International Journal for Ignited Minds (IJIMIINDS)

Root Cause Failure Analysis of Current Transformer Core Shaft Assembly and Improvement Using Finite Element Analysis

Shivachandra S[a], Dr. Mohamed Haneef[b] & Mohammed Imran[c]

[a]*PG Scholar, Dept. of Mechanical Engg, Ghousia College of Engineering, Ramanagara, India.*
[b]*Principal & HOD, Dept. of Mechanical Engg, Ghousia College of Engineering, Ramanagara, India.*
[c]*Asst. Prof, Dept. of Mechanical Engg, Ghousia College of Engineering, Ramanagara, India.*

ABSTRACT

Vibrations are the major cause of failure of engineering structures. Even the failure of small component in an assembly, it will results to complete failure of the whole assembly. So it is always better to design the components individually as well as for assembly conditions. Also virtual simulation techniques can be used effectively to find the structural conditions for stress, deformation, size, shape, material for obtaining optimized structures. The analysis is done for two cases of boundary conditions. One is for installation and working conditions and other for transportation conditions. Three dimensional meshing is done for all the components and results are obtained for individual components. For both the conditions structural safety is checked for all the components. The results for core shaft and insulation paper analysis shows failure of the component for both stress and modal conditions. The obtained natural frequency value is almost near to the automobile operational frequency. So possibility of resonance is certain in the core shaft. Even for stress condition also the core shaft insulation paper is failing. Further boundary conditions are suggested and analyzed for stress and deformation.

Keywords *- Natural Frequency, Modal Analysis, Resonance, Deformation, Stress, Core Shaft.*

1. INTRODUCTION

Vibration is the common term in the dynamic design of structures. Vibrations are the main causes of failure of the structures under dynamic conditions. So any structure subjected to transient loading conditions should be designed based on vibrational conditions. Due to the advances in the computer technology, through virtual simulations, one can estimate the nature of vibration, type of vibration and magnitude of vibrations.

Pot holes are formed due to wear out of the road and the depth may varying from shallow depth to around 150mm. These are also formed due to dipping of water into the road cracks. The shape of the pot hole vary from circular any irregular shape.

When a moving vehicle falls on the pot holes, transient loads occurs in the automobile and that will be passed on to the structures mounted on the body. These vibrations cause cracks in the welds of machine parts. By providing proper damping, the extent of vibration can be controlled, but it is expensive.

Current Transformer is generally used to measure current passing through the equipment. Along with potential transformers, these are known as Instrument Transformers. Whenever excessive current is passing through the circuit, these current transformers helps in reducing the current to pass it to different instruments used in the system. Also it works like fuse or relay to break the circuit in case of excessive current passing through the system.

This is also very critical to find the safety of the structure by checking the stress and modal conditions for safety. For proper functioning, the stress levels should be less than the allowable stress limits and modal frequencies should not match with the operational frequencies.

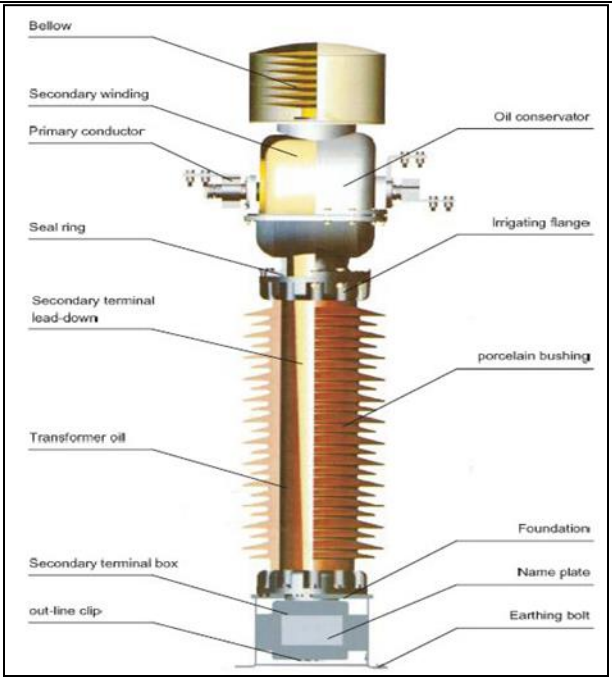

Fig 1: Parts of Current Transformer.

