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Finite Element Analysis of Ceramic Coating on Heat Pipes for Reducing Heat Emission to the Environment in Thermal Power Plant

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A B S T R A C T

In Thermal Power Plants, large amount of heat is passing through a pipe is easily gets corroded. The salty water that passes through the steel pipe erodes the surface and it reduces the life time of the steel pipe. Hence by means of coating on steel pipe reduce the corrosion and increase the thermal barrier. So that the energy losses and environmental heat pollution could be minimized. Also Environmental Health and safety in industries plays a major role in India and the reduction of Heat radiation to the environment from Thermal Power Plants is a vital criteria to be monitored and controlled scrupulously. In this Project the steel pipes were modeled using CATIA software and analysis was carried out using ANSYS software with different ceramic powders like Alumina, Zirconia and Titania and the results will be compared with un-coated ceramic pipe. These materials given different results. Finally the results were compared with which one of the material gives best quality of the surface and could be utilized for coating on heat pipes in Boiler and Turbine areas of Thermal Power Plant for effective utilization of heat pipes to reduce heat radiation to the environment and the results were presented in the paper.

Keywords: Ceramic coating, Alumina, Titania, Zirconia, ANSYS software

1. Introduction

Coatings have historically been developed to provide protection against corrosion and erosion that is to protect the material from chemical and physical interaction with its environment. Corrosion and wear problems are still of great relevance in a wide range of industrial applications and products as they result in the degradation and eventual failure of components and systems both in the processing and manufacturing industries and in the service life of many components. Various technologies can be used to deposit the appropriate surface protection that can resist under specific conditions. They are usually distinguished by coating thickness: deposition of thin films (below 10 to 20 µm according to authors) and deposition of thick films. The latter, mostly produced at atmospheric pressure have a thickness over 30 µm, up to several millimeters and are used when the functional performance and life of component depend on the protective layer thickness. Both coating technology can also be divided into two distinct categories: ”wet” and” dry” coating methods, the crucial difference being the medium in which the deposited material is processed.

The attainment of high temperatures has been important in the development of civilization for many countries. Structural materials in many front-line high technology areas have to operate under extreme conditions of temperature, pressure and corrosive environment. So, Materials degradation at high temperatures is a serious problem in several high tech industries. Gas turbines in aircraft, fossil fueled power plants, refineries, and petrochemical industries, and heating elements for high temperature furnaces are some examples where corrosion limits their use or reduces their life, considerably affecting the efficiency.

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World-wide, the majority of electricity is generated in coal-fired thermal plants, in which the coal is burned to boil water: the steam so produced is expanded through a turbine, which turns a generator. The steam at the low pressure exit end of the turbine is condensed and returned to the boiler.

Coal is a complex and relatively dirty fuel that contains varying amount of sulfur and a substantial fraction of noncombustible mineral constituents, commonly called ash . The coal used in Indian power stations has large amounts of ash (about 50%), which contain abrasive mineral species such as hard quartz (up to 15%), which increase the erosion propensity of coal.

The vast technical literature available is evidence that corrosion and deposits on the fireside of boiler surfaces or in gas turbines represent important problems. Metals and alloys may experience accelerated oxidation when their surfaces are coated by a thin film of fused salt in an oxidizing gas.

This mode of attack is called hot corrosion, and the most dominant salt involved is Na2SO4. High temperature degradation is one of the main failure modes of hot-section components in the gas turbines, so an understanding of this high temperature oxidation is very necessary.

Solid particle erosion (SPE) is a serious problem for the electric power industry, costing an estimated US$150 million a year in lost efficiency, forced outages, and repair costs. Erosive, high temperature wear of heat exchanger tubes and other structural materials in coal-fired boilers are recognized as being the main cause of downtime at power-generating plants, which could account for 50-75% of their total arrest time. Maintenance costs for replacing broken tubes in the same installations are also very high, and can be estimated at up to 54% of the total production costs.

High temperature oxidation and erosion by the impact of fly ashes and unburned carbon particles are the main problems to be solved in these applications. Therefore, the development of wear and high temperature oxidation protection systems in industrial boilers are a very important topic from both engineering and an economic perspective.

2. Explanation for Methodology

A) *Problem Identification :*

Steel is an alloy material. Two problems are mainly consider for this project, Such as erosion and corrosion.

B) *Data Collection :*

Collection of data from North Chennai Thermal Power Station (stage II) and conducting a detailed study on Ceramic coating on steel pipes for effective.

C) *Identification and Selection of material:*

Metals and alloys may experience accelerated oxidation when their surfaces are coated by a thin film of fused salt in an oxidizing gas. This mode of attack is called hot corrosion. The reduction of corrosion by using ceramic powder like alumina, zirconia and Titania are used for this project.

