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Steam Pipe Insulation using Silica Aerogel and Coconut Fibre Composite

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Abstract: Thermal insulation is the reduction of the heat transfer between objects in thermal contact area. The act of insulation is accomplished by encasing an object in material with low thermal conductivity. Thermal insulation provides a region of insulation in which thermal conduction is reduced. Low thermal conductivity is equivalent to high insulating capability. Thermal insulation is mainly used in where the heat transfer rate is high. Thermal industries generally use cotton ropes, mineral wool, glass wool, polyethylene, saw dust as insulators etc.... From the literature survey it has been found that there are other insulators which are more effective than the conventional insulators. Silica aerogel which act as good insulator. It has a low density, low thermal conductivity of 0.017W/m K. It is equivalent to high insulating capability. Coconut fiber is a natural fiber extracted from the husk of coconut. Coconut fiber has a thermal conductivity ranging from 0.046 to 0.068W/m K which was close to those conventional insulation materials such as cellulose fiber and mineral wool. In this experimental work the effectiveness of steam pipe insulation with silica aerogel and coconut fiber as insulators are compared with that of cotton rope. Silica aerogel and coconut fiber are expected to be a promising insulator for steam pipe insulation.
Keywords: Insulation, Silica aerogel, Coconut fiber, cotton rope.

I. INTRODUCTION

Thermal insulation for steam pipe line is to reduce the heat loss due to heat transfer. Thermal insulation can be achieved with specially engineered methods or processes as well as with suitable objects shapes and materials. Thermal insulator which have a low thermal conductivity and low density are a good insulator. Materials that are poor conductors of thermal energy are called thermal insulator. The optimal economic selection of pipe size and insulation thickness for Steam piping [1] The production of low density thermal insulation boards made from coconut husk was to develop a thermal insulation with lower environmental footprint than conventional materials Thermal conductivity values ranging from 0.046 to 0.068W/m K which were close to those of conventional insulation materials [2] Two thousand fibres were randomly taken from a coir fibre stack that length of the fibres was in the range between 8 and 337 mm. The fibres amount with the length range of 15–145 mm was 81.95% of all measured fibres. Composite boards were fabricated by using a heat press machine with the coir fibre as the reinforcement natural fibres have been increasingly adopted to replace synthetic polymers in the industrial applications [3]

Silica aerogel/glass fiber composites were fabricated by press forming of silica aerogel powders and depressed glass fibers. Silica aerogel shoes a low thermal conductivity and solid thermal conductivity the strength of the composite was improved but the heat insulation property was determined [4] Silica aerogel is a nanostructured material with high specific surface area, high porosity, low density, low dielectric constant and excellent heat insulation properties drying which is a critical step in aerogel synthesis and makes the production of this material more economical and commercial. that the thermal conductivity of an aerogel is in the order of 0.017 W/m K calculating the thermal conductivities of silica aerogel composite insulating materials by considering the heat conduction [5] silica gel was applied to improve the mechanical properties of silica aerogel/glass fibre composite without compromising its thermal conductivity. The effects of the silica gel on the thermal conductivity and strength of the composite were investigated. The results indicated that the composite possessed not only ultra-low thermal conductivity of 0.0179 $W \cdot (m \cdot K)^{-1}$, but also excellent mechanical strain and low bulk density of 0.246 g/cm^3, and was dust-free.[6]

Silica aerogels have drawn a lot of interest both in science and technology because of their low bulk density hydrophobicity, low thermal conductivity, high surface area, and optical transparency. the surprising properties of aerogels, the present review address synthesis of silica aerogels by the sol-gel method, as well as drying techniques and applications in current industrial development and scientific research. [7] The thermal conductivity of silica aerogel developed in this research program was measured using the transient hot-wire technique. The thermal conductivity of monolithic samples drops significantly from 9.3 m W/m K to 3.2 m W/m K with modest pressure reduction from 1atm to 0. 1atm.The same aerogel in granular form has a thermal conductivity of 15.0 m W/m K at ambient gas pressure with a modest compression applied to compact the granules and reduce the air void sizes. [8]

