present scenario IS:4454 grade 3 part 1 steel wire material is used as the contact springs respectively. They are manufactured by cold drawn round wires by coiling operation. Contact spring is under high temperature surrounding in contact system which is developed by current carrying path.Steel springs do not rust,making them ideal for the industry. Steel spring tensile strength is approximately 1470 N/mm^2.

1. **Coiling: Forming process is used to coil the spring. Various wire diameter,number of coils,pitch distance,free length are being put in the machine setup to manufacture of spring[26].**

2. **Stress Relief/Heat treatment: In order to prevent micro stress cracks in the springs Stress Relief processes are done after the coiling is done on the Springs.This is done in the Oven. In this steel spring stress relieving must be done on 220°C and 350°C for 2 minutes to 1 hour depending on the wire diameter. The objective of the heat treatment is to relieve the stress which is formed during the forming process.Stress relieving also increases the elastic limit of the material and stabilizes the spring dimensions.**

3. **Grinding /end coils: Grinding both ends of the spring square provides a reliable bearing surface. For end coils, there is a number of choices available for the compressions springs. For the spring XB00658, a closed and ground grinding is being done additional for the better stability than other formation. In the application of the force, the ground end provides good force transfer.**

4. **Scragging operation: when the spring is pressed to its solid height this procedure is called as Scragging or set removal. Every spring does not need of this procedure. Over stressed springs are mostly processed such practices,also required deflection of spring it can be done. Scragging of springs can be beneficial for the spring, high load capacity increases and without over stressing it. Randomness in load value of the springs can be solve by performing these operation and it is good for the redistribution of uneven stresses in the springs. Scragging also helps to control CREEP phenomenon due to stresses.**

3.1.1 Chemical composition of steel spring

In table 3.1 Chemical composition of steel spring is shown,and in table 3.2, dimension of steel spring is given.

Table 3.1: Chemical composition of Grade 3 steel spring[2]

Grade	3
Carbon%	0.50-0.75
Silicon%	0.10-0.35
Manganese %	0.8
Sulphur%	0.03
Phosphorous%	0.03
Phosphorous + Sulphur %	0.05
Copper %	0.12

Table 3.2: Dimensions of grade 3 steel spring

Outer Diameter	7.9 mm
No. of coils	6
Free length	15.3 mm
Mean diameter (M_d)	6.3 mm
Wire diameter(d)	1.6 mm
Modulus of rigidity(G)	81370 N/mm^2
Deflection (f)	2.4 mm
No. of active coils (N_a)	4

3.2 Calculations

To calculate shear stresses in spring,following calculations are carried out[25].

- **Load value F**

$$F = \frac{G * d^4 * f}{8 * M_d^3 * N_a}$$

$$F = \frac{81370 * 1.6^4 * 2.4}{8 * 6.3^3 * 4} \tag{3.1}$$

$$F = 16.3kgf$$

$$F = 159.90N/mm^2$$

For load value tolerance of $16.3 \pm 10\%$ **is allowable**

- **Calculated stresses**

$$Calculated\,shear\,stress = \frac{8 * F * M_d}{\pi * d^3}$$

$$Calculated\,shear\,stress = \frac{8 * 16.3 * 6.3}{\pi * 1.6^3} \tag{3.2}$$

$$Calculated\,shear\,stress = 63.86 kgf/mm^2$$

$$Calculated\,shear\,stress = 626.44 N/mm^2$$

- **Spring index**

$$C = \frac{M_d}{d}$$

$$C = \frac{6.3}{1.6} \tag{3.3}$$

$$C = 3.93$$

- **Wahl Correction factor**

$$K = \frac{4C - 1}{4C - 4} + \frac{0.615}{C}$$

$$K = \frac{4 * 3.93 - 1}{4 * 3.93 - 4} + \frac{0.615}{3.93} \tag{3.4}$$

$$K = 1.41$$

Corrected shear stress = Corrected shear stresses * K

$$Corrected\,shear\,stresses = 63.86 * 1.41$$

$$Corrected\,shear\,stresses = 90.14 kgf/mm^2 \tag{3.5}$$

$$Corrected\,shear\,stresses = 884.27 N/mm^2$$

Permissible shear stress is 1039.86 N/mm^2, with Factor of safety 2. So the design is acceptable to manufacture.

3.3 Existing Spring design

Table 3.3: Dimensions of grade 3 steel spring

Outer Diameter(OD)	7.9 mm
No. of coils	6
Free length	15.3
Mean diameter (M_d)	6.3 mm
Wire diameter(d)	1.6 mm
Spring index(C)	3.93
No. of working coils(N_a)	4
Modulus of rigidity(G)	81370 N/mm^2
Deflection (f)	2.4mm
Calculated shear stress	626.44 N/mm^2
Corrected shear stress	884.27 N/mm^2
Load at 12.9mm	159.90 N/mm^2
Safety margin	14%
Spring rate	6.79 kg/mm

3.3.1 FEA Analysis

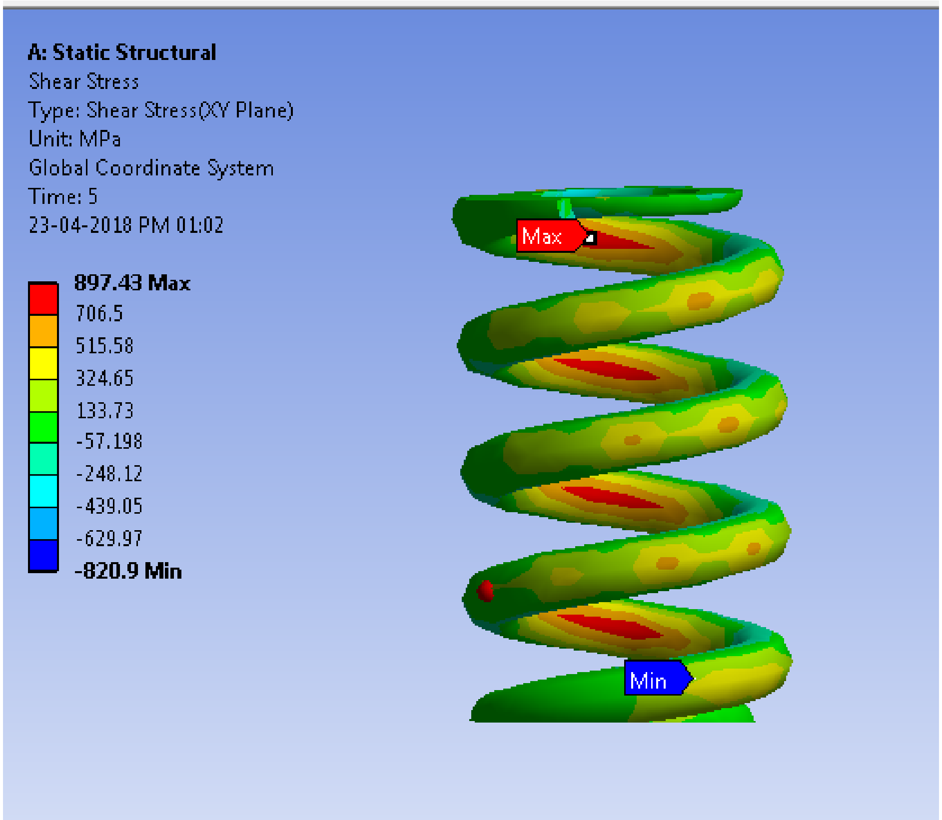


Figure 3.2: FEA analysis in steel spring

To analyse the stresses in the steel spring FEA analysis is done in ansys. Model of spring is done in PTC CREO. Number of elements are 101768.Material of the spring is Steel. Shear stresses are stresses which are springs are mainly subjected too. Spring is 12.9 mm of length in the MCCB,at which shear stress are generated inside the spring diameter which is found to be 897.43 MPa.As seen in the fig 3.2,Shear stresses are maximum at the inner radius of the spring. Stress value may vary different in different springs,as they are generated during manufacturing processes.