ALUMINA is a porous, granular substance that is used as a substrate for catalysts and as an adsorbent for removing water from gases and liquids.

ZIRCONIA (Z) is the cubic crystalline form of zirconium dioxide (ZrO_2). The synthesized material is hard, optically flawless and usually colorless, but may be made in a variety of different colors.

TITANIA also known as Titanium Dioxide is the naturally occurring oxide of titanium, chemical formula Tio2. Generally, it is sourced from limonite, rutile and anatase.

D) *Modeling of Steel pipe:*

Modeling of steel pipe by using CATIA software.

E) *Analysis of Steel pipe:*

WITH CERAMIC COATING:

1. Ceramic coating offers good protection of steel pipe surface. It is resistant to corrosion at high temperature.
2. The coating of surface using different techniques such as thermal spraying, plasma spraying etc. ceramic material gives good appearance and shining of the surface.
3. The main advantages of ceramic coating is increasing the life time of the pipe.

WITHOUT COATING:

1. When the power plant produce large amount of heat is passing through a pipe and is easily gets corroded.
2. The salty water that passes through steel pipe erodes the surface and it reduces the life time of the steel pipe.
3. Corrosion is a natural process, which converts a refined metal to a more chemically-stable form, such as its oxide, hydroxide, or sulfide.

F) *Testing Of Coated and Un-coated pipe:*

The main objective of the project is reducing thermal expansion. Normal steel pipe are using a power plant is generate heat from outside of the pipe.

G) *Evaluation of result:*

Three types of ceramic powder are used in this project. These materials give different results. Finally the results are compared with which one of the material gives best quality of the surface.

H) Outcome of the Project:

1. It can prevent the rest formation and scale formation.
2. Maximum temperature uploads the pipeline and temperature cannot affect the ceramic coating.
3. It increase life time of the pipe and it resist to corrosion of material.
4. It has thermal barrier capacity.

3. Softwares: An Overview

A) CATIA:

CATIA is one of the world's leading CAD/CAM/CAE package. Being a solid modeling tool, it not only unites 3D parametric features with 2D tools, but also addresses every design through manufacturing process.

CATIA- **C**omputer **A**ided **D**imensional **I**nteractive **A**pplication**.**

CATIA, developed by Desalt systems, France, is a completely re-engineered, next generation family of CAD/CAM/CAE software solution.

CATIA serves the basic design task by providing different workbenches, some of the workbenches available in this package are

- Part design workbench
- Assembly design workbench
- Drafting workbench
- Wireframe and surface design workbench
- Generative shape design workbench
- DMU kinematics
- Manufacturing
- Mold design

i) PART DESIGN WORKBENCH

The part workbench is a parametric and feature-based environment, in which we can create solid models. In the part design workbench, we are provided with tool those convert sketches into other features are called the sketch-based features.

ii) ASSEMBLY DESIGN WORKBENCH

The assembly design workbench is used to assemble the part by using assembly constraints. There are two type of assembly design,

- Bottom –up
- Top- down

In bottom –up assembly, the parts are created in part workbench and assembled in assembly workbench.

In the top-down workbench assembly, the parts are created in assembly workbench itself.

iii) WIREFRAME AND SURFACE DESIGN WORKBENCH

The wire frame and surface design workbench is also parametric and feature based environment. The tools available in this workbench are similar to those in the part workbench, with the only difference that the tool in this environment are used to create basic and advance surfaces

iv) DRAFTING WORKBENCH

The drafting workbench is used for the documentation of the parts or the assemblies created in the form of drafting.

There are two types of drafting techniques:

- Generative drafting
- Interactive drafting

The generative drafting technique is used to automatically generate the drawing views of parts and assemblies.

In interactive drafting, we need to create the drawing by interactive with the sketcher to generate the views.

v) DMU KINEMATICS

This workbench deals with the relative motion of the parts.DMU kinematics simulator is an independent CAD product dedicated to simulating assembly motions. It addresses the design review environment of digital mock-ups (DMU) and can handle a wide range of products from customer goods to very large automotive or aerospace projects as well as plants, ships and heavy machinery.

B) ANSYS: OVERVIEW

i) ANSYS EVALUATION

ANSYS is a complete FEA simulation software package developed by ANSYS Inc – USA. It is used by engineers worldwide in virtually all fields of engineering.

- StructuralA
- Thermal
- Fluid (CFD, Acoustics, and other fluid analyses)
- Low-and High-Frequency Electromagnetic.

PROCEDURE**:**

Every analysis involves three main steps:

- Pre-processor
- Solver
- post processor

ii) STRUCTURAL ANALYSIS

Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

iii) TYPES OF STRUCTURAL ANALYSIS

The seven types of structural analyses available in the ANSYS family of products are explained below. The primary unknowns (nodal degrees of freedom) calculated in structural analysis are displacements. Other quantities, such strains, stresses and reaction forces, are then derived from nodal displacements. Structural analyses are available in the ANSYS Multiphysics, ANSYS Mechanical, ANSYS Structural, and ANSYS Professional programs only.