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By employing modelling and experimental verification, the thermal performance of granule compacts was studied. . The thermal performance of these granule compacts, at ambient pressure and vacuum, is similar to that of aerogel monoliths without the cost and processing problems of monoliths.[9] The thermal insulation ability of silica aerogel decreases at high temperature. The silica has been used for thermal insulation board recently. The thermal conductivity of the compact made of fumed silica is close to that of silica aerogels. Silica board with low thermal conductivity, light weight, and machining-ability was successfully prepared in this study. Further analysis is still needed for the improvements of strength and thermal insulation.[10]

In our survey it has been identified the silica aerogel act as a good insulator. The silica aerogel has a low thermal conductivity up to 0.017W/ (m K) and it has low density. Silica aerogel is a light weight material when compare to other materials. Synthesis of the silica aerogel, its properties and applications are identified from this review. It was found that silica aerogels exhibit unusual softening when compressed. It can able to withstand the heat up to(1473K). The coconut fiber composite is used for preparing insulation panels.

II. EXPERTIMENTAL

Silica aerogel, coconut fiber composite and cotton rope these materials are used in experiment for testing. Silica aerogel material insulated at the first (Length =1m, Thickness = 6mm). Coconut fiber composite is prepared with the use of epoxy resin and hardener the mixing ratio of 1:0.15. Cotton rope is also used a conventional insulator which is used to compare the above materials.

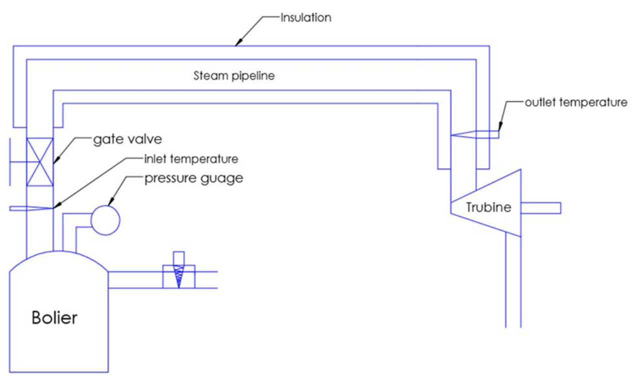

Fig 2.1 2D Layout of steam production

Table 2.1 Super-heated steam

S.NO	MATERIALS	T[inlet] °C	T[outlet] ° C
1	SILICA AEROGEL BLANKET	157	118
2	COCONUT FIBRE COMPOSITE	158	117
3	COTTON ROPE	168	112

Table 2.2 Wet steam

S.no	Materials	t[inlet] °c	T[outlet] ° c
1	Silica aerogel blanket	80	78
2	Coconut fiber composite	80	77
3	Cotton rope	82	78

A. *Calculation*

- $Q = \Delta T / R$
- $\Delta = T_{in} - T_{out}$
- $R = 1/(2\pi KL)\ \ln(r_2/r_1)$

Where,

- ✓ Q – Heat Transfer rate.
- ✓ ΔT –Temperature difference.
- ✓ R –Resistance.
- ✓ K –Thermal conductivity.
- ✓ L – Length of pipe insulation.
- ✓ r_1 –Pipe radius without insulator.
- ✓ r_2 – Pipe radius with insulator.

1) *Calculation For Super-Heated Steam*

a) *Silica Aerogel Blanket:* Temperature inlet is 157°C, Temperature outlet is 118°C, length is 0.4572m, Radius r_1 is0.0095m Radius r_2 is 0.0215m, K= 0.017W/m K.
R=16.7302 K/W, ΔT=39K, Q = 2.3308 W.

b) *Coconut Fibre Composite:* Temperature inlet is 158°C, Temperature outlet is 117°C, length is 0.3048m, Radius r_1 is0.0095m Radius r_2 is 0.0432m, K= 0.046W/m K.
R = 17.2114 K/W, ΔT=41K, Q=2.3821W.

c) *Cotton Rope:* Temperature inlet is 168°C, Temperature outlet is 112°C, length is 0.3048m, Radius r_1 is0.0095m Radius r_2 is 0.0165m, K= 0.03W/m K.
R=9.614 K/W, ΔT=56 K, Q=5.8248 W

B. *Calculation for Wet Steam*

1) *Silica Aerogel Blanket:* Temperature inlet is 80°C, Temperature outlet is 78°C, length is 0.4572m, Radius r_1 is0.0127m Radius r_2 is 0.0257m, K= 0.017W/m K.
R=14.4417 K/W, ΔT=2K, Q=0.1384W

