



Research Paper

ANALYSIS OF THERMAL STRESSES OF SOLAR PARABOLIC TROUGH COLLECTOR FOR SOLAR POWER PLANT BY FEM

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When a component is designed, it is necessary to ensure that the stresses induced in that component in actual working conditions are within the specified limits. Also while designing, the economical aspects should also be taken into consideration. So for economical design with adequate mass and inertia and also to improve the product quality, it is necessary to evaluate the stresses induced in the part. There are many reasons because of which parabolic trough get deformed and efficiency of the plant gets lowered. Hence the work in this paper deal with the "evaluation of the thermal stresses in the parabolic trough". For this purpose the finite element analysis technique is used. The analysis is done on the ANSYS software. In this paper the thermal analysis is done by considering the highest temperature of 550°C.

Keywords: Thermal Stresses, Solar power plant, Parabolic trough collector

INTRODUCTION

Shortage of mineral oil and natural gas supplies and increasing demand for electricity have caused many problems on future power supply around the world. And as the population in many countries continues to grow, this demand will continue to increase. One of the renewable source of energy which can significantly contribute to this future energy demand within the next decade the "Solar Concentrated Power Systems (CSP)". All solar technologies make use of sunlight, but they differ in the ways they capture and use solar energy to produce heat or electricity. Most solar water- and space-heating

technologies, for example, use sunlight directly to produce low-temperature heat, while photovoltaic (PV) systems convert sunlight directly to electricity using semiconductor materials in solar panels. The difference of concentrating solar power (CSP) technologies with those systems is that they first concentrate the sun's energy using reflective devices such as troughs or mirror panels and then the resulting concentrated heat energy is transferred to a heat-transfer medium (HTF), which is used to power a conventional turbine and produce electricity.

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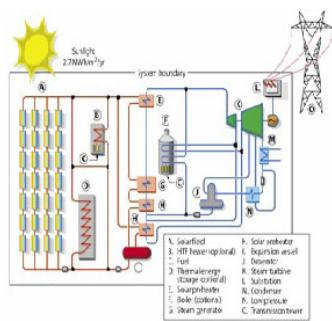
There are three main CSP systems

1. Parabolic trough
2. Solar tower
3. Solar dish

Trough technology is the most advanced one, since it has 354 MW of commercial experience during 20 years. Therefore there's a low technical and financial risk in developing near-term plants. For this reason these systems have received the greatest attention over the years. It is the simplest of the technologies and has the lowest efficiency, but economic factors are favorable thanks to the long commercial experience.

SOLAR PARABOLIC TROUGH TECHNOLOGY FOR POWER GENERATION

Figure 1: Block Diagram of CSP System



This is the form of a CSP system, where the solar collector field is composed of rows of trough shaped solar collector elements, usually mirrors, with an integral receiver tube. This concept is pictured below. The reflectors are parabolic in one dimension only and form a long parabolic shaped trough of up to 150m in length. The collectors are usually installed in rows and the total solar field is composed of several parallel rows. The collectors are connected to a single motor, controlled by a solar tracking control system, which ensures that the maximum amount of sunlight enters

the concentrating system throughout the day. The solar receiver is a black-coated, vacuum glass tube containing the heat transfer fluid, either oil or water. The concentrated sunlight heats the heat transfer fluid to temperatures of up to 400°C, which can be used to generate electricity using a turbine and an electrical generator.

FINITE ELEMENT MODELLING OF PARABOLIC TROUGH

Finite element methods are among the powerful scientific tools which can be used to study in detail the deformation of the trough collector under static weight and various wind-loads, as well as to obtain the natural frequencies and mode shapes of the collector system. In this Appendix the specially designed parabolic trough collector is modeled using CATIA and ANSYS software. For the designing of the trough data have taken from the ASME journal of solar plant. for the stress analysis considered the small part of the trough for the study. The given below diagram shows the trough we are using in solar power plant. The tough is tested against maximum temperature up to 55 degree cen. for the thermal stress analysis.

CATIA MODEL OF THE TROUGH FOR PLANT

The following figure shows the small model of the parabolic trough created on the CATIA software.

