DESIGN AND FINITE ELEMENT ANALYSIS OF A 15 MVA TRANSFORMER TANK

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ABSTRACT

The present work is a customized design of a transformer tank as per the specification given by the industrial manufacturer. The objective of present work is to design transformer tank and the modification is carried out in order to improve strength to weight ratio of transformer tank. Transformer tank size is large and having the weight of several tones (without coil assembly and oil). The housing of a transformer comprises of various compartments fabricated from mild steel plates. Loaded transformer housing is subjected to its own weight plus coils and oil. Hence, Reduction in weight keeping the required strength for application will obviously result in to cost saving. The size of transformer tank is large and having the weight of 4 ton approx. (without coil assembly and oil) which is usually elevated at certain height from ground level. The housing contains coil assembly and the oil. The total weight of such transformer is 32 ton which include weight of oil, coil and core assembly, conservator, radiator etc. Large capacity of transformers tanks can weigh to several hundred tons. Strength and rigidity are the important criteria of design. Hence it is necessary to evaluate existing design to improve strength to weight ratio and similar strategy can be applied to other size of transformer to reduce weight.

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1. Introduction

A transformer is an electrical device that transfers electrical energy between two or more circuits through electromagnetic induction [10]. Electromagnetic induction produces an electromotive force across a conductor which is exposed to time varying magnetic fields. Commonly, transformers are used to increase or decrease the voltages of alternating current in electric power applications [10] A varying current in the transformer's primary winding creates a varying magnetic flux in the transformer core and a changing magnetic field impinging on the transformer's secondary winding[10]. This change in magnetic field at the secondary winding induces a varying electromotive force (EMF) in the secondary winding due to electromagnetic induction. Making use of Faraday's Law in conjunction with high magnetic permeability core properties, transformers can thus be designed to efficiently change AC voltages from one voltage level to another within power networks.

Types of Transformer Tank

a. Rectangular tanks
b. Shaped tanks
c. Corrugated tank
d. Bell shaped tanks

Transformer consists of different sub-assemblies and they are coil and core assembly, transformer tank, radiator, conservator tank, OLTC chambers, boosting terminals, etc. In this project the focus is on design of transformer tank.

Transformer has wide range of products depending on the requirements of customers and according to that different shaped of transformer tank are designed and they are categorized in four different types. The present work is done on the shaped type of tank in which the shell type shape at the end of the transformer tank to increase the strength. This type of transformer tank are specially designed for the 15 MVA and 16 MVA of transformer [1].

2. Design of Transformer Tank

In this paper, the design of tranformer tank is carried out on the basis of loading condition and the design criteria. In the present work, the loading condition of transformer tank walls are different for top plate, bottom plate, and side plate of transformer tank. The design criteria for transformer tank wall are given below[3]:

2.1 Design For tank Bottom Plate

Plate thickness (T_b)

$$T_b = \left[\sqrt{\frac{P_b \times b^2 \times a^2}{4\,\sigma\,(al^2+bl^2)}}\right] \text{ m}$$

Deflection Of Bottom Plate At Center (D)

$$D = \frac{k \times P_b \times bl^4 \times 12\,(1-mu^2)}{E \times {T_b}^3}$$

2.2 Design for side plate

Plate thickness ($\mathbf{T_S}$)

$$T_S = \left[\sqrt{\frac{0.312\,p_s \times bl^2 \times al^2}{\sigma\,(al^2+bl^2)}}\right] \text{ m}$$

Deflection Of Tank Wall

$$D = \frac{0.0124\ p_s \times bl^3 \times 12\,(1-mu^2)}{e \times {t_s}^3\,(1+2.21\,(bl/al)^3)} \text{ m}$$

2.3 Design for top cover

Conventional Type Tank Cover plate thickness (T)

$$T = \left[\sqrt{\frac{P \times bl^2 \times al^2}{2\,\sigma\,(al^2+bl^2)}}\right] \text{ m}$$

