Heat storage system based on copper-coates granules of polyethylene

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***Abstract* – The possibility of using copper granules of polyethylene as a basis for creating effective heat-accumulating systems is considered. It is shown that the efficiency of using metallized polyethylene granules to create heat storage systems is higher.**

***Keywords* – polyethylene; copper; heat accumulator; metallization; metal-filled polymer composite.**

Introduction

Metal-filled composites can be considered a promising type of polymer composite materials. Such composites combine the characteristics of materials that differ significantly in their properties. For example, in terms of electrical, thermal and magnetic properties, metals and polymers are materials with extremely opposite properties. Thus, the combination of metals and polymers in one composite makes it possible to obtain new materials that have unique properties and in the future may have very wide areas of application: medicine, construction, aviation, etc. [1].

Taking into account the improved heat-conducting properties of metal-filled polymer composites, a promising direction of their use is alternative energy, namely their use as highly efficient heat storage systems. The problem of accumulation, storage and further use of energy is typical for both traditional and non-traditional energy. [2]. The introduction of preferential "night" tariffs aims to equalize daily energy consumption by encouraging the end user to use energy more intensively at night. One of the most energy-intensive systems, the operation of which can be organized according to the night tariff, is the heating system. The introduction of heating systems with energy storage will solve a number of problems related to the inconsistency of energy production and consumption schedules in both traditional and non-traditional energy sources. Among various types of heat storage systems, those that use phase transition heat can be considered promising. Their significant advantage is the ability to store energy with high density in a narrow temperature range [3].

Crystalline polymers can be used as a basis for creating heat-accumulating systems with a phase transition [4]. However, at the same time, polymers are inherently materials with low thermal conductivity, which imposes certain limitations on highly efficient heat storage systems developed on their basis. Cooling of the surface layers of the polymer in contact with the heat exchange surface leads to a significant decrease in the ability to remove heat from the heated inner layers, which reduces the efficiency of the use of the heat storage systemSuch a shortcoming requires the development of new materials that will provide the possibility of rapid and uniform heating of the polymer (charge) and efficient removal of accumulated heat (discharge).

Experimental

Thus, there is a need to develop a polymer heat-accumulating material that will have increased thermal conductivity due to the introduction of a metal filler and high values of the density of stored energy due to the phase transition of crystalline polymers. In this work, an analysis of experimental studies of the possibility of using commercially available polyethylene granules as a phase transition material is carried out. The introduction of metal into the polymer matrix occurred as a result of metallization of polymer granules. The developed material was evaluated using an experimental setup simulating the operation of a heat accumulator (Fig. 1)[5].

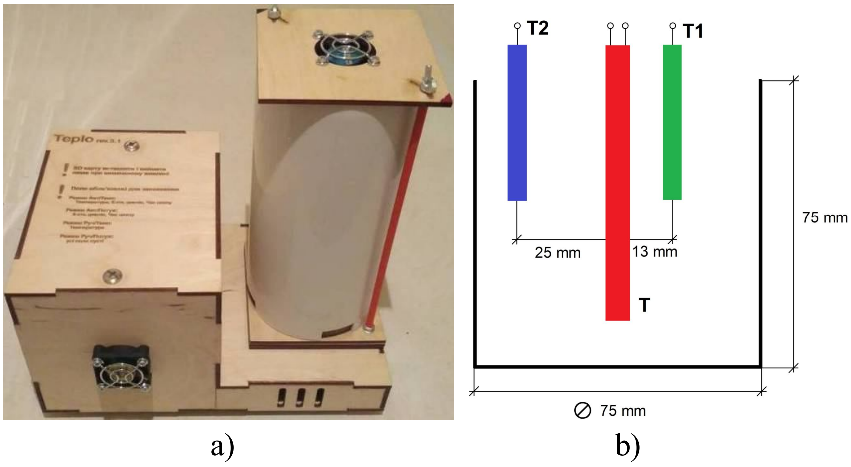

Fig. 1. Experimental setup for simulating the operation of a heat accumulator

a) general view, b) geometric dimensions of the measuring cell

The measuring cell is placed inside the insulating shell, in the lower part of which slots are made to ensure air circulation during battery discharge. A fan is placed in the upper part of the heat-insulating shell to increase air circulation. The measuring cell consists of a metal container in which the phase transition material is placed, a heater and two thermocouples for measuring the temperature change of the material during charging and discharging of the battery.