3.4 Drawbacks of the existing steel spring

Creep in springs/Relaxation:

When springs are coiled during the manufacture there are un-even distribution of stresses in the coils of the springs. As the spring is assembled in compressed state there are presence of stresses and high temperature around the spring. The spring lose its internal energy during a period of time due to high temperature. This lost of energy in constant stresses and constant temperature give rise to plastic deformation of the spring and this is called CREEP[12].Relaxation is the term related to the spring in which spring loses its stiffness[13].

As there is drop of load of spring which gives back force to upper contact there is gradual decrease in contact pressure at the point of contact of upper contact and lower contact. CREEP are classified in 3 stages viz. primary secondary and tertiary. CREEP is understood to be continuous increase in strain when a constant load or stress is maintain on solid material over a period of time. It is not necessary that CREEP is always associated with elevated temperature for creep has been observed at low temperature also,but elevated temperature enhance creep deformation and its rate particularly temperature in the vicinity of half of melting point of solid greatly increase the creep rate. Material which occurs at temperature lower than this may not be greatly in danger of failures due to creep.

Variation of CREEP strain with respect to time under constant stress and temperature[14]. It may be seen for constant temperature the strain may be vary differently for two different stress levels with respect to time,after a given interval of time higher creep strain will be produce for higher stress level. The effect of temperature will be similar for both stress level same.Similarly constant stress the strain may be vary differently for two different temperature levels with respect to time,after a given interval of time higher creep strain will be produce for higher temperature level.

The effect of stress will be similar for both temperature level same on practical basis existing spring is validated under working temperature.It is found that there is gradual decrease in load value before oven test. Also reduction in free length is seen.
So our main concern is that the spring is getting setting problem and also during a period of time load value is decreasing in existing spring.

Spring set issue:

Compression spring is compressed in the driveshaft under the moving contact, it is ready for the operation as the breaker is in working condition the temperature in the contact system is around 120°-140° Celsius. After operating in such environment over a period of time it is found that the contact pressure of the contact system is decreased . When the spring is analyzed after removing from the breaker it is found that the load value and free length of the spring is decreased. Load value plays important role in achieving contact pressure in between the upper and lower contact. Free length is found to be decrease. This is referred to as taking a set or setting in spring.

3.5 Creep test on Steel springs

3.5.1 Experimental procedure of accelerated creep test

To Analyze the steel spring performance,accelerated creep test is carried out [27]. The springs are assembled in the MCCB and the MCCB is kept in ON position in the oven at 140° Celsius for 7 days.
This ressembles the working environment of the spring within the MCCB.

Table 3.4: Contact pressure in MCCB

Contact Pressure in the MCCB poles						
MCCB Ratings	Before test			After test		
	R	Y	B	R	Y	B
630A	3.70 kg	4.10 kg	3.80 kg	2.90 kg	3.25 kg	3.15 kg
400A	3.55 kg	3.95 kg	3.78 kg	2.74 kg	2.9 kg	3.20 kg

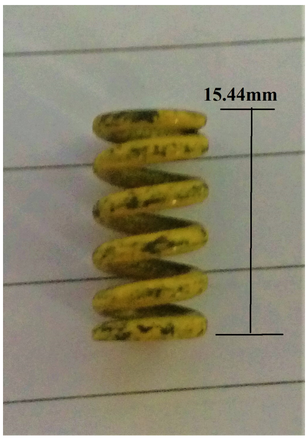
CP readings are taken before and after the test. The steel spring 10 numbers tested for creep in the oven ,free length of each spring is measured before and after creep test by Vernier caliper. The load value of each spring at 12.9mm compression is also measured with the help of load testing machine.
Result obtain after creep test are as shown in table 3.4 and 3.5,After test is over springs are dismantled and free length and load value is measured at 12.9mm compression. Result disclose that there is apparently drop in load value around 20% to 30% after creep test that is around 3-5 kg of load value drop is seen. Free length is found to be less after the creep test around 1 mm of free length is dropped. As the springs are losing there load value capacity so the contact pressure decrease at the contact point,which increases the milli volt drop and hence temperature rises.

Spring No.	Load(at 12.9 mm)before creep test(Kg)	Free length before creep test(mm)	Free length after test (mm)	Load value after test (kg)	Load value difference after test (kg)	Reduction in load value in percentage
1	13.14	15.31	14.96	10.18	2.96	23%
2	12.88	15.29	14.90	9.94	2.93	23%
3	13.32	15.41	14.85	8.31	5.01	38%
4	13.56	15.38	14.89	10.20	3.36	25%
5	12.81	15.30	14.86	9.14	3.66	29%
6	13.20	15.32	14.79	8.81	4.38	33%
7	13.49	15.34	14.91	9.30	4.19	31%
8	13.58	15.41	14.86	9.56	4.01	30%
9	13.61	15.40	14.92	1029	3.32	24%
10	12.93	15.31	14.78	9.57	3.35	26%

Table 3.5: Highly accelerated creep test on grade 3 Steel springs in oven

Table 3.4 shows the value of contact pressure measured after the creep test,there is fall in the contact pressure around 1-1.5 kg.

(a) Comparison of steel spring



(b) Before creep test

(c) After creep test

Comparison of steel spring is given in fig.3.3,Reduction in free length can be seen before and after the test.Initial measurement shows 15.44 mm is reduced to 14.88 mm of length.

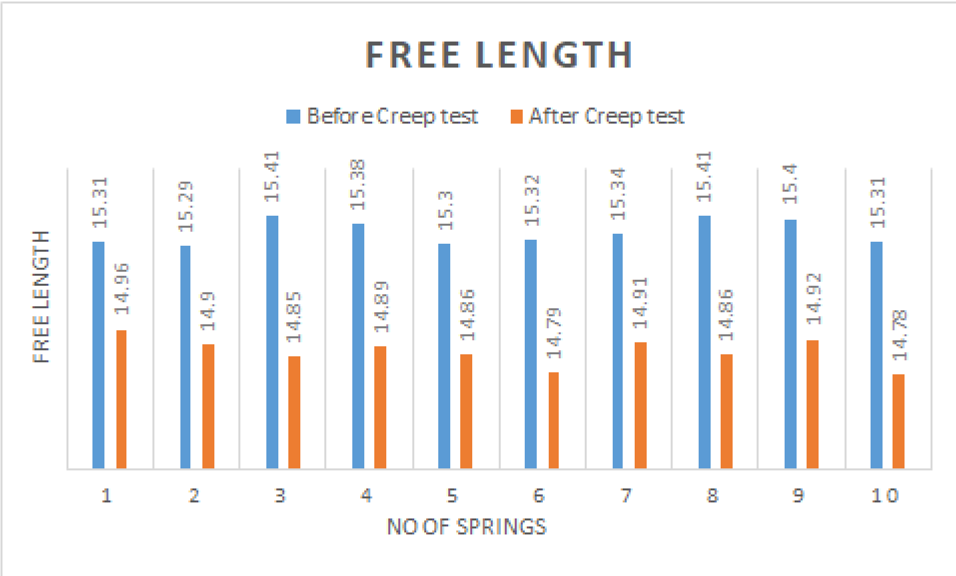


Figure 3.4: free length of spring

As seen from the fig 3.4,comparison in free length of all the 10 springs tested before and after the creep test is given. It is found that there is apparently decrease in the free length of the spring which is about 1 mm. All the springs are found to be shortened after the creep test.

