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A Review on Phase-Changing Material in Battery Management Systems

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Abstract: Phase change materials (PCMs) are substances that assimilate or deliver a lot of supposed "idle" heat when they go through an adjustment of their actual state, for example from strong to liquid as well as the reverse way around. Even though a ton of progressions have been made in electric vehicle batteries which helps in conveying more power while requiring fewer charges, the capacity to plan a viable cooling framework is as yet a major worry for the security of a battery. Warm capacity is utilized to build the cooling limit during the hot days while utilizing the colder air around evening time to re-energize the warm stockpiling. CNT helps in working on the warm conductivity of the composite. The disadvantage of issues like PCM bundling, plan specifying, volume change, and spillage ought to be recognized for the further improvement of Phase Change Material based Battery Management Systems.

I. INTRODUCTION

Phase Change Material is a substance that absorbs or releases adequate energy at the transition phase to provide functional heat or cooling. PCM, air-cooling and fan cooling were all of them where unsuccessful to match the energy efficiency, weight requirement, and size, though they all are easy to implement for practical and maintenance as liquid cooling. PCM can ingest energy by altering its phase from solid to liquid.

While changing state, it can withstand a large amount of heat and very less temperature difference.

PCM cooling has accurate cooling requirements of the battery pack, though the only restriction during its application is its volume change. PCM material can only absorb a very large amount of heat but it cannot transfer that heat out which means it will not be able to deduct the overall temperature when it is compared to another system.

Hence, not advantageous for use in vehicles, PCMs are beneficial for thermal performance in buildings as it helps to reduce the internal temperature and also help in reducing peak cooling loads.

PCM is not a practical solution as: -

1) The system's volume is acquired.
2) It stores the heat once transferred.

II. POWER COOLING BATTERIES FOR ELECTRIC VEHICLES

PCM is used for its very high latent heat, cold depository capacity, and thermal depository, and mainly PCM is used widely for temperature fluctuation centre energy storage.

According to phase change form, PCM is differentiated into 4 form types:

1) "Solid- Solid"
2) "Solid– Liquid"
3) "Solid– Vapor"
4) "Liquid-Vapor"

We see in solid-vapor and liquid-vapor that an enormous volume change occurred before and after the phase change and the phase deformation is due to their phase transition or mobility. Hence that it affects the stability of the energy storage system so it is not a practical solution.

PCM is divided into 3 different phase change temperatures:

- Low phase change temperature (-50

Celsius to -90 Celsius)

- Medium phase change temperature (90 degrees Celsius to -550 degrees Celsius)
- High phase change temperature (>550 degrees Celsius)

A low-temperature phase change is broadly used in buildings energy utilization, and also used in daily life energy, hence this range of change temperature is used the most. Further PCM is divided into two forms, Organic Phase Change Material and Inorganic Phase Change Material.
Organic Phase Change Material includes fatty acids, esters, polyols, paraffin, etc. and it is classified as a Chemical composition of PCM.

And Inorganic PCM has mainly hydrated salts, molten salts, crystalline, and alloys. PCM plays an important role in building energy conservation, solar energy storage, waste heat recovery, power shifters/transferring, cold chain logistics, and others.
Compared to fan cooling, liquid cooling, and air cooling, PCM has more temperature control technology and a better control effect. It also gives us good efficiency and green characteristics and it is environmentally friendly as well. The battery thermal management system has a variety of applications and performs better when compared to others.
Zhao said that, when a battery reaches 39 degrees Celsius, it almost runs 1800 times the pure paraffin and copper mesh or paraffin at 25 degrees Celsius. He said that, when the temperature of the battery surface decreases by 14 degrees Celsius, the temperature was stabilized at the same point. Also, there was a temperature balance between the battery cells.
Subsequent to adding shaped copper, it was demonstrated that the warm administration execution of unadulterated PCM is lacking and results showed that BTMS shows a decent temperature to further develop the cycle dependability. A lot of Scientists have made the thermal management capability of PCM-based BTMS better by using cooling methods.