The study of the operation of the heat accumulator consisted in measuring the change in the temperature of the phase transition material (polyethylene and metallized polyethylene) over time in charge and discharge modes (Fig. 2). The temperature of the heater was the same in all cases. From the obtained dependencies, the temperature of the thermocouples was set at fixed time intervals, by which the efficiency of using metallized polyethylene was evaluated.

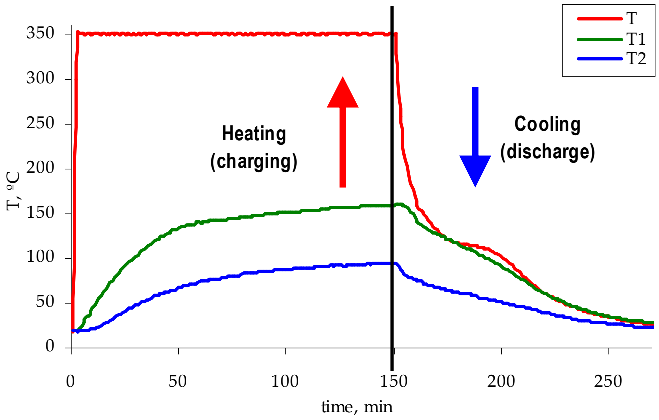

Fig. 2. Temperature change of Liten PL-10 polyethylene

1 – heater temperature (T), 2 – temperature of thermocouple 1 (T1), 3 – temperature of thermocouple 2 (T2)

Using the developed installation that simulates the operation of a thermal battery, a study of the effect of the amount of metal on the operation characteristics of the installation in charge and discharge modes was conducted. The research consisted of measured changes in the temperature of the phase transition material over time. Several charge-discharge cycles were carried out in order to compact the material and obtain a monolithic block. The resulting dependences of material temperature changes during heating and cooling are shown in the table.

Table

Temperature of the polyethylene-based Liten PL-10 phase transition material

Time	1 cycle		2 cycle		3 cycle		4 cycle	
	T1	T2	T1	T2	T1	T2	T1	T2
Copper content 0 wt.%								
Heating								
30	102	48	112	58	115	70	117	72
60	139	74	135	76	132	82	141	84
90	149	85	151	84	155	90	157	94
120	155	91	159	88	164	97	168	101
150	159	95	161	93	164	99	171	105
Cooling								
30	115	62	116	59	117	63	119	63
60	76	46	76	45	77	47	80	49
90	41	30	42	30	44	32	44	33
120	28	24	29	24	30	24	30	25
Copper content 7 wt.%								
Heating								
30	106	67	113	77	117	75	121	74
60	144	96	145	96	145	95	147	92
90	156	111	160	108	161	108	163	108
120	163	119	167	118	171	118	172	114
Cooling								
30	115	77	122	74	123	71	124	65
60	72	49	79	50	81	49	82	48
90	38	30	42	31	44	32	44	31
120	27	23	28	24	30	25	29	23
Copper content 15 wt.%								
Heating								
30	116	76	118	96	116	97	119	101
60	155	111	146	117	147	119	150	122
90	167	135	161	133	161	138	166	142
120	172	142	168	141	170	145	174	150
Cooling								
30	116	90	115	91	120	98	125	111
60	62	54	63	55	71	62	84	75
90	33	30	34	32	38	35	44	43
120	23	23	25	24	26	25	31	29

The obtained results allow us to state that the use of metallized polyethylene as a basis for creating heat accumulators with a phase transition is promising. The limit temperatures that were achieved during heating compared to non-metallized PE are higher by 10-15ºC. The time to reach the maximum temperature, which was achieved for pure polyethylene (159ºC), in the case of a copper content of 7 wt.%, is reduced from 150 to 100 min. An increase in the metal content to 15 wt.% results in an even more significant reduction in the charging time (70 min). The obtained values of temperature and time of charge and discharge of the battery model testify to the higher thermal conductivity of the obtained metal-filled system. As mentioned earlier, higher thermal conductivity of heat accumulators based on polyethylene is a necessary condition for creating highly efficient heat accumulators.

Conclusions

Thus, the obtained results allow us to assert the prospects of using metallized polyethylene as a basis for creating heat storage systems. The charging and discharging time of the battery, in the case of using metallized polyethylene, is significantly shorter compared to the original polyethylene, which indicates a higher thermal conductivity of the polymer system with a metal filler.

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