STATIC ANALYSIS--Used to determine displacements, stresses, etc. under static loading conditions. Both linear and nonlinear static analyses. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep.

MODAL ANALYSIS--Used to calculate the natural frequencies and mode shapes of a structure. Different mode extraction methods are available.

HARMONIC ANALYSIS--Used to determine the response of a structure to harmonically time-varying loads.

TRANSIENT DYNAMIC ANALYSIS--Used to determine the response of a structure to arbitrarily time-varying loads. All nonlinearities mentioned under Static Analysis above are allowed.

SPECTRUM ANALYSIS--An extension of the modal analysis, used to calculate stresses and strains due to a response spectrum or a PSD input (random vibrations).

BUCKLING ANALYSIS--Used to calculate the buckling loads and determine the buckling mode shape. Both linear (eigenvalue) buckling and nonlinear buckling analyses are possible.

EXPLICIT DYNAMIC ANALYSIS--This type of structural analysis is only available in the ANSYS LS-DYNA program. ANSYS LS-DYNA provides an interface to the LS-DYNA explicit finite element program. Explicit dynamic analysis is used to calculate fast solutions for large deformation dynamics and complex contact problems.

In addition several special-purpose features are available :

- Fracture mechanics
- Composites, Fatigue
- Review the results

iv) ELEMENTS USED IN STRUCTURAL ANALYSES

Most ANSYS element types are structural elements, ranging from simple spars and beams to more complex layered shells and large strain solids. Most types of structural analyses can use any of these elements.

v) MATERIAL MODEL INTERFACE

If we are using the GUI, we must specify the material we will be simulating using an intuitive material model interface. This interface uses a hierarchical tree structure of material categories, which is intended to assist in us choosing the appropriate model for our analysis.

vi) TYPES OF SOLUTION METHODS

Two solution methods are available for solving structural problems in the ANSYS family of products: the h-method and the p-method. The h-method can be used for any type of analysis, but the p-method can be used only for linear structural static analyses. Depending on the problem to be solved, the h-method usually requires a finer mesh than the p-method. The p-method provides an excellent way to solve a problem to a desired level of accuracy while using a coarse mesh. In general, the discussions in this manual focus on the procedures required for the h-method of solution.

vii) STRUCTURAL STATIC ANALYSIS

A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads.

A static analysis can, however, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes).

Static analysis is used to determine the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. The kinds of loading that can be applied in a static analysis include:

- Externally applied forces and pressures
- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (nonzero) displacements
- Temperatures (for thermal strain)
- Fluences (for nuclear swelling)

viii) PERFORMING A STATIC ANALYSIS

The procedure for a static analysis consists of these tasks:

- Build the Model
- Set Solution Controls
- Set Additional Solution Options
- Apply the Loads
- Solve the Analysis

LOAD TYPES

All of the following load types are applicable in a static analysis.

DISPLACEMENTS (UX, UY, UZ, ROTX, ROTY, ROTZ)

These are DOF constraints usually specified at model boundaries to define rigid support points. They can also indicate symmetry boundary conditions and points of known motion. The directions implied by the labels are in the nodal coordinate system.

FORCES (FX, FY, FZ) AND MOMENTS (MX, MY, MZ)

These are concentrated loads usually specified on the model exterior. The directions implied by the labels are in the nodal coordinate system.

PRESSURES (PRES)

These are surface loads, also usually applied on the model exterior. Positive values of pressure act towards the element face (resulting in a compressive effect).

TEMPERATURES (TEMP)

These are applied to study the effects of thermal expansion or contraction (that is, thermal stresses). The coefficient of thermal expansion must be defined if thermal strains are to be calculated. We can read in temperatures from a thermal analysis [LDREAD], or we can specify temperatures directly, using the BF family of commands.

FLUENCES (FLUE)

These are applied to study the effects of swelling (material enlargement due to neutron bombardment or other causes) or creep.

GRAVITY, SPINNING, ETC.

These are inertia loads that affect the entire structure. Density (or mass in some form) must be defined if inertia effects are to be included.

APPLY LOADS TO THE MODEL

Except for inertia loads, which are independent of the model, we can define loads either on the solid model (key points, lines, and areas) or on the finite element model (nodes and elements). We can also apply boundary conditions via TABLE type array parameters. Applying Loads Using TABLE Type Array Parameters) or as function boundary conditions

APPLYING LOADS USING FUNCTION BOUNDARY CONDITIONS

"Loads Applicable in a Static Analysis" summarizes the loads applicable to a static analysis. In an analysis, loads can be applied, removed, operated on, or listed.

ix) COMPOSITES IN ANSYS

Composite materials have been used in structures for a long time. In recent times composite parts have been used extensively in aircraft structures, automobiles, sporting goods, and many consumer products.Composite materials are those containing more than one bonded material, each with different structural properties.