In the present work, from the design criteria different thickness of transformer tank walls with changing the stiffeners is obtained which is tabulated in table given below for side and bottom plate. And modeling of transformer tank is carried out using creo 3.0

Table 2.1 Stiffeners on Bottom Plate

	Stiffener on length	Stiffener on width	Thickness(mm)
Bottom plate	0	0	14
	1	0	12
	2	0	10
	2	2	5

Table 2.2 Stiffeners on Side Plate

	Stiffener on length	Stiffener on width	Thickness(mm)
Tank side plate	0	0	17
	1	0	12
	2	0	9
	3	0	6

Table 2.3 Number of stiffeners and thickness of tank plates

	Stiffener on length	Stiffener on width	thickness
Side plate	3	0	6 mm
Bottom plate	2	2	10 mm
Top plate	0	1	12 mm

3. FEA of Transformer Tank

FEA of transformer tank is carried out using ANSYS 17.0 workbench from which we get the accurate results of deformation, the stress behavior of the model and the strain value. The material used for transformer tank is as per IS 2062:1999 Fe410W and the density of the material is 7850kg/m^3. **Boundary conditions:** In the present work, Transformer comprises of core& coil assembly with oil inside the tank. So the nature of loading will occur due to the height of oil and due to the self -weight of core and coil assembly. Therefore this is a case of hydrostatic pressure and pressure due to the weight of the coil and core assembly. The base structure of transformer tank is fixed with the foundation. The maximum stress value generated in the tank is around 83 MPa and the value of deformation is 3.52 mm shown in figure 3.2 and figure 3.3