2. LITERATURE SURVEY

Gobbi, et al. [1], has analyzed about road vehicle subsystem optimization. Vehicle subsystem models are built for accurate simulations considering various design parameters like spring stiffness, damper values and suspended masses. The methodology is based on multiple objectives instead of normal single objective optimization. Number of global optimization techniques are suggested to handle the dynamic problems. He has concentrated on body and engine suspension for the main study. The comfort rail, holding of road and handling are studies and methods are suggested to improve these through suspension system parameters.

G.T. Michalto's, et al., [2], has stressed the need of cumulative fatigue damage in vehicle components for the given time of running on the road. Adams software to estimate the stress and fatigue behavior of the components. The models are built based on the road even and simulation is carried out using Adams, a famous software in the multi-body simulation software. Transient dynamic analysis is carried out to find the dynamic response of the system. The simulation results are for 200000kg in the actual environment.

A.V. Pesterev, et al., [3], has studied contact forces arising due to transient conditions after passing road irregularities by modelling a multi-degree of freedom model. A MDOF model decomposed to aggregate of independent occisalators in the design moving along an uneven surface such that response of each system is calculated independently. This technique is used for calculation of harmonic components of contact forces after moving over a cosine type of pot whole surface. The extension of damping force, spring mass and acceleration of mass for various parameters are analyzed.

3. PROBLEM DEFINITION

3.1 Problem Definition

Current transformers are used in the power industry to prevent excessive current or during shortage of the overhead lines. It has the structure to with stand the loads generating from the electrical effects along with wind loads. On the top of the transformer, a dome structure is provided to cool the temperature generated due to shorting of the transformer through bellow type arrangement which gives more surface area for cooling.

Analysis of failure of current transformer core shaft structure using finite element analysis is the main objective of the problem.

The objectives include

- Geometrical modelling of the current transformer.
- Finding the structural thickness of insulation paper on stress generation.
- Modal analysis to find possible resonance conditions.
- Finding the cause of failure.

4. GEOMETRY AND FE MODELING

4.1 Geometry Modeling

The figure shows geometrical model of the current transformer in the industrial applications. Inner core shaft used for current transfer is also shown along with bottom fixation positions and top bellow based dome structure for cooling or for dissipating heat generated during short circuit.

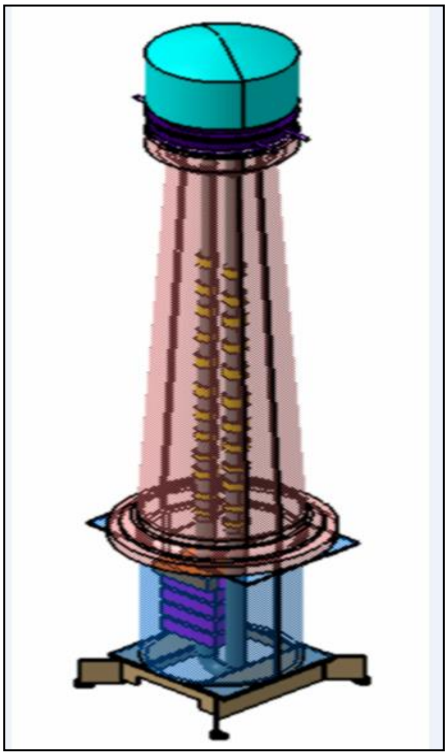

Fig 2: Geometrical Model of Current Transformer.

4.2 FE Modeling

Solid45 element with tetrahedral option is used for meshing. Free mesh is used due to complexity of the problem. The connectivity is maintained through coupling elements. The appropriate material properties are attached and problem is analyzed for different loading conditions.

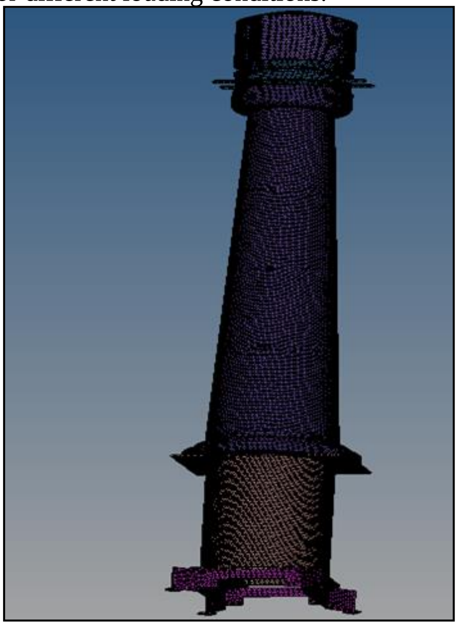

Fig 3: FE Mesh of complete assembly.