The main advantage of composite materials is the potential for a high ratio of stiffness to weight. Composites used for typical engineering applications are advanced fiber or laminated composites, such as fiberglass, glass epoxy, graphite epoxy, and boron epoxy.

ANSYS allows us to model composite materials with specialized elements called layered elements. Once we build our model using these elements, we can do any structural analysis (including nonlinearities such as large deflection and stress stiffening).

C) MODELING COMPOSITES

Composites are somewhat more difficult to model than an isotropic material such as iron or steel. We need to take special care in defining the properties and orientations of the various layers since each layer may have different orthotropic material properties. In this section, we will concentrate on the following aspects of building a composite model:

- Choosing the proper element type
- Defining the layered configuration
- Specifying failure criteria
- Following modeling and post-processing guidelines

i) CHOOSING THE PROPER ELEMENT TYPE

The following element types are available to model layered composite materials: SHELL99, SHELL91, SHELL181, SOLID46, and SOLID191. Which element we choose depends on the application, the type of results that need to be calculated, and so on. Check the individual element descriptions to determine if a specific element can be used in our ANSYS product. All layered elements allow failure criterion calculations.

- **SHELL99 - Linear Layered Structural Shell Element**

SHELL99 is an 8-node, 3-D shell element with six degrees of freedom at each node. It is designed to model thin to moderately thick plate and shell structures with a side-to-thickness ratio of roughly 10 or greater. For structures with smaller ratios, we may consider using SOLID46. The SHELL99 element allows a total of 250 uniform-thickness layers. Alternately, the element allows 125 layers with thicknesses that may vary bilinearly over the area of the layer. If more than 250 layers are required, we can input our own material matrix. It also has an option to offset the nodes to the top or bottom surface.

- **SHELL91 - Nonlinear Layered Structural Shell Element**

SHELL91 is similar to SHELL99 except that it allows only up to 100 layers and does not allow us to input a material property matrix. However, SHELL91 supports plasticity, large-strain behavior and a special sandwich option, whereas SHELL99 does not. SHELL91 is also more robust for large deflection behavior.

- **SHELL181 - Finite Strain Shell**

SHELL181 is a 4-node 3-D shell element with 6 degrees of freedom at each node. The element has full nonlinear capabilities including large strain and allows 255 layers. The layer information is input using the section commands rather than real constants. Failure criteria are available using the FC commands.

- **SOLID46 - 3-D Layered Structural Solid Element**

SOLID46 is a layered version of the 8-node, 3-D solid element, SOLID45, with three degrees of freedom per node (UX, UY, UZ). It is designed to model thick layered shells or layered solids and allows up to 250 uniform-thickness layers per element. Alternately, the element allows 125 layers with thicknesses that may vary bilinearly over the area of the layer. An advantage with this element type is that you can stack several elements to model more than 250 layers to allow through-the-thickness deformation slope discontinuities. The user-input constitutive matrix option is also available. SOLID46 adjusts the material properties in the transverse direction permitting constant stresses in the transverse direction. In comparison to the 8-node shells, SOLID46 is a lower order element and finer meshes may be required for shell applications to provide the same accuracy as SHELL91 or SHELL99.

- **SOLID191 - Layered Structural Solid Element**

SOLID191 is a layered version of the 20-node 3-D solid element SOLID95, with three degrees of freedom per node (UX, UY, UZ). It is designed to model thick layered shells or layered solids and allows up to 100 layers per element. As with SOLID46, SOLID191 can be stacked to model through-the-thickness discontinuities. SOLID191 has an option to adjust the material properties in the transverse direction permitting constant stresses in the transverse direction. In spite of its name, the element does not support nonlinear materials or large deflections.

In addition to the layered elements mentioned above, other composite element capabilities exist in ANSYS, but will not be considered further in the chapter:

- ✓ **SOLID95,** the 20-node structural solid element, with KEYOPT(1) = 1 functions similarly to a single layered
- ✓ **SOLID191** including the use of an orientation angle and failure criterion. It allows nonlinear materials and large deflections.
- ✓ **SHELL63,** the 4-node shell element, can be used for rough, approximate studies of sandwich shell models.

A typical application would be a polymer between two metal plates, where the bending stiffness of the polymer would be small relative to the bending stiffness of the metal plates.

The bending stiffness can be adjusted by the real constant RMI to represent the bending stiffness due to the metal plates, and distances from the middle surface to extreme fibers (real constants CTOP, CBOT) can be used to obtain output stress estimates on the outer surfaces of the sandwich shell. It is not used as frequently as SHELL91,SHELL99, or SHELL181, and will not be considered for anything other than sandwich structures in this section.

