WEIGHT OPTIMIZATION OF CAM

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ABSTRACT - Weight optimization of a cam of circuit breaker mechanism is carried out using SolidWorks 2015 & Ansys Workbench 14.5. Four different possibilities of cam have been checked. Equivalent Stresses acting on cam are calculated along with maximum possible deformation. Overall performance of new designed cam, which is used in mechanism assembly of Vacuum Circuit Breaker is practically tested using the testing setup available at Shreem. Results are then verified as per the Standard technical specifications of vacuum circuit breaker. Hence a new design of cam is found having a less weight as well as production cost.

Index Terms- cam, optimization, stress, vacuum

1. INTRODUCTION

With the technological advances in all fields of engineering, there is need to find newer and newer techniques to be a developing industry. Switchgear is an important link in any power system network, including transmission and distribution systems. These days, increased emphasis is being given to designing the best possible switchgear and associated equipment system.

The primary function of a circuit breaker mechanism is to provide the means for opening and closing the contacts. Initially this seems to be a rather simple and straight forward requirement. However considering the fact that most circuit breakers once placed into service will remain in the closed position for long period of time and yet on few occasions when they are called upon to open or close, they must do so reliably without any delay. For given contact gap, the dielectric strength of vacuum is approximately eight times that of air.

1.1 Vacuum Interrupter - The compact and environment friendly design of Vacuum Switchgear with the highest reliability has proven the preference worldwide against the gas, oil or air switchgears. Vacuum Interrupter Tubes are vacuum-sealed-off devices incorporated in circuit breakers. The contacts (generally Cu-Cr alloy) of the vacuum interrupter are closed under normal circuit conditions. In the event of a fault current, the vacuum circuit breaker mechanism affects withdrawal of the movable contact from the fixed contact.

1.2 Technical Specifications of Vacuum Circuit Breaker

Frequency	: 50Hz
Voltage	: 12kV
Current	: 800A
Control Voltage	: 24V DC
CO time	: < 80ms
OCO time	: < 320ms
Mechanism	: Spring operated
Motor Voltage	: 230V AC
Spring Charging Time	: < 15sec
Standard	: IS 13118

2. STRESS CALCULATION

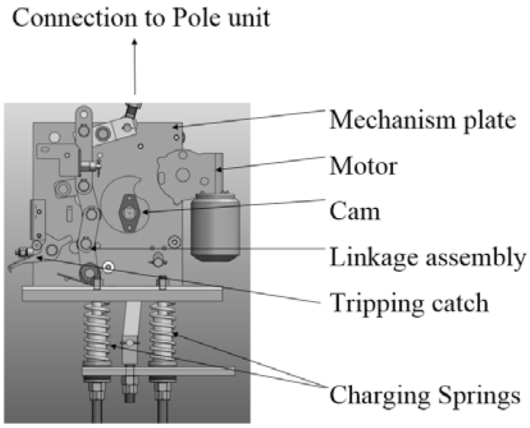


Fig. 1- Mechanism Parts Nomenclature

The Mechanism consists of a cam located as shown in 'Figure 1- Mechanism Parts Nomenclature' which was an area of interest. In the mechanism, cam rotates anticlockwise. One complete rotation of cam indicates one complete operation of vacuum circuit breaker (i.e. one ON and one OFF). Also it is to be noted that the force with which cam is operating is nothing but spring force created by the springs located below the mechanism called charging springs.

Details of charging spring used in the mechanism are as follows,

Modulus of Rigidity : 78500N/mm2
Wire Diameter (d) : 5.50mm
Outer diameter : 43.5mm
Mean Coil Diameter (Dm) : 38.00mm
Number of Active turns (N) : 14.5
Free Length : 212.00mm
Mounting Length : 170.00mm
Working Length : 125.00mm

2.1 Spring Force Calculations:

Spring Rate, $k = \frac{G(D_m)^4}{8d^3N}$ in N/mm

Where, G = Modulus of Rigidity of Spring (N/mm^2)
Dm = Mean Coil Diameter of spring (mm)
d = Wire diameter of spring (mm)
N = Number of active turns of spring
k = 11.29 N/mm

1. Mounting Load = Spring Rate x (Free Length – Mounting Length)
= 473.98 N

2. Total Mounting Load = Number of springs x Mounting Load
= 1.896 kN

3. Working Load = Spring Rate x (Free Length – Working Length)
= 981.82 N

4. Total Working Load = Number of springs x MountingLoad = 3.927 kN

Considering maximum load 3.927kN i.e. approximately 4kN for design verification of modified cam and comparing its effect over the mechanism working.

