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Short Communication

Selection of High Temperature Phase Change Materials for Energy Storage

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Abstract

In this study two way multi-criteria decision-making approaches are used to select and rank the best phase change material for energy storage from a given set of alternatives. Firstly, multi-objective optimization on the basis of ratio analysis (MOORA) plus full multiplicative form (MULTIMOORA) is applied to select the best candidate material. Result shows that 88Al:12Si is the best material considering the selection strategy. Again, multi-objective optimization on the basis of simple ratio analysis (MOOSRA) is used to measure the performance of the candidate material. Study also reveals that Aluminium, commercial purity, 1-0 wrought is the optimum material for energy storage described by MOOSRA method.

Keywords: Energy storage; Phase change materials; Multi-criteria decision making; Selection

Introduction

As rapidly developed living standards around the globe forces the community to find the optimal materials for energy storage. Extensive utilization of fossil energy has caused serious ecological damage, which attract the governments and researchers around the globe. Enthusiastically endorsing green energy has undoubtedly become a significant means of the ecological damage. Concentrated solar power (CSP) technology is one of the most auspicious forms of green energy [1]. This technology possesses huge energy reserves without emission of any harmful gases. Past researchers also believe that vigorously evolving CSP technology is one of the furthermost operative traditions to reveal the energy supply glitches in near future [1]. For continuity in energy supply, phase change materials (PCMs) are playing a crucial role on energy storage followed by sensible heat storage (SHS) and latent heat storage (LHS) [2]. SHS comprises storing the energy in the form of heat by varying the internal energy of a material without phase change whereas, a material endures a phase change mode when LHS energy is stored [2]. Phase change materials fascinate or release heat at persistent temperature which is a vital reflection of efficient power generation [2]. With the copiousness and emergent numeral of novel materials being testified in the current researches, phase change materials selection is becoming more shared. Through this is a fundamental issue that must be solved by exploiting the optimal PCMs for energy storage. Therefore, this work has attempted to screen and rank various PCMs for energy storage application using hybrid multi-criteria decision-making (MCDM) approach [1-3].

Materials and Methods

The selection of phase change materials for energy storage be subject to various factors, such as material possessions, stowing volume, performance, functioning temperature etc. [1]. Traditional material selection from side to side documented strategies, such as collected works have limitation in terms of information and right to use of germane data [2]. Therefore, this study considers the technologically important PCMs for energy storage applications, such as Magnesium, commercial purity (A_1); Aluminium, commercial purity, 1-0 wrought (A_2); Zinc, commercial purity, high grade, min 99.9% (A_3); 88Al:12Si (A_4) and 60Al:34Mg:6Zn (A_5). The significant properties of the aforementioned materials are latent heat (KJ/Kg) (C_1); melting point (°C) (C_2); density (Kg/m^3) (C_3) and total energy stored (KJ/Kg) (C_4) documented in Table 1.

Table 1: Properties of materials [2].

Materials	Criterion			
	C1	C2	C3	C4
A1	365	648	1740	693
A2	388	661	2700	613
A3	112	419	7140	120
A4	560	576	2700	942
A5	312	443	2380	365

Many different methods are available to screen and rank the phase change materials, including experimental methods [1,4,5], theoretical calculations and numerical simulations [1,6,7]. In this study authors have attempted to screen and rank various PCMs for energy storage applications using hybrid MCDM techniques. Two MCDM techniques have been used namely multi-objective optimization on the basis of ratio analysis (MOORA) plus full multiplicative form (MULTIMOORA) and multi-objective optimization on the basis of simple ratio analysis (MOOSRA) to measure the performance of the candidate materials [8-11]. All these techniques together have been used as an efficient tool for initial ranking and screening the materials for various phase change materials based storage applications. Shannon's entropy method is used to calculate the relative importance of the properties on the decision making process [3,12-14].

Results and Discussion

To demonstrate the applicability of the MOORA plus multiplicative form MULTIMOORA and MOOSRA methods in the selection dilemma, this work considers four criteria, viz. latent heat, melting point, density and total energy stored and five alternatives Magnesium, commercial purity; Aluminium, commercial purity, 1-0 wrought; Zinc, commercial purity, high grade, min 99.9%; 88Al:12Si and 60Al:34Mg: 6Zn from a published literature [2]. The decision matrix of the selected problem is shown in Table 1. Before applying MOORA plus multiplicative form MULTIMOORA and MOOSRA methods, weight of each criteria is calculated using Shannon's entropy method and shown in Table 2.

Table 2: Weights of each criteria.

	Criterion			
	C1	C2	C3	C4
Weights	0.074	0.123	0.698	0.112

MOORA and MULTIMOORA methods are easy to calculate, does not require huge mathematics fully depends on ratio system. Firstly, the decision matrix shown in Table 1 is normalized and then depending on the beneficial and non-beneficial criteria overall performance of the candidate materials is computed. Table 3 shows the overall performance and the ranking of the candidate materials. 88Al:12Si is the best PCM according to the ratio system part of MOORA and full multiplicative form MULTIMOORA [2].

Table 3: Overall performance and ranking by MOORA & MULTIMOORA method.

	A1	A2	A3	A4	A5
Performance	0.123	0.044	-0.472	0.295	0.009
Ranking	2	3	5	1	4

The initial steps of MOOSRA method are similar to MOORA method. But in this case weighted normalized decision matrix is computed. Shannon's entropy method is used to calculate the weights of each criteria. Thereafter, the sum of the beneficial criteria is divided by the sum of non-beneficial criteria, to find the overall performance score and ranking of each alternative shown in Table 4 [2].

Table 4: Overall performance and ranking by MOOSRA.

	A1	A2	A3	A4	A5
Performance	0.081	0.299	0.004	0.076	0.037
Ranking	2	1	5	3	4

According to the MOOSRA method, Aluminium, commercial purity, 1-0 wrought is the best PCM for energy storage material selection problem. The MOORA and full multiplicative form MULTIMOORA methods produce same rankings, whereas MOOSRA method gives different ranking shown in Figure 1.

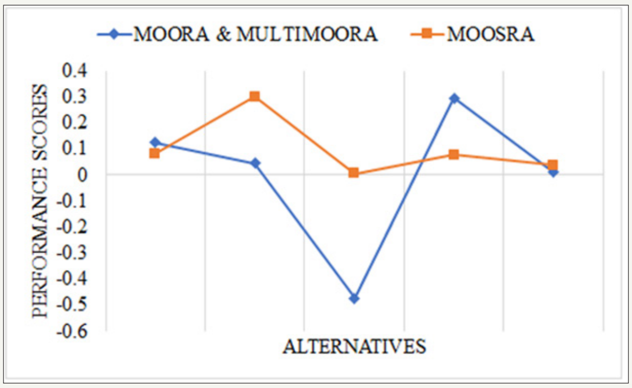

Figure 1: Performance rankings.

Conclusion

Energy storage materials selection is very significant for the expansion of high-temperature CSP technologies. Based on the collection and scrutiny of pertinent data associated with this work following conclusions are drawn.

A. In this work multi-objective decision making dilemma for energy storage material is fingered and explained by MOORA and its full multiplicative form MULTIMOORA and MOOSRA methods.

B. Results suggest that 88Al:12Si is the best storage material by MOORA and MULTIMOORA methods and Aluminium, commercial purity, 1-0 wrought is the best alternative by MOOSRA method.

Finally, these approaches are visualized as a suitable tool for selecting the best alternative from a set of candidate materials. In future, studies like high-temperature phase change materials for energy storage problem can be solved by other multi-objective decision making methods with any other number of criterions and alternatives.

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