- ✓ **SOLID65,** the 3–D Reinforced Concrete Solid Element, models an isotropic medium with optional reinforcing in 3 different user-defined orientations.
- ✓ **BEAM188** and **BEAM189,** the 3–D finite strain beam elements, can have their sections built up with multiple materials.

ii) ELEMENT TYPE USED IN THE PROJECT:

a) SOLID45 Element Description

SOLID45 is used for the 3-D modeling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions.

The element has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities.

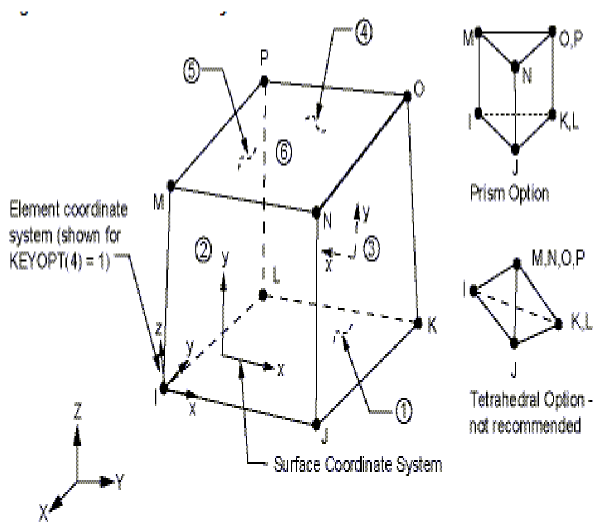

Fig.1 SOLID45 Geometry

b) TARGE170 Element Description:

TARGE170 is used to represent various 3-D "target" surfaces for the associated contact elements (CONTA173, CONTA174, CONTA175, CONTA176 & CONTA177). The contact elements themselves overlay the solid, shell, or line elements describing the boundary of a deformable body and are potentially in contact with the target surface, defined by TARGE170. This target surface is discretized by a set of target segment elements (TARGE170) and is paired with its associated contact surface via a shared real constant set. We can impose any translational or rotational displacement, temperature, voltage, and magnetic potential on the target segment element. we can also impose forces and moments on target elements.

For rigid target surfaces, these elements can easily model complex target shapes. For flexible targets, these elements will overlay the solid, shell, or line elements describing the boundary of the deformable target body.

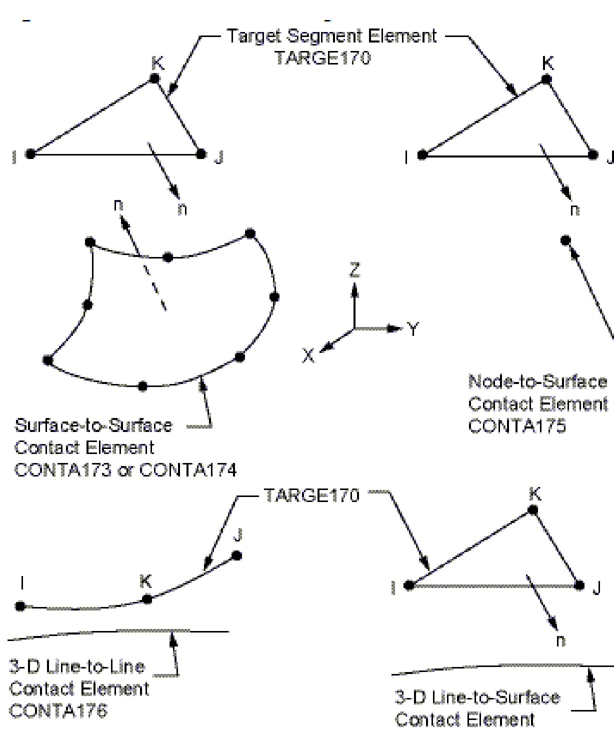

Fig.2 TARGE 170 Geometry

4. Experimental Analysis of Heat Pipe Using Catia & Ansys Software

A) INPUT PARAMETERS REQUIRED :

Boiler & Turbine Pipes Specification:

Boiler Pipes:

Material	:	Carbon Steel
Outer Diameter (OD)	:	51 mm
Temperature	:	300 ^{0}C to 1400 ^{0}C

Turbine pipes:

Material	:	P91 Alloy Steel
Temperature at Inlet	:	540 ^{0}C
Temperature at Outlet	:	350 ^{0}C
Pipe OD at Inlet/thick & Outlet OD/thick at HP Turbine area	:	447/43 mm & 965/37 mm

Total Heat Flux : It is defined as the amount of heat transferred per unit area per unit time from a surface.