- Phase Change Material based hybrid BTMS can efficiently decrease temperature levels and the difference along with the battery outputs in multiple environmental conditions.
- Coordination of air cooling and PCM cooling in half breed battery warm administration which brought about predominant of warm boundaries in contrast with different batteries.
- Hybrid BTMS incorporated Phase Change Material and required air for heat squandering for a lithium-ion battery and they were paralleled with Phase Change Material based BTMs with paraffin. Studies have shown that this hybrid can increase authenticity of Phase Change Material based BTMS without any complications like excessive heat accumulation and temperature control.
- A combination of PCM and active thermal management systems produces hybrid systems which elevate the cycle stability of PCM-based BTMS, thus proving them to be excellent in BTMS. The drawback of problems like PCM packaging, design detailing, volume change, and leakage should be acknowledged for the upcoming improvement of Phase Change Material based BTMS.
- The formation of ternary composites from graphite, low-density polyethylene, and paraffin which are mixed with low fins and then conjoined with battery modules. Its greater ability to dissipate heat in the surrounding efficiently highlights its stupendous performance.
- A cooling system involved PCM and a liquid cooling plate that solidified it during charging and controlled temperature under varying conditions.

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III. TABLE GIVEN BELOW IS A COMMON CLASSIFICATION FOR PCM AND THEIR PROPERTY COMPARISON.

Classification of common phase change materials and comparison of their properties.

Kind	Name		Melting point /°C	Latent heat/J g^{-1}	property
Inorganic phase change materials	$LiClO_3{\cdot}3H_2O$		8.1	253	large phase change latent heat value, high thermal conductivity, high undercooling degree, easy phase separation, poor reversibility
	$CaCl{\cdot}6H_2O$		25.8	125.9	
	H_3PO_4		26	147	
	$LiNO_3{\cdot}2H_2O$		30	296.8	
	$LiNO_3{\cdot}3H_2O$		30	189	
	$NaSO_4{\cdot}10H_2O$		32.4	257	
	$Na_2HPO_4{\cdot}10H_2O$		35.2	265/280	
	$Na_2S_2O_3{\cdot}5H_2O$		48	188/201	
	$Na(CH_3COO){\cdot}3H_2O$		58	226/264	
	$Ba(OH)_2{\cdot}8H_2O$		78	267/280	
	$Mg(NO_3)_2{\cdot}6H_2O$		89/90	149.5/162.8	
	$MgCl_2{\cdot}6H_2O$		116	165/168.6	
	$NaNO_3$		307	172	
	$MgCl_2$		714	452	
	MgF_2		1263	938	
Organic phase change materials	Paraffin	$C_{18}H_{38}$	28	243	high latent heat, low thermal conductivity, good stability, good reversibility, no obvious over-cooling
		$C_{22}H_{46}$	44.4	249	
		$C_{26}H_{54}$	56.1	256	
	Non-paraffin	Lauric acid (dodecanoic	44–45	225	
		acid)	54–55	220	
		Myristic acid	63–64	215	
		(tetradecanoic acid)	69–71	243	
		Palmitic acid	26	184	
		(hexadecanoic acid)	29	205	
		Stearic acid (octadecanoic	43	177	
		acid)	57	242.85	
		Glycerol ($C_3H_8O_3$)			
		Isoamyl laurate ($C_{17}H_{34}O_2$)			
		Isobutyl octanoate			
		($C_{12}H_{24}O_2$)			
		1-octadecyl alcohol			
		($C_{18}H_{38}O$)			

A major role is played by the PCM heat exchanger and they are built to corroborate the low weight heat exchanger. Due to the poor thermal conductivity of paraffin waxes, they are built in these exchangers. This raises the demand for extra amenities like fins which efficiently melts PCMs with easy thermal resistance. Development of a proper solution to combat the same can be done using accurate valves for thermal conductivities.