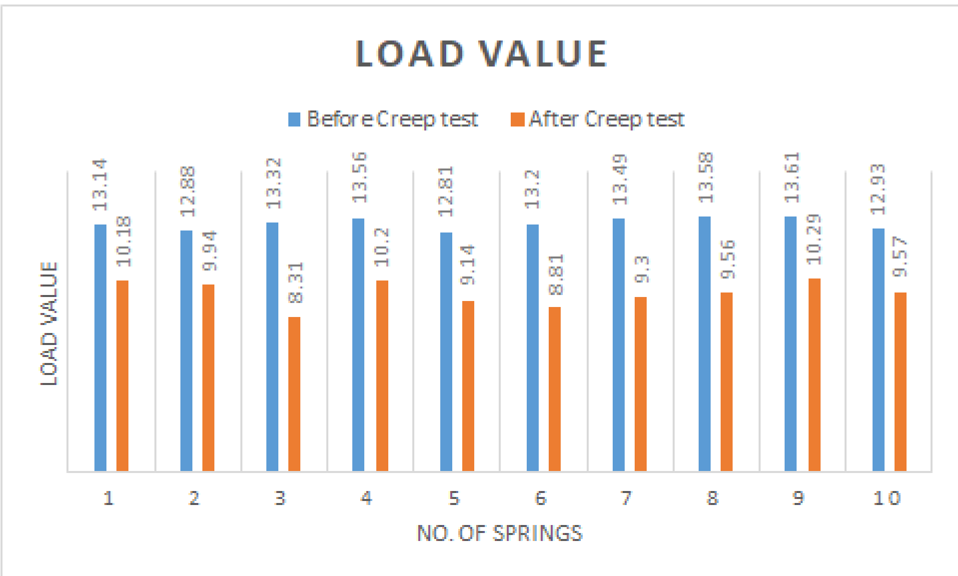


Figure 3.5: Load value of spring

As showns in fig 3.5,Comparison in load value of all the 10 springs tested before and after the creep test is given in fig 3.4. It is found that there is apparently decrease in the load value of the spring which is about 3-5 kg. All the springs are found to be decrease in the load value after the creep test.

As seen in the steel springs, there is apparently loss of contact pressure with the load and free length loss. Proposal to choose a material with high tensile strength and resilience to high temperatures[28].A Chrome silicon material for the spring is proposed.
Its working temperature is 246 °Celsius.Chrome silicon 2D wire spring has good reliability in shock loads[2]. It is also cost-efficient. Chrome silicon springs can be used where there is the application of high stress. Silicon content raises the tensile strength without sacrificing ductility or toughness. Chromium content will increase tensile,hardness,toughness,reduces the need of high carbon content and increases ability to withstand high temperature. It has good cyclic life as compare to steel spring. Its tensile strength is 2040 N/mm^2.[28]

3.6 Design and testing of Chrome-Silicon Spring

A spring from the chrome silicon spring material is manufacture as per the dimension shown in table 3.2,the chemical composition of chrome silicon spring[29] are as shown in table 3.7.

Table 3.6: Chemical composition of Chromium-silicon spring

Carbon%	0.51-0.80
Silicon%	1.20-1.60
Chromium %	0.60-0.80
Manganese %	0.50-0.80
Sulphur%	0.025 max
Phosphorous%	0.025 max
Copper %	0.2

Table 3.7: Dimensions of chrome silicon spring

Outer Diameter	7.9 mm
No. of coils	6
Free length	15.3 mm
Mean diameter (M_d)	6.3 mm
Wire diameter(d)	1.6 mm
Modulus of rigidity(G)	79500 N/mm^2
Deflection (f)	2.4 mm
No. of active coils (N_a)	4

3.7 Calculations

To calculate shear stresses in spring,following calculations are carried out[25].

- **Load value F**

$$F = \frac{G * d^4 * f}{8 * M_d^3 * N_a}$$

$$F = \frac{79500 * 1.6^3 * 2.4}{8 * 6.3^3 * 4} \tag{3.6}$$

$$F = 15.93kgf$$

$$F = 156.27N/mm^2$$

For load value tolerance of $16.3 \pm 10\%$ **is allowable**

- **Calculated stresses**

$$Calculated\, shear\, stress = \frac{8 * F * M_d}{\pi * d^3}$$

$$Calculated\, shear\, stress = \frac{8 * 15.93 * 6.3}{\pi * 1.6^3} \tag{3.7}$$

$$Calculated\, shear\, stress = 62.39kgf/mm^2$$

$$Calculated\, shear\, stress = 612.04N/mm^2$$

- **Spring index**

$$C = \frac{M_d}{d}$$

$$C = \frac{6.3}{1.6} \tag{3.8}$$

$$C = 3.93$$

- **Wahl Correction factor**

$$K = \frac{4C - 1}{4C - 4} + \frac{0.615}{C}$$

$$K = \frac{4 * 3.93 - 1}{4 * 3.93 - 4} + \frac{0.615}{3.93} \tag{3.9}$$

$$K = 1.41$$

Corrected shear stress = Corrected shear stresses * K

$$Corrected\, shear\, stresses = 62.39 * 1.41$$

$$Corrected\, shear\, stresses = 88.07 kgf/mm^2 \tag{3.10}$$

$$Corrected\, shear\, stresses = 863.96 N/mm^2$$

Permissible shear stress is 1024.24 N/mm^2, with Factor of safety 2. Spring design is accepted and can be manufacture.

