IJARSCT International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

Impact Factor: 6.252
Volume 2, Issue 8, June 2022

# Design and Analysis of Insulation of Pipe Carrying Hot Fluid Using Composite Materials

**Prof. R. A. Solunke[1] Mr. Mandar Sutar[2], Ms. Jalindar Sure[3], Mr.Romit More[4], Mr. Parag Sondkar[5]**

Assistant Professor, Mechanical Engineering, NBNSSOE, Pune, India[1]
UG Student, Mechanical Engineering, NBNSSOE, Pune, India[2,3,4,5]

**Abstract:** *Fiber-reinforced composites are a well-recognized option for repair and rehabilitation of the pipelines for the oil and gas industry. The filled composite sleeve system provides an effective rehabilitation solution, where the sleeve acts as prime reinforcement without any direct contact with steel. However, the long-term performance of the repair is dependent, in part, on the effect of hydrothermal ageing of the composites. In this publication, the main application of the insulation pipe is taken as used in Industry. The CFD analysis is performed on the normal pipe without insulation and then performed with insulation of composite material like glass fiber. Compared the temperature results of 2 iterations and evaluated the optimized model for the insulation pipe.*

**Keywords:** Fibre-reinforced Composites, Hydrothermal Ageing, CFD, Simulation, etc.

## I. INTRODUCTION

The purpose of insulation is to reduce the heat being dissipated from our system to the surroundings in this case we are only considering insulation of a pipe carrying hot fluid therefor pipe is our system. When the pipe is carrying hot fluid mostly steam in the power plants to strike on the turbine and rotate with high speed in terns to generate electricity, we know from the third law of thermodynamics that when the temperature of the steam is more than more amount of energy is produced and more electricity is generated. When the steam travels through pipe to the turbine, substantial quantity of heat energy is wasted due to dissipation of this heat to the environment through the pipe. To reduce this dissipation of heat to the surrounding we need to insulate the walls of the pipes. Properly designed and installed insulation system will immediately increase the efficiency, improve productivity and enhanced environmental quality.

## II. LITERATURE SURVEY

Dr. Sara Mangs in this paper entitled "Insulation materials in district heating pipes" explained that, the aim of this thesis is to investigate the long-term thermal and environmental performance of district heating pipes insulated with foam made of polyethylene terephthalate (PET) and polyurethane (PUR). Two main comparisons have been considered:

- Cyclopentane and 1,1,1,3,3- pentafluoro butane (HFC-365mfc) as blowing agents in PUR foam.
- PET and PUR foam insulation the insulating capacity of district heating pipes deteriorates over time due to the mass transport of insulating gas out of and air into the foam insulation.

The main part of the work was focused on determining the thermal aging characteristics of the foams. During the use of district heating pipes, emissions from the heat produced to compensate for the heat losses gives rise to environmental impacts. From an environmental perspective, the entire life-cycle of the pipes: pipe production, network construction, network use and post-use handling is of importance, although the use phase produces the greatest environmental impacts [Fröling 2002a, Fröling 2004a, Fröling 2004b, Persson 2005c]. [1]

Dr. Bahman Zohuri in this paper entitled "Basic principles of heat pipe and history" explained that, the original idea of heat pipe was considered in 1944 by Gaugler and in 1962 by Trefethen. Although Gaugler patented a very lightweight heat transfer device, that was essentially a very basic presentation of heat pipe. During that time period, the technology did not require a need for such sophisticated yet constructively simple two-phase and passive heat transfer device, and there was not much attention that was paid to it. First suggested by Trefethen in 1962 and then was appeared through a patent application of heat pipe again in 1963 by Wyatt. It was not widely considered and publicized until 1964 when George Grove and his co-worker at the Los Alamos National Laboratory independently reinvented the same concept for their existing space program and its application.

He is the one who named this most satisfactory and simplistic heat transmission device “heat pipe” and developed its applications. Heat pipes are two-phase flow heat transfer devices where a process of liquid to vapor and vice versa circulates between evaporator and condenser with high effective thermal conductivity. Due to the high heat transport capacity, heat exchanger with heat pipes has become much smaller than traditional heat exchangers in handling high heat fluxes. With the working fluid in a heat pipe, heat can be absorbed on the evaporator region and transported to the condenser region where the vapor condenses releasing the heat to the cooling media.