2.2 Stress acting on cam:

Cam starts rotating after giving a supply of 230V AC to electric motor mounted on mechanism plate. Cam starts rotating in anticlockwise direction up to the position shown in Figure 2- Position of Cam- Springs Charged. Material used for cam is SAE 8620

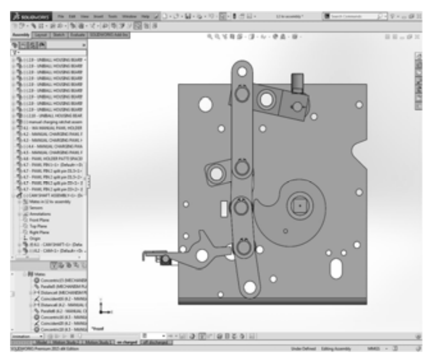


Fig. 2- Position of Cam- Springs Charged

3. OPTIMIZATION

For finding the optimum weight of cam, there was a geometrical constraint regarding thickness of cam. Thickness of cam should be preserved equal to 12mm. This is because all the other design i.e. linkages, rollers used in linkage are according to 12mm cam thickness.

We checked following alternate designs of cam, for stresses acting on it using static structural analysis from ANSYS 14.5

3.1 Configurations of cam

3.1.1 Cam with revision 0:

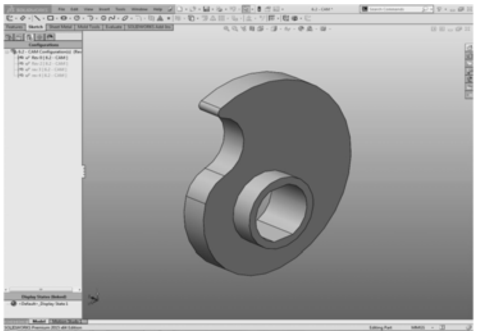


Fig. 3- Cam Revision 0

3.1.2 Cam with revision 1:

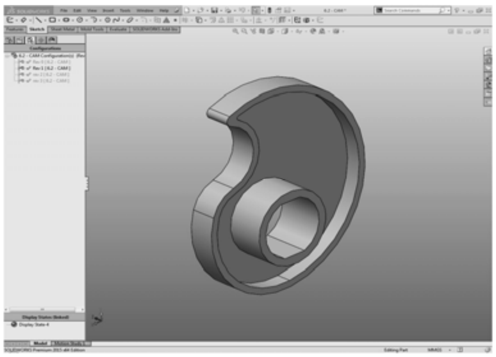


Fig. 4- Cam Revision 1

3.1.3 Cam with Rev 2:

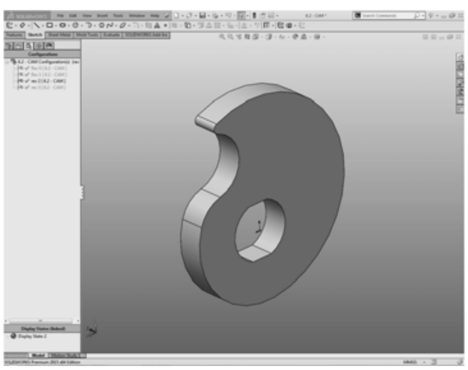


Fig. 5- Cam Revision 2

3.1.4 Cam with revision 3:

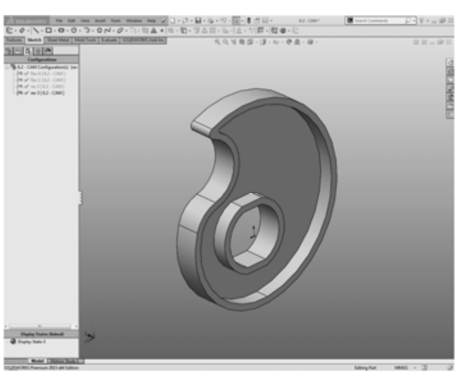


Fig. 6- Cam Revision 3

Table below shows comparison of Weight & Cost of Production between the four cams

Table 1- Weight & Cost Comparison

Sr. No.	Cam Revision	Weight (grams)	Cost (Rupees)
1	Revision 0	498.22	980
2	Revision 1	289.92	1780
3	Revision 2	470.52	675
4	Revision 3	268.58	1235

3.2 Static Analysis of Cam:

For geometrical input we used cam directly from SolidWorks with file name ‘cam.sldprt’. While applying constrains following things are to be considered as per the working of complete mechanism,

To apply a fixed support at internal portion of a cam &

To apply maximum force of charging springs i.e. @4kN at the mating surface of cam and roller in the linkage assembly.

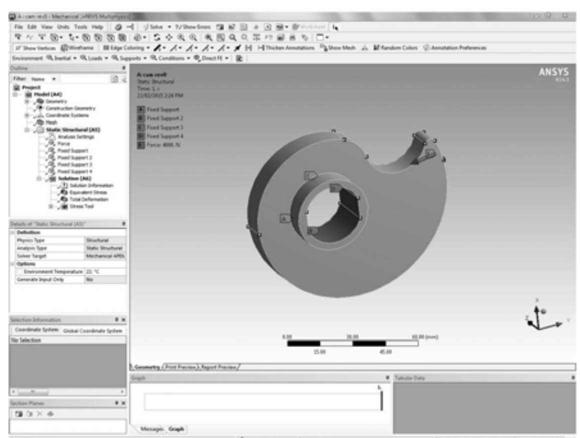


Fig. 7- Constrains & Load Application

Meshing: Mesh controls allow establishing such factors as the element shape, midside node placement, and element size to be used in meshing the solid model. This step is one of the most important of entire analysis; this stage in model development will profoundly affect the accuracy and economy of analysis.