Table 1: Detail of Parabolic Trough Collector

Item	Value
Collector aperture area	5.40 m ²
Collector aperture	2.21 m
Aperture to length ratio	0.9
Rim angle	750
Receiver diameter	38 mm
Collector intercept factor	0.9506
Tracking mechanism type	Electronic
Mode of tracking	N-S horizontal

Figure 1: The Above Figure Shows the Complete Model of the Parabolic Trough

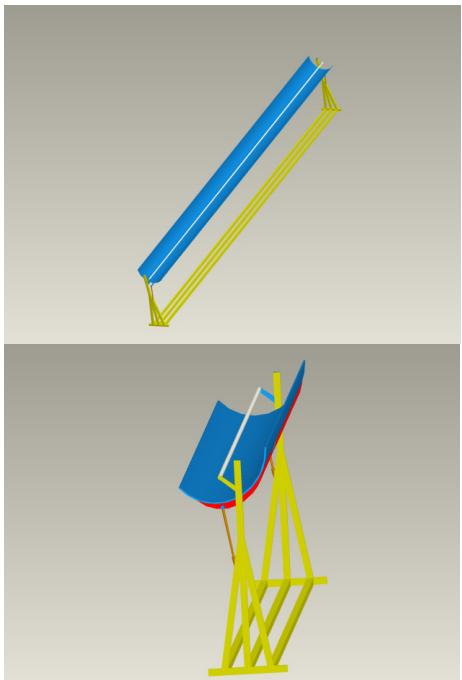
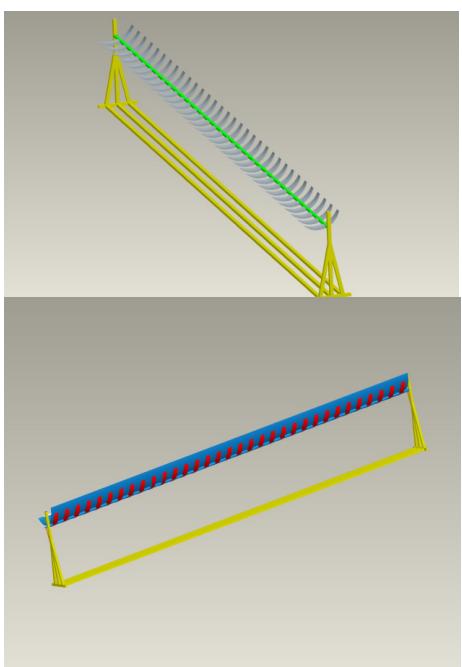


Figure 2: The Above Figure Shows the Support Structure Provided for the Trough



EVALUATION OF THERMAL STRESSES

When the temperature of the body increases or decreases then the expansion or contraction takes place in the body and no stresses produces in the body but when the body is prevented from the deformation then the thermal stresses produces in the body and corresponding strain is known as the thermal strain. Before going to design the parabolic trough it is very needful to calculate the thermal stresses and strain for hot desert area to check its suitability and deformation.

MODEL

The bounding box for the model measures 0.1 by 1.63×10^{-2} by 7.55×10^{-3} m along the global x, y and z axes, respectively.

The model has a total mass of 2.15×10^{-3} kg.

The model has a total volume of 2.74×10^{-7} m³.

Table 1: Bodies

Name	Material	Bounding Box(m)	Mass (kg)	Volume (m ³)	Nodes	Elements
"Solid"	"Structural steel"	0.1, 1.63×10^{-2} , 7.55×10^{-3}	2.15×10^{-3}	2.74×10^{-7}	524 36	2531 2

Mesh:-

"Mesh" associated with "Model" has an overall relevance of 0.

"Mesh" contains 52436 nodes and 25312 elements.

Environment:-

"Environment" contains all loading conditions defined for "Model" in this scenario.

Thermal loading

Table 2: Convection Loads

Name	Figures	Type	Ambient Temperature	Film Coef
"Convection"	A1.3	Constant	0.0°C	0.6 W/m

Table 3: Thermal Loads

Name	Figures	Description	Value	Reaction
"Given Temperature"	A1.4	Surface Temperature	55.0°C	2.68×10^{-3} W

Structural Supports:-

Table 4: Structural Supports

Name	Type	Reaction Force	Reaction Force Vector	Reaction Movement	Reaction Movement Vector
Weak Springs	N/A	5.88×10^{-9} N	$[5.87 \times 10^{-10}$ N x, -5.13×10^{-9} N y, 2.82×10^{-9} N z]	"Given Temperature"	"Given Temperature"