Heat pipe technology has found increasing applications in enhancing the thermal performance of heat exchangers in microelectronics; energy saving in classical heating, ventilating, and air conditioning (HVAC) systems for operating rooms, surgery centers, hotels, clean rooms, etc.; temperature regulation systems for the human body; and other industrial sectors including spacecraft and various types of nuclear reactor technologies as a fully inherent cooling apparatus. The heat pipe is a self- contained structure which achieves very high thermal energy conductance by means of two-phase fluid flow with capillary circulation.

A heat pipe operates within a two-phase flow regime as an evaporation–condensation device for transferring heat in which the latent heat of vaporization is exploited to transport heat over long distances with a corresponding small temperature difference. Heat added to the evaporator is transferred to the working fluid by conduction and causes vaporization of the working fluid at the surface of the capillary structure. Vaporization causes the local vapor pressure in the evaporator to increase and vapor to flow toward the condenser, thereby transporting the latent heat of vaporization. Since energy is extracted at the condenser, the vapor transported through the vapor space is condensed at the surface of the capillary structure, releasing the latent heat. Closed circulation of the working fluid is maintained by capillary action and/or bulk forces. An advantage of a heat pipe over other conventional methods to transfer heat such as a finned heat sink is that a heat pipe can have an extremely high thermal conductance in steady-state operation. Hence, a heat pipe can transfer a high amount of heat over a relatively long length with a comparatively small temperature differential.

Heat pipe with liquid-metal working fluids can have a thermal conductance of a thousand or even tens of thousands folds better than the best solid metallic conductors, silver or copper. In a heat pipe energy is transported by utilizing phase change of the working substance instead of a large temperature gradient and without external power. Also, the amount of energy transferred through a small cross section is much larger than that by conduction or convection. Heat pipes may be operated over a broad range of temperatures by choosing an appropriate working fluid. However, this useful device has some operating limitations such as the sonic, the capillary, the entrainment, and finally the boiling limit, which will be discussed throughout the book. When any of these limitations is encountered, the capillary structure may dry out leading to failure of the heat pipe. In addition to these limitations, when liquid metal is used as the working fluid, start-up difficulty may take place due to possible solid state of the working fluid and extremely low vapor density.[2]

Dr. Dipen Kumar Rajak in this paper entitled "Fiber reinforced polymer composites manufacturing, properties and application" explained that, Rapid growth in manufacturing industries has led to the need for the betterment of materials in terms of strength, stiffness, density, and lower cost with improved sustainability.

Volume 2, Issue 8, June 2022

Impact Factor: 6.252

Composite materials have emerged as one of the materials possessing such betterment in properties serving their potential in a variety of applications. Composite materials are an amalgamation of two or more constituents, one of which is present in the matrix phase, and another one could be in particle or fiber form. The utilization of natural or synthetic fibers in the fabrication of composite materials has revealed significant applications in a variety of fields such as construction, mechanical, automobile, aerospace, biomedical, and marine Research studies from the past two decades have presented composites as an alternative over many conventional materials as there is a significant enhancement in the structural, mechanical, and tribological properties of fiber-reinforced composite (FRC) material. Though composite materials succeeded in increasing the durability of the material, currently a strong concern regarding the accumulation of plastic waste in the environment has arisen.

This concern has compelled researchers around the world to develop environmentally friendly materials associated with cleaner manufacturing processes. Several different composite recycling processes also have been developed to cope with the thousands of tons of composite waste generated in a year. Mechanical recycling includes pulverization, where decreased sized recycles are being used as filler materials for sheet moulding compounds. In thermal recycling, degradation of composite waste by pyrolysis is done or an enormous amount of heat energy is obtained by burning composite materials with a high calorific value. There also exist more efficient processes such as chemical recycling (solvolysis) and high-voltage fragmentation (HVF). The addition of natural fillers such as natural fibers, cellulose nanocrystals, and nano fibrillated cellulose in the polymers matrix to fabricate eco-friendly composites has improved material properties while minimizing the problem regarding residue accumulation.