B) CERAMIC POWDER AND THEIR PROPERTIES:

Sl. No.	Name of Ceramic Powder for Coating used	Melting Point temp in ^{0}C	Boiling Point temp in ^{0}C	Appearance
1.	ALUMINA or Aluminium oxide (Al2O3)	2072 ^{0}C	2977 ^{0}C	White Solid
2.	ZIRCONIA or Zirconium dioxide (Zro2)	2715 ^{0}C	4300 ^{0}C	White Powder
3.	TITANIA or Titanium dioxide (TiO2)	1843 ^{0}C	2972 ^{0}C	White Solid

The Experimental Analysis and Results find out using CATIA & ANSYS SOFTWARE photos are shown below:

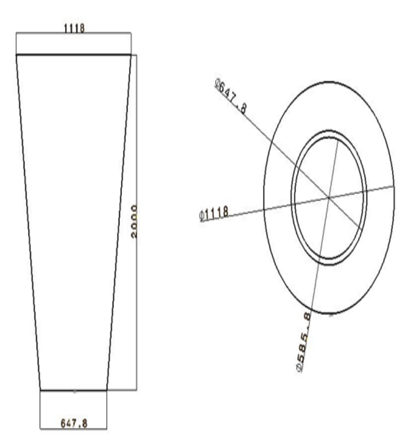

Fig.3 2D Model – CATIA Software

International Journal of Research Publication and Reviews Vol (2) Issue (3) (2021) Page 80-92

