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FINITE ELEMENT ANALYSIS OF 16 M^2 SCHEFFLER SOLAR CONCENTRATOR STRUCTURE FOR WEIGHT

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Abstract : In world conventional energy resources goes on rapidly decreases. So it needs to concentrate towards non conventional or renewable energy resources. Out of the available energy resources, solar energy is one of the most important and easily available sources of energy. As the technocrat main aim is to develop an economical mode of utilization of solar energy. Using solar concentrator solar energy for various applications is utilized. Now a day's different types of concentrator are designed, one of them is Scheffler solar concentrator. This is one of the popular concentrator in India which are used for direct and community cooking application. So the aim of project is to analyse the strength and distortion characteristics of 16 m2 Scheffler solar concentrator using FEA. The geometrical modeling of 16 m^2 Scheffler solar concentrator is done in CATIA V5R17. The Pre-processing of the model for material Steel and Aluminum and for thickness variants of 2 mm, 1.5 mm and 1 mm is done with HyperMesh, analysis is done with ANSYS 11.0 and Post-Processing is done with HyperView. Finally the design improvement study of the Scheffler is successfully performed resulting in the good cost reduction.

I. INTRODUCTION

For the utilization of solar energy many solar systems are designed like solar concentrators, Photovoltaic's, solar water heaters etc. Solar concentrators are capable of delivering process temperatures in the range of 80°C to 300°C with reasonable efficiency and hence can be excellent alternatives to replace fossil fuels in industries for mid temperature applications. Majority of the solar dish concentrators designs practiced in the world are paraboloidal dishes symmetrical about their axes. Wolfgang Scheffler launched an idea of oblique paraboloid solar reflectors, now known as Scheffler solar concentrators. Scheffler solar concentrators are termed as flexible surface concentrators. This is the only known commercially available technology that brings sun inside the kitchen for cooking. An Australian developer Wolfgang Scheffler is developed fixed focus solar cooker which is very popular because of comfortable cooking is possible

The paper titled "Finite Element Analysis of 16 m^2 Scheffler solar concentrator structure for weight of Steel and Aluminum material" is implementation of the FEA software for the assessment of the strength and distortion characteristics of the Scheffler Solar concentrator.

Structural Details of 16 m2 Scheffler solar concentrator

The 16 m^2 Scheffler solar concentrator's structural details are taken from PRINCE NGO working at Dhule. This type of concentrator installed from last eight years at MIDC Dhule by PRINCE, which is working in well condition at all environmental changes in Dhule [33]. This is optimum design according to manufacturer of Scheffler solar concentrator, But there is no any analysis reported on this concentrator to find strength and distortion characteristics. The details of Scheffler solar concentrator also taken from www.solare-bruecke.org [02].

The Fig. 1.1 and Fig. 1.3 shows the orthographic view of 16 m^2 Scheffler solar concentrator Frame in which all dimensions are given in mm. The elliptical shape of frame is of square and rectangular pipes of different sizes which are welded each other. That frame provides folding flanges at the middle for folding purpose. In Fig. 1.1 the seven cross bar are shown having 14 members which are denoted by F1 to F14. The details dimensions are shown in Fig. 1.1 - 1.2 and Table 1.1.

The Assembly of Scheffler solar concentrator is clearly understood from Fig. 1.3 Table 1.2. It shows Dish, Rotating Pipe, Dish holding side bracket, Dish holding central bracket, Rotating arm for dish, Bracket for telescopic pipe lower side, Telescopic pipe assembly upper side, Telescopic pipe assembly lower side. From this it is clear the constraint for dish i.e. mounting points.

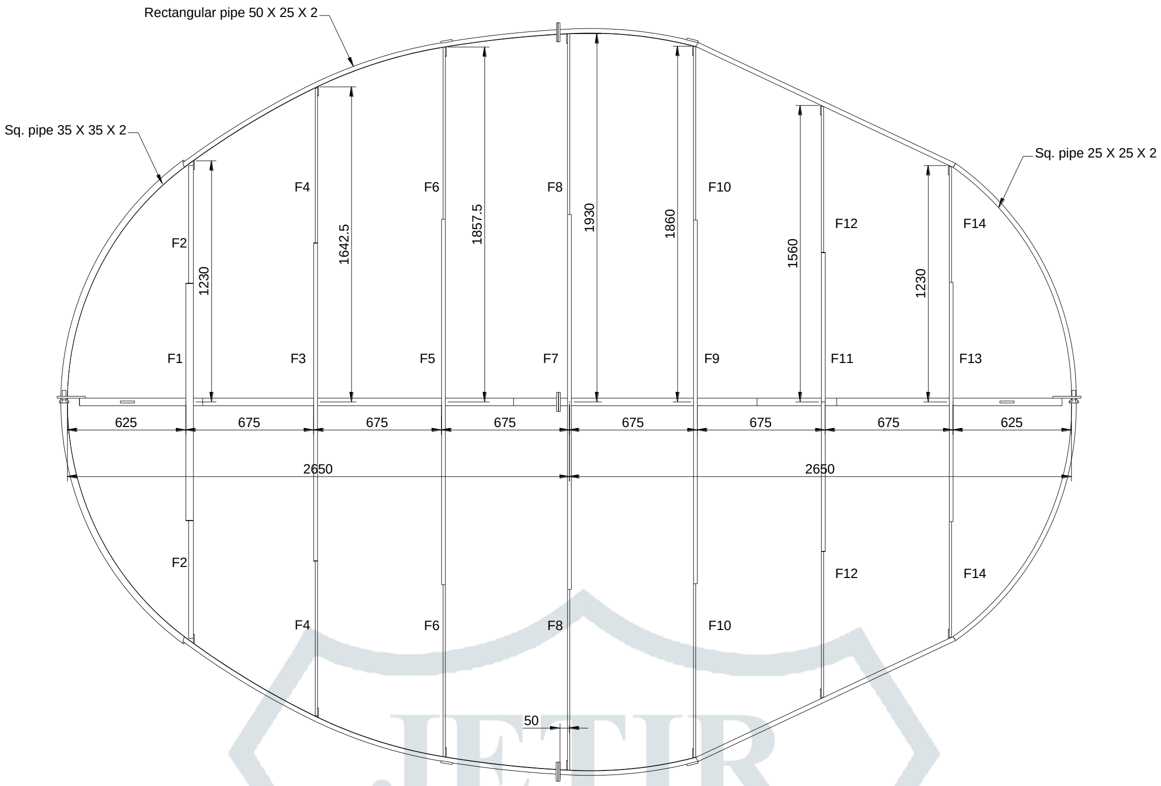

Fig. 1.1 Orthographic view of 16 m² Scheffler solar concentrator frame (T.V) (all dimensions in mm) [33]

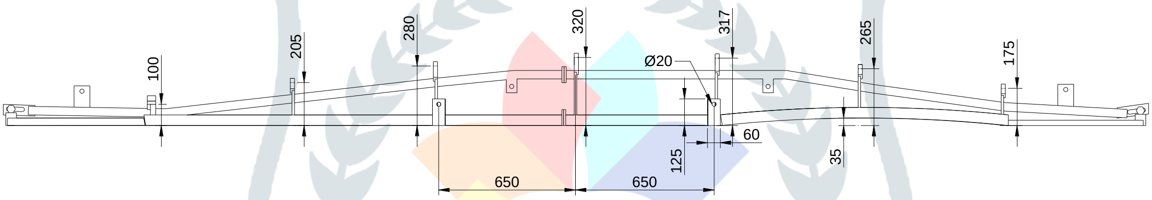

Fig. 1.2 Orthographic view of 16 m² Scheffler solar concentrator (F.V) (all dimensions in mm) [33]

Table 1.1 Details of cross bar [33]

Member	Section used	Length of the section	Qty
F1	Sq. Pipe 40 X 40 X 2	1240 mm	1
F2	Sq. Pipe 25 X 25 X 2	620 mm	2
F3	Sq. Pipe 20 X 20 X 2	1660 mm	1
F4	Sq. Bar 12 X 12	825 mm	2
F5	Sq. Pipe 20 X 20 X 2	1910 mm	1
F6	Sq. Bar 12 X 12	925 mm	2
F7	Sq. Pipe 20 X 20 X 2	1960 mm	1
F8	Sq. Bar 12 X 12	980 mm	2
F9	Sq. Pipe 20 X 20 X 2	1900 mm	1
F10	Sq. Bar 12 X 12	940 mm	2
F11	Sq. Pipe 20 X 20 X 2	1565 mm	1
F12	Sq. Bar 12 X 12	780 mm	2
F13	Sq. Pipe 20 X 20 X 2	1250 mm	1
F14	Sq. Bar 12 X 12	615 mm	2

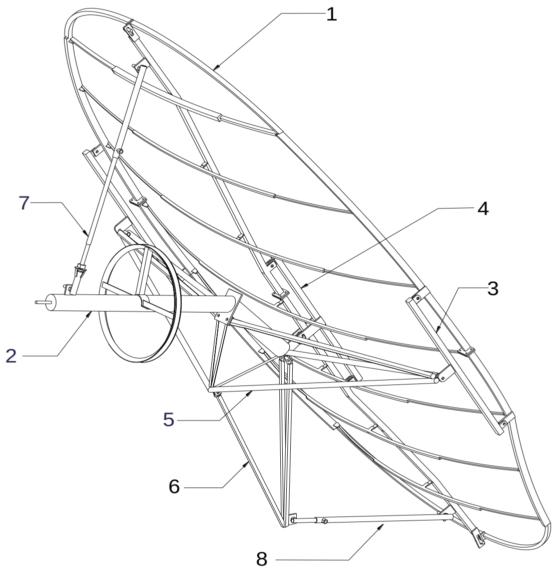

Fig. 1.3 Pictorial view of assembly drawing for 16 m2 Scheffler showing different parts

Table 1.2 Part list of assembly drawing for 16 m2 Scheffler as shown in fig. 1.3

Sr. No.	Name of the part	Quantity
1	Dish	1
2	Rotating Pipe	1
3	Dish holding side bracket	2
4	Dish holding central bracket	1
5	Rotating arm for dish	1
6	Bracket for telescopic pipe lower side	1
7	Telescopic pipe assembly upper side	1
8	Telescopic pipe assembly lower side	1

1.4 Objective and Methodology

The objective is to analyse the strength and distortion characteristics of 16 m2 Scheffler solar concentrator. Based on this objective following are the Methodology.