## III. PAPER CONTENT

### Composite Material

A composite material is a combination of two materials with different physical and chemical properties. When they are combined, they create a material which is specialized to do a certain job, for instance to become stronger, lighter or resistant to electricity. They can also improve strength and stiffness. The reason for their use over traditional materials is because they improve the properties of their base materials and are applicable in many situations.

Some common composite materials include:

- **Ceramic matrix composite:** Ceramic spread out in a ceramic matrix. These are Glass Fiber Material. The strength of glass is usually tested and reported for "virgin" or pristine fibers those that have just been manufactured. The freshest, thinnest fibers are the strongest because the thinner fibers are more ductile. The better than normal ceramics as they are thermal shock and fracture resistant.
- **Metal matrix composite:** A metal spread throughout a matrix.
- **Reinforced concrete:** Concrete strengthened by a material with high tensile strength such as steel reinforcing bars.
- **Glass Fiber reinforced concrete:** Concrete which is poured into a glass Fiber structure with high zirconia content.
- **Translucent concrete:** Concrete which encases optic Fibers.
- **Fiberglass:** Glass Fiber combined with a plastic which is relatively inexpensive and flexible.
- **Carbon Fiber reinforced polymer:** Carbon Fiber set in plastic which has a high strength-to-weight ratio carbon or plastic the surface is scratched, the less the resulting tenacity. Because glass has an amorphous structure, its properties are the same along the fiber and across the fiber. Humidity is an important factor in the tensile strength. Moisture is easily adsorbed and can worsen microscopic cracks and surface defects, and lessen tenacity.

  In contrast to carbon fiber, glass can undergo more elongation before it breaks. Thinner filaments can bend further before they break. The viscosity of the molten glass is very important for manufacturing success. During drawing, the process where the hot glass is pulled to reduce the diameter of the fiber, the viscosity must be relatively low. If it is too high, the fiber will break during drawing. However, if it is too low, the glass will form droplets instead of being drawn out into a fiber.

Uses for regular glass fiber include mats and fabrics for thermal insulation, electrical insulation, sound insulation, high strength fabrics or heat and corrosion resistant fabrics. It is also used to reinforce various materials, such as tent poles, polevault poles, arrows, bows and crossbows, translucent roofing panels, automobile bodies, hockey sticks, surfboards, boat hulls, and paper honeycomb. It has been used for medical purposes in casts. Glass fiber is extensively used for making FRP tanks and vessels. Open-weave glass fiber grids are used to reinforce asphalt pavement. Non-woven glass fiber polymer blend mats are used saturated with asphalt emulsion and overlaid with asphalt, producing a waterproof, crack resistant membrane. Use of glass fiber reinforced polymer rebar instead of steel rebar shows promise in areas where avoidance of steel corrosion is desired.

**Carbon Fiber Material**

Carbon fiber is frequently supplied in the form of a continuous tow wound onto a reel. The tow is a bundle of thousands of continuous individual carbon filaments held together and protected by an organic coating, or size, such as polyethylene oxide (PEO) or polyvinyl alcohol (PVA). The tow can be conveniently unwound from the reel for use. Each carbon filament in the tow is a continuous cylinder with a diameter of 5–10 micrometers and consists almost exclusively of carbon.

The earliest generation (e.g., T300, HTA and AS4) had diameters of 16–22 micrometers. Later fibers (e.g., IM6 or IM600) have diameters that are approximately 5 micrometers. The atomic structure of carbon fiber is similar to that of graphite, consisting of sheets of carbon atoms arranged in a regular hexagonal pattern (graphene sheets), the difference being in the way these sheets interlock. Graphite is a crystalline material in which the sheets are stacked parallel to one another in regular fashion. The intermolecular forces between the sheets are relatively weak Van der Waals forces, giving graphite its soft and brittle characteristics.

**Properties of Major Insulation Materials**

Insulations are defined as those materials or combinations of materials which retard the flow of heat energy by performing one or more of the following functions:

- Conserve energy by reducing heat loss or gain.
- Control surface temperatures for personnel protection and comfort.
- Facilitate temperature control of process.
- Prevent vapour flow and water condensation on cold surfaces.