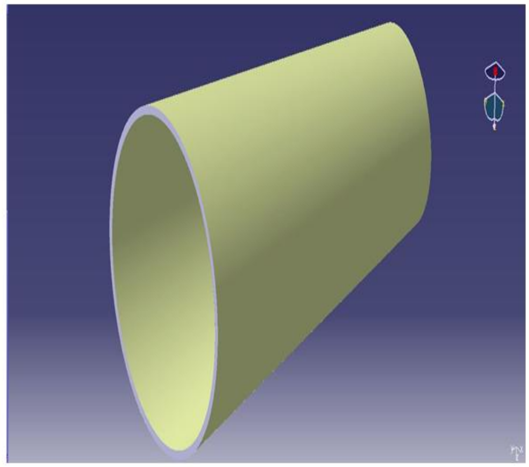

Fig.4 D Model – CATIA Software – Ceramic coated pipe

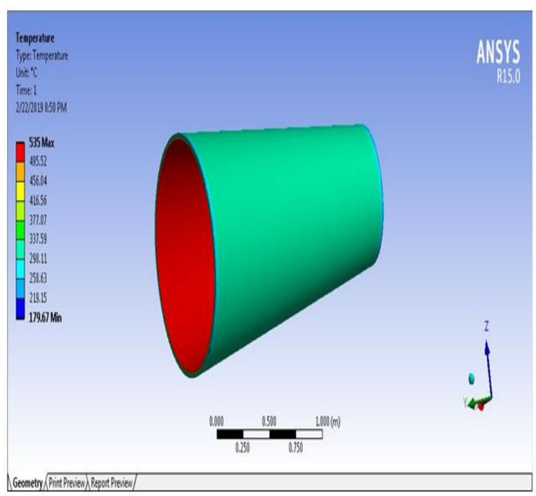

Fig.5 ALUMINA Powder coating –Temperature

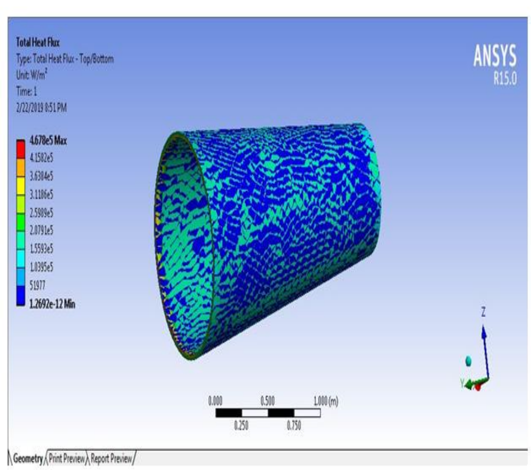

Fig.6 ALUMINA Powder coating – Total Heat Flux

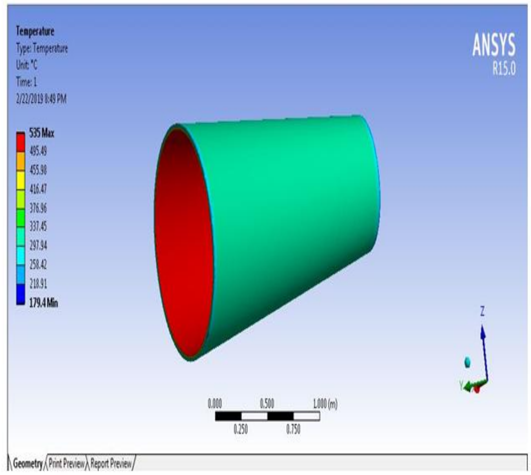

Fig.7 TITANIA Powder coating – Temperature

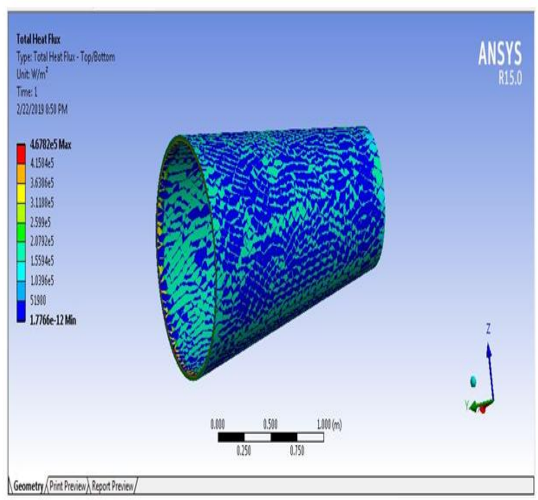

Fig.8 TITANIA Powder coating – Total Heat Flux

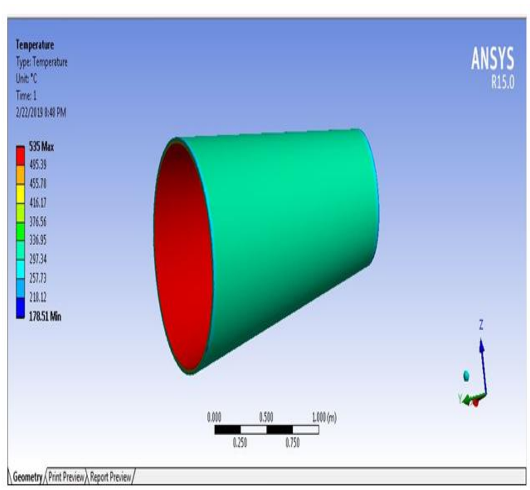

Fig.9 ZIRCONIA Powder coating – Temperature

International Journal of Research Publication and Reviews Vol (2) Issue (3) (2021) Page 80-92