1. Geometrical Modeling of 16 m^2 Scheffler solar concentrator in CATIA V5R17.
2. Pre-processing of the model for material Steel and Aluminum and for thickness of 2 mm, 1.5 mm and 1 mm with HYPERMESH.
3. Analysis of model for strength and distortion characteristics with ANSYS solver and Post processing with HYPERVIEW.
4. Compare the result for minimum thickness of steel and aluminum with respective weight and cost of the structure.

1.5 Assumptions

The assumption made while doing analysis and loading conditions as

- The wind load acting on dish is consider as static load
- The maximum wind velocity is 36 km/hr[30,31]

II FE ANALYSIS OF 16M^2 SCHEFFLER SOLAR CONCENTRATOR

2.1 Governing Equation

Typically in a structural analysis the kind of equation solved is:

$$\mathbf{K}_{ij}\mathbf{u}_j = \mathbf{f}_i \qquad \text{.........................} (1)$$

Where u is the displacement and f is externally applied forces at the nodal points. The formation of the K matrix is dependent on the type of problem being attacked, dimensions of the components and material used.

2.2 Geometrical Modeling of the 16 m^2 Scheffler solar concentrator

A solid model of the 16 m^2 Scheffler solar concentrator, as shown in Fig. 2.1, was generated using CATIA V5 R17 according to Structural detail as discussed in chapter 1.This modeled dish is exported to IGES format, which is able to retrieve by HyperMesh for the preprocessing.

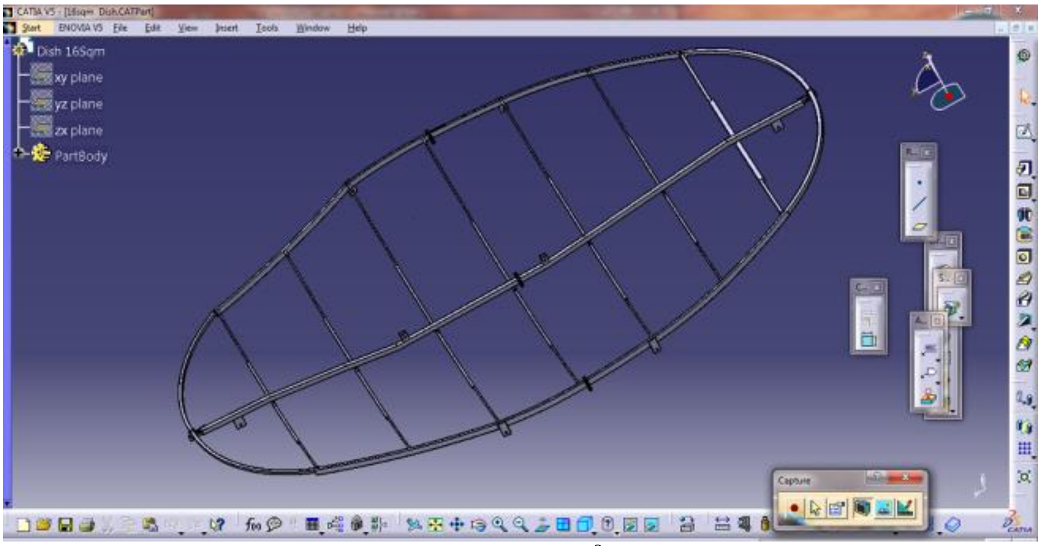

Fig 2.1 A solid model of the 16 m^2 Scheffler solar concentrator

2.3 Mesh Generation

Finite element mesh was generated using 4 node Quad elements, 3 node Triangular element, Rigid Body element and Mass Element as shown Table 2.1. First the 16 m^2 Scheffler solar concentrator solid model is imported from CATIA V5R17 software in HYPERMESH as shown in Fig.2.2. Studying the geometry of component, the setting of quality parameters is done.

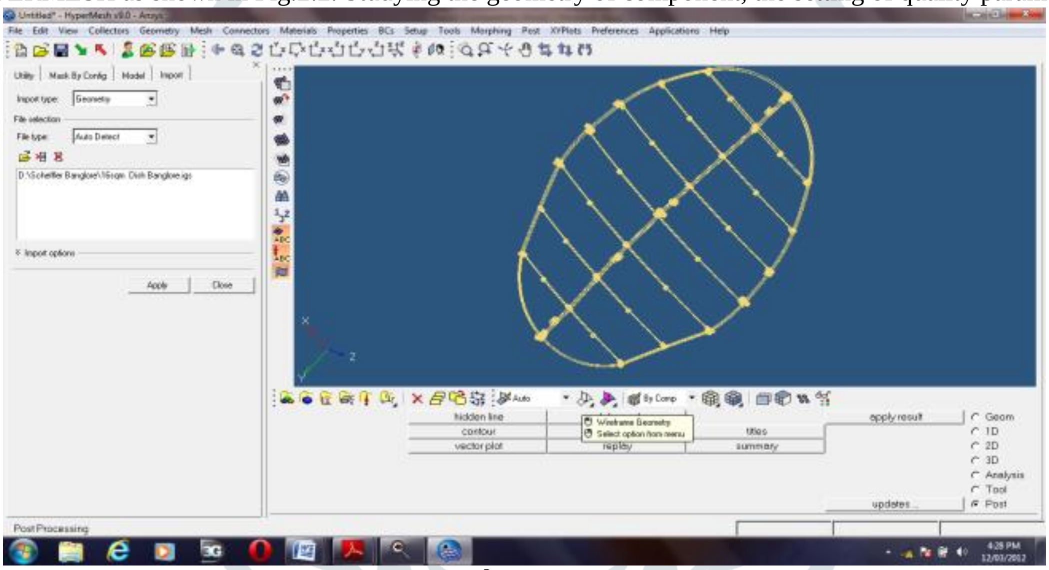

Fig. 2.2 Import solid model of the 16 m^2 Scheffler solar concentrator in HYPERMESH

Fig. 2.3 shows the front side mesh model of the cooling module.

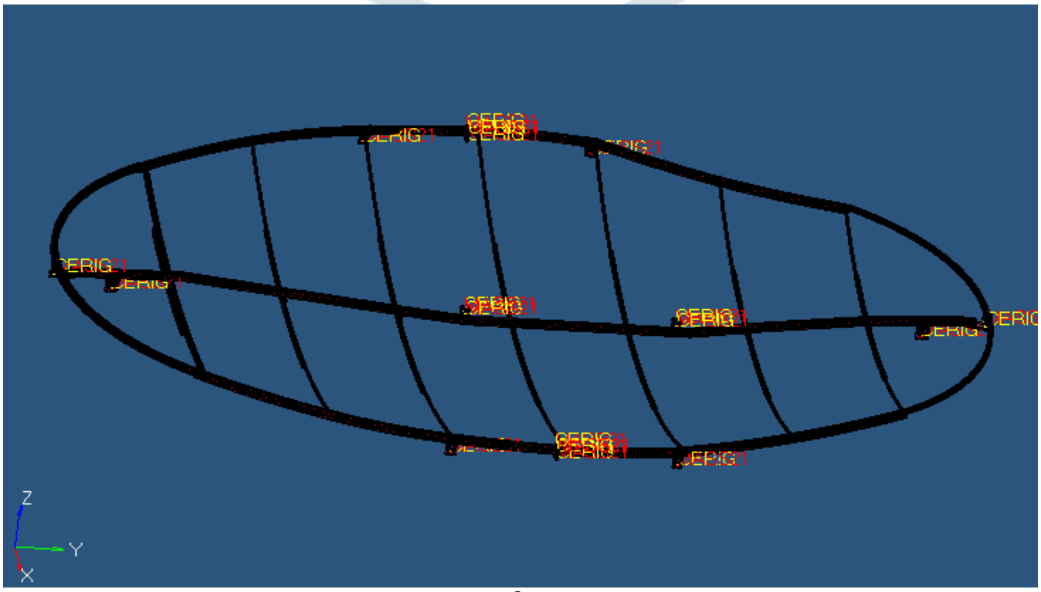

Fig 2.3 FEA model of 16 m^2 Scheffler solar concentrator

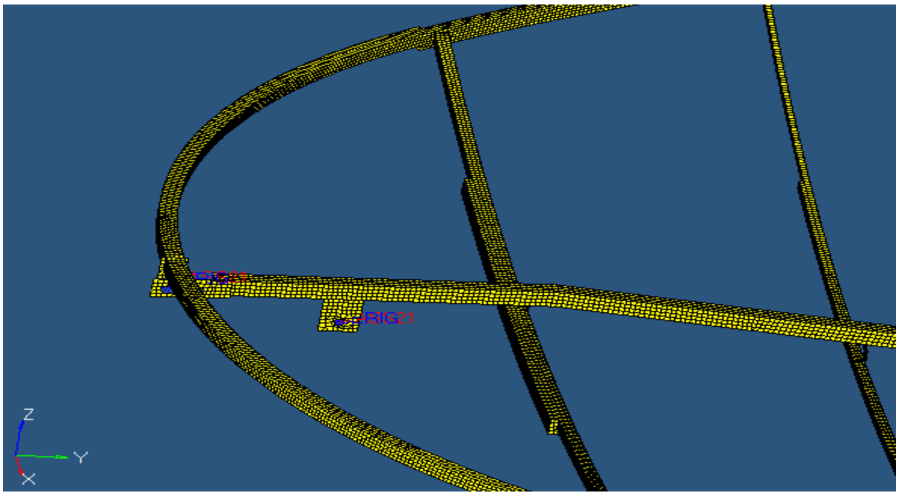

Fig 2.4 Mesh model of 16 m^2 schefflern solar concentrator

Fig. 2.4 shows the zoom view of Scheffler. The meshing is done with 3 & 4 node SHELL181 element. Fig.2.5 shows the mesh generation in HYPERMESH.