Increase operating efficiency of heating/ventilating/cooling, plumbing, steam, process and power systems found in commercial and industrial installations.

- Prevent or reduce damage to equipment from exposure to fire or corrosive atmospheres.
- Assist mechanical systems in meeting criteria in food and cosmetic plants.
- Reduce emissions of pollutants to the atmosphere.

There are many insulating products on the market today which cover all temperature ranges and all conceivable installation situations. Although there are too many products to mention, it is important to have a good understanding of some of the different products available and their applications. One must have a grasp of the correct method of insulation construction and be able to understand a works specification. The temperature range within which the term "thermal insulation" will apply, is from -75°C to 815°C. All applications below -75 are termed "cryogenic", and those above 815 are termed "refractory".

**Calcium Silicate**

Plumbing, steam, process and power systems found in commercial and industrial installations.

- Prevent or reduce damage to equipment from exposure to fire or corrosive atmospheres.
- Assist mechanical systems in meeting criteria in food and cosmetic plants.
- Reduce emissions of pollutants to the atmosphere.

There are many insulating products on the market today which cover all temperature ranges and all conceivable installation situations. Although there are too many products to mention, it is important to have a good understanding of some of the different products available and their applications. One must have a grasp of the correct method of insulation construction and be able to understand a works specification. The temperature range within which the term "thermal insulation" will apply, is from -75°C to 815°C. All applications below -75□ are termed "cryogenic", and those above 815□ are termed "refractory".

**A. Calcium Silicate**

Service temperature range covered is 35°C to 815°C. Flexural and compressive strength is good. Calcium silicate is water absorbent. However, it can be dried out without deterioration. The material is non-combustible and used primarily on hot piping and surfaces. Jacketing is field applied.

**B. Mineral Fiber**

Glass: Available as flexible blanket, rigid board, pipe covering and other pre-moulded shapes. Service temperature range is -40°C to 232°C. Fibrous glass is neutral; however, the binder may have a pH factor. The product is non-combustible and has good sound absorption qualities.

Rock and Slag: Rock and slag Fibers are bonded together with a heat resistant binder to produce mineral Fiber or wool. Upper temperature limit can reach 1035°C. The same organic binder used in the production of glass Fiber products is also used in the production of most mineral fiber products. Mineral Fiber products are non-combustible and have excellent fire properties.

**C. Cellular Glass**

Available in board and block form capable of being fabricated into pipe covering and various shapes. Service temperature range is -273C to 200°C and to 650°C in composite systems. Good structural strength, poor impact resistance. Material is non- combustible, non-absorptive and resistant to many chemicals.

**D. Expanded Silica, Or Perlite**

Insulation material composed of natural or expanded perlite ore to form a cellular structure; material has a low shrinkage coefficient and is corrosion resistant; non-combustible, it is used in high and intermediate temperature ranges. Available in pre-formed sections and blocks.

**E. Elastomeric Foam**

Foamed resins combined with elastomers to produce a flexible cellular material. Available in pre-formed sections or sheets, Elastomeric insulation offer water and moisture resistance. Upper temperature limit is 105□. Product is resilient. Fire resistance should be taken in consideration.

**F. Foamed Plastic**

Insulations produced from foaming plastic resins create predominately closed cellular rigid materials. "K" values decline after initial use as the gas trapped within the cellular structure is eventually replaced by air. Check manufacturers' data. Foamed plastics are light weight with excellent cutting characteristics. The chemical content varies with each manufacturer.

**G. Refractory Fiber**

Refractory Fiber insulations are mineral or ceramic Fibers, including alumina and silica, bonded with extremely high temperature inorganic binders, or a mechanical interlocking of Fibers eliminates the need for any binder. The material is manufactured in blanket or rigid form. Thermal shock resistance is high. Temperature limits reach 1750°C.