4.3 Material Modeling

Parameters	Steel	Porcelain	Copper
Young's Modulus, Pa	$200x10^9$	$63\ x10^9$	$80\ x10^9$
Poison's ratio	0.3	0.3	0.3
Density, kg/m^3	7800	2800	11000

Table 1: Material Properties Used in the Analysis.

5. RESULT AND DISCUSSIONS

5.1 Static Analysis

Analysis has been carried out to find the structural stability and region for failure of the insulation on the core shaft has been carried out for different boundary conditions based on installation and transportation conditions. Through analysis, the structural safety parameters are obtained to check and find the failure region along with requirements for safety

Maximum deformation is around 35.5 microns. Maximum deformation is observed at the top region which can be attributed to compression of the top member. Maximum Stress of 7.31 Mpa can be observed for the problem under self-weight as shown in Fig 4.

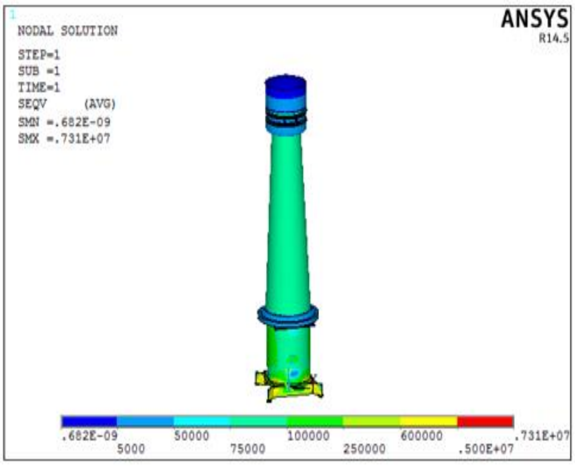

Fig 4: Stress due to Installation Condition.

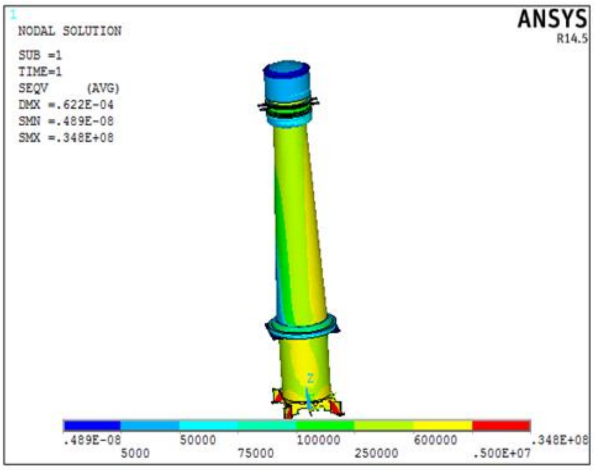

Fig 5: Stress due to Self-Weight and External Load Condition.

Along with the self-weight external loads are considered along with wire tension loads on the current transformer for finding the safety. The bottom of the structure is constrained in all the directions and external loads (wind load + wire tension loads).

The stress value is around 34.8Mpa as shown in Fig 5 red color region. The maximum stress is region is at the bottom of structure due to cantilever type arrangement of the structure.

5.2 Modal Analysis

The mode shape corresponding to the first fundamental natural frequency. The type of vibration observed is lateral and the highest deformation is observed at the end due to cantilever type arrangement. The status bar shows variation of deformation from zero represented by blue to maximum deformation of 0.026465mm with red color as shown in the figure.

Maximum deformation is observed at the top due to cantilever type boundary condition of the problem. Model shapes helps in finding the weaker regions along with the direction of weakness in the structure. Even mode shapes can be used to predict the nature of vibration. Mode shapes directly depends on the value of natural frequency of the system.

