Selection of Phase Change Material using Shenon Entropy and Vikor Method

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Abstract – Latent heat thermal energy storage (LHTES) with phase change materials (PCMs) earns attention as it anticipates high energy density and small temperature changes with melting/solidifying. Phase change materials (PCMs) are gaining attention in the fields of space cooling and heating in buildings, off-peak energy storage, solar applications and heat exchanger enhancement. Latent heat thermal energy storage (LHTES) offers a huge opportunity to reduce fuel dominance and habitat impact generated by consumption of fossil fuel. The use of phase change materials (PCM) is to store the sensible heat and latent heat, due to this large quantity of thermal energy is stored in smaller volumes. The popularity of Multi-criteria decision making (MCDM) methods is increasing in solving various PCM selection problems. This paper presents selection of Phase changing materials with the help of Vikor and Entropy methods.

Key Words: Phase Change Material, Latent heat thermal energy storage (LHTES), Vikor and Entropy Method.

1. INTRODUCTION

There is a widening interest in the heating due to the increasing demand for heating of water for different applications. However, the variable characteristic of heating system presents a challenge to applications that needs a constant energy supply. Recently, thermal Energy Storage (TES) has advantages of absorbing flowing heat and stores it. In recent comparison of TES systems, Latent Heat Thermal Energy Storage (LHTES) system charges and discharges the heat power by utilizing phase transformation of Phase Change Materials (PCMs). Being able to provide high storage density and constant temperature output, LHTES is regarded as a very promising energy storage technique.

This paper shows various heat storage materials and its selection procedure. Sensible heat storing devices are heavier in size and having less heat storing capacity as compared to latent heat storage devices.

1.1 Sensible heat storage systems

Sensible heat storage can be achieved by increasing the temperature. Materials used for an efficient sensible heat storage system should have high specific heat capacity and should be adaptable to the container material in which heat storage takes place. Number of materials are being used today for sensible heat storage systems classified as liquid heat storage materials and solid heat storage materials . A list of different materials used for sensible heat storage materials include metals like aluminium, concrete, water, copper, steel, lead etc. These materials consists of high thermal conductivity and hence reduce charging and discharging time but they are having high density, low heat capacity, and are costly that make system expensive to use.

1.2. Latent heat storage systems

Latent heat storage materials undergo phase change from solid to liquid when they absorb heat. The requirements to store sufficient amount of latent heat in case of phase change materials is, they should have high latent heat of fusion, high specific heat, high thermal conductivity. The stability of the materials should be high for repeating thermal cycles. The materials should also have resistance to poison, corrosion and flame and should be available on bulk scale at lower price.

2. SELECTION OF PHASE CHANGE MATERIAL

The phase change material can be selected by following approach:

- Weighted sum method (WSM)
- VIKOR

2.1 Weighted sum method(WSM)

The weighted sum method, also called the simple additive weighted method, is one of the simplest and most widely used MCDM methods. In general, WSM deals with benefit criteria, for example, the thermal conductivity criteria are altered into benefit criteria. After the alteration, the lowest thermal conductivity criterion becomes the largest and the largest thermal conductivity becomes the lowest. Then, a normalized matrix can be created by dividing each criterion value by the sum of all criteria. Finally, the total score of each alternative is multiplied by its weight. The best option has the highest total score among all the options.

Phase change material	Melting point in deg.C	Latent heat of melting in J/gm	Solidifying temperature in deg.C	Latent heat of solidifying in KJ/kg	Thermal conductivity in W/mK
n-octadecalamine /F-MWCNT's	54.6	122.1	48.2	119.6	0.5322
paraffin / L-type MWCNT's	58.4	172	50.6	180.39	0.39
paraffin /Anisotropic graphene Aerogels	47.8	193.7	46.05	198.2	2.99
Palmitric acid-steric acid	octadecanol/ reduced graphene oxide graphene nanoplate agrogel 53.59	163	53.8	160.5	0.341
octadecanol/ reduced graphene oxide graphene nanoplate agrogel	61	202.8	54	250.6	5.92
palmitric acid-graphene oxide	60.45	101.23	60.05	101.49	1.02
PEG6000/polyurethelene/graphene	59.4	150.1	32.9	129.9	20
PEG6000/ti4o7 /sio2	59.8	129.7	133.3	145	0.45