IV. THERMAL STORAGE TO INCREASE COOLINIG CAPACITY DURING OT DAYS

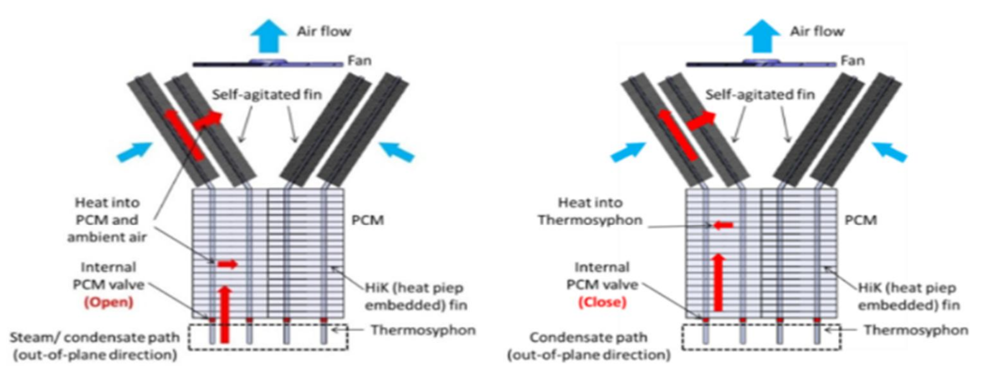

Figure 2: Left: System utilization, the thermosyphon internal valve is open and the heat from steam or coolant water can be removed to both PCM and the ambient air. Right: System regeneration, the internal valve is closed and the heat from PCM can be removed to the ambient to regenerate PCM.

Fig : 1

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Generally, the ideal temperature choice of a battery is lower than that of the range of a vehicle and thus the operating climate of an EV gets operated by BTMS. It's a relative mean which operates under an approach governed by an electronic unit to ensure battery maintenance within optimum ranges of temperatures.

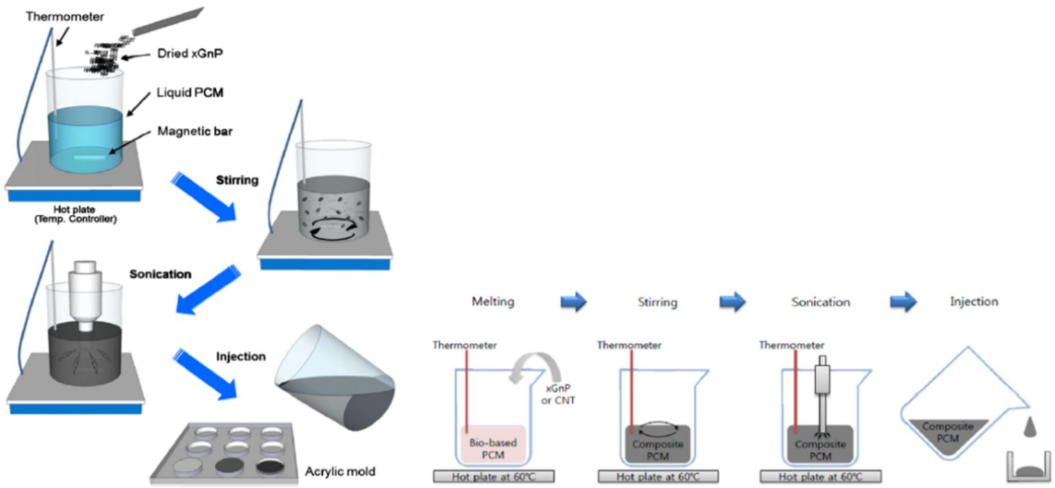
Its idiosyncrasies include written cost with great reliability, compactness, and importantly its concord with the vehicle. It uses minimal power to provide airing for the batteries so that they give out harmful gases with complete ease.

For balanced maintenance of operating temperature ranges in batteries when the environment temperature exceeds 308.15 kelvin, the latest EVs and HEVs are used as active cooling methods rather than passive cooling as the latter fails in the above qualities. But in adverse conditions, active liquid cooling systems may fail in temperature maintenance of batteries along with a large amount of energy consumption from the batteries.

V. PCMS WITH CARBON NANO-TUBE (CNT) MATERIALS

Today, greater focus is on the enhancement of PCM thermal conductivity which is done by using the addition of solid partials. Improvement in latent heat of fusion was discovered by SHAIK ET AL using a differential scanning calorimeter.

This change was due to the addition of substances like carbon nano-fibres, and single and multi-wall CNTs in pure wax.



a) Composite PCM loaded with xGnp *b) Bio PCM loaded with xGnp or CNT*

Fig. 3. Fabrication of nanomaterials incorporated PCMs (Nano-PCMs) [11, 52].