2) *Coconut Fibre Composite:* Temperature inlet is 80°C, Temperature outlet is 77°C, length is 0.1524m, Radius r_1 is0.0125m Radius r_2 is 0.0538m, K= 0.046W/m K.
R=33.1705 K/W, ΔT=3K, Q=0.0904

3) *Cotton Rope:* Temperature inlet is 82°C, Temperature outlet is 78°C, length is 0.3048m, Radius r_1 is0.0127m Radius r_2 is 0.0207m, K= 0.03W/m K.
R=8.5074K/W, ΔT=4K, Q=0.4702W

III. RESULT AND DISCUSSION

The conventional insulators like cotton rope, mineral wool, glass wool in our experiment testing silica aerogel which is a better insulator when compared to another conventional insulator. And also, coconut fiber which is equal to silica aerogel. The experimental testing steam is passed through steel pipe with the help of boiler, here we are insulating material silica aerogel and coconut fiber composite. The silica aerogel inlet temperature is 157 ° C and heat transfer rate Q is 2.3308 W. The coconut fiber composite inlet temperature is 158 ° C and heat transfer rate Q is 2.3821WThe above mentioned two materials are compared with cotton rope. Cotton rope also act as a good insulator but the silica aerogel which reduce the heat loss when compared to other insulator. The experiment final result is heat transfer rate cotton rope value is less than the silica aerogel and coconut fiber composite.

Table 3.1 Comparison value of superheated steam and wet steam

EXPERIMENT MATERIALS	HEAT TRANSFER FOR SUPERHEATED STEAM, Q (W)	HEAT TRANSFER FOR WET STEAM, Q (W)
SILICA AEROGEL	2.3308	0.1384
COCONUT COIR COMPOSITE	2.3821	0.0904
COTTON ROPE	5.8248	0.4702

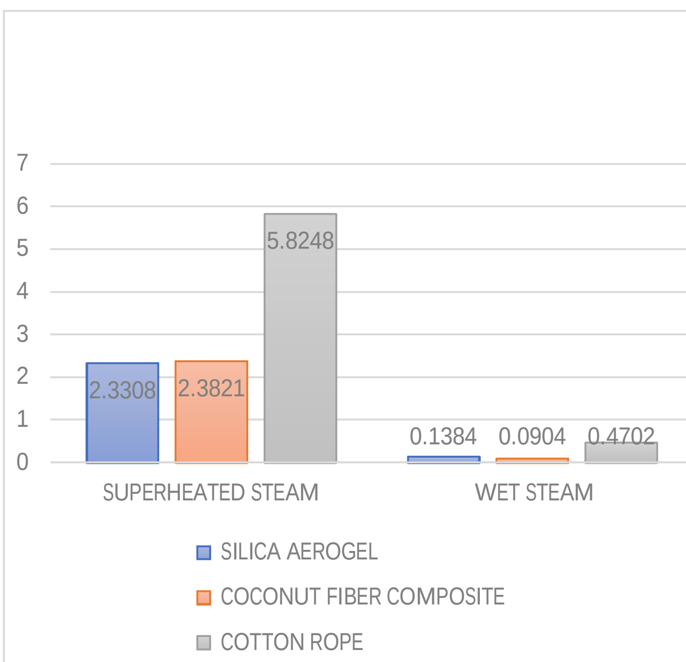

Fig 3.1Comparison of super-heated steam and wet steam

IV. CONCLUSIONS

The thermal insulation plays the major role in steam pipelines. In thermal power plants insulators like mineral wool, glass wool, cotton ropes, were conventionally used and it is not found to be much effective. From the literature work silica aerogel is found to have better insulation properties these materials are used as an insulator for superheated steam and wet steam heat transfer. From the experimentation work the following conclusion have been made.

A. During the heat transfer of wet steam that has been found that all the three insulators are found to be better insulators.
B. That has been found that silica aerogel and coconut fibers composite are found to be better insulators compared to the conventional cotton rope insulator.

Considering the availability, preparation and cost of this insulating materials silica aerogel has been found to be a better insulator for the plant which uses the superheated steam for various applications.

V. SCOPE FOR FUTURE WORK

A. We have experimentally tested the silica aerogel and coconut fiber composite which has been compared with cotton rope.
B. For future scholar there is a very good opportunity to explore the present area of research.
C. The present work can be extended by adding new low-cost material, many cheap natural fiber composites can be add, then the pipe thickness may be increased and increases the performance.

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