Shell i.e. 2D mesh is used for meshing of the components. Corresponding thickness is assigned to mesh. **Total 51010 Nodes and 51194 elements are used.**

Different element types are shown below.

Table 2.1 Elements used for meshing

Element	**Element type used in Hypermesh**
4 node Quad element	SHELL 181
3 node Triangular element	SHELL 181
Rigid Body element	CERIG
Mass Element	MASS 21

2.4 Thickness Definition Using Real Constants

The thickness of the shell may be defined at each of its nodes. The thickness is assumed to vary smoothly over the area of the element. If the element has a constant thickness, only TK (I) needs to be input. If the thickness is not constant, all three thicknesses must be input.

2.5 Constraint Definition

Scheffler is fixed at mounting points. All these mounting points are fixed in all three (xyz) directions. Center node of CERIG is fixed in all direction. Fig. 2.5 shows the support or mounting points which are fixed in all xyz direction as shown by red circles.

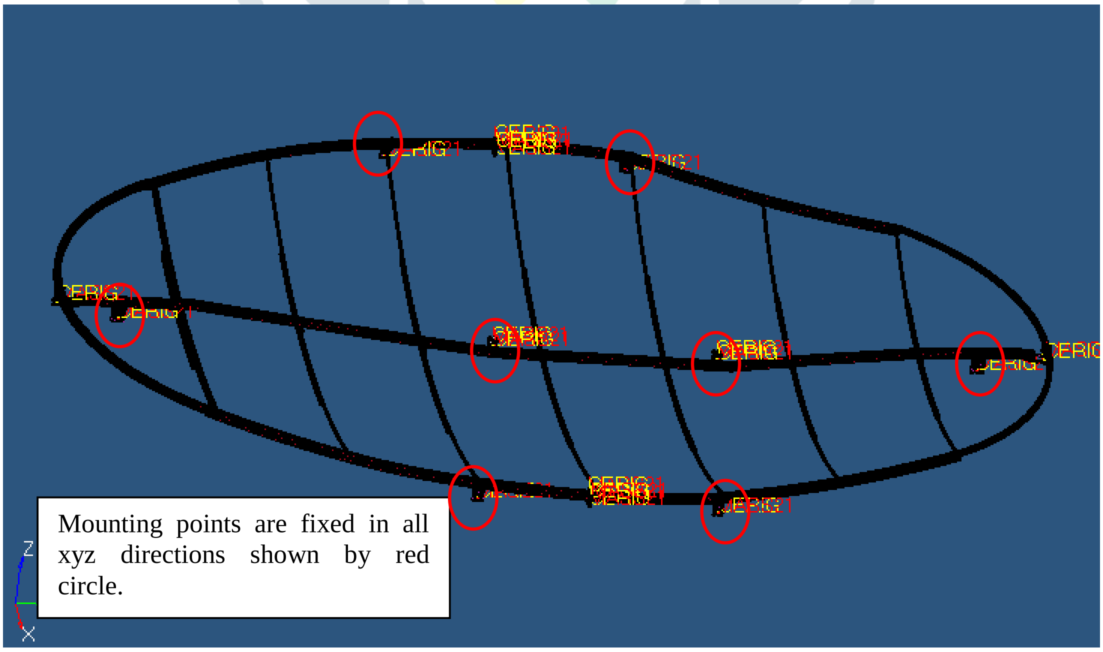

Fig. 2.5 Supports

2.6 Loading Conditions

Main load acting on the Scheffler is wind load. The FEA of Scheffler solar concentrator is based on Static Analysis. The wind load acting on Scheffler concentrator is considered as a static load which is uniformly distributed over the surface of the structure of Scheffler solar concentrator. The wind loads calculation as follows:

The maximum wind speed is 36 km/hr. and minimum wind speed is 10 km/hr. at this region. Therefore the wind speed is taken as maximum.

V = 36 km/hr = 10 m/s

- The density of air at 20°c is 1.205 kg/m^3 and At 40°c is 1.125 kg/m^3 So taking maximum density (ρ) = 1.205 kg/m^3 [30]
- The area of Scheffler solar concentrator (A) = 16 m^2
- The Static load acting on Scheffler

$$P = \rho . A . g . V$$
$$= 16*10*1.205*9.81$$
$$= 1891.36 \text{ N/s}$$

Therefore this static load is uniformly distributed over the total surface of structure. Therefore for analysis purpose the wind load is rounding off then wind load acting on dish is 2000 N. This wind load of 2000 N acted in negative Z direction on Scheffler solar dish. Also weight 150kg of mirrors and Aluminum track are applied by changing the density of material. Therefore due to change in density it increases the total weight of dish by 150 kg. This change in density means to apply the weight of mirror and aluminum track uniformly on dish.

- **The total loading on dish is 2000 N in negative Z direction** as shown in fig. 2.6

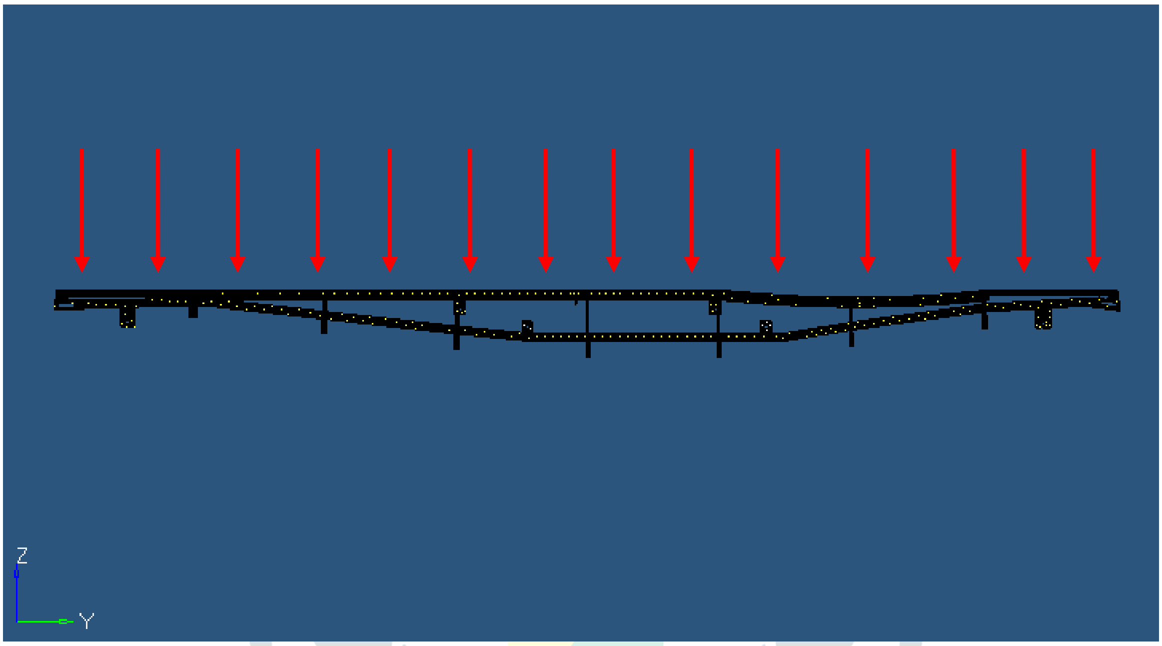

Fig. 2.6 Loading of the 16 m^2 Scheffler solar concentrator

2.7 Geometric Data and Material Properties

a. Geometric Data

In this project the material used for 16 m^2 Scheffler solar dish is Steel and Aluminum. The Total 6 variants of geometry are analysed and compared for both materials.

Table 2.2 Geometrical data for sub variants

Variant	Thickness [mm]	Variant	Thickness [mm]
Steel_2	2.0	Aluminum_2	2.0
Steel_1.5	1.5	Aluminum _1.5	1.5
Steel_1	1	Aluminum _1	1

b. Material Data

Table 2.3 shows geometrical data of sub variants. Steel and Aluminium with thickness is considered 2 mm, 1.5 mm and 1mm for the purpose of analysis.

Both aluminum and steel provides good strength, economic efficiency. They offer high performance at low costs and low weight. Aluminum has low weight; excellent durability and corrosion resistance; manufactured with an environment friendly; process guarantee; a favorable and cost-effective solution. Superior durability and reliability in conjunction with its excellent specific values for costs, performance and weight warrant a favorable solution. Durability, external and internal corrosion resistance are emphasized as essential characteristics of the aluminum.

Table 2.3 Material data isotropic Variant

No.	Material Name	E [N/mm^2]	μ	ρ [kg/mm^3]
1	Aluminum	70000	0.30	2.7E-9
2	Steel	2.1E5	0.30	7.85E-9

III RESULTS AND OBSERVATION

3.1 Analysis of 16 m^2 Scheffler solar concentrator (STEEL)

Total three variants are calculated and results are studied. Fig. 3.1- 3.3 shows analysis of 16 m^2 Scheffler solar concentrator of steel having thickness 1 mm.

Fig. 3.4- 3.6 shows analysis of 16 m^2 Scheffler solar concentrator of steel having thickness 1.5 mm.

Fig. 3.7- 3.9 shows analysis of 16 m^2 Scheffler solar concentrator of steel having thickness 2 mm.