Table -1: Properties of PCM

The calculation of Shannon's entropy weight is presented as follows,

Assuming that m alternatives ($A_1, A_2, ..., A_m$) and n criteria ($C_1, C_2, ..., C_n$) for a decision problem. Then initial decision matrix is

$$\begin{bmatrix} z_{11} & z_{12} & .. & .. & z_{1n} \\ z_{21} & .. & .. & .. & z_{2n} \\ : & : & .. & .. & : \\ : & : & .. & .. & : \\ z_{m1} & z_{m2} & .. & .. & z_{mn} \end{bmatrix} = \left[z_{ij} \right]_{m*n}$$

where its elements a_{ij} denote i^{th} alternative of j^{th} criterion.

Step 1: Normalize the decision matrix

$$p_{ij} = \frac{z_{ij}}{\sum_{i=1}^{m} z_{ij}}, i = 1,2...., m$$

Phase change material	Melting point in deg.C	Latent heat of melting in J/gm	Solidifying temperature in deg.C	Latent heat of solidifying in KJ/kg	Thermal conductivity in W/mK
n-octadecalamine /F-MWCNT's	0.119989451	0.098896026	0.100647317	0.093024703	0.016812565
paraffin/ L-type MWCNT's	0.128340366	0.139312993	0.105658801	0.140307075	0.012325001
paraffin/Anisotropic graphene Aerogels	0.10504571	0.156889108	0.096157862	0.154159666	0.094491673

Palmitric acid-steric acid	0.117769866	0.132023359	0.112340781	0.124836662	0.010776475
octadecanol/ reduced graphene oxide graphene nanoplate agrogel	0.134054149	0.164259738	0.112758405	0.194916309	0.187087191
palmitric acid-graphene oxide	0.132845464	0.081992176	0.125391522	0.078938772	0.032234617
PEG6000/polyurethelene/graphene	0.130537975	0.121574885	0.068699102	0.101036028	0.632051323
PEG6000/ti4o7 /sio2	0.131417018	0.105051716	0.27834621	0.112780785	0.014221155

Table -2: Normalized decision matrix

Step 2: Compute entropy

$$e_{ij} = -K\sum_{i=1}^{m} p_{ij} \ln p_{ij},\ j = 1,2,.....n$$

$$where, K = \frac{1}{\ln m}$$

Properties	e_j
Melting point in deg.C	0.998593561
Latent heat of melting in J/gm	0.988705317
Solidifying temperature in deg.C	- 0.954928466
Latent heat of solidifying in KJ/kg	1.858524155
Thermal conductivity in W/mK	11.63469677

Table -3: Entropy Calculation

Step 3: The weights of each criterion are calculated

$$W_{tj} = \frac{1-e_j}{\sum_{i=1}^{n}(1-e_j)},\ j = 1,2,......n$$

Properties	Weights
Melting point in deg.C	-0.000122989
Latent heat of melting in J/gm	-0.00098769
Solidifying temperature in deg.C	-0.003941388
Latent heat of solidifying in KJ/kg	0.0750755689
Thermal conductivity in W/mK	0.929976379

Table -4: Calculation of weights

VIKOR Method

VIKOR was developed to solve decision problems based on various criterias. In the VIKOR model, probable ranking can be carried out by comparing the estimate of closeness to the perfect solution.

The VIKOR method has the following four steps .

Step 1 : Determine the positive-ideal solution q_j^* (PIS) and negative ideal solution q_j^- (NIS)

$$q_j^* = \{\max q_{ij} | j \in I_1\}, q_j^* = \{\min q_{ij} | j \in I_2\}$$
$$q_j^- = \{\min q_{ij} | j \in I_1\}, q_j^- = \{\max q_{ij} | j \in I_2\}$$

where I_1 and I_2 are sets of benefit and thermal conductivity criteria, respectively.