3.7.1 Chrome silicon Spring design

Table 3.8: Design of chrome silicon spring

Outer Diameter	7.9 mm
No. of coils(OD)	6
Free length(L)	15.3
Mean diameter(Md)	6.3 mm
Wire diameter(d)	1.6 mm
Spring index(C)	3.93
No. of working coils(Na)	4
Modulus of Rigidity(G)	79500 Kg/mm^2
Deflection (f)	2.4mm
Uncorrected stress	62.39 kg/mm^2
Corrected stress	88.07 Kgf/mm^2
Load	15.93 kgf
Safety margin	15.39%
Spring rate	6.79 kg/mm

3.7.2 FEA Analysis

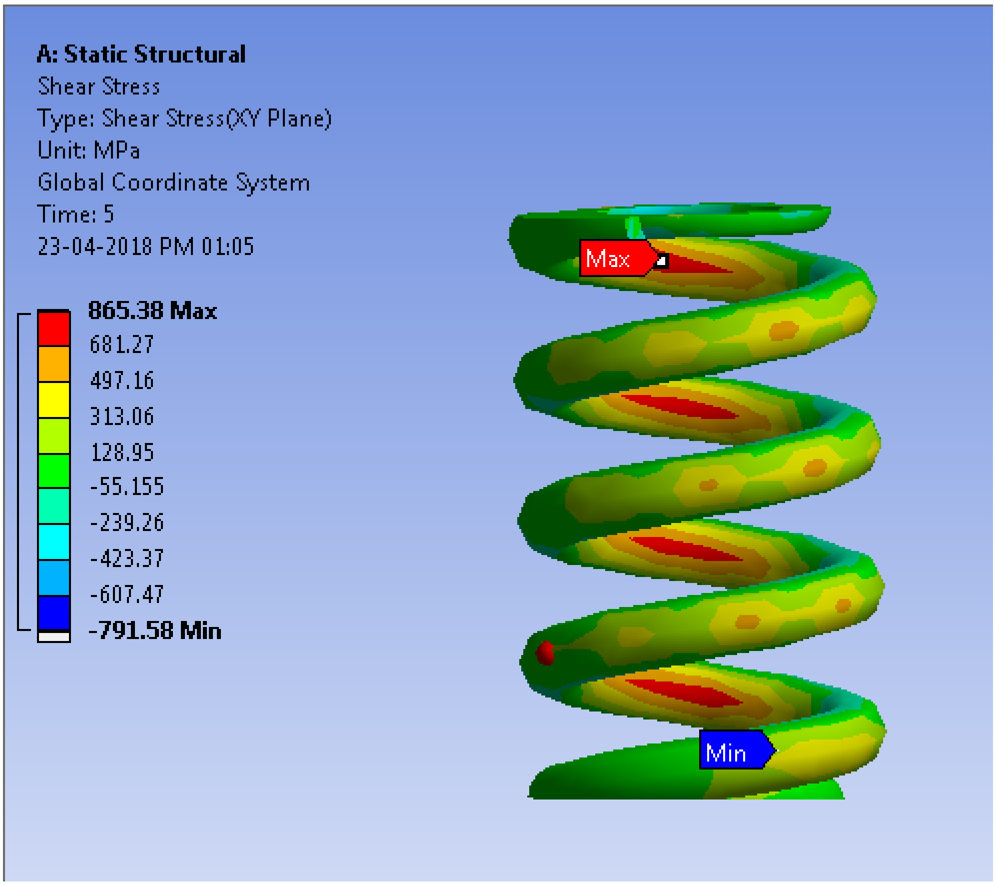


Figure 3.6: FEA analysis in cr-si spring

To know the shear stresses in the springs FEA analysis on spring is done on ansys,Spring modelling is done on PTC CREO. Spring material is chrome silicon.No. of elements generated 106817. Shear stresses are obtained from analysis, shear stress are maximum at the inside diameter of the spring which is maximum 865.38 MPa at inner radius as shown in fig 3.6. These stresses are less as compare to the steel spring. These stresses are generated during the coiling operation in manufacturing.Springs may have variation in the stresses during manufacturing.

3.8 Creep test on chrome silicon spring

3.8.1 Experimental procedure

To Analyze the chrome silicon spring performance,accelerated creep test is carried out[27]. The springs are assembled in the MCCB and the MCCB is kept in ON position in the oven at 140° Celsius for 7 days. This ressembles the working environment of the spring within the MCCB.

Table 3.9: Contact pressure in MCCB

Contact Pressure in the MCCB poles						
MCCB Ratings	Before test			After test		
	R	Y	B	R	Y	B
630A	3.80 kg	4 kg	3.48 kg	3.35 kg	3.50 kg	3.15 kg
400A	3.45 kg	3.72 kg	3.67 kg	3.22 kg	3.36 kg	3.24 kg

CP readings are taken before and after the test. The chrome silicon spring 10 numbers tested for creep in the oven ,free length of each spring is measured before and after creep test by Vernier caliper. The load value of each spring at 12.9mm compression is also measured with the help of load testing machine.

Result obtain after creep test are as shown in table 3.9,After test is over springs are dismantled and free length and load value is measured at 12.9mm compression. Result disclose that there is apparently drop in load value around 10% to 20% after creep test that is around 2-3 kg of load value drop is seen. Free length is found to be less after the creep test around 0.2-0.5 mm of free length is dropped. As the springs are losing there load value capacity so the contact pressure decrease at the contact point,which increases the milli volt drop and hence temperature rises.

Spring no.	Load before creep test(at 12.9 mm in kg)	Free length before creep test	Load value after creep test	Free length after test	Difference in load in Kg	Reduction in load value in percentage
1	12.94	15.38	11.16	15.28	1.78	14%
2	13.45	15.42	10.90	15.23	2.54	19%
3	13.35	15.44	12.14	15.2	1.21	9%
4	13.25	15.36	10.84	15.3	2.40	18%
5	13.25	15.42	11.17	15.17	2.07	16%
6	13.35	15.45	11.53	15.31	1.81	14%
7	13.87	15.5	11.52	15.22	2.34	17%
8	13.81	15.47	11.72	15.3	2.08	15%
9	13.21	15.45	11.62	15.22	1.59	12%
10	13.08	15.44	11.71	15.3	1.37	11%

Table 3.10: Creep Test at 140° Celsius for 7 days on Cr-Si springs

Table 3.9 shows the value of contact pressure measured after and after the creep test,there is fall in the contact pressure around 0.5 kg.

Figure 3.7: Comparison of chrome silicon spring

(a) Before creep test

(b) After creep test

Comparison of steel spring is given in fig.3.7,Reduction in free length can be seen before and after the test.Initial measurement of cr-si spring before test and after test is shown and it is reduced by 0.15mm in free length.

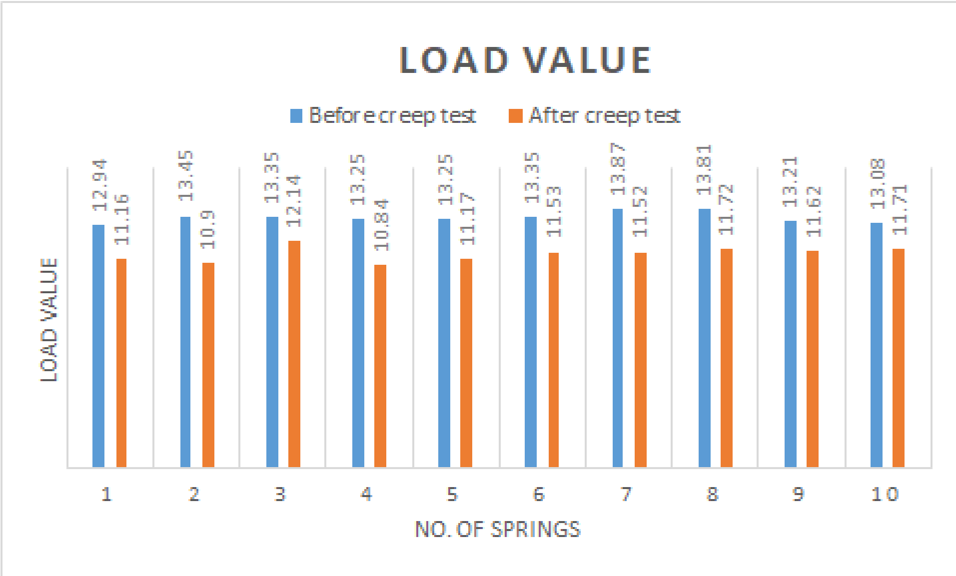


Figure 3.8: Load value

Fig.3.8 shows the reduction in the load value before and after the creep test.10 springs results is shown and can be seen that around 2-3 kg of load value is dropped in the springs.Drop in the load value of springs will decrease the contact pressure of the contact system.