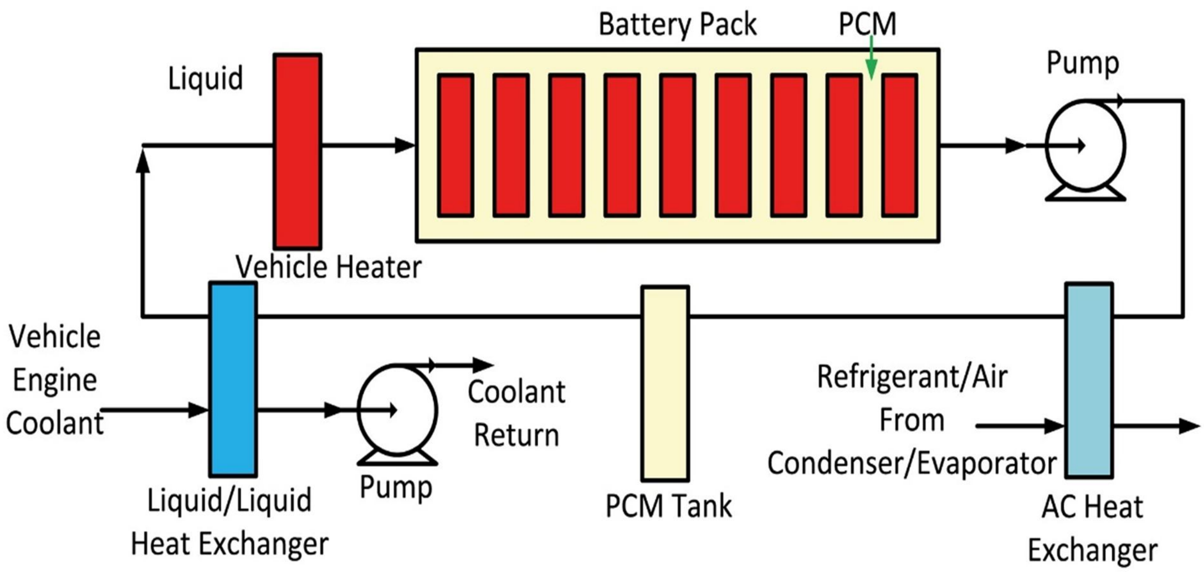
Including small amounts of multiwall CNT also called MWCNTS in liquid paraffin enhances thermal conductivity producing a Nano-fluid PCM. The transient hot-wire method is used to observe the after-effects of carbon additives on thermal conductivities, heat transfer rates of PCM, and dispersion stabilities' It was thus found that the addition of graphite causes dispersion stability of PCMs to last for 3 days whereas for griffin it was 8 days and MWCNT for 10 days.

Hence, it was concluded that there is an increment in thermal conductivities of PCM when there is an increment in the concentration of carbon additives (graphite, graphene, etc.). Further increase was found in the addition of water-soluble polymer povidone or polyvinylpyrrolidone. The increase in thermal conductivity was reported to be 21.5% when graphene was added to 0.1% of volume.

VI. LATEST TECHNOLOGY IN PCM APPLICATION IN HEVs

Today PCM technology is progressing and thus the primary attention lies in developing more efficient thermal conductivity and enhancing the stability of PCM so that it becomes a productive source for commercial purposes. The last advancement in PCM innovation was phase change composite (PCC) for vehicle applications which contains the utilization of wax graphite and composite materials. One of the major pluses of PCC includes its ability to remain solid during wax melting without any leakage from the PCCs. The increment in life cycles of cells rises by more than 50% when PCCs are used in small EVs, that is electric scooters that have no active thermal management.

Mercantile battery packs for the small EVs use PCCs along with high energy density cells, thus increasing by driving range from 30km to 55km.



VII. CONCLUSION

The concept of Phase Change is used in multiple fields and it is a necessary application that is used in various processes on a daily basis. In Battery Management Systems Phase change of materials plays an important role as the entire process is based on PCM. It helps in the temperature reduction depending upon the environmental conditions. With the development in technology, the application of PCM in the battery management systems have changed and upgraded from time to time. The latest technology uses carbon fibres and substances like CNT in wax. This field is evergreen and development of new technologies is inevitable. Scientists are fining different ways to increase it's thermal efficiency so that it can be used in much commercial applications.