	Melting point in deg.C	Latent heat of melting in J/gm	Solidifying temperature in deg.C	Latent heat of solidifying in KJ/kg	Thermal conductivity in W/mK
MIN q^*	0.10504571	0.081992176	0.068699102	0.078938772	0.010776ss475
MAX q^-	0.134054149	0.164259738	0.27834621	0.194916309	0.632051323

Negative Min	0.10504571	0.081992176	0.068699102	0.078938772	0.010776475
Positive Max	0.134054149	0.164259738	0.27834621	0.194916309	0.632051323

Table-5: Determination of Positive and negative ideal solution

Step 2 : Compute the values a_i and b_i

$$a_i = \sum_{j=1}^{n} W_{tj} (q_j^* - q_{ij}) / (q_j^* - q_j^-)$$
$$b_i = \max \left[W_{tj} (q_j^* - q_{ij}) / (q_j^* - q_j^-) \right]$$

where W_{tj} are the weights of criteria.

PCM	a_i	b_i
n-octadecalamine/F-MWCNT's	0.017286634	0.00911824
paraffin/ L-type MWCNT's	0.040561686	0.03972552
paraffin/Anisotropic graphene Aerogels	0.172589222	0.12531194
Palmitric acid-steric acid	0.02823598	0.02971106
octadecanol/ reduced graphene oxide graphene nanoplate agrogel	0.33705338	0.26391669
palmitric acid-graphene oxide	0.030936662	0.03212035
PEG6000/polyurethelene/graphene	0.943697281	0.92997638
PEG6000/ti4o7/sio2	0.022733177	0.02190694

Table-6: Determination of a_i and b_i

Step 3 : Compute the value R_i

$$R_i = v \frac{(a_i - a^*)}{(a^- - a^*)} + (1-v) \frac{(b_i - b^*)}{(b^- - b^*)}$$

where a^* = min a_i, a^-=max a_i, b^*=min b_i , b^-=max b_i and v is identified as a weight for planning of maximum group utility and (1-v) is the weight of the individual concern. Usually, the value of v is considered to be 0.5. However, v can set any value from 0 to 1.

PCM	R_i
n-octadecalamine/F-MWCNT's	-0.00936
paraffin/ L-type MWCNT's	0.007236
paraffin/Anisotropic graphene Aerogels	0.05376
Palmitric acid-steric acid	0.001822
octadecanol/ reduced graphene oxide graphene nanoplate agrogel	0.128952
palmitric acid-graphene oxide	0.003096
PEG6000/polyurethelene/graphene	0.490612
PEG6000/ti4o7/sio2	-0.00245

Table-7: Calculation of R_i

Step 4 : Alternatives should be ranked as per the decreasing order of R_i

PCM	Rank
n-octadecalamine/F-MWCNT's	7
paraffin/ L-type MWCNT's	4
paraffin/Anisotropic graphene Aerogels	3
Palmitric acid-steric acid	5
octadecanol/ reduced graphene oxide graphene nanoplate agrogel	2

palmitric acid-graphene oxide	8
PEG6000/polyurethelene/graphene	1
PEG6000/ti4o7/sio2	6

Table-8: Ranking

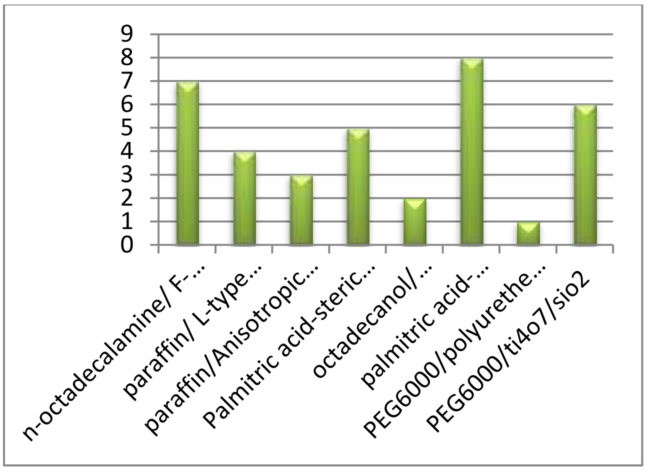

Chart -1: PCM v/s Rank

3. CONCLUSION

From the calculations of Shenon Entropy and VIKOR method, it is concluded that material having maximum thermal conductivity is selected for required application which is PEG6000/polyurethelene/grapheme. Also the material having highest rank is suitable for particular application.Proper selection of phase change material leads to efficient utilization of latent heat thermal energy storage system.

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