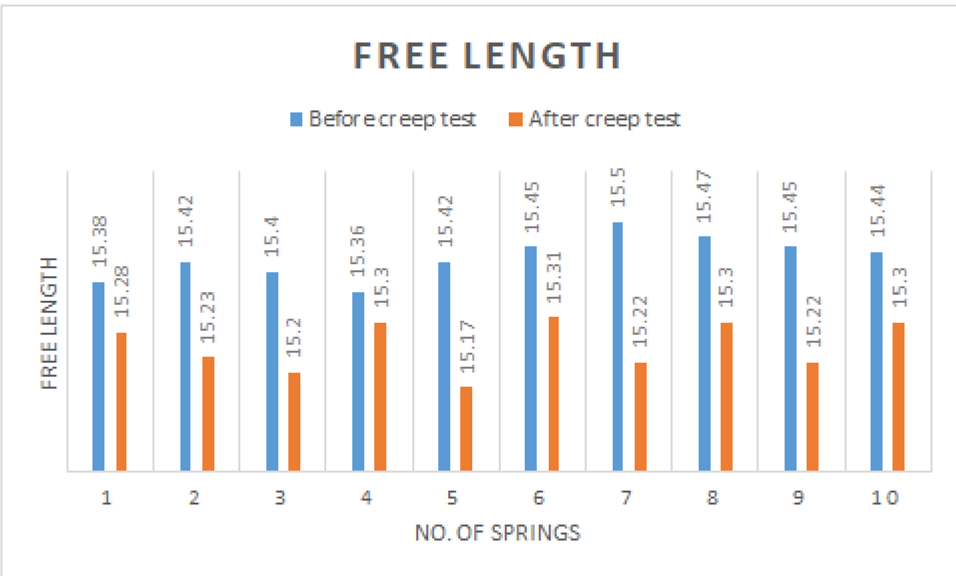


Figure 3.9: Free length

As seen from the fig 3.9,comparison in free length of all the 10 springs tested before and after the creep test is given. It is found that there is apparently decrease in the free length of the spring which is about 0.3 mm. All the springs are found to be decrease in the free length after the creep test.free length reduction is less as compare to steel spring by 0.5 mm.

Advantages of chrome silicon over steel spring

1. **It is resilient in high working temperature 246° Celsius as compare to steel grade 3 spring.**
2. **It can withstand high temperature as compared to steel springs.**
3. **The set issue is comparatively less as compared to steel spring when checked in Oven test.**
4. **Less loss of load as compare to steel spring.**
5. **High carbon, chromium gives high strength as compare to steel grade 3. High cyclic life than steel spring.**

3.9 Creep Control in chrome silicon spring

Though Chrome silicon spring exhibit lower spring set under working environment creep in the spring can be reduced if the working stresses and temperature are reduced.

3.9.1 Controlling Stresses in chrome silicon spring

To control stresses,Scragging [2]operation is done on spring,in which the springs are compressed and release at required deflection and several times. This removes the uneven distribution of the stresses,and helps springs which are over stressed.

Scragging operation redistributes the uneven stresses in the springs which helps the springs to get rid off of residual stresses,it makes spring more flexible to perform operation.The variation in the load value of springs is eliminated and maintain load value range in proper range by doing Scragging operation.

3.9.2 Controlling Temperature

Temperature plays an important role in CREEP phenomenon.Constant temperature rate increases creep,as the temperature in the contact system is around 140° Celsius due to the current pathway the springs faces high temperature.Creep phenomenon deforms the free length of the compressed springs and they lose there load value at compressed length.To protect springs from high temperature they need to coat from temperature insulating material so the effect of temperature on springs can be reduce thus reducing creep.PTFE(Teflon) coating[10] can be done on the springs to reduce the effects of temperature on springs.This will act as an insulation protecting spring from high temperature,PTFE can withstand high temperature can help to controls the CREEP in springs.PTFE comes with many other properties which are wear,abrasive,chemically inert,hydrophobisity which makes them more reliable[16].

3.10 PTFE Coating on Chrome silicon springs

Polytetrafluoroethylene(PTFE) also known as teflon is excellent heat resistant material is coated on spring after scragging operation is done.Its working temperature is -100 to ° Celsius.Pocess used for coating is electrostatic process with coating thickness of 20 microns.

3.10.1 Properties of PTFE

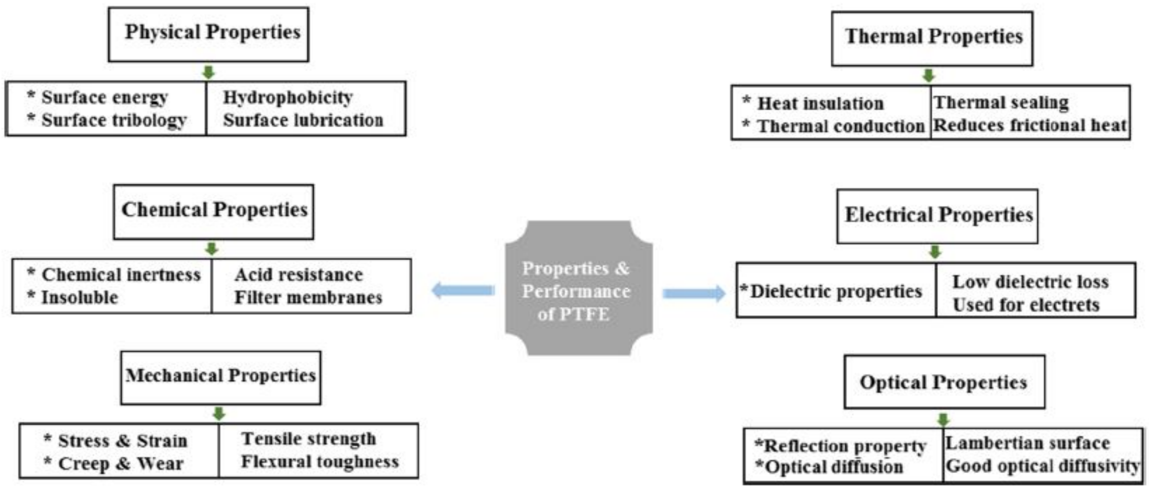


Figure 3.10: Properties of PTFE[1]

1. PTFE comes with many unique property like CREEP resistant,hydrophobicity,chemic resistant,heat resistant etc.

2. PTFE comes with low Creep rate property and the property is improved by adding nano silicon oxides in powder form PTFE.

3. PTFE is non reactive and inert due to its two fluoron atom bonded with carbon atom.PTFE is insoluble in common solvents like hydrocarbons,chlorinated hydrocarbon,phenol.

4. PTFE coating improves the load bearing capacity of the springs.

3.11 Creep test on PTFE chrome-silicon springs

3.11.1 Experimental procedure

To Analyze the PTFE coated chrome silicon spring performance,accelerated creep test is carried out[17]. The springs are assembled in the MCCB and the MCCB is kept in ON position in the oven at 140° Celsius for 7 days.

