Coupled Field Analysis of A Chimney Used in Cement Industry

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Abstract
Chimney, which form the last component of a system using a flue gas such as boiler, play a vital role in maintaining efficiency, draft, etc, of a system and also in minimizing the atmospheric pollution. Steel chimneys are also known as steel stacks. The steel chimneys are made of steel plates and supported on foundation. The steel chimneys are used to escape and disperse the flue gases to such a height that the gases do not contaminate surrounding. In this thesis, chimney will be designed considering dead load and wind load. The Bureau of Indian Standards (BIS) design codes procedures will be used for the design of the chimney. The chimney was considered as a cantilever beam with annular cross section.
3D model of the chimney is done in Pro/Engineer and coupled field analysis is done on the chimney in ANSYS. A simplified model of chimneys with various thicknesses like 10mm, 12mm, 14mm and 16mm were modeled atmosphere.

Keywords
Chimney, Flue Gases, Coupled Field Analysis

I. Introduction
Chimneys or stacks are very important industrial structures for emission of poisonous gases to a higher elevation such that the gases do not contaminate surrounding atmosphere. These structures are tall, slender and generally with circular cross-sections. Different construction materials, such as concrete, steel or masonry, are used to build chimneys. Steel chimneys are ideally suited for process work where a short heat-up period and low thermal capacity are required. also, steel chimneys are economical for height up to 45m. Fig. 1 shows a photograph of self-supporting steel chimneys located in an industrial plant.

Fig. 1: Shows a Photograph of Self-Supporting Steel Chimneys Located in an Industrial Plant

There are many standards available for designing self supporting industrial steel chimneys: Indian Standard IS 6533: 1989 (Part-1 and Part-2), Standards of International Committee on Industrial Chimneys CICIND 1999 (rev 1), etc. Geometry of a self supporting steel chimney plays an important role in its structural behavior under lateral dynamic loading. This is because geometry is primarily responsible for the stiffness parameters of the chimney. However, the basic geometrical parameters of the steel chimney (e.g., overall height, diameter at exit, etc.) are associated with the corresponding environmental Conditions.

II. Literature Review
1. Menon and Rao(1997) reviews the code measures to estimate the across wind response of reinforced concrete chimney.In this paper, the difficulties in the codal evaluation of across wind moments and load factor provisions are examinedthrough reliability approach. This paper mainly suggest that it is essential to design at certain conditions for the acrosswind loading [3].
2. K.R.C. Reddy, O.R.Jaiswal and P.N.Godbole (2011) discusses about wind and earthquake analysis of tall reinforced concrete chimney. In this paper two reinforced concrete chimneys are analysed for wind and earth quake loads. Earth quake analysis is done as per IS 1893 (part 4): 2005 and wind analysis is done as per IS 4998 (part 1): 1992. The combination of along & across wind loads of chimney is done as per ACI 307-98 code. Finally they computed the governing load for design of chimneys.
3. B. SivaKonda Reddy, C.Srikanth, V.RohiniPadmavathi (2012) discusses about wind load effects on tall reinforced concrete chimneys. In this paper they considered 275m reinforced concrete lined chimney. The study of this paper is along &across wind effects on this RCC Chimney for I and VI wind zones of India. Finally they concluded that, forWind zone –I across wind loads are governing and for wind zone-VI along wind loads are governing rather than the across wind loads .

III. Problem Description & Methodology
The objective of this project is to make a 3D model of the chimney and study the thermal and static behavior of the chimney by performing the finite element analysis. 3D modeling software (PRO-Engineer) was used for designing different geometries (10mm, 12mm, 14mm and 16mm thickness) and analysis software (ANSYS) was used for thermal and static analysis.

The methodology followed in the project is as follows:
- Create a 3D model of the steam chimney using parametric software pro-engineer.
- Perform thermal analysis and linear layer thermal analysis on the chimney for thermal loads, to find out the temperature distribution and heat flux
- Perform static analysis and linear layer static analysis on the chimney for thermal loads, to find out the deformation, stress and strain distribution.

