



DESIGN AND DEVELOPMENT OF CROSS BAR FOR ACB: A CASE STUDY IN SWITCH GEAR MANUFACTURING INDUSTRY

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Abstract:

This paper presents design of crossbar which is used to support different moving and stationary parts and frame of Air Circuit Breaker (ACB). The main objective of paper is to identify deformation and stress develops in crossbar due to force acting by breaker charging mechanism and stationary weight of FRCD. The current crossbar have U-shaped cross-section. It is fastened to the frames present on both the sides by means of nut and bolts. Crossbar will be subjected to deformation on account of bending moment produced by the force acting on it. The cost of a crossbar has impact on cost of breaker. The current geometry of component which is U shaped type has to be analyzed and changed into L shaped type. Stress induced in L shaped crossbar is greater than U shaped crossbar but it is less than yield stress limit of material of crossbar.

Key Words: Air Circuit Breaker, Stress Analysis, Cross Bar, FEA & Stress Distribution

1. Introduction:

All manufacturers strive to produce a good quality as product for competitive reasons and it is important to achieve the best possible products at the lowest possible cost. To reduce cost of product without compromising quality, we have to find component of product which can redesign and develop it. Air circuit breaker is Switchgear, which works as switching and current interrupting device. Under normal conditions, it works as a safety device to protect the system from short circuit conditions, overload etc. arising as a result of a fault in connected circuit. The fault current can damage the equipment if allowed to fall for a longer duration. In order to avoid such damage, every part of power system is provided with a protective relaying system and an associated switching device.

The component under investigation is in form of a crossbar. This bar is used to support different moving and stationary parts of the air circuit breaker. It is fastened to the frames present on both the sides by means of nut and bolts. Thus it is clear that the bar will be subjected to deformation on account of bending moment produced by the loads acting on it.

The figure 1 describes the positioning of the cross bar. A and B are support ends of the cross bar. There are thick plates welded on both the ends of the crossbar. The crossbar is fixed by fastening the thick plates present on both sides to the frame of air circuit breaker by means of nut and bolts. 'C' is the point at which the stationary assembly is attached to the cross bar. In addition to the stationary assembly, a handle is pivoted at point C. This handle is used for charging the breaker manually. The breaker is charged by rotating the handle in counter clockwise direction.

The operation of charging means that the ACB is connected to power from mains. This handle is used for compressing a spring. It implies that there is moment acting on point C in counter-clockwise direction. It was found that the back side of crossbar was not involved in performing any kind of activity. The back side of crossbar was not attached to any other machine member of air circuit breaker.

This observation ignited the idea for bringing the changes in the current geometry. It was concluded that the back side of the U shaped crossbar was a redundant member. The new geometry was obtained by removing the back side of the current U shaped crossbar. The resultant geometry obtained was L shaped crossbar.

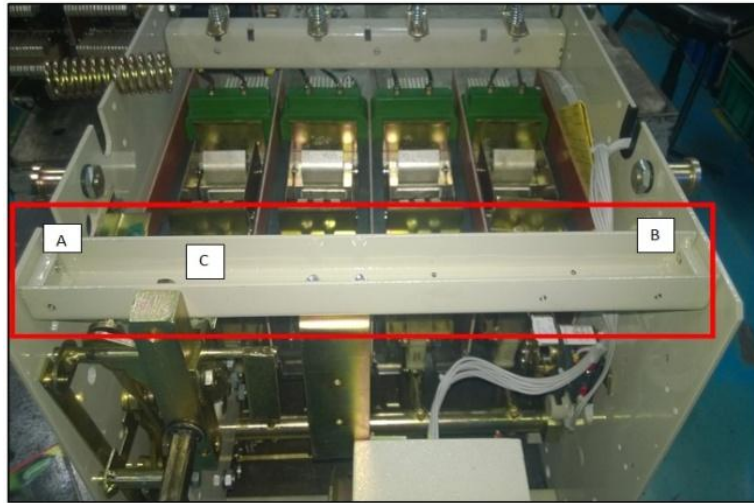


Figure 1: Position of crossbar in ACB



Figure 2: Back plate of crossbar

2. Force Analysis:

In this section the positioning of forces and moments acting on both geometries as discussed in above section are explained. There are two different types of loading cases. First case represents the charging of air circuit breaker and the next case represents the lifting of air circuit breaker by means of crane. It must be noted that both cases are applicable to U and L shaped crossbar geometry.