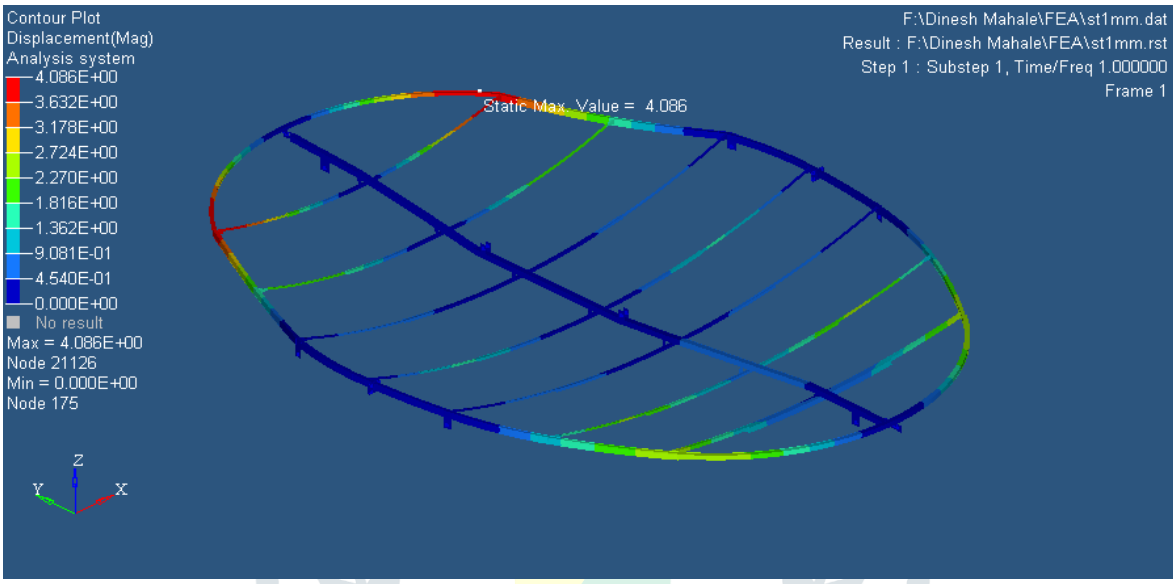

Fig. 3.1 Maximum displacement – 1mm thickness - Steel

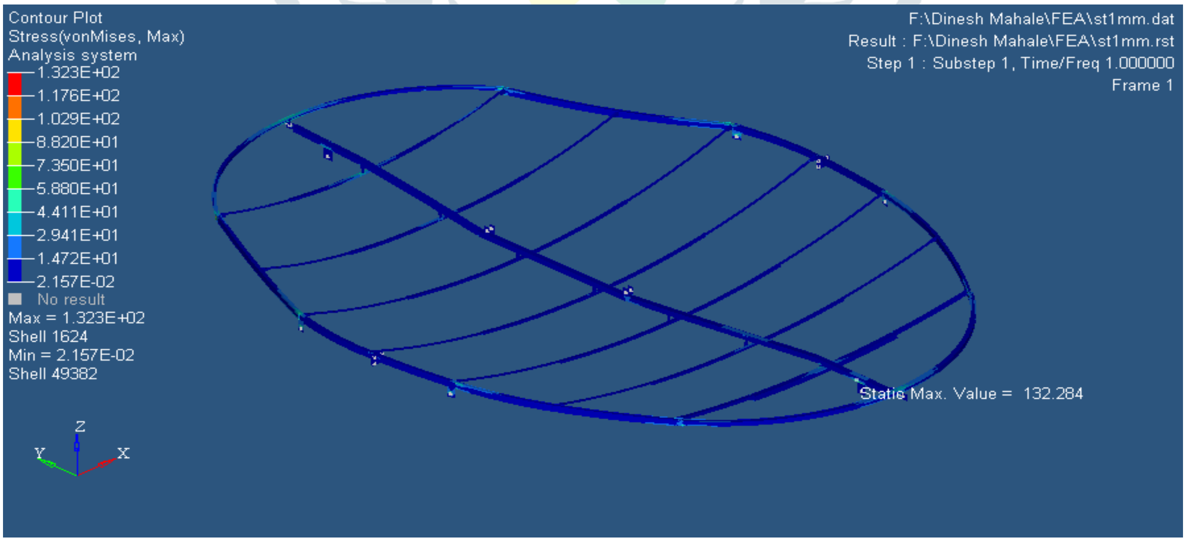

Fig. 3.2 Maximum stress – 1mm thickness - Steel

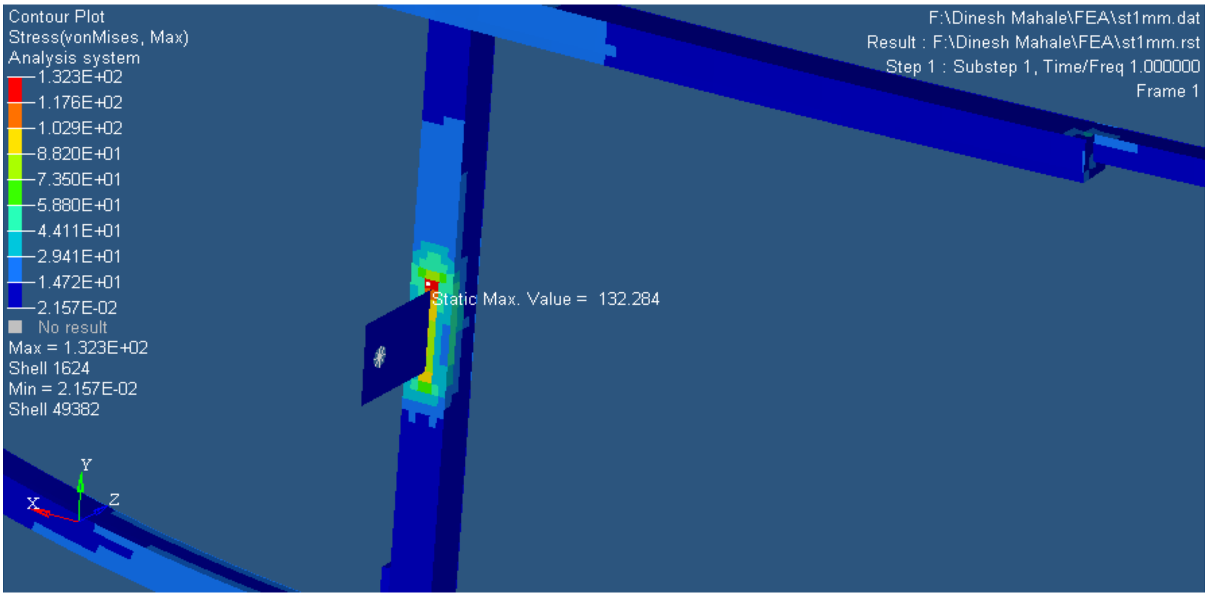

Fig. 3.3 Maximum stress – 1mm thickness - Steel

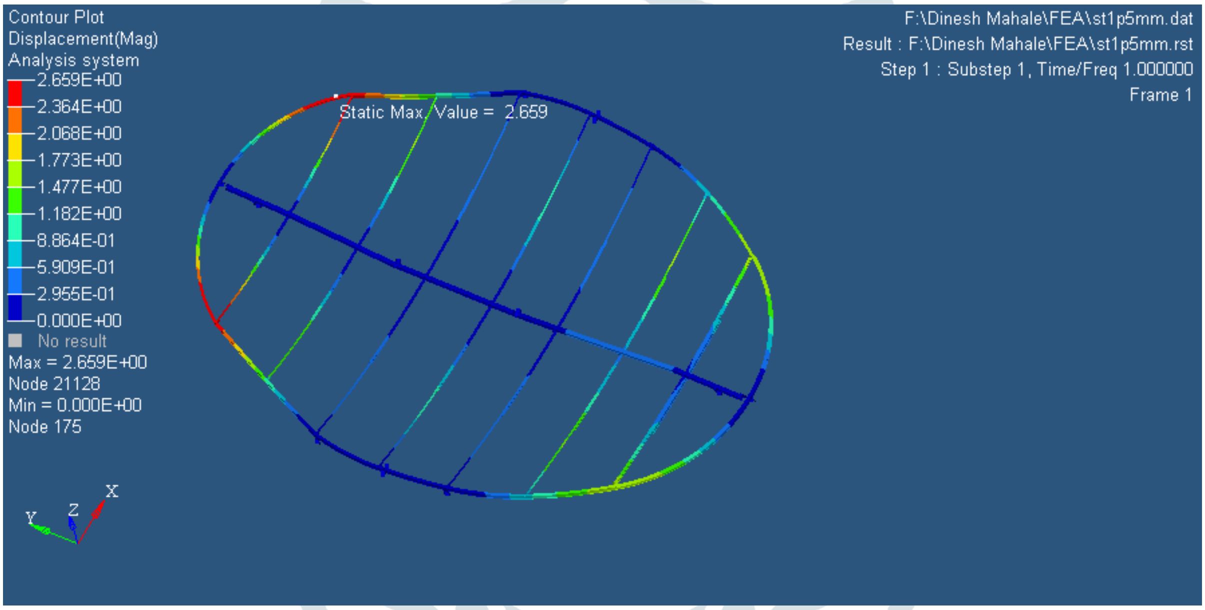

Fig. 3.4 Maximum displacement – 1.5 mm thickness - Steel

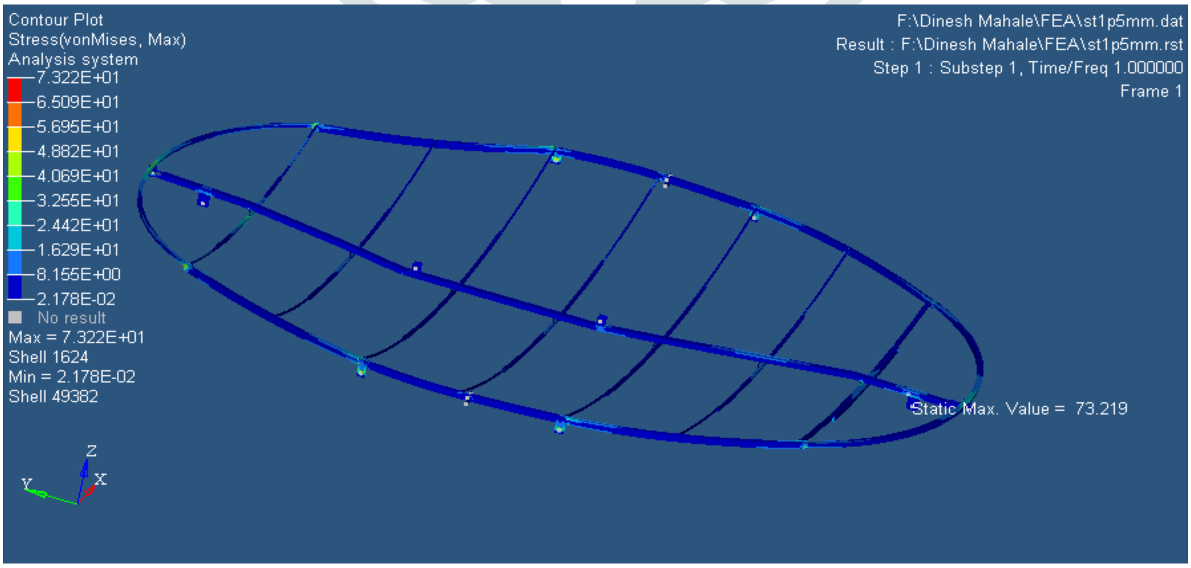

Fig. 3.5 Maximum stress – 1.5 mm thickness - Steel

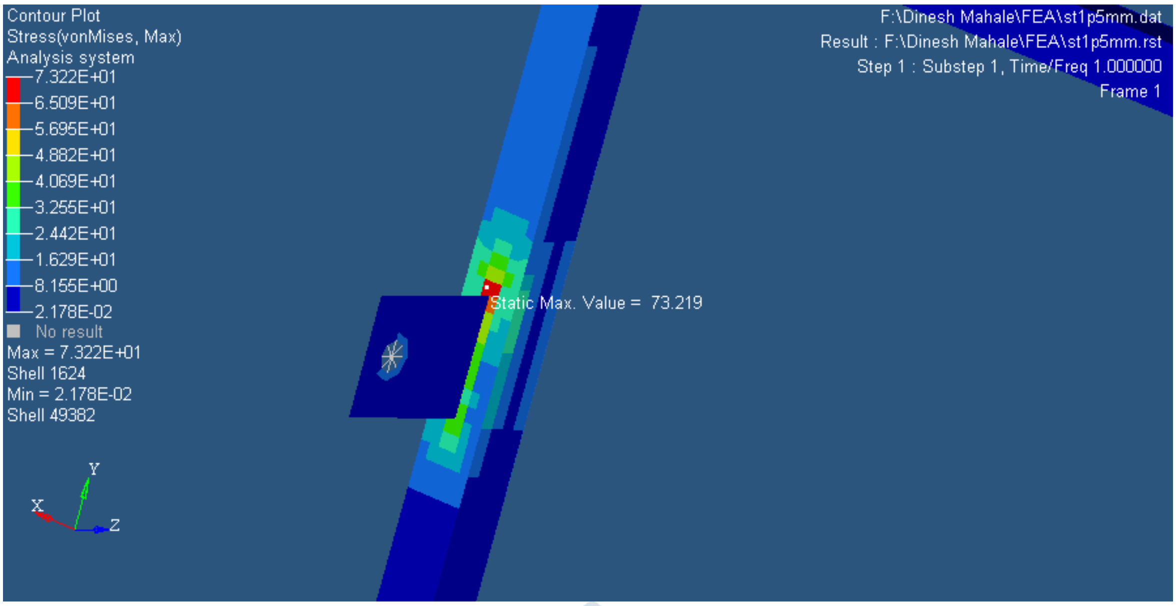