IV. Introduction to CAD
Throughout the history of our industrial society, many inventions have been patented and whole new technologies have evolved. Perhaps the single development that has impacted manufacturing more quickly and significantly than any previous technology is the digital computer.

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1. Introduction to PRO/Engineer

Pro/ENGINEER, PTC's parametric, integrated 3D CAD/CAM/CAE solution, is used by discrete manufacturers for mechanical engineering, design and manufacturing. Created by Dr. Samuel P. Geisberg in the mid-1980s, Pro/ENGINEER was the industry's first successful parametric, 3D CAD modeling system. The parametric modeling approach uses parameters, dimensions, features and relationships to capture intended product behavior and create a recipe which enables design automation and the optimization of design and product development processes.

B. Introduction to Finite Element Method

Finite Element Method (FEM) is also called as Finite Element Analysis (FEA). Finite Element Method is a basic analysis technique for resolving and substituting complicated problems by simpler ones, obtaining approximate solutions Finite element method being a flexible tool is used in various industries to solve several practical engineering problems. In finite element method it is feasible to generate the relative results. ANSYS is an Engineering Simulation Software (computer aided Engineering). Its tools cover Thermal, Static, Dynamic, and Fatigue finite element analysis along with other tools all designed to help with the development of the product. The company was founded in 1970 by Dr. John A. Swanson as Swanson Analysis Systems, Inc. SASI. Its primary purpose was to develop and market finite element analysis software for structural physics that could simulate static (stationary), dynamic (moving) and heat transfer (thermal) problems.

V. Modelling and Analysis

A. Models of Narrow Plate Using Pro-e Wildfire 5.0

The vertical narrow plate is modeled using the given specifications and design formula from data book. The isometric view of vertical narrow plate is shown in below figure. The vertical narrow plate profile is sketched in sketcher and then it is extruded vertical narrow plate using extrude option.