This resembles the working environment of the spring within the MCCB.

Table 3.11: Contact pressure in MCCB

Contact Pressure in the MCCB poles						
MCCB Ratings	Before test			After test		
	R	Y	B	R	Y	B
630A	3.85 kg	4 kg	3.85 kg	3.74 kg	3.85 kg	3.76 kg
400A	3.5 kg	4.3 kg	3.90 kg	3.36 kg	4.10 kg	3.90 kg

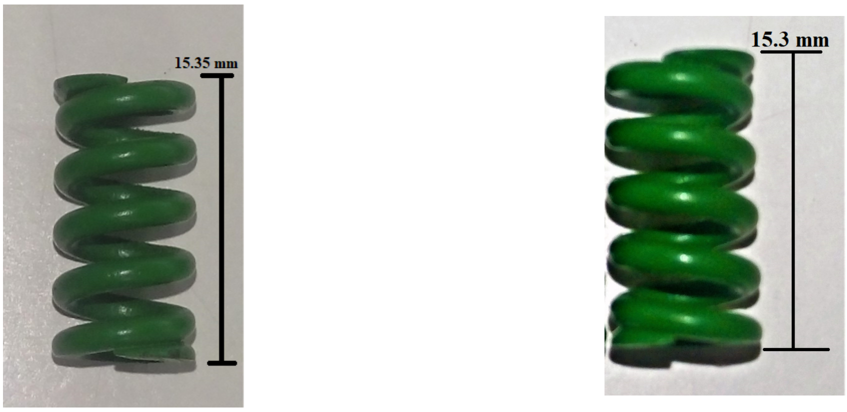
CP readings are taken before and after the test. The PTFE coated chrome silicon spring 10 numbers tested for creep in the oven,free length of each spring is measured before and after creep test by Vernier caliper. The load value of each spring at 12.9mm compression is also measured with the help of load testing machine.

Result obtain after creep test are as shown in table 3.12,After test is over springs are dismantled and free length and load value is measured at 12.9mm compression. Result disclose that there is drop in load value around 1% to 5% after creep test that is around 0-0.6 kg of load value drop is seen. Free length is found to be less after the creep test around 0.1-0.2 mm of free length is dropped. PTFE coated springs load value capacity is dropped very negligible. Also free length is reduced minor compare to steel and non-coated chrome silicon spring.This will result in less milli-volt drop and hence temperature rise is controlled.

Table 3.12: Creep test PTFE Cr-Si springs

Spring no.	Load(at 12.9 mm) in kg	Free length before test(mm)	Free length after test (mm)	Load value after test (kg)	Reduction in load value in kg	Percentage reduction in load value
1	15.10	15.35	15.3	14.78	0.32	2%
2	16.20	15.5	15.4	15.80	0.40	2%
3	16.00	15.4	15.36	15.50	0.50	3%
4	15.30	15.3	15.3	14.78	0.17	3%
5	15.90	15.5	15.4	15.08	0.81	5%
6	14.27	15.3	14.95	13.86	0.40	3%
7	14.87	15.48	15.3	14.68	0.20	1%
8	14.78	15.35	15.3	14.16	0.61	4%
9	14.67	15.45	15.4	14.27	0.40	3%
10	15.70	15.45	15.4	14.88	0.81	5%

Table 3.12 shows the value of contact pressure measured after and after the creep test,there is fall in the contact pressure around 0.1-0.2 kg.



(a) Before creep test

(b) After creep test

Figure 3.11: Comparison of chrome silicon spring

Comparison of PTFE coated cr-si spring is given in fig.3.7. Reduction in free length can be seen before and after the test. Free length is reduced from 15.35 mm to 15.30 mm which is very less compare to non-coated cr-si spring and steel spring.

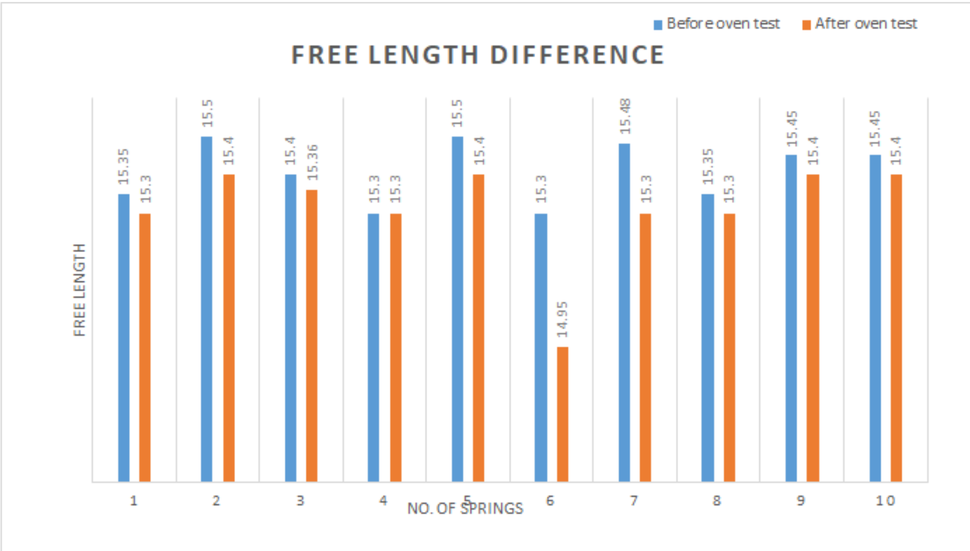


Figure 3.12: free length

Graph shown reduction in the free length before and after the creep test. The sprigs are coated by PTFE so the temperature effects on springs are controlled,springs free length are reduced to very negligible. Maximum decrease in free length is 400 micron. Results are improved and creep is controlled.

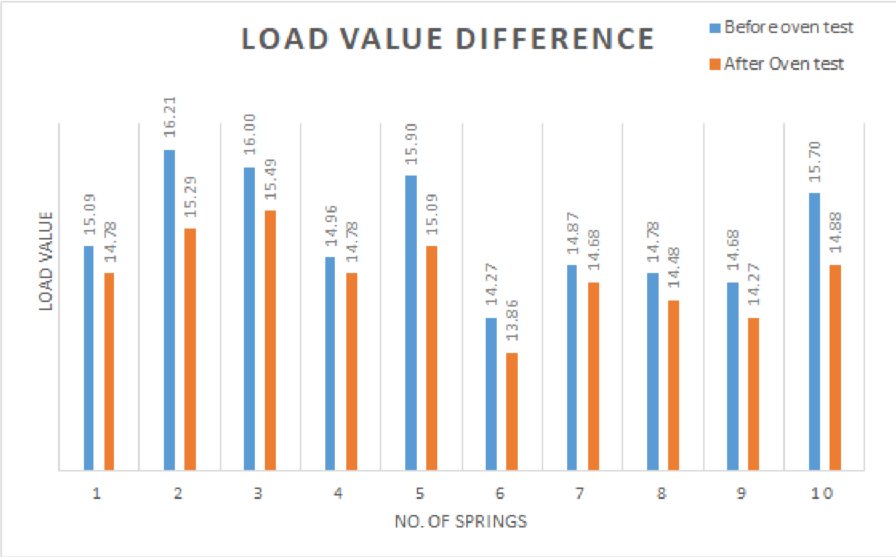


Figure 3.13: Load value

Graph shown is reduction in load value. As we see there is decrease load value very less as compare to non coated springs.The decrease in the load value is around 1 to 5 % for all the springs,this is good sign for the contact system to maintained its contact pressure in the contact system.