Fig. 3.6 Maximum stress – 1.5 mm thickness – Steel

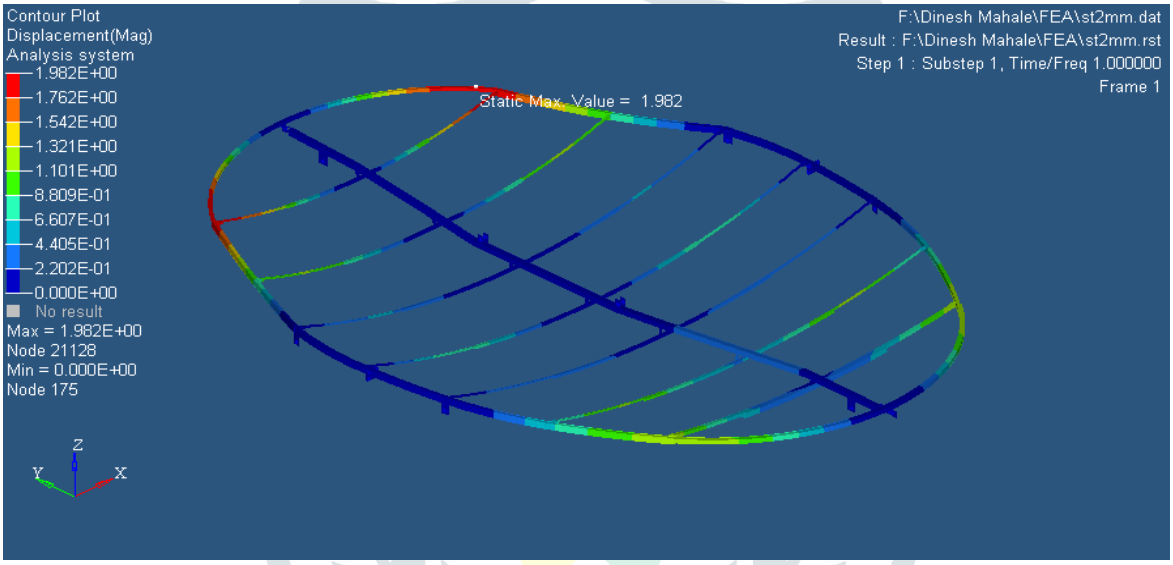

Fig. 3.7 Maximum displacement – 2 mm thickness - Steel

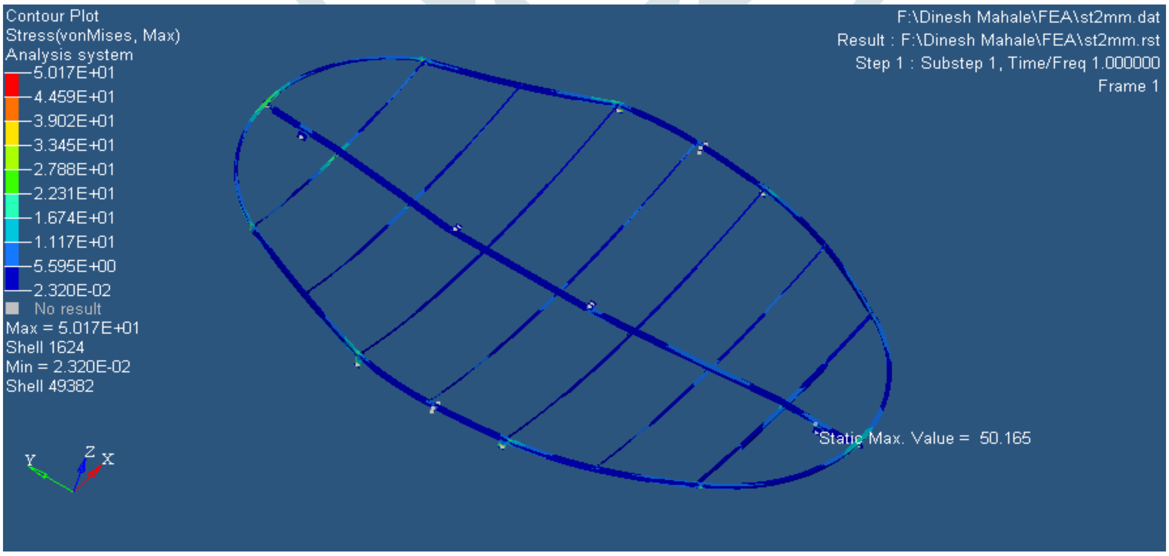

Fig. 3.8 Maximum stress – 2 mm thickness - Steel

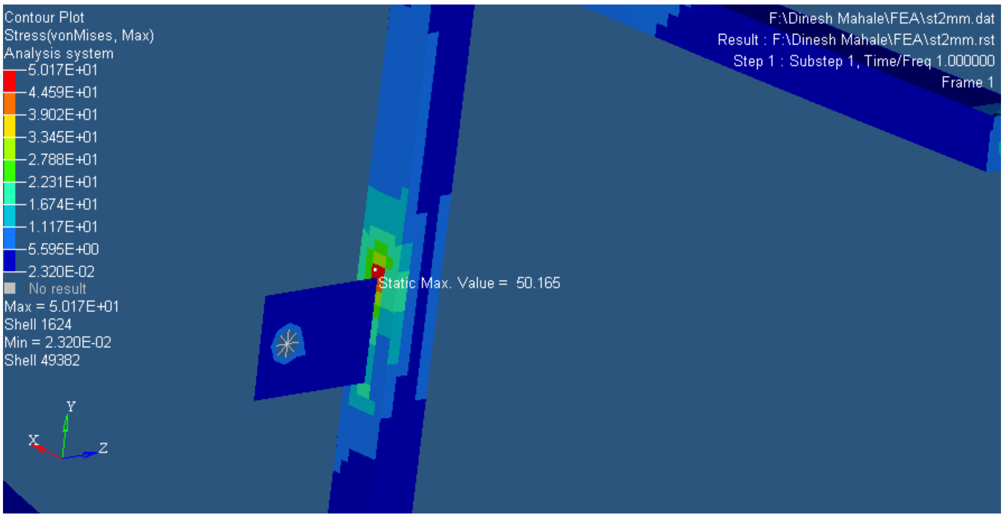

Fig. 3.9 Maximum stress – 2 mm thickness - Steel

3.2 Analysis of 16 m^2 Scheffler solar concentrator (ALUMINUM)

Total three variants are calculated and results are studied. Fig. 3.10- 3.12 shows analysis of 16 m^2 Scheffler solar concentrator of Aluminum having thickness 1 mm.