B. Original Chimney 3D and 2D Models

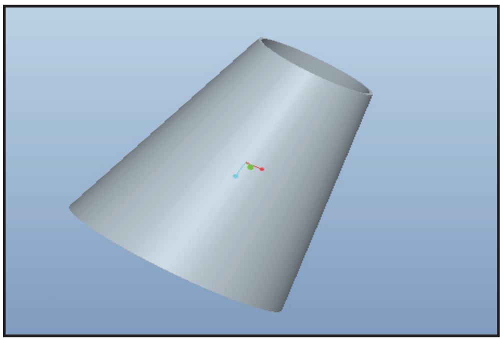


Fig. 2: 3D Chimney Model

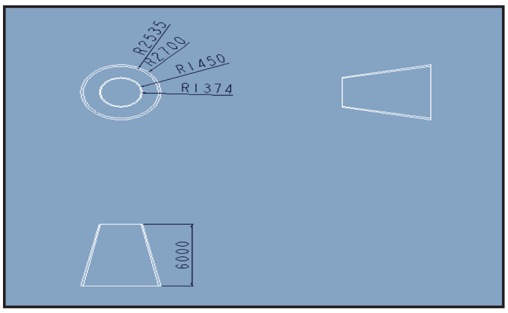


Fig. 3: 2D Chimney Model

C. Thermal Analysis

1. Material Concrete

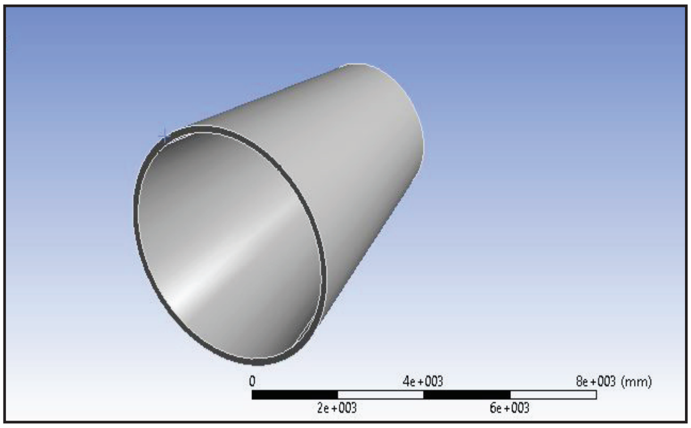


Fig. 4: Imported Model

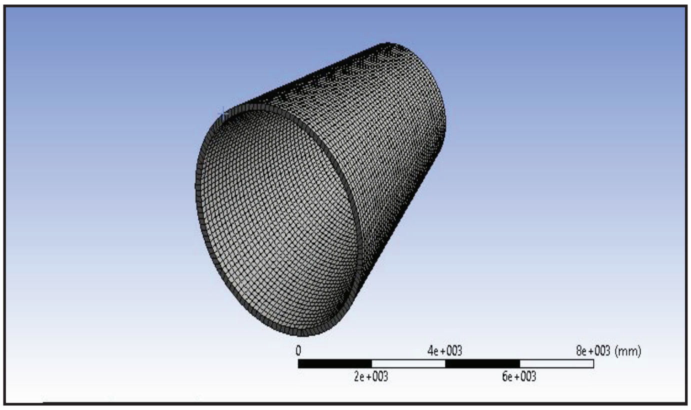


Fig. 5: Meshed Model

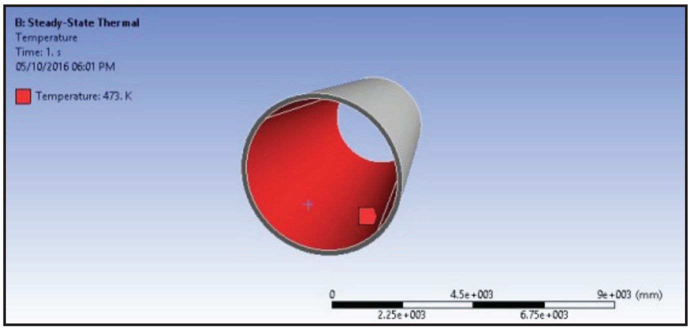


Fig 6 applied temperature

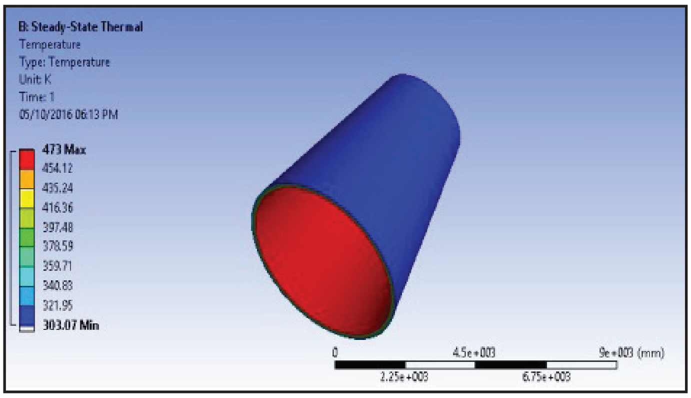


Fig. 7: Temperature Disturbtion

According to the contour plot, the temperature distribution maximum temperature at inside of the chimney because the temperature passing from the bottom inside of the chimney. So we are applying the temperature inside of the chimney and applying the convection except inside of the chimney.

D. Heat Flux

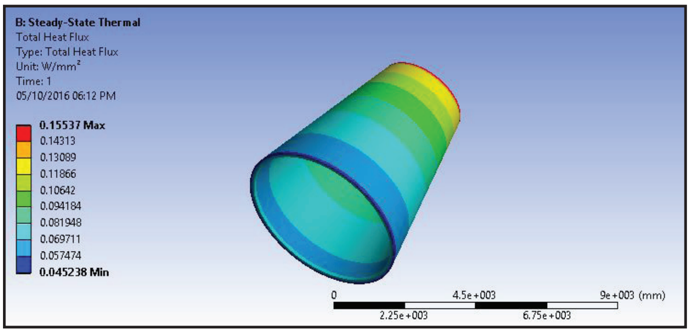


Fig. 8: Heat Flux

According to the contour plot, the maximum heat flux at inner side top portion of the chimney. Minimum heat flux bottom of the chimney.According to the above contour plot, the maximum heat flux is 0.15537w/mm² and minimum heat flux is 0.045238w/mm².

