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Aerogels-The Future

Vishnu Chidambaran, Vivek Praveen, Visakh Praveen, Rohith. S. Menon
Mechanical, Calicut University/Vidya Academy of science and technology/Thrissur, Kerala, India

ABSTRACT

Aerogels are synthetic porous ultra-light materials derived from a gel, in which the liquid component of the gel is replaced with a gas. Aerogels exhibit an uncanny array of extreme material properties. Most notably aerogels are known for their extreme low densities. The potential to replace conventional insulation by aerogel in various sectors like building, construction as well as in industrial insulation is quite significant. The main purpose of the paper is to describe the application of aerogel in catalytic converters in automobiles and their economical aspects.
Keywords: Synthetic Porous, Densities

I. INTRODUCTION

Aerogels are the world's lightest solid materials, composed of up to 99.98% air by volume. Transparent super insulating silica aerogels exhibit the lowest thermal conductivity of any solid known. Ultrahigh surface area carbon aerogels power today's fast-charging super capacitors. In addition, ultra strong, bendable x-aerogels are the lowest-density structural materials ever developed.

In automobiles, catalytic converters play an important role of converting harmful exhaust gases into less toxic gases by catalyzing a redox reaction. With more stringent exhaust gas regulations all over the world, their importance is increasing, and new methods to improve their efficiency are being investigated by automobile manufacturers. [1]

The scope of this paper is limited to discussing the possible application of aerogels for thermal insulation in catalytic converters in automobiles.

II. CATALYTIC CONVERTERS

A catalytic converter is an emissions control device that converts toxic gases and pollutants in exhaust gas to less toxic pollutants by catalysing a redox reaction (an oxidation and a reduction reaction). Catalytic converters are used with internal combustion engines fuelled by either petrol or diesel—including lean-burn engines as well as kerosene heaters and stoves.

The construction of catalytic converters can be summarised as follows

1) The catalyst substrate-Generally a ceramic monolith with a honeycomb structure.

2) The wash coat-Acts as a carrier for the catalytic materials and disperses them over a large area.

3) Ceria or Ceria Zirconia-Oxygen storage promoters.

4)Catalyst-Mix of precious metals. Usually Platinum. Rhodium and Palladium are used.

Earlier, catalytic converters only performed two reactions; one, oxidation of carbon monoxide to carbon dioxide and two, oxidation of hydrocarbons to carbon dioxide and water. Therefore, they were called two-way catalytic converters. These converters later gave way to three way catalytic converters, which performed the additional reaction of reducing nitrogen oxides to nitrogen and oxygen. Three way catalytic converters are the most widely used converters today.

A. *Efficiency of catalytic converters*

Catalytic converters exhibit the most efficient conversion of harmful exhaust gases to inert ones at a temperature of about 426 C.

Auto manufacturers indicate that 60% of all HC emissions occur during ‘cold start’ periods when the catalyst is at temperatures below it’s ‘light-off’ temperature.

Figure 1 shows the variation of efficiency of catalytic converters with exhaust temperature.

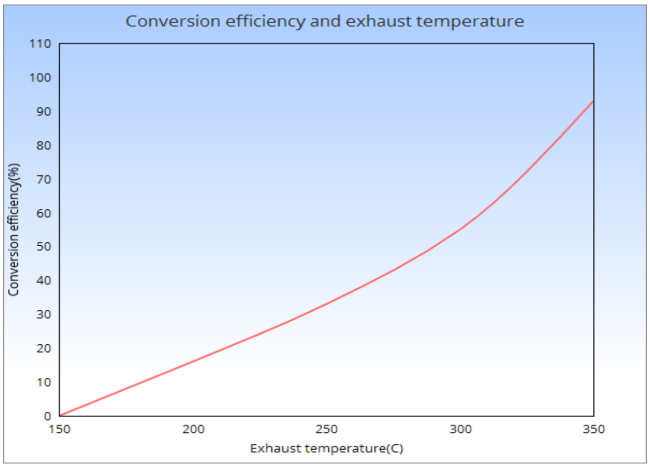

Figure 1

This high temperature required by the converter is a challenging aspect in automobile design. In the initial days, the catalytic converters were placed close to the engine to ensure faster heating. However, This location can cause two problems.

One is vapor lock. Vapor lock involves the engine fuel turning into gaseous form while still in the delivery system. The second problem is that the converter acts as a significant heat source that increase the under hood air temperature and the direct radiation to surrounding components with limited heat tolerance, like plastics, coolant hoses etc.

These two problems led manufacturers to shift the converters to under the vehicle , a third of the way back from the engine. However, this shift has resulted in increasing the time required for the catalyst to reach it's 'light off' temperature. [2]

B. Current insulation methods

Even when under the vehicle, the catalytic converters require careful thermal management treatments due to the exothermal reactions taking place inside it. The catalytic converter should also withstand extreme cases like misfire.

Methods like heating the converter electrically to rapidly bring it to light-off temperatures are used. However, these systems are complex and expose the converter to severe thermal gradients.