Fig. 3.13- 3.15 shows analysis of 16 m^2 Scheffler solar concentrator of Aluminum having thickness 1.5 mm

Fig. 3.16- 3.18 shows analysis of 16 m^2 Scheffler solar concentrator of Aluminum having thickness 2 mm.

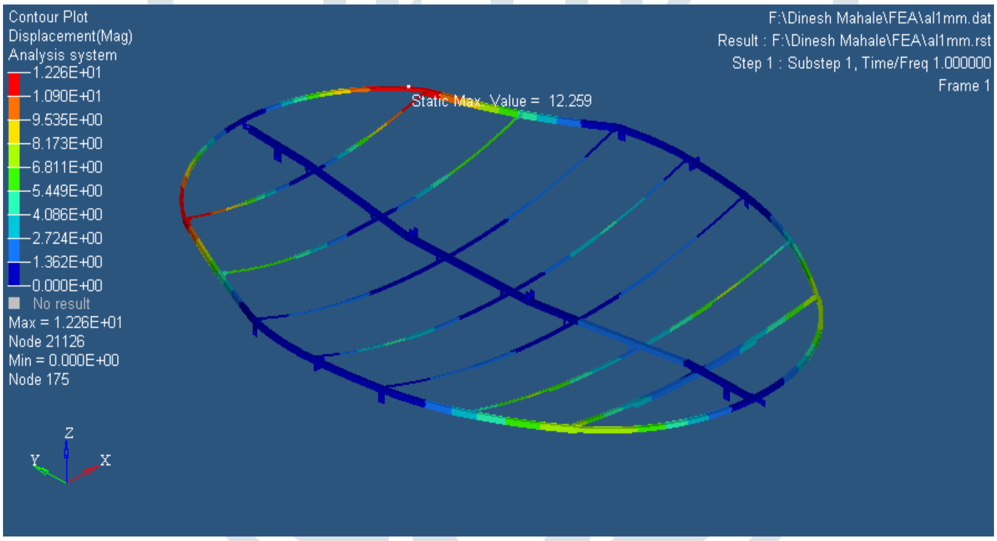

Fig. 3.10 Maximum displacement – 1mm thickness – Aluminum

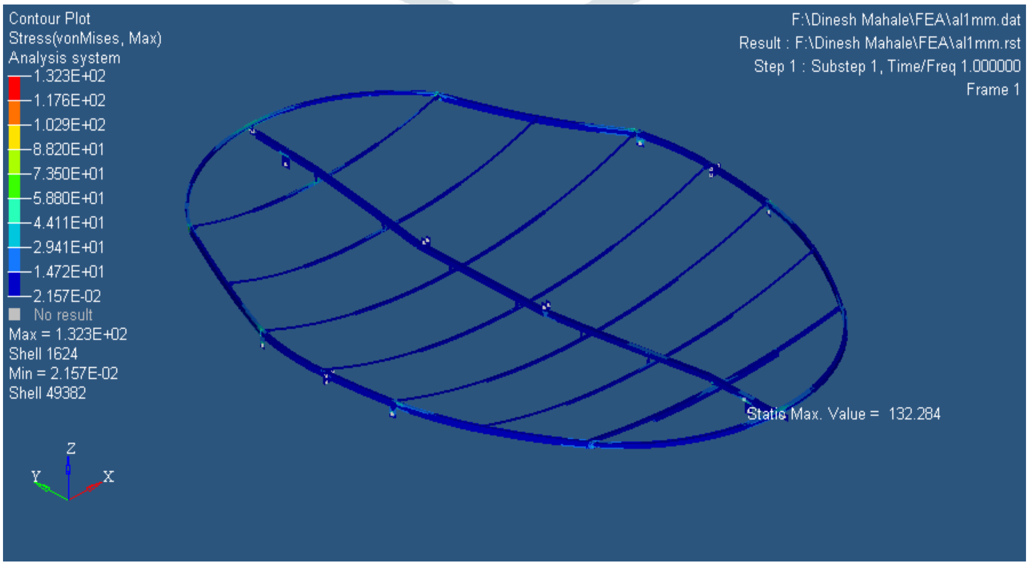

Fig. 3.11 Maximum Stress – 1mm thickness – Aluminum

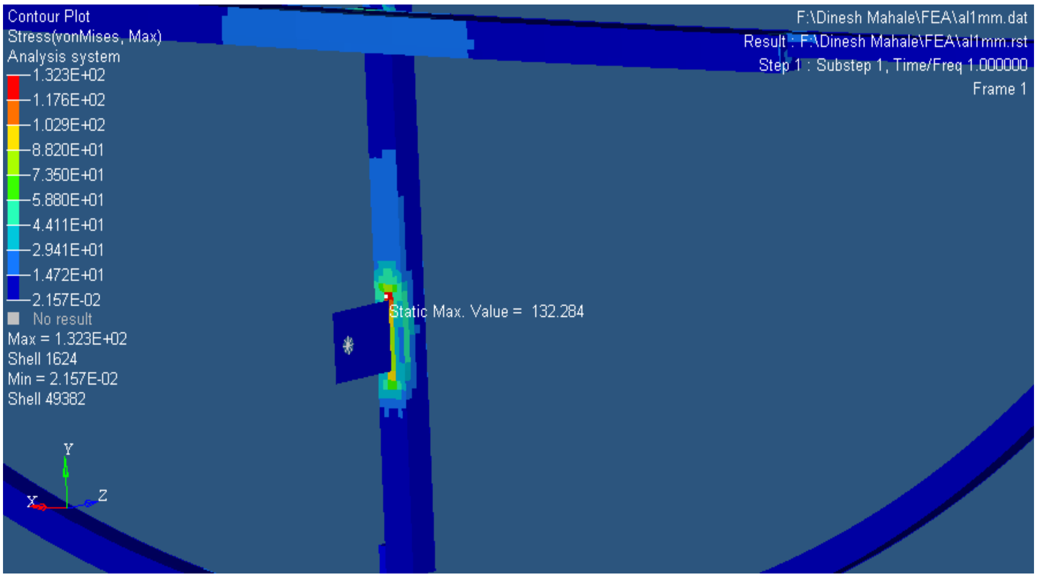

Fig. 3.12 Maximum stress – 1mm thickness - Aluminum

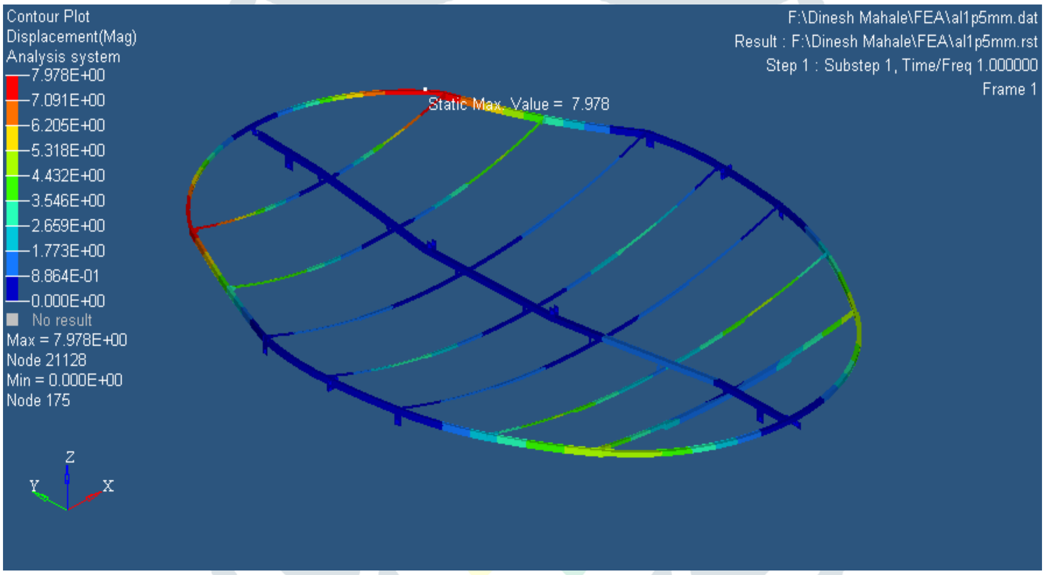

Fig. 3.13 Maximum displacement – 1.5 mm thickness - Aluminum

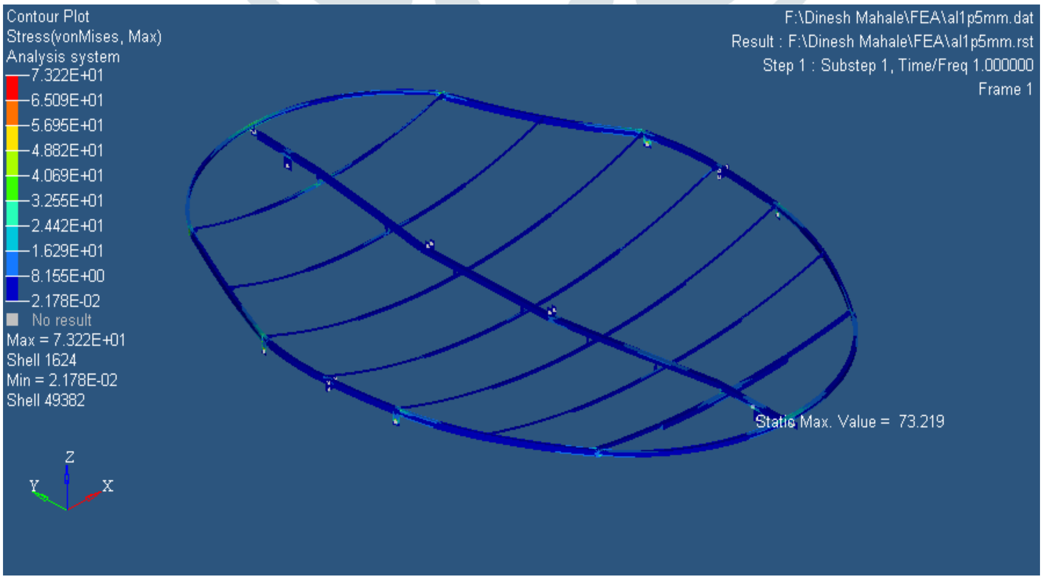

Fig. 3.14 Maximum stress – 1.5 mm thickness - Aluminum