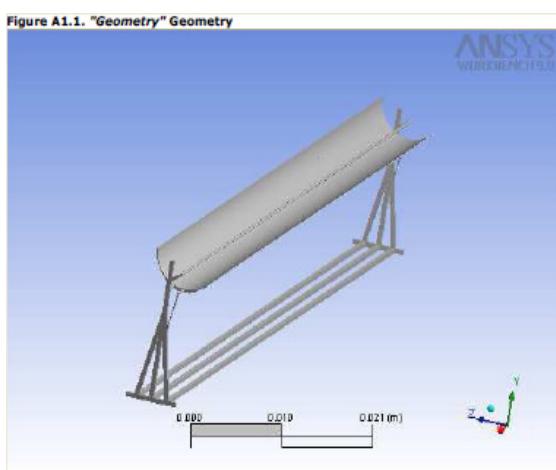
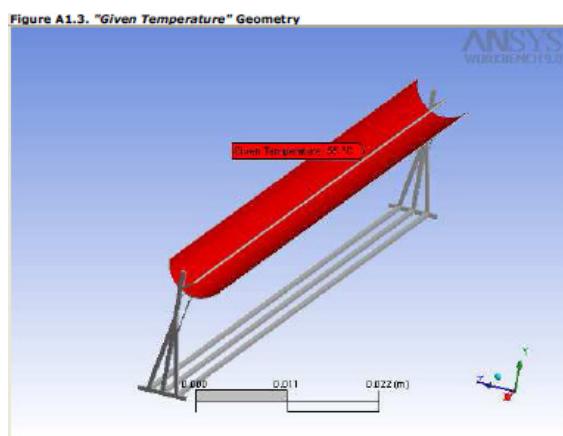
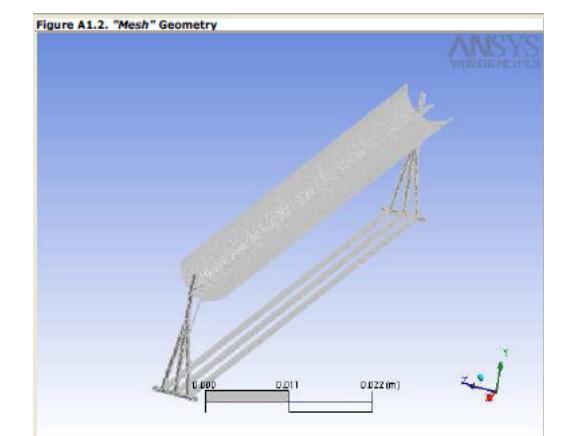
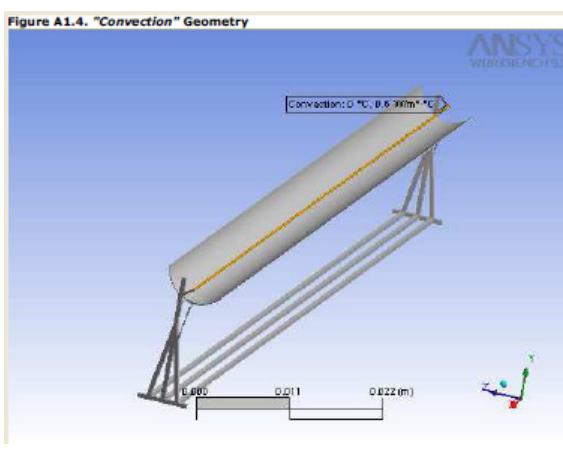
Figure 3: Geometry of Parabolic Trough Collector**Figure 4: Temperature Geometry****Figure 5: Mesh Geometry****Figure 6: Convection Geometry**

Table 5: "Structural Steel" Constant Properties

Name	Value
Compressive Ultimate Strength	0.0 Pa
Compressive Yield Strength	2.5x108 Pa
Density	7850.0 kg/m ³
Ductility	0.2
Poisson's ratio	0.3
Tensile yield strength	2.5x108 Pa
Tensile ultimate strength	4.6x108 Pa
Young's modulus	2.0x108 Pa
Thermal expansion	1.2x108 Pa
Specific Heat	434.0 j/kg.0c
Relative permeability	10,000.0
Resistivity	1.7x105 ohm-m

Table 8: Structural Result

Name	Fig.	Scope	Orientation	Minimum
Maximum shear stress	A1.5	Model	Global	1.72 pa
Directional deformation	A1.6	Model	Y axis	-3.79x10 ⁻⁵ m
Maximum principal elastic strain	A1.7	Model	Y axis	8.53x10 ⁻¹² m/m

was $2.664 \times 10^4 \text{W/m}^x$, the stresses induced were: max. shear stress $2.147 \times 10^7 \text{Pa}$, max. directional deformation $0.036 \times 10^{-4} \text{m}$, max. principal elastic strain $0.191 \times 10^{-3} \text{m/m}$, In this way we have found the stresses induced in the different parts of the parabolic trough collector.

FUTURE SCOPE

From the above results, my ideas are very clear for the optimization of stresses induced in the parabolic trough collector.

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Table 6: Thermal Conductivity

Temperature °C	Thermal conductivity w/m°C
21.0	60.5

Table 7: Strain Life Parameter

Strength coeff.	9.2x108 Pa
Strength exponent	-0.11
Ductility coeff.	0.21
Ductility exponent	-0.47
Cyclic strength coeff. pa	1.0x109 Pa
Cyclic strain hardening component	0.2

CONCLUSION

From the above thermal analysis of parabolic trough collector it is found that at the max. temp. of 55°C considered, the temperature was found from 45.772-55.001°C, the thermal error was $0.176 \times 10^{-4} \text{J}$, total heat flux