E. Static Analysis

1. Deformation

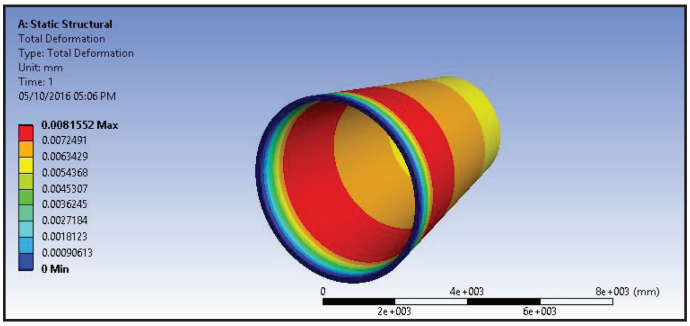


Fig. 9: Deformation

According To the Counter Plot, the maximum deformation at outer surface of the chimney and minimum deformation at bottom of chimney. The maximum deformation is 0.0081552 mm and minimum deformation is 0.0090613 mm.

2. Stress

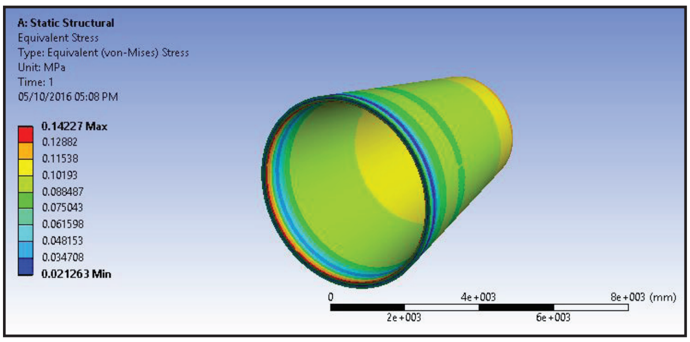


Fig. 10: Stress

According To the Counter Plot, the maximum stress at bottom end of the chimney and minimum stress at bottom surface of the chimney. The maximum stress is 0.1422 mm and minimum is 0.02126 mm.

3. Strain

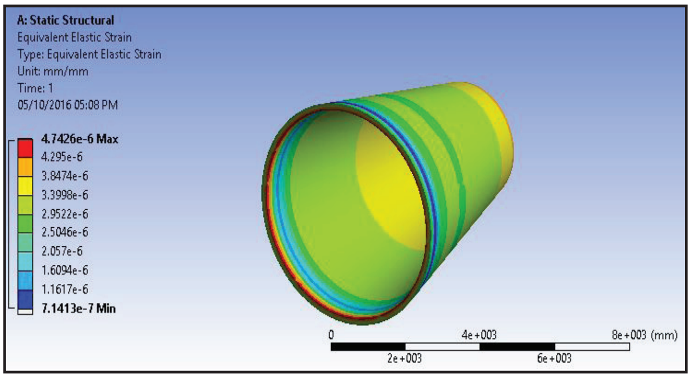
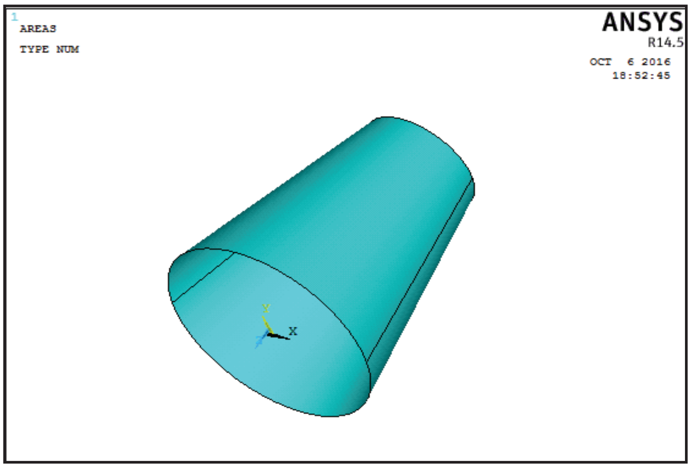