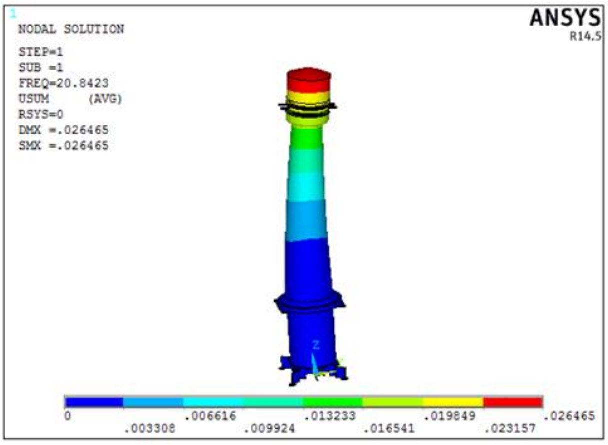

Fig 6: Natural Frequency based on Installation Condition.

Mode shape of the problem corresponding to the first natural frequency of 122.476Hz shown in Fig 7. Maximum deformation is observed at the center region due to simply supported configuration. The values are not real displacements, but they are proportional factors.

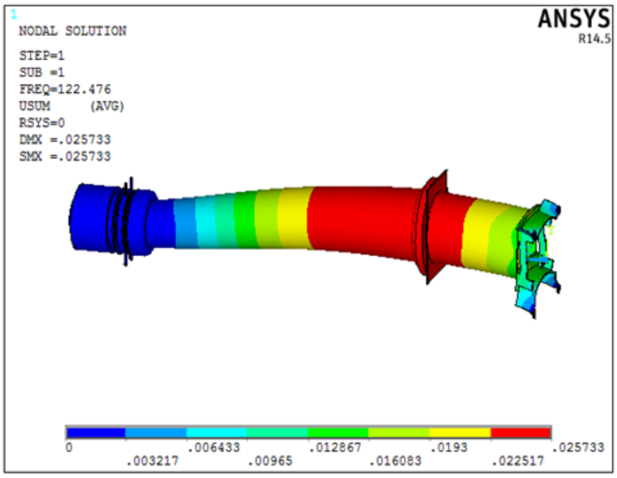

Fig 7: Natural Frequency based on Transportation Condition.

5.2 Core Shaft Analysis

The present problem is failing of insulation paper on the core shaft so analysis should be done to find the best cause of failure. Here initially static analysis is carried out and later it is done for modal conditions.

The natural frequencies are closed to operational frequency of the automobile. So there is possibility for resonance of the system which may create failure of the component. This stress is also more than the allowable stress of insulation paper. The possibility for failure can be attributed to stress generated due to transport conditions.

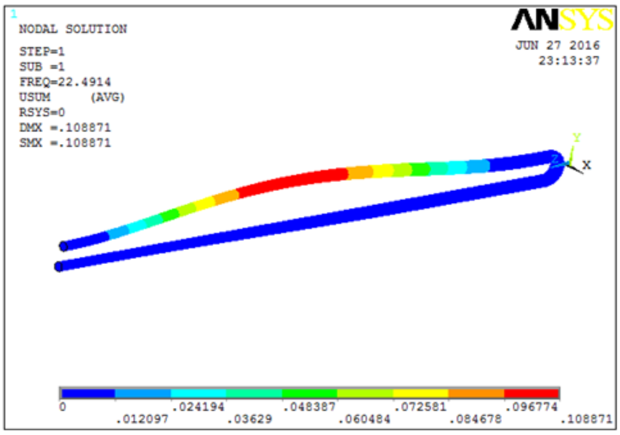

Fig 8: Mode Shape for Intermediate Condition.

Since the natural frequencies are near the automobile frequency and so the stress generation in the paper is more and is failing which is causing short circuit in the problem. So an intermediate support is proposed joining both the shaft ends at the center. Modal analysis is carried out with the changed configuration. The natural frequency is obtained for the changed boundary conditions.

Natural Frequencies for changed boundary condition problem with intermediate support. The results shows the obtained natural frequency is around 84.501Hz as shown in Fig 9. This frequency is much higher than the operating frequency of 22Hz. So one problem of resonance is eliminated. Further structure need to be checked for structural safety conditions.