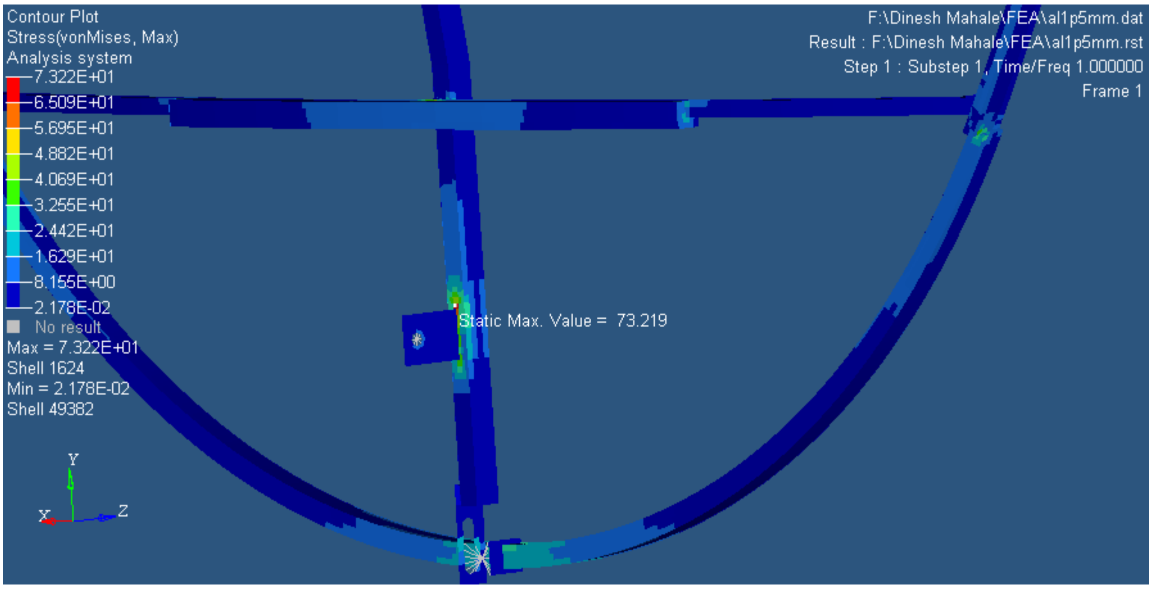

Fig. 3.15 Maximum stress – 1.5 mm thickness - Aluminum

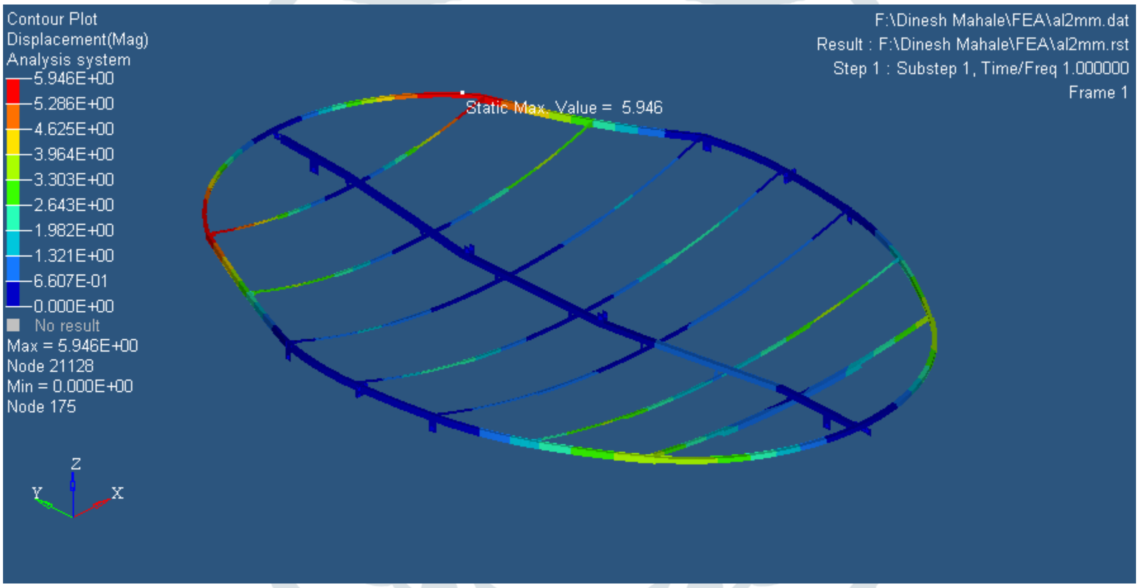

Fig. 3.16 Maximum displacement – 2 mm thickness - Aluminum

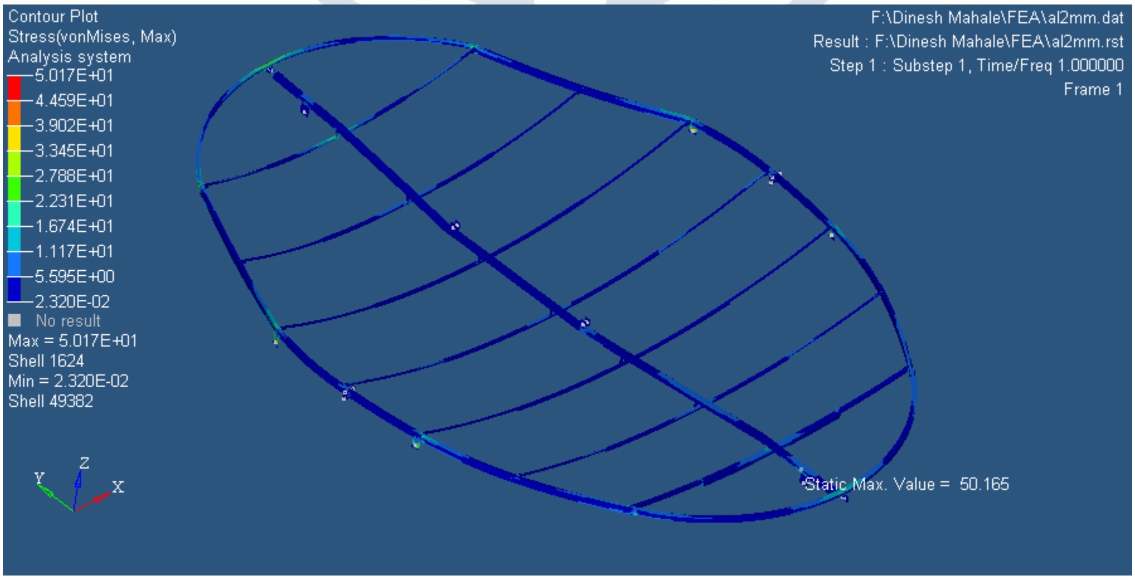

Fig. 3.17 Maximum stress – 2 mm thickness - Aluminum

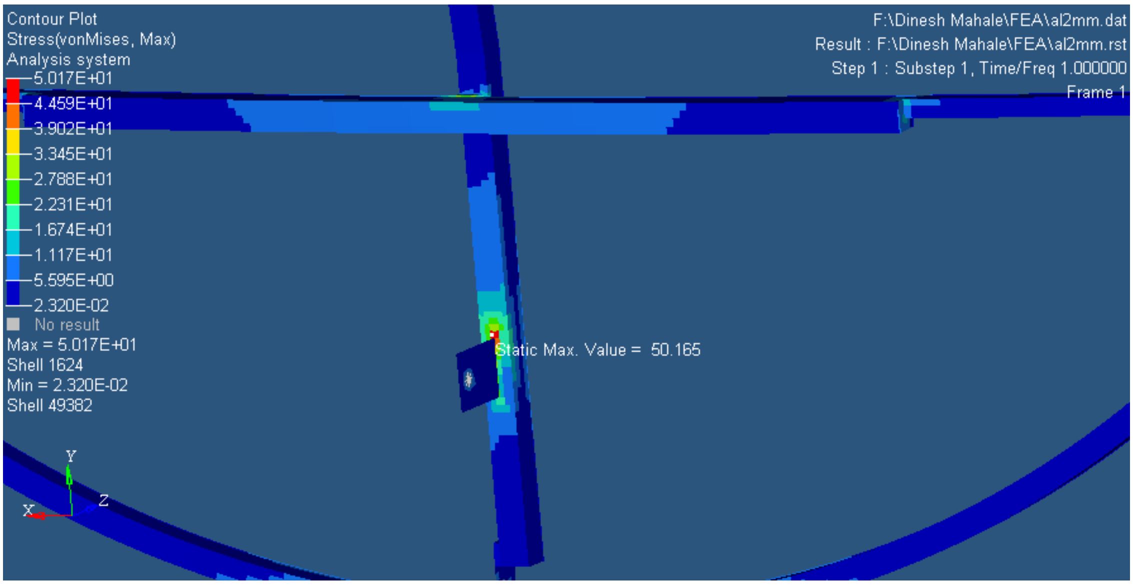

Fig. 3.18 Maximum stress – 2 mm thickness – Aluminum

IV OBSERVATIONS

Table 4.1 Stress and displacement Analysis result

Variant Thickness	**Steel**		**Aluminum**	
	Displacement [mm]	**Stress [Mpa]**	**Displacement [mm]**	**Stress [Mpa]**
1.0 mm	4.086	132.284	12.259	132.284
1.5 mm	2.659	73.219	7.978	73.219
2.0 mm	1.982	50.165	5.946	50.165