Fig. 11: Strain

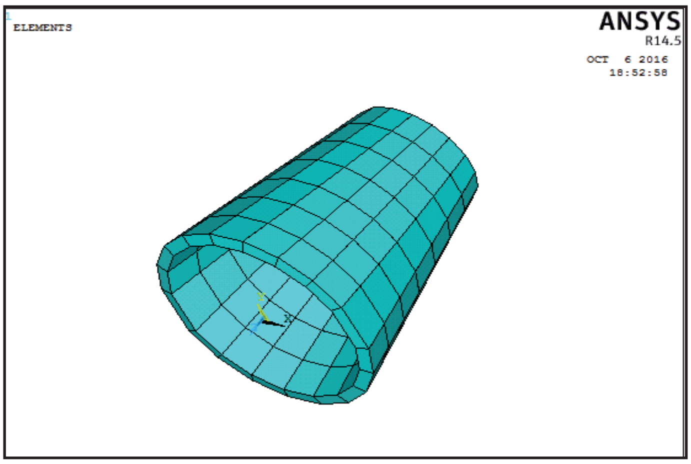
According To the Counter Plot, the maximum strain at bottom end of the chimney and minimum strain at bottom outer surface of the chimney. The maximum strain is 4.7426e-6 mm and minimum deformation is 7.1416e-7 mm.

F. Linear Layer Thermal Analysis

1. Imported Model

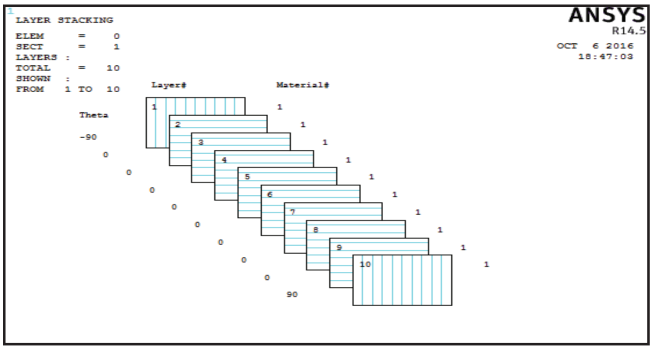


2. Meshed Model



Finite element analysis or FEA representing a real project as a “mesh” a series of small, regularly shaped tetrahedron connected elements, as shown in the above fig. And then setting up and solving huge arrays of simultaneous equations. The finer the mesh, the more accurate the results but more computing power is required.