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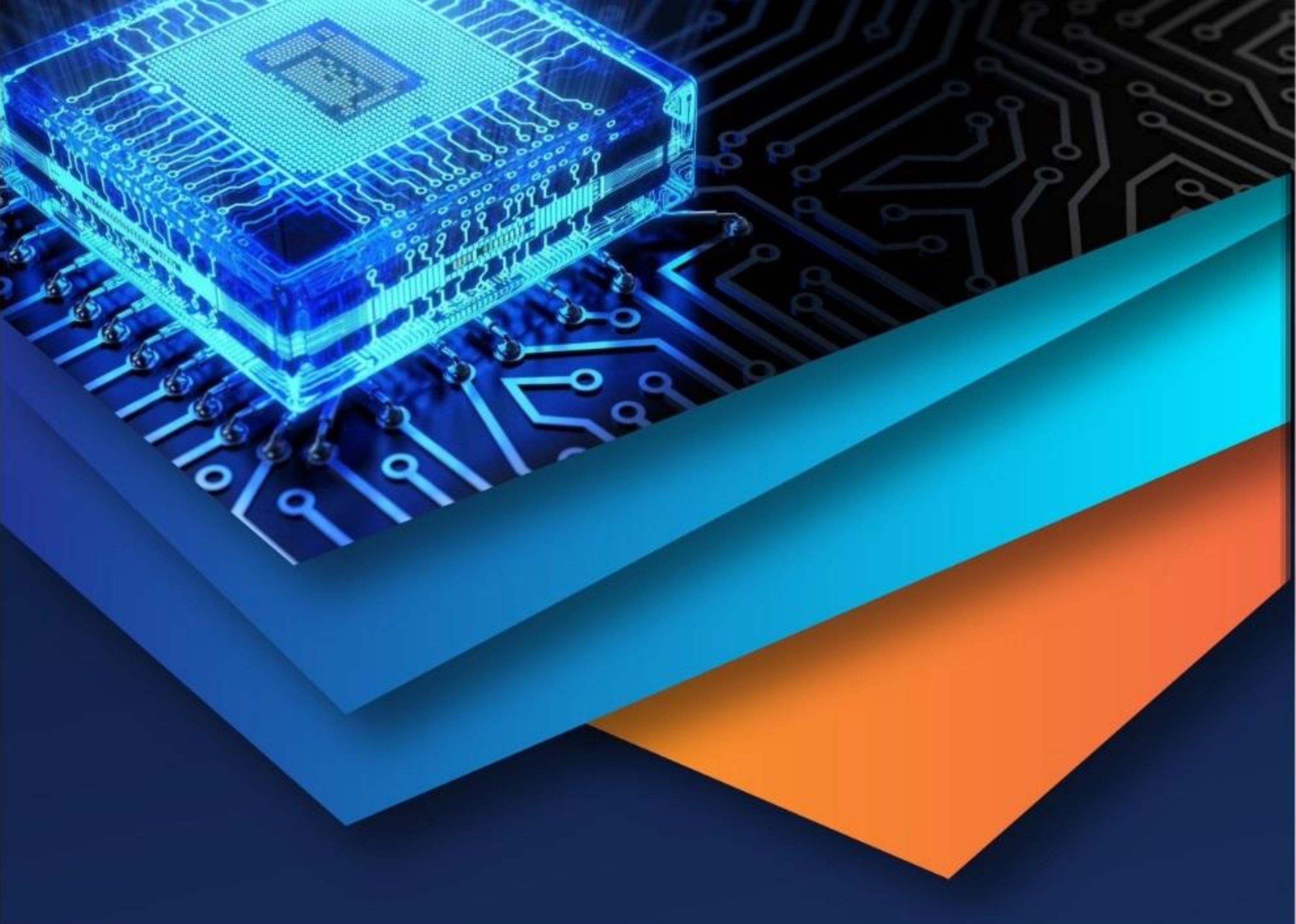

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