Figure 3: Free body diagram of U shaped crossbar



Figure 4: Free body diagram of L shaped crossbar

A and B represent the fixed supports. The supporting is achieved by the fastening of thick plates present at the ends of the crossbar to the frame of air circuit breaker by means nut and bolts. Stationary load F1 acts on point C. Load F1 arises on account of weight of FRCD plate assembly. Mass of FRCD plate assembly is 9.134 kilograms.

$$F1 = \text{acceleration due gravity} \times \text{mass of FRCD plate assembly}$$

$$F1 = 9.81 \times 9.134$$

$$F1 = 89.605N$$

The moment M is created because of motion of handle pivoted at point C. The function of handle is to charge the breaker. Charging operation involves compression of a spring. The dimensions of spring are given in Table1.

Table1: Spring Design Specifications

Material	Spring Steel
Type of spring	Square and Grounded
Modulus of Rigidity (G)	84 GPa
Number of turns (n)	13
Wire diameter (d)	3.6 mm
Inner diameter (Di)	20.1 mm
Outer diameter (Do)	27.3 mm
Mean Diameter (D)	23.7 mm
Free length (L)	90 mm
Compressed length (y)	$n \times d = 13 \times 3.6 = 46.8 \text{ mm}$

Calculation of spring stiffness (K)

$$K = \frac{G \times d^4}{8 \times D^3 \times n}$$

$$K = \frac{84000 \times 3.6^4}{8 \times 23.7^3 \times 13}$$

$$K = 10.1909 N/mm$$

Calculation of Moment (M)

Free length (x)

$$x = L - y$$

$$x = 90 - 46.8$$

$$x = 43.2 \text{ mm}$$

Spring force (F)

$$F = k \times x$$

$$F = 10.1909 \times 43.2$$

$$F = 440.247N$$

$$\text{Moment}(M) = \text{Length of handle pivoted at point C} \times \text{Spring Force}(F)$$

$$M = 241 \times 440.247$$

$$M = 106099.527N - mm$$

Hence a moment of 106099.527 N-mm acts in counter clockwise direction.

3. Stress and Deformation Analysis:

The results obtained from FEA using ANSYS Workbench. The deformation and stress distribution of cross bar under of loading in both cases are shown below. There is variation of deformation and stress distribution over the entire cross bar. The deformation and stress distribution in U and L shaped crossbar.