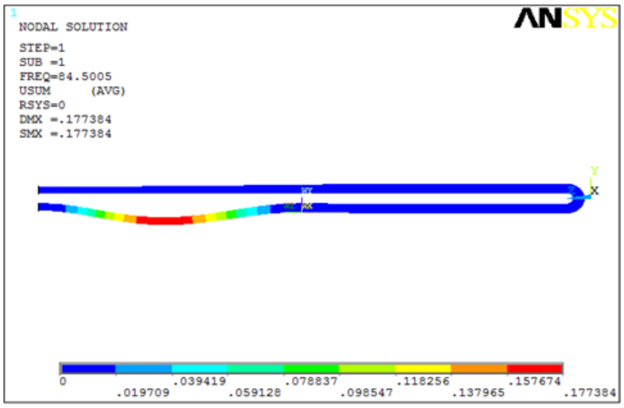

Fig 9: Mode Shape for Support Condition.

Layers	**Stress**	**Deformation**	**Modal Frequency**
3 Layer	16.8	0.003928	22.267
4 Layer	16.7	0.00385	22.491
5 Layer	16.6	0.00385	22.51

Table 2: Results Without Intermediate Support.

Layers	**Stress**	**Deformation**	**Modal Frequency**
3Layer	3.7	0.000275	84.5

Table 3: Results With Intermediate Support.

The results shows without intermediate support, the results are not much varying with reference to increased thickness of insulation paper. The deformation, stress and modal frequencies are marginally influenced by the thickness of layer and the stress is more than allowable for the insulation paper. So by increasing the thickness of insulation paper, the safety can't be maintained. Further analysis with intermediate layer shows lot of improvement in the problem. Initial problem shows failure of the insulation paper from stress and fundamental natural frequency. With the modified conditions, the structure is completely safe for modal frequencies along with static stress response. So it is better to give intermediate support for the structure compared to increasing the thickness of insulation paper.

6. CONCLUSION

The following conclusions were obtained from the analysis and optimization of structure:

Analysis is carried out for two conditions. The first one with erected or installed condition. Other analysis is done with transport conditions.

- The initial vertical condition results shows, structural safety of the components. Both outer frame and core structure results are represented for stress and deformation.
- For installed conditions, wind loads and cable tension is considered along with the self-weight. The results shows safety of the structure and its components.
- The analysis with the transport conditions shows failure of the paper for the given loading conditions.
- Analysis of current transformer structure has been done and results are obtained for structural safety

parameters like deformation, stress and natural frequencies. Two types of boundary conditions are used in the problem. The first boundary conditions are for erection condition and the other is for transportation conditions. The results shows exceeding stress values for insulation paper for transportation conditions along with matching natural frequency of the system for road vibration. So the failure of insulation paper is happening due to higher stress generation along with resonance conditions. So initially analysis is carried out to improve structural safety by increasing the thickness of insulation paper. But the iterative results shows marginal improvement in the structural safety. But addition of intermediate support has greater effect on improvement of structural safety parameters like stress, deflection and natural frequency. So to improve the life of current transformer, it is advisable for intermediate support which will reduce the unsupported free length which is critical for structural problems.

REFERENCES

1. Ruhani Thakur, et.al, "*Analysis of Fuselage Floor Beam*", Volume 2 – No.6, December 2015.
2. Rahul Sharma, et.al, "*Design Modification and Analysis for an Attachment Bracket of Fuselage Floor Beam*", Vol.3, Issue 12, December 2014.
3. Allen, et al., "*A Framework for Hyper-Heuristic Optimizations of Conceptual Aircraft Structural Designs*", Durham theses, Durham University (2014).
4. Jeffrey H. Wood, John H.Fogarty, Floor beam assembly, system and associated method; Patent US7775478B2 in 2010.
5. Marampalli Shilpa* et al., "*Design & Analysis of Fuselage Structure Using Solidworks & ANSYS*" IJESRT, Sep 2014.
6. Patent Russia 244/2440278 [2], was examined on Fuselage floor bearing carcass and its support beam
7. R.E de Kok, "*The Airbus Floor Beam*", Faculty of Aerospace Engineering, delft university of technology, January 1992
8. Appendix A, "Floor Beam Design Project".
9. Mechanics of Solids by S.S. Bhavikatti, published by New Age International (P) Ltd, 2010.
10. www.web.mit.edu/../props.pdf.com