Current methods used include vacuum insulation and phase change insulation.
Vacuum insulation consists of a gas-tight enclosure surrounding a rigid core, from which the air has been evacuated.

The phase change insulation system includes a thicker layer of insulative material and a second thinner layer of insulative material, with an intermediate layer of phase change material sandwiched in-between.

III. AEROGELS IN CATALYTIC CONVERTERS

Metal aerogels are already proposed for use in catalytic converters as a substitute for catalyst material.

The authors opine that application of aerogels in catalytic converters can be extended to thermal insulation of the converter, as an alternative to the current vacuum insulation and phase change insulation techniques.

Aerogels are high performance thermal insulators in ambient or partial vacuum environments because of their extremely small pore sizes, which greatly impede the communication of gas molecules by thermal conduction. A properly designed thermal insulation system based on aerogel material will also minimise heat transfer by surface convection.

Table 1compares the thermal conductivity of aerogels with other materials.

THERMAL CONDUCTIVITY k-Value(ambient)	
Material	W/m-K
Aerogel Blanket	0.011 – 0.012
Polyurethane Foam	0.021 – 0.025
Polyester Foam	0.038 – 0.041
Polyester Batting	0.037 – 0.041
Fiberglass	0.038 – 0.041

Table 1

Application of aerogel for thermal insulation can have many benefits. First, aerogel insulation can lead to overall simplicity of the insulation system compared to vacuum or phase change insulation

A. Aerogel vs. Vacuum insulation

The main disadvantages of vacuum insulation are it's fragility, cost, complexity and high density. The proposed aerogel insulation is better in all these areas. Aerogels are extremely strong materials for their weight. The cost of aerogel blankets is often comparable to vacuum insulation panels. Aerogel blankets are simpler in construction. In the case of density, aerogels are the least dense materials known today.

B. Aerogel vs. Phase Change Insulation

Phase change insulation has some disadvantages like high cost, low availability, complexity of design etc. Aerogels, if manufactured in high volumes can be a potential solution to all these problems and have the added advantage of better thermal insulation. In addition, in countries with a cold climate, the conditioning of the phase change material can be difficult. An aerogel insulation does not require conditioning, and thus will serve the purpose better under such conditions.

If catalytic converters are insulated using aerogels, the location of converters can be shifted back to the engine compartment, without causing damages to the temperature sensitive components in the engine compartment. This in turn can have many advantages like decreasing the cold start emissions, increasing the thermal storage capacity of the converters, preventing theft of catalytic converters etc.

Another added advantage of using aerogels in catalytic converters is the feasibility of manufacturing flexible aerogel blankets. These can be used for insulating catalytic converters under varying design or spatial requirements, eliminating the need of custom-making insulation systems.

IV. ECONOMICAL ASPECTS

One of the key questions for any new technology is whether it can be manufactured reliably and practically. Large-scale production of aerogel insulation systems will depend on the economic feasibility of manufacturing such systems and applying and maintaining them in automobiles.

Figure 2 shows the decreasing cost (in USD) of aerogel insulation in the last few years.

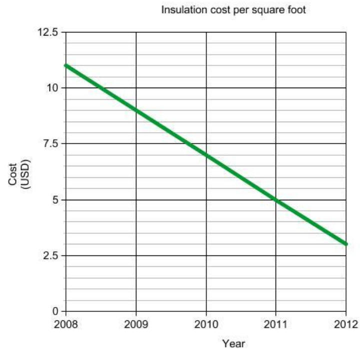

Figure 2

The usage base of aerogel for various scientific and industrial applications is rising. This will surely lead to the decrease of prices in coming years. However, the economical aspects of their use cannot be limited to the initial investment. It should be taken into consideration that aerogel insulated catalytic converters can decrease maintenance costs, harmful exhaust gas emissions etc. which significantly adds to their value for cost.

V. CONCLUSION

Increased concern among governments on emissions from automobiles and their harmful effects on the environment are leading to stringent norms for controlling emissions. In this context, catalytic converters play an increasingly important role of mitigating the harmful effects of exhaust emissions. Consequently, even marginally increasing their efficiency can go a long way in meeting high set standards of present and future emission norms.

Even after eighty years of their discovery, aerogels remains an area of much research and discussion. This is an evidence for their seemingly revolutionary potential as a material of tomorrow. Application of aerogels in various areas like Space research, Biomedicine, Construction, Thermal insulation etc. is testimony to their vast potential.

Using aerogels in catalytic converters is not a new idea. Carbon aerogels are already used in converters in addition with precious metals for catalysing reactions. However, usage of silica-aerogel for thermal insulation in catalytic converters is a novel idea. The low thermal conductivity, very low density and high strength of aerogels can be used to augment the efficiency of catalytic converters, as discussed in this paper. This paper also looked into the economical viability of such a usage, obviously within the scope of the author's research for this paper.

VI. REFERENCES

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