Chapter 4

Upper contact

4.1 Introduction

During making and breaking of the circuit, the upper contacts play an important role in the breaker. The main function of the moving contact is to break the contact during the abnormal condition. The moving contact is assembled to drive shaft which is linked with the mechanism. Springs are used to pushing and lift the driveshaft assembly which can manually be also done. Upper contact is made from the copper material and the manufacturing process used to make upper contact is extrusion process. Later the machining is done and made up of proper dimensions

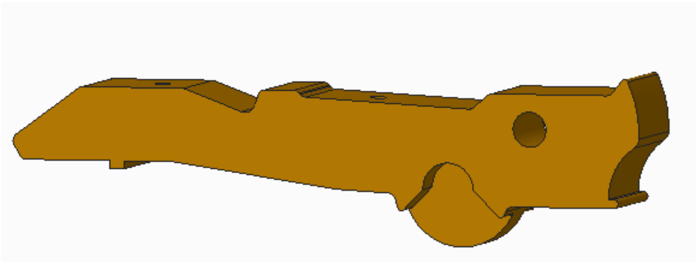


Figure 4.1: Existing Upper contact

The main objective of the design modification is to improve contact pressure,which will result in MCCB's working performance.Based on modified dimensions new prototypes are tested and compared with the existing design.

4.2 Existing Design

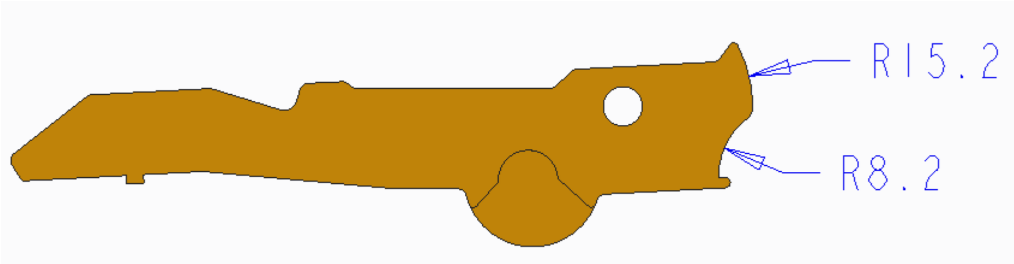


Figure 4.2: Existing Upper contact

As shown in fig 4.2,upper contact is assembled on the drive shaft.The button are brazed on the tip of the upper contact which is in contact with the lower contact. Ribbing operation is done on the upper contact which provides strength to the upper contact during the short circuit.

4.2.1 Drawbacks with existing design

Disadvantage of this design is during the duration of time the end profile is not able to make the suitable contact pressure during the over a time. Due to this, it results in decrease in contact pressure and chances of nuisance tripping of the breakers occurs.

Design assembly of contact system

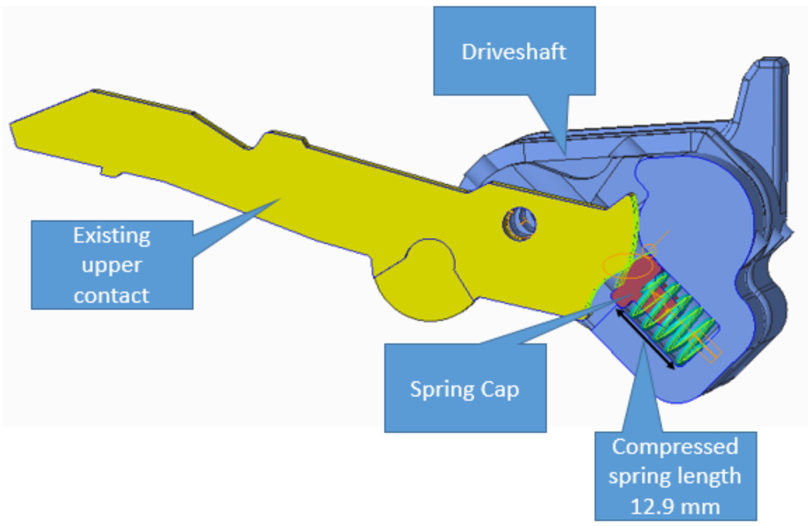


Figure 4.3: Existing Contact system

Assembly of Contact system is shown in fig 4.3,After assembling upper contact,the contact spring gets compressed with deflection from 15.3 mm to 12.9 mm. Existing upper contact is assembled in contact system and simulated the same in PTC CREO software.The compressed position of contact spring gives back force to upper contact and which helps to achieve contact pressure[30].

4.2.2 Existing upper contact test results

Existing design has tested and results are noted.

- Experimental methodology

  Existing upper contact are installed in MCCB, and following tests are done to know the contact pressure and other parameters.

  Contact pressure is tested.As upper contact rests on lower contact,force gauge is used to measure the contact pressure.

  Over travel:It is the distance travel by the upper contact in absence of lower contact.

  Milli volt test:At 100A DC Lost of milli volt from upper contact to lower contact is measure with the help of Voltmeter.

Table 4.1: Testing results

Rating	R	Y	B	Average
Contact pressure (kg)	3.3	3.6	3.35	3.45
Over travel(mm)	4.47	4.22	4.33	
Milli-volt test@ 100ADc	17.32	17.1	17.59	

From the above table 4.1,The limits for over travel are between 4-6 mm and for milli-volt test its 17-21 milli-volt.The obtained over travel and milli volts are within acceptable limit.Its observed that average contact pressure of R,Y,B poles is obtained as 3.45 kg.

4.3 Proposed Design

PROTOTYPE 1

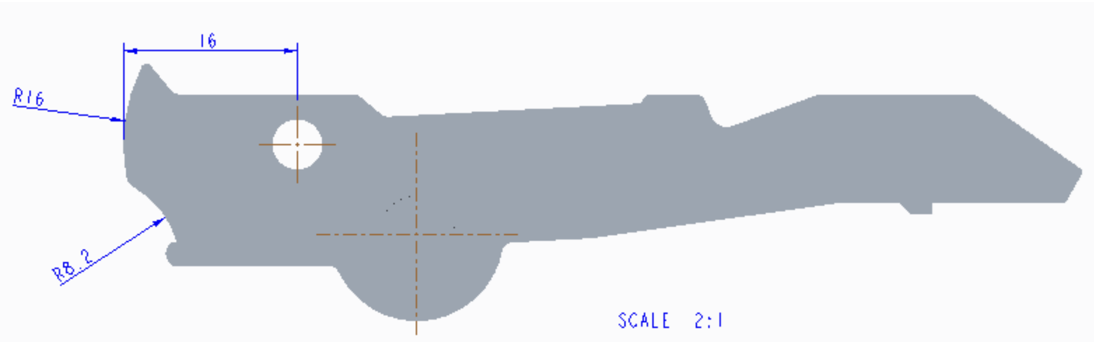


Figure 4.4: Proposed Design Moving contact

In new design,dimensions are modified.Earlier end profile curvature radius was 15.2 mm which is modified to 16 mm keeping other dimension same.