## IV. DESIGN OF PROPOSEDWORK

**Insulation of Material and Application**

The purpose of insulation is to reduce the heat being dissipated from our system to the surroundings in this case we are only considering insulation of a pipe carrying hot fluid therefor pipe is our system. When the pipe is carrying hot fluid mostly steam in the power plants to strike on the turbine and rotate with high speed in terns to generate electricity, we know from the third law of thermodynamics that when the temperature of the steam is more than more amount of energy is produced and more electricity is generated. When the steam travels through pipe to the turbine, substantial quantity of heat energy is wasted due to dissipation of this heat to the environment through the pipe. To reduce this dissipation of heat to the surrounding we need to insulate the walls of the pipes. Properly designed and installed insulation system will immediately increase the efficiency, improve productivity and enhanced environmental quality. Composite Materials are replacing conventional materials in various fields. Also, we are finding out the Composite Materials having improved properties than that of the conventional ones as the research is progressing day by day in this field.

**Low Temperature Range**

The major design problems on low temperature installations are moisture penetration and operating efficiency. For below ambient applications, insulation should have low moisture absorption. Vapour retarders are extensively used, but in practice it is difficult to achieve the perfect retarder in extreme applications. The pressure of the vapour flow from the warm outside surface to the cooler inside surface is such that, even with waterproof insulation, vapour may diffuse through the material, enter through unsealed joints or cracks, and condense, then freeze and cause damage. Since the cost of refrigeration is higher than the cost of heating, more insulation is often justifiedin low temperature applications.

The low temperature range is further divided into application classifications. Refrigeration (0°C through -75°C) Water vapour which passes through the vapour-retarder will not only condense, but will freeze. Built up frost and ice will destroy the insulation system.

Cold and chilled water (15°C through 0°C) unless properly insulated, water vapour will condense on the metal causing corrosion and failure of the insulation assembly. The presence of the vapour retarder should be no higher than 0.02 Perms. The insulations generally used in this temperature range are:

- Cellular Glass
- Elastomeric Foamed Plastic
- Glass Fiber
- Mineral Fiber
- Phenolic (foamed)
- Polyethylene
- Polyisocyanurate
- Polyurethane

**Intermediate Temperature Range**

This temperature range includes conditions encountered in most industrial processes and the hot water and steam systems necessary in commercial installations. Selection of material in this range is based more on its thermal values than with low temperature applications.

However, other factors such as mechanical and chemical properties, availability of forms, installation time, and costs are also significant. The materials generally used in the intermediate range are:

- Calcium Silicate
- Cellular Glass

## V. CONCLUSION AND DISCUSSION

In this paper we developed a database of composite materials and finding out their thermal conductivities with the help of mathematical models as discussed in the research papers and validating the results obtained from that with the help of Experimentation. And then to get them in use on the pipe carrying hot fluid in the industries. Different composite samples are to be distinguished based upon following parameters:

-  Different resin.
-  Different fibers.
-  Effect of heat flow direction.
-  Fiber volume fraction.
-  Effect of additive materials and particle size of additive.
-  Different manufacturing methods.

## REFERENCES

[1] Dr. Sara Mangs,"Insulation materials in district heating pipes", Close-up of PET foam, Vol.33 (14), 2005, page no.17.

[2] Dr. Bahman Zohuri,"Basic principles of heat pipe and history"https://www. researchgate. Net/publication/ 301721981, Vol. 12(11), April 2016, page no.1.

[3] Dr. Dipen Kumar Rajak, Durgesh D. Pagar, Pradeep L. Menezes and Emanoil Linul,"Fiber reinforced polymer composites: manufacturing, properties, and appli cation", doi:10.3390/polym11101667, Vol.23(21) September 2019, Page no.3.

[4] Dr. Md Shamsuddoha "Mechanical and thermal properties of glass fiber-vinyl ester resin composite for pipeline repair exposed to hot-wet conditioning": Journal of Composite Materials, Vol. 51(11), and May 2017.

[5] Dr. Her-Yung Wang, Kao-Halo Chang “Effect of high temperature on the strength and thermal conductivity of glass fiber concrete”, Wei-Chien Wang, Shao Yu Wang.https://doi.org/10.1016/j.conbuildmat. 2020.118387.Vol 9(12), Feb 2010.

[6] Dr. Ohk Kun Lim, Woo Jun You “Evaluating the fire risk of pipe insulation depending on installation conditions, Case Studies in Thermal Engineering https:// doi.org/10.1016/j.csite.2020.100673, Vol 7(65), Received 12 May 2020.