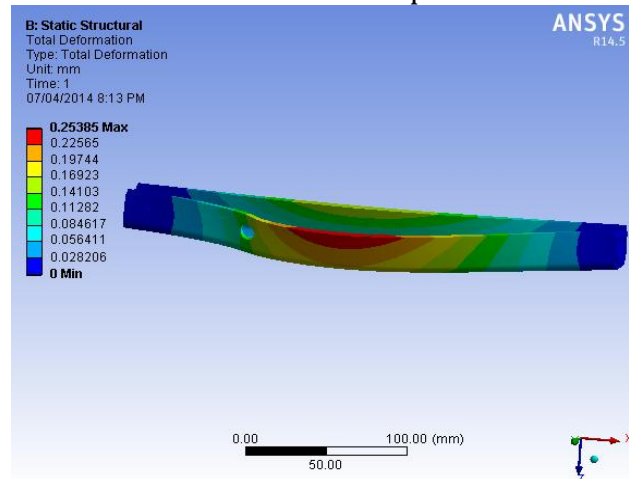


Figure 5: Deformation in U shaped crossbar

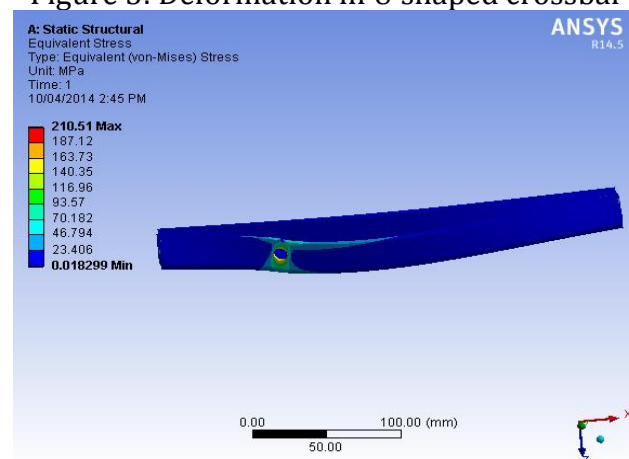


Figure 6: Stress distribution in U shaped crossbar

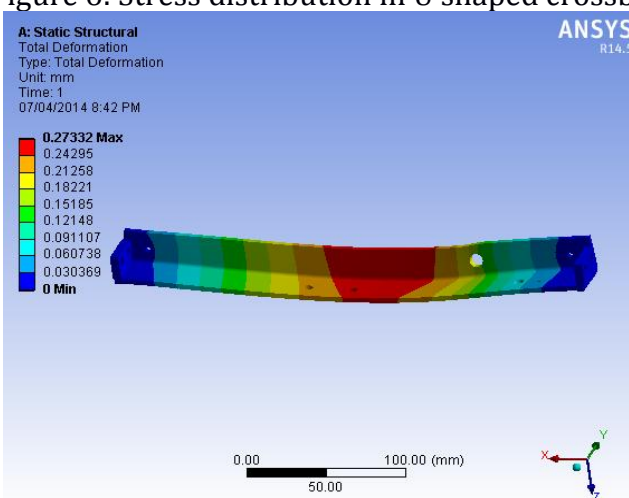


Figure 7: Deformation in L shaped crossbar

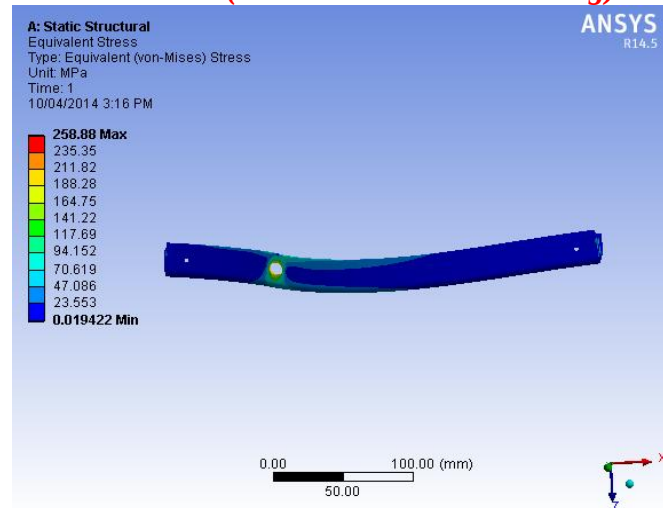


Figure 8: Stress distribution in L shaped crossbar

Figure 5 describes the deformation pattern for U shaped crossbar. It is observed that the maximum deformation occurs at the front plate of the crossbar. The area marked by the colour red has maximum deformation of 0.25385 mm. It validates our previous data that the area upon which moment is (on account of compression of spring by means of handle pivoted) acting is the critical area.

Figure 6 contour plots show the variation of stress along the span of the U shaped crossbar. The section marked by color red is critical section. The maximum stress produced is 210.51 MPa. This is less than the yield strength of the material that is 280 MPa. Hence the deformation taking place is elastic.

Figure 7 shows the variation of deformation pattern along the span of L shaped crossbar. The section marked by colour red is the critical section. The moment on account of compression of spring by handle to charge the breaker causes maximum deformation of the front plate of crossbar. The maximum deformation is 0.27332 mm.

Figure 8 shows the stress distribution of L shaped crossbar for case1. The maximum induced stress is 258.88 MPa. This value is less than the yield stress of material used for crossbar. The yield stress of crossbar is 280 MPa. Hence no plastic deformation takes place.

4. Result and Conclusion:

The project started with study of Strength of Material theory and Finite element analysis. It was decided to study the component by doing its FEA. FEA brings more clarity in the results obtained. Helps to understand the results easily and provides solution for every element which is a part of the mesh. The given component's role was studied and the loads acting on it were analysed. The L shaped crossbar was selected as an alternative to the presently used U shaped crossbar in air circuit breaker (ACB) model 800C. Both geometries were modeled by using CREO Parametric software. The tool used for FEA was ANSYS Workbench.

Table 2: Result Comparison

	U Shaped Crossbar	L Shaped Crossbar
Deformation Comparison	0.25385 mm	0.27332 mm
Stress Analysis Comparison (Yield Stress Of Crossbar (280 MPa))	210.51 MPa	258.88 MPa
Manufacturing Cost Comparison(INR)	50	35

The results included the contour plots of deformation pattern and stress distribution. For the first case the deformation of L shaped crossbar is more than the U shaped crossbar by marginal value of 0.01974 mm. We can conclude that the U shaped crossbar can be replaced by L shaped crossbar by achieving the desired safety requirements. In addition to this L shaped crossbar won't be subjected to permanent deformation. With this substitution we can get satisfactory results.

Despite of getting considerable difference in deformation for geometry should be taken into account that the maximum induced stresses are less than the yield strength of material. Hence we derive the conclusion that the strain induced for both geometries are within elastic limit, it means no permanent deformation will occur. Thus it is applicable to substitute the U shaped crossbar with L shaped crossbar. L shaped crossbar will perform its function of supporting the static machine members as well as giving support to the frame of ACB without causing any hindrance.

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