SOLID187 element is a higher order 3-D, 10-node element. SOLID187 has a quadratic displacement behavior and is well suited to modeling irregular meshes (such as those produced from various CAD/CAM systems).

The element is defined by 10 nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, hyperelasticity, creep, stress stiffening, large deflection, and large strain capabilities.

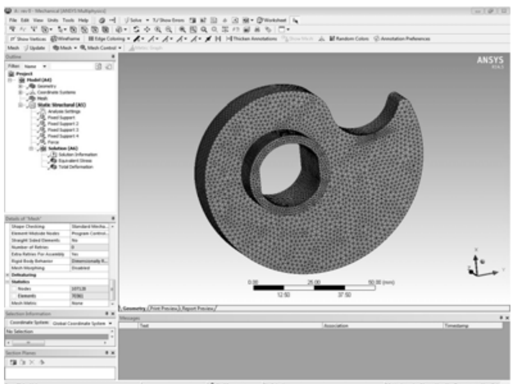


Fig. 8- Meshing- cam revision 0

Table 2- Mesh Convergence

Sr. No.	Cam	No of Nodes	No. of Elements	Max Stress (MPa)
1	Old	1903	919	116.1
2	Old	7314	3886	224.35
3	Old	22660	12856	369.4
4	Old	107128	70361	373.43
5	New	1538	750	117.45
6	New	5720	3011	227.97
7	New	20292	11576	372.23
8	New	95869	64317	372.8

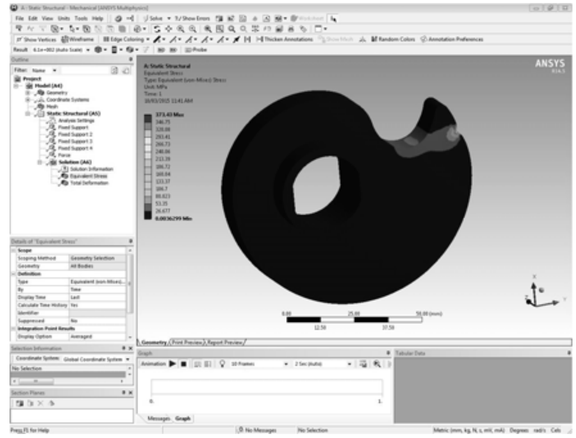


Fig. 9- Stress- cam revision 0

Following table shows stress & deformation details obtained from static analysis,

Table 3- Stress & Deformation

Sr. No.	Cam	Max Equivalent Stress (MPa)	Max Deformation (mm)
1	Revision 0	373.43	0.0111
2	Revision 1	518.77	0.1338
3	Revision 2	372.23	0.011
4	Revision 3	526.56	0.136

4. EXPERIMENTAL RESULTS

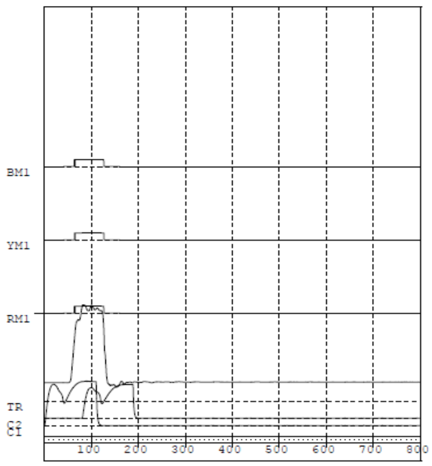
After finalizing cam design, next step was to validate new designed cam. Validation is carried out on the testing setup of vacuum circuit breaker namely 'AutoScan'- a circuit breaker tester.

Fig. 10- AutoScan Test Setup

A new cam is manufactured as per the dimensions and is assembled in the mechanism.

After the complete assembly of mechanism and vacuum circuit breaker, the vacuum circuit breaker is now ready for carrying out the testing. All the test setup was completed as per instruction manual of 'AutoScan'- a circuit breaker tester, with the required electrical connections.

Following graphs are the output of testing and shows important parameters affecting Vacuum Circuit Breaker performance.



Graph 1- 'CO' operation with old cam

In the above graph X-Axis represents Time in milliseconds and Y-Axis represents Position of Vacuum Circuit Breaker (i.e. either COLSE or OPEN). All the data obtained from results can be tabulated as

Table 4- AutoScan Readings

Sr. No.	Cam	CO time (milliseconds)		
		'R' phase	'Y' phase	'B' phase
1	Old	62.8	62.6	62.8
2	New	58.2	58	58.2
3	Required	< 80		

5. **CONCLUSION:**

Static Analysis of cam is carried and obtained a new cam with low weight and without affecting the overall performance of mechanism as well as vacuum circuit breaker.

Manufacturing Cost is considerably reduced as compared to old cam.

Table 5- Weight & Cost Comparison of cam

Sr. No.	Cam	Weight (grams)	Reduction	Cost (Rupees)	Reduction
1	Old	498.22	-	980	-
2	New	470.52	5.56 %	675	31.12%

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