(i). Layer stacking



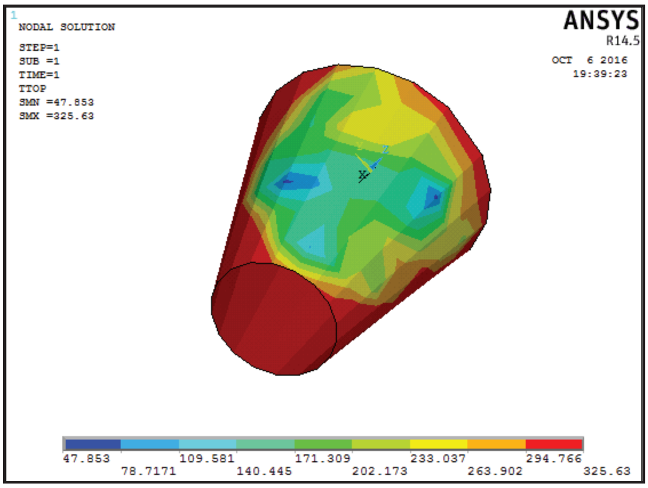


Fig. 12: Temperature

G. Heat Flux

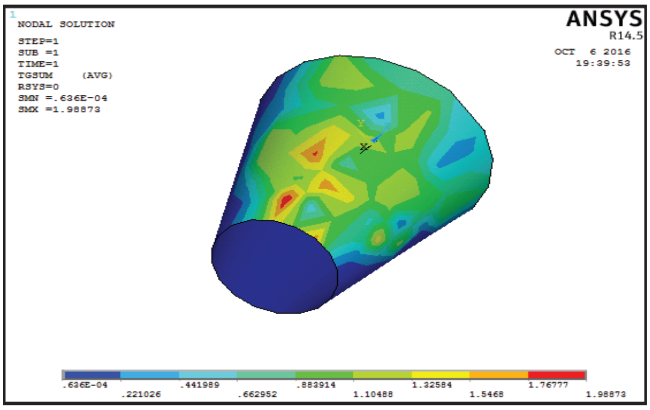


Fig. 13: Heat Flux

H. Linear Layer Static Analysis

1. Deformation

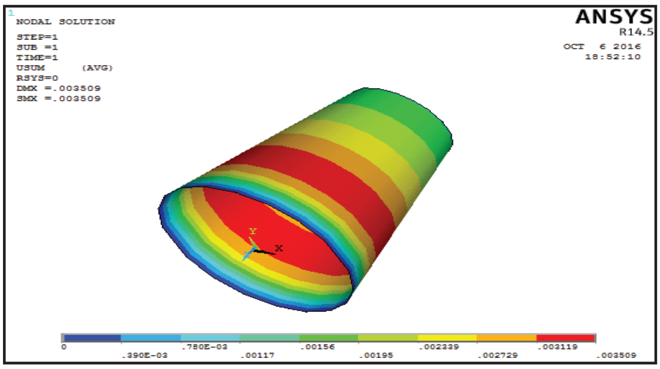


Fig. 14: Deformation

2. Stress

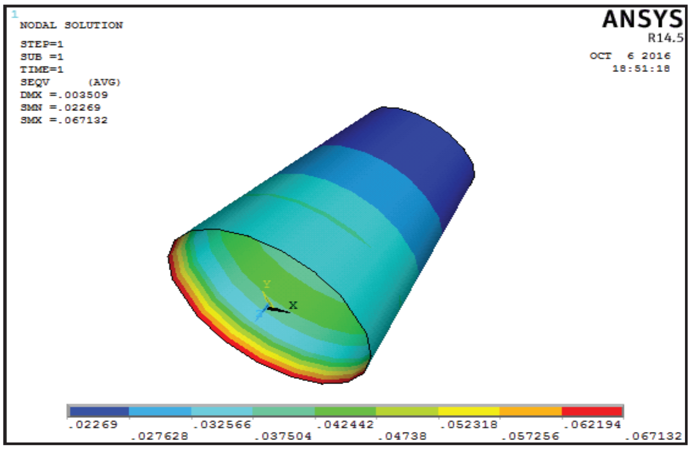


Fig. 15: Stress

3. Strain

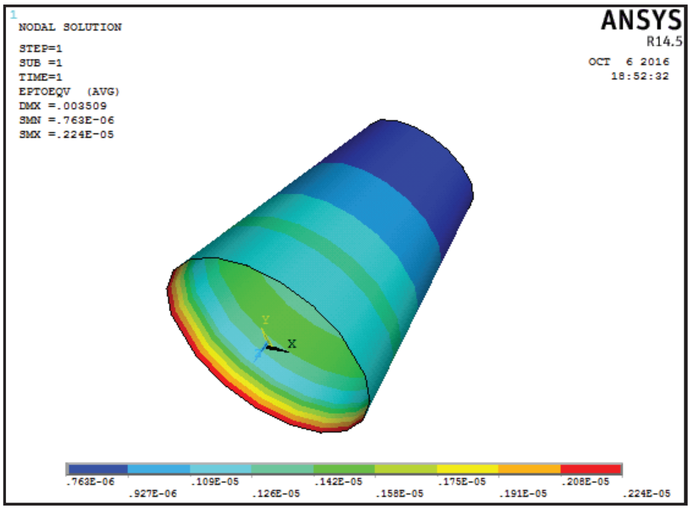


Fig. 16: Strain

VI. Results and Discussion

A. Thermal Analysis Results Table

Chimney thickness (mm)	Temperature (K)		Heat flux (W/mm²)
	Min	max	
Original model	303.07	473	0.15537
10	303.02	473	0.14822
14	303.06	473	0.143
18	303.08	473	0.137
22	303.05	473	0.1290