4.3.1 Advantages of proposed design

Changed in the profile dimension will help to get more back force from the spring this will probably increase the contact pressure.

Prototype 1 assembly

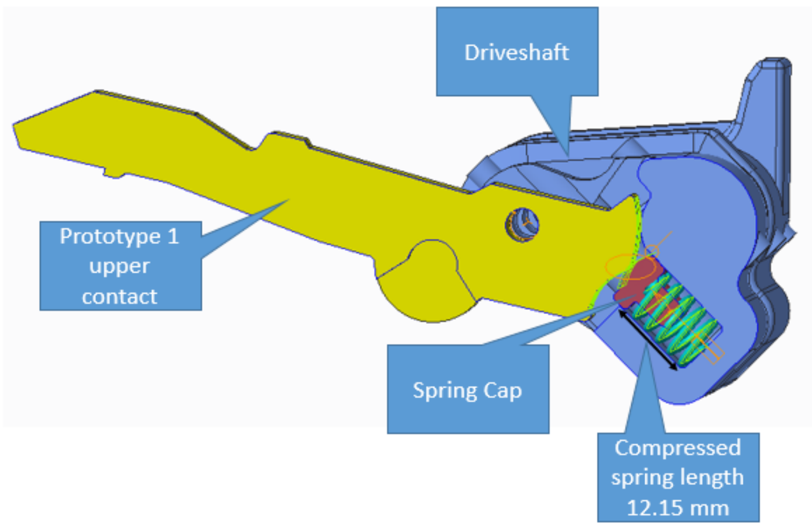


Figure 4.5: Proposed Design upper contact

Assembly of Contact system is shown in fig 4.3,After assembling upper contact,the contact spring gets compressed with deflection from 12.9 mm to 12.15 mm. Existing upper contact is assembled in contact system and simulated the same in PTC CREO software.The compressed position of contact spring gives back force to upper contact and which helps to achieve contact pressure.

4.3.2 Prototype 1 tests results

Prototype 1 of upper contact is installed in MCCB,Same is tested with the earlier methodology and following results are obtained.

Table 4.2: Test results

Rating	R	Y	B	Average
Contact pressure (kgs)	4.55	4.8	4.7	4.75
Over travel(mm)	4.43	4.45	4.52	
Milli-volt test@ 100ADc	17.43	17.7	18.23	

- **As seen from above table 4.2,There is rise in the CP of the MCCB.On an average the CP has increase from 3.45 to 4.75 kg.For other test data is within acceptable limit.**

4.4 Prototype 2

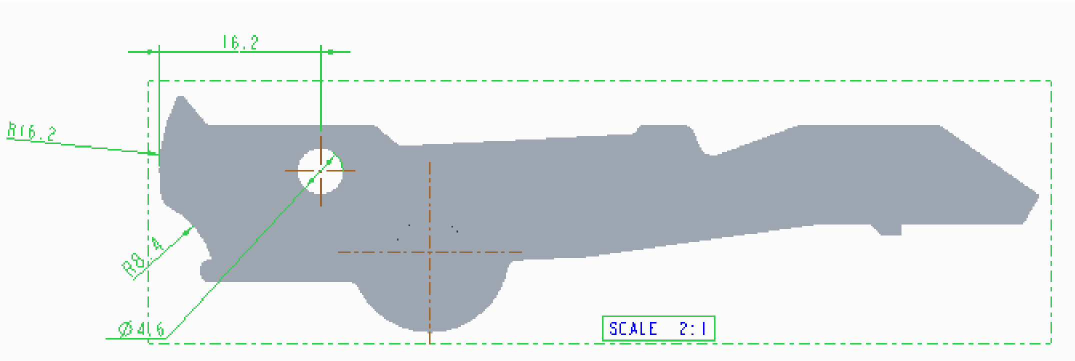


Figure 4.6: Proposed Design Moving contact

In new design,dimensions are modified.Earlier end profile curvature radius was 15.2 mm which is modified to 16.2 mm and radius 8.2 mm modified to 8.4 mm.

Prototype 2 assembly

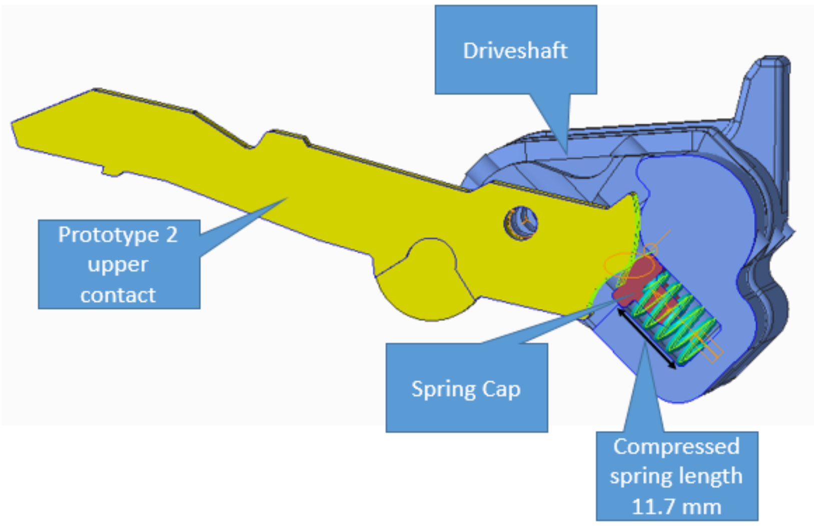


Figure 4.7: Proposed Design Moving contact

From the above fig 4.7,compression in the contact spring is increase from 12.9 mm to 11.7 mm.
Prototype 1 of upper contact is installed in MCCB,Same is tested with the earlier methodology and following results are obtained.

4.4.1 Prototype 2 test results

Prototype 2 of upper contact is installed in MCCB,Same is tested with the earlier methodology and following results are obtained.

Table 4.3: Test results

Rating	R	Y	B	Average
Contact pressure (kgs)	5.5	5.8	5.3	5.65
Over travel(mm)	4.56	4.25	4.8	
Milli-volt test@ 100ADc	18.33	17.3	19.2	

- **As seen from above table 4.3,There is rise in the CP of the MCCB.On an average the CP has increase from 3.45 to 5.65 kg.For other test data is within acceptable limit.**

Chapter 5

Conclusion

The following conclusions are derived from the present study:

1. Creep test is carried on existing steel spring,reduction in free length of is found around 1mm and decrease in stiffness lies in the range of 20-30% after creep test.

2. Creep test carried on chrome silicon spring,free length reduction after the test is around 0.2-0.5mm. Reduction in load value is around 10-20% after test. Hence,set in silicon spring is less as compared to steel spring.

3. Creep test carried on PTFE coating prototypes of springs are tested and results are found that set in PTFE coated spring is very less compared to steel,non-coated cr-si spring. Free length is reduced 0.1-0.2 mm after the test. Stiffness is reduced by 1%-5% after the test.

4. Upper contact modification is done and validated,found that change in the curvature radius affects the Contact pressure of contact system.Increase in curvature radius results into increases in Contact pressure of contact system.

5.1 Future work

- PTFE springs will be proposed to implement in the contact system.

- Upper contacts will be proposed to implement in the contact system along with the PTFE coated springs.

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