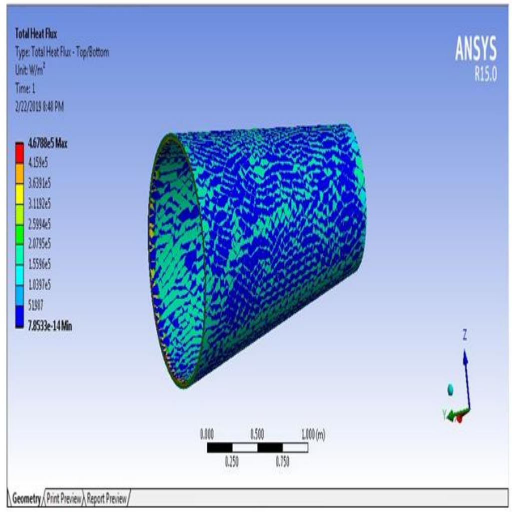

Fig.10 ZIRCONIA Powder coating – Total Heat Flux

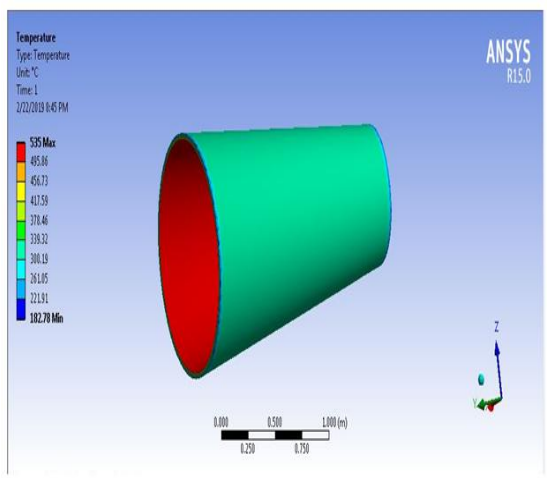

Fig.11 Uncoated pipe – Temperature

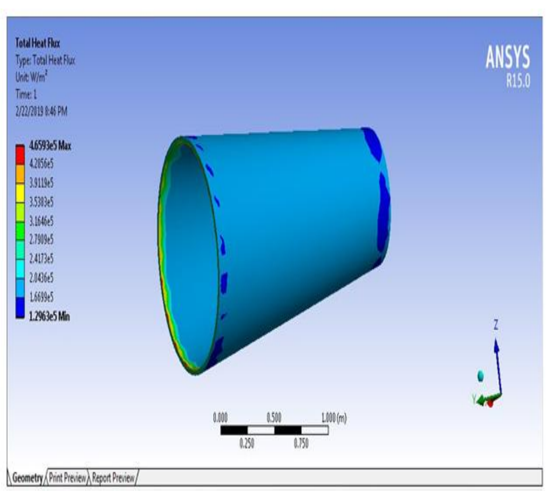

Fig.12 Uncoated pipe – Total Heat Flux

5. Results And Discussion

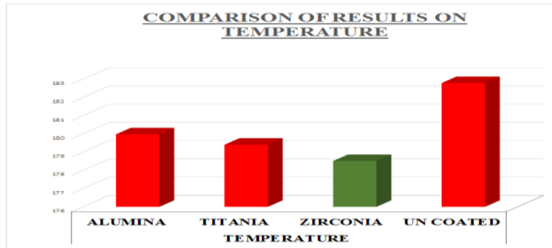

Fig.13 Comparison of Results on temperature using Bar Chart

From the above comparison of results on Temperature criteria, it is clearly find out that Boiler & Turbine pipes coating with Zirconia Powder will leads to less temperature release to the atmospheric environment is identified. By the way, Instead of Insulation on pipes the above coating will give good heat resistant capability would be achieved.

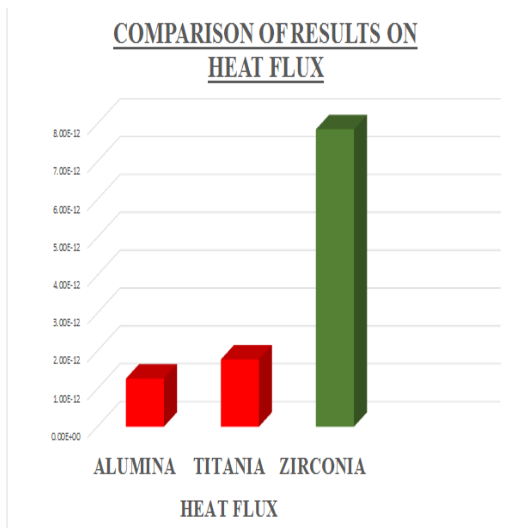

Fig.14 Comparison of Results on Heat flux using Bar Chart

From the above comparison of results on Heat Flux criteria, it is clearly find out that Boiler & Turbine pipes coating with Zirconia Powder will leads to High heat flux absorbance cum less heat release to the atmospheric environment is identified and successful results would be achieved.

COMPARISION OF RESULTS ON TEMPERATURE – BEFORE AND AFTER COATING

Sl. No	Description of Item (Without Insulation of Pipe)	Temperature in deg °C
1.	Outside Temperature of the Turbine pipe (Before coating)	60°C
2.	Outside Temperature of the Turbine pipe (After coating with Alumina Powder)	39°C
3.	Outside Temperature of the Turbine pipe (After coating with Titania Powder)	35 °C
4.	Outside Temperature of the Turbine pipe (After coating with Zirconia Powder)	32 °C (Maintained Atmospheric Temperature)

Fig.15 Comparison of Results on Temperature – Before and After Coating

From the above comparison of results on Before and after coating on heat pipes with various Ceramic Powders such as Alumina, Titania and Zirconia, it is understood that Boiler & Turbine pipes coating with Zirconia Powder will gives best results on heat absorbance on the pipes and simultaneously very minimum heat release to the atmospheric environment is identified and successful results would be achieved.

6. Conclusions

- In Thermal Power Generating stations, hot corrosion and erosion in boilers, Turbines and its related components/ pipes are responsible for huge losses (both direct & indirect losses) during power generation. Moreover, Environmental Health and safety in industries plays a major role in India and the reduction of Heat radiation to the environment from Thermal Power Plants is a vital criteria to be monitored and controlling measures should be taken scrupulously.

- The salty water that passes through the steel pipe erodes the surface and it reduces the life time of the steel pipe. An understanding of these problems and thus to develop suitable protective Coating system is essential for maximizing the utilization of such components. So that the energy losses and environmental heat pollution could be minimized.

- In this project work, various Data was collected from North Chennai Thermal Power Station/ Stage II/ Ennore/Chennai-120 and conducted a detailed study on Ceramic coating on steel pipes and their performances in reducing heat emission to the environment. For that, three types of ceramic powders such as Alumina, Titania and Zirconia were utilised for Finite Element Analysis on heat pipes. The Computer softwares such as CATIA and ANSYS were used for modeling and experimental purposes respectively. Those three ceramic powders gave different results.

- From the above Comparative and Finite element experimental analysis it was understood that, Ceramic coating on Boiler and Turbine heat pipes using **"ZIRCONIA"** powder given best results when compared with Alumina and Titania Powder coating for attaining least heat emission to the environment from Heat pipes, instead of using Insulation wool for covering pipes in Thermal Power Plants. By this method, environmental heat pollution from thermal power plants could be reduced effectively.

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