B. Static Analysis Results Table

Thickness (mm)	Deformation (mm)	Stress (N/mm²)	Strain
original	0.0081522	0.14227	4.7426 e-6
10	0.00785715	0.1537	5.126 e-6
14	0.0077429	0.13701	4.5672 e-6
18	0.0075227	0.13347	4.49 e-6
22	0.00721	0.12788	4.269 e-6

C. Linear Layer Thermal Analysis Results Tabels

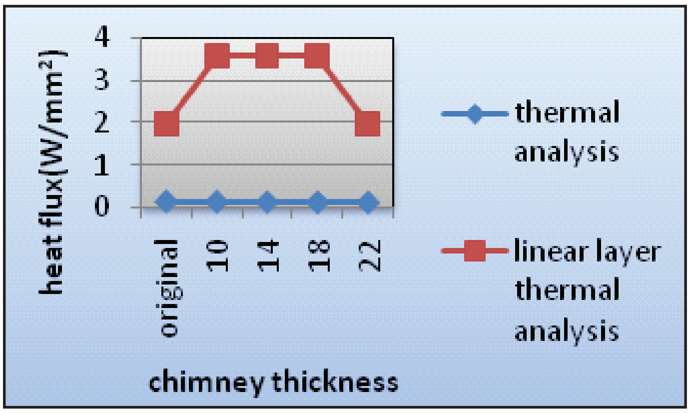
Chimney thickness (mm)	Temperature (K)	Heat flux (W/mm²)
Original model	325	1.980
10	324.319	3.574
14	323.818	3.564
18	323.33	3.562
22	322.865	1.971

D. Linear Layer Static Analysis Results Tabels

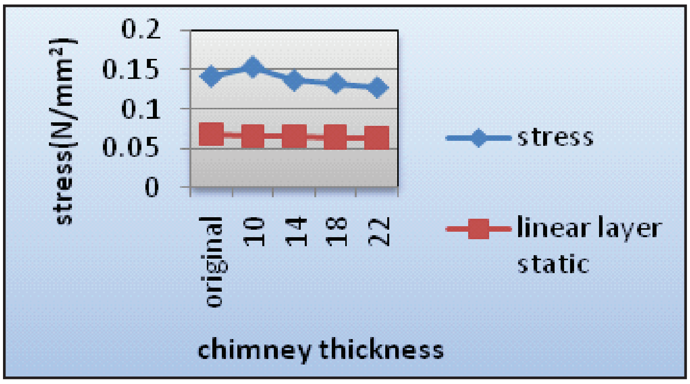
Thickness (mm)	Deformation (mm)	Stress (N/mm²)	Strain
original	0.0025909	0.067132	0.224e-5
10	0.003404	0.065302	0.215e-5
14	0.00226	0.064556	0.214e-5
18	0.062317	0.063826	0.213e-5
22	0.002275	0.063111	0.210e-5

E. Graphs

1. Heat flux



2. Stress



VII. Conclusion

3D model of the chimney is done in Pro/Engineer and coupled field analysis is done on the chimney in ANSYS. A simplified model of chimneys with various thicknesses like 10mm, 14mm, 18mm, and 22mm were modeled.

By Observing the thermal analysis the heat flux value is more for original model of chimney and linear layer thermal analysis the heat flux value is more for 10mm thickness of chimney model. When we compare the thermal analysis and linear layer thermal analysis the heat flux more for linear layer thermal analysis of chimney.

By observing the static analysis the deformation and stress values are less for 22mm thickness of the chimney and linear layer static analysis the deformation and stress values are less for 22mm thickness of chimney model. When we compare the static analysis and linear layer static analysis the stress values are less for linear layer static analysis of chimney.

So it can be conclude the 22 mm thickness of the chimney model is the best model when we do linear layer thermal and static analysis.

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