Table 4.2 Weights of Scheffler solar concentrator structure

	Weight of Scheffler solar concentrator structure (kg) *(Approximate value)	
Variant Thickness	**For Steel**	**For Aluminum**
2.0 mm	57*	20*
1.5 mm	52*	18*
1.0 mm	47*	16*

From above results and Table 4.1- 4.2 it has been observed that

- All variants show maximum deformation at same location.
- All variants show maximum stress at same location.
- For both steel and aluminum, maximum stress occurred for thickness of 1.0 mm.
- For both steel and aluminum, maximum deformation occurred for thickness of 1.0 mm.
- Maximum deformation of the aluminum is higher than steel for corresponding thickness.
- Yield strength for steel is approx. 250 to 270MPa. Considering 250MPa and factor of safety 2, allowable stress is 125MPa. This shows that variant with thickness of 1.0 mm shows stress beyond allowable limit. Other variants show stress within allowable limit.
- Ultimate strength for aluminum is 250MPa. Considering factor of safety 2, allowable stress is 125MPa. This shows that variant with thickness of 1.0 mm shows stress beyond allowable limit. Other variants show stress within allowable limit.
-

V CONCLUSION AND FUTURE SCOPE

5.1 Concluding Remarks

- Total six different geometrical variants are studied for the effect of force load to get the improved geometry. Optimum is selected on lowest stress basis.
- From Table 4.1 it is observed that out of all variants, variant with 1.0 mm thickness is not suitable for our application.
- For Steel, variant with 2.0 mm thickness is already in working condition. Variant with thickness 1.5 mm can be used. It will reduce total weight by approx. 5 to 6 Kg.
- For Aluminum, variant with 2.0 mm thickness shows less weight than steel by approx. 37 kg. Variant with thickness 1.5 mm can be used. It will reduce total weight by approx. 39 to 40 Kg.
- Approx. Cost of Steel is about 60 – 65 Rs/kg and that of Aluminum is 120 to 140 Rs/kg. Going for Aluminum with 1.5 mm gives huge reduction in the weight of the Scheffler. So overall cost is reducing. But another conclusion is that use of Aluminum for manufacturing of Scheffler is costly so the steel with 1.5 mm is most preferable.
- Design improvement study of the Scheffler is successfully performed resulting in the good cost reduction.

5.2 Future Scope

More result can be obtained with variable loading and with different Latitude angles. That is the same analysis can be extended for different location with different wind velocity.

Further, changing of the dimensions can also play significant role in future work. It leads to the change in the number of cross bar and its geometry.

The analysis can be extended for other size and type of solar concentrator. This dissertation gives input and can acts as reference for CAD design engineer so as to make the optimized design of Scheffler at the initial stages of the design saving lot of time and money in prototyping and ultimately project duration.

This analysis is done using ANSYS Solver however similar result can be obtained using other software.

REFERENCES

[1] Soteris Kalogirou, 2009, Cyprus University of Technology, Solar Energy Engineering, British Library Cataloguing-in-Publication Data, ISBN 978-0-12-374501-9, pp. 01-48.
[2] Idea of Scheffler Solar Concentrator, available from www.solare-bruecke.org.
[3] Wolfgang Scheffler, Introduction to the Revolutionary Design of Scheffler Reflectors, Solare Bruecke, Graf von Werdenbergstr. 6, Aislingen, D-89344, Germany.
[4] J. A. Duffie a. o., 1991, Solar Engineering of Thermal Processes, John Wiley & Sons Inc., USA, 1991.
[5] I. ViJa a. o.,2008, On the Dependence between the Step Orientation and the Received Direct Solar Radiation of a PV Panel, CD Proceedings of The International Conference on Renewable Energy and Power Quality, Santander, Spain, 2008.
[6] R. Lates, I. ViJa, 2005, Solar Collectors – An Overview, Proceedings of Conference of Sustainable Energy, Brasov, Romania, 7-9 July 2005.
[7] Chandak Ajay Girdarilal, Dhule, 2008, Paraboloidal solar concentrator with square/rectangular sections, Indian Patent, Patent no-581/MUM/2008 A, Publish on 23/10/2009.
[8] Kalogirou, S., 2004, Solar Thermal Collectors and Applications. Prog. Energ. Combust.Sci. 30 (3), 231–295.
[9] Delyannis, A., 1967, Solar stills provide island inhabitants with water, Sun at Work 10 (1), 6-8.
[10] Meinel, A.B., Meinel, M.P., 1976, Appl. Solar Energ.—An Introduction, Addison- Wesley Publishing Company, Reading, MA.
[11] Delyannis, E., Belessiotis, V., 2000, The history of renewable energies for water desalination, Desalination 128, 147–159.
[12] Delyannis, E., 2003, Historic background of desalination and renewable energies, Solar Energy 75 (5), 357–366.
[13] Mouchot, A., 1878, Resultat des experiences faites en divers points de l'Algerie, pour l'emploi industrielle de la chaleur solaire [Results of Some Experiments in Algeria, for Industrial Use of Solar Energy], C. R. Acad. Sci. 86, 1019–1021.
[14] Mouchot, A., 1880, Utilization industrielle de la chaleur solaire [Industrial Utilization of Solar Energy]. C. R. Acad. Sci. 90, 1212–1213.
[15] Kreider, J.F., Kreith, F., 1977, Solar Heating and Cooling, McGraw-Hill, New York.
[16] Jordan, R.C., Ibele, W.E., 1956, Mechanical energy from solar energy, In: Proceedings of the World Symposium on Applied Solar Energy, pp. 81–101.
[17] Kreith, F., Kreider, J.F., 1978, Principles of Solar Engineering, McGraw-Hill, New York.
[18] SERI, 1987, Power from the Sun: Principles of High Temperature, Solar Thermal Technology.
[19] Kalogirou, S., 1997, Solar water heating in Cyprus—current status of technology and Problems, Renewable Energy (10), 107–112.
[20] Turner, Clough, Martin,1956, Topp,Analusis of delta wing by beam theory, Journal of Aeronautical Sciences, 1956, Vol. 23, pp 805-823.
[21] El-Sayed, M.E.M. and Lund, E. H., 1990, Structural optimization with fatigue life constraints, Engineering Fracture Mechanics, Vol. 37, No. 6, pp. 1149-1156.
[22] A. Miliozzi, D. Nicolini, G. Arsuffi, L. Sipione 2008, Numerical Evaluation Of Wind Actions On Parabolic Trough Collectors, 8th. World Congress On Computational Mechanics (Wccm8), June 30 – July 5, 2008 Venice, Italy.
[23] Mihai Tiberiu Lates, 2008, Mechanical Behavior Analysis with the Finite Elements Method of Solar Collector's Tracking Systems, WSEAS Transactions On Applied And Theoretical Mechanics, ISSN: 1991-8747, Issue 7, Volume 3, July 2008, p.p 244 to 253.
[24] Rupesh Patil, Gajanan K. Awari and Mahendra P. Singh, 2011, Formulation of Mathematical Model and Neural Network Analysis of Scheffler Reflector, VSRD International Journal of Mechanical, Auto. & Prod. Engg. ISSN No. 2249-8303, Vol. 1 (1), 2011
[25] B.K.Jayasimha,2004, Application Of Scheffler Reflectors For Process Industry, Hadapsar, Pune, India, 2004.
[26] Robert Cook, 2004, Concep1ts and Application of FEA, John Wily, 4/engineering, 2004.
[27] Abu-Zour, A., Riffat, S., 2006, Environmental and economic impact of a new type of solar louver thermal collector, Int. J. Low Carbon Technol, 1 (3), 217–227.
[28] Prof. Ajay Chandak. Dr. S.K. Somani,2009, Design of multistage evaporators for integrating with Scheffler Solar concentrators for food processing applications, International Solar Food Processing Conference 2009.
[29] R. Lates, I. ViJa, C. LLpuJan,2008, Mathematical Optimization of Solar Thermal Collectors efficiency Function Using MATLAB, Proceedings of The 4th IASME / WSEAS International Conference on Energy, Environment, Ecosystems and Sustainable Development (EEESD'08), University of Algarve, Faro, Portugal, 11 – 13 June 2008. pp. 42-46.
[30] The properties of air, Available from, http://www.engineeringtoolbox.com/air-properties-d_156.html
[31] Weather Overview, wind velocity at Dhule, 13 June 2011, Available from http://www.timeanddate.com/weather/india/dhule
[32] Meshing And Modeling Guide, Theory reference for ANSYS and ANSYS workbench**, ANSYS 11.0** tutorials.
[33] Prof. Ajay Chandak, Vikas Gulve, Scheffler Solar concentrator, PRINCE INDIA PVT. LTD. Dhule
[34] "DESIGN DATA", Faculty of Mech. Engg., P.S.G. College of Technology, Coimbtore, © 1968, Revised Edition 1978, Reprinted in May, 2005.