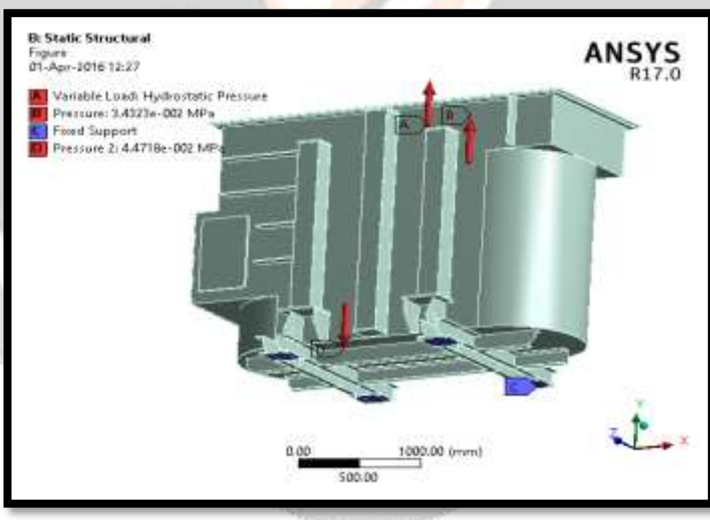

Figure 3.1 Boundary Condition

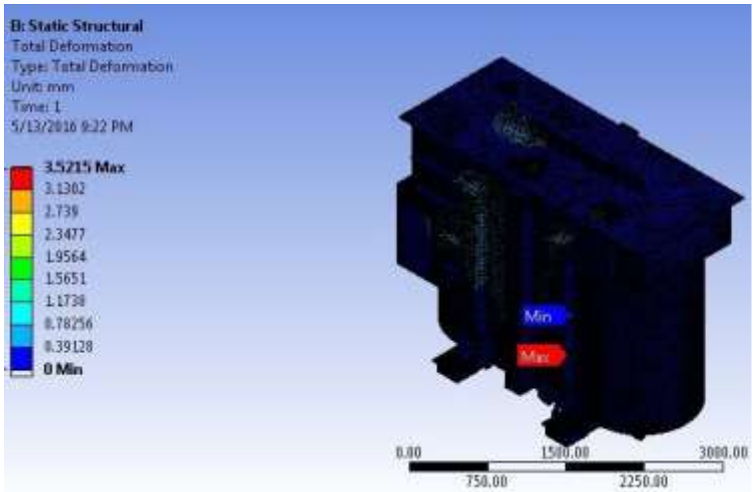

Figure 3.2 Deformation of tank

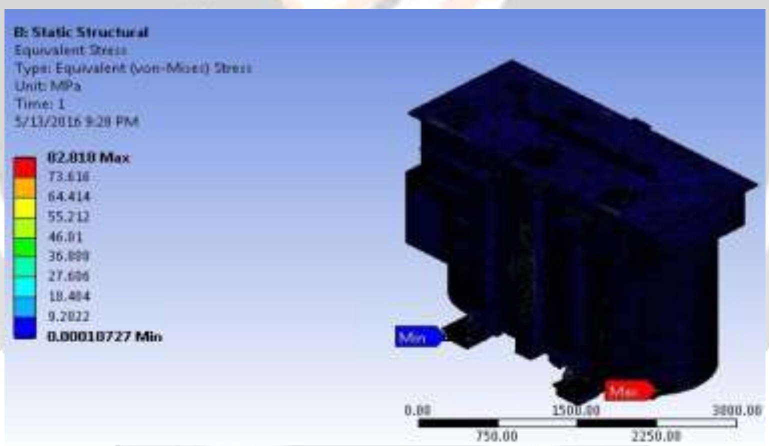

Figure 3.3 Stress value of tank

In the present work, the design modification is carried out in order to improve strength to weight ratio and 12 different cases are taken with change in tank wall thickness and cross section of stiffeners. FEA of all the 12 cases is carried out using ANSYS 17.0 workbench and results are tabulated shown below

Table 3.1 Results Of 12 Different Cases

Cases	Maximum stress value MPa	Deformation mm	Initial weight of transformer tank(kg)	Weight of transformer tank	improvement of weight
Case 1A	165.3	4.72	2587.9	2487.3	100.6
Case1 B	168.3	4.71		2472.2	115.7
Case1 C	170.15	4.76		2457.2	130.7
Case1 D	203.98	4.70		2442.2	145.7
Case2 A	174.95	4.72		2367.1	220.8
Case2 B	183.92	4.68		2352.2	235.7
Case2 C	194.76	4.74		2337.6	250.3
Case2 D	216.77	4.73		2322.9	265
Case3 A	194.86	4.74		2237.9	350
Case3 B	203.86	4.70		2222.6	365.3
Case3 C	221.33	4.91		2207.1	380.8
Case3 D	331.33	5.099		2192.9	395

4. DISCUSSION OF RESULTS

From the analysis the result obtained for 12 cases For the case 1A, 1B, 1C, 1D, 2A, and 2B they are within the permissible range of stress and deformation but they are neglected due to less reduction in weight compare to other cases. For cases 2D, 3C, and 3D the weight reduction is more but equivalent stress value is exceeded the permissible design stress. Therefore cases can be selected with a view point of strength to weight ratio. It is shortlisted from the values of the values deformation, stress, and reduction in weight with respect to initial weight of tank shown in table 3.1 From comparision of remaining cases its is decided that case 3A is the best among all the cases. For case 3A the value of equivalent stress is 194.86 which is within the permissible design stress of side wall and top cover and bottom plate.

5. Conclusion

In the present work, on the basis of loading condition and design criteria the design of transformer tank is carried out and analysis of design is done using ANSYS 17.0 workbench and results obtained is within the permissible range. The results shows that case 3A is the best design alternative as the value of stress and deformation is within the permissible limit. Reduction in weight of about 15% is achieved. The weight of existing transformer tank is 2587 kg and weight of best modified design is 2237 kg, reduction in weight of 350 kg is obtained which improves strength to weight ratio. Around 350 kg of transformer tank weight is reduced. hence, reduction in cost of one transformer tank is 21000 INR.

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