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New Approach to the Issue of Recycling Glass-Containing Household Waste

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Abstract-The article represents a new direction in the processing of glass-containing household waste. The essence of the direction to study the process of processing in the melt of the heat carrier to a marketable product. The article discusses the eutectic mixture of metals as a heat carrier in technology. We have identified the optimal modes for further experimental studies with a mass ratio of heat carrier to glass mass equal to 1: 6 at 773 and 823 K.

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Keywords-*Melt, Heat-Carrier, Eutectic Mixtures, Metal Salts, Household Waste*

I. Introduction

In Ukraine, up to 12 million tons of household waste is generated annually. Waste is sent to the landfill about 95%, and only 2-3% is recycled. In Ukraine, landfills occupy about 7% of the official, and most of them formed spontaneously. As you know, most of the waste that is located in landfills begins to decompose only after several years. Therefore, the catastrophic ecological situation in Ukraine was noted [1, 2].

Household waste is a different composition, such as organic matter; plastic; polyethylene; metal and glass. Metal and glass is one of the hardly recyclable waste. It is known that their processing is associated with a high melting point in furnaces and rapid solidification in air. Next, the melt is mixed with a binder component and poured into the forms of the finished product [3].

In this article, we will analyze the possibility of recycling glass-containing household waste in the melt of the heat carrier. This question is interesting to us, as it will reduce the area of landfills and will provide an opportunity to receive a secondary product for the needs of the population.

It is a known fact that each type of glass has its own melting point. Table 1 lists some of them [4].

In the EUNU named after V. Dahl, we have developed a technology in which chemical transformations occur in the heat carrier melt [5]. This technology has proven itself for the processes of producing hydrogen from natural gas [6] and coal gasification to produce synthesis gas in a high-temperature heat carrier melt [7]. We also investigated the process of neutralization of acidic tar from coke-chemical wastes with preliminary purification from sulfur and its compounds [8]. With this we propose to solve the issue of neutralization of industrial waste according to the technology with the melt of the heat carrier. Next, we studied the processing of petroleum products in various heat carriers, including low-temperature [9].

TABLE I. MELTING POINT OF VARIOUS TYPES OF GLASS

Name of glass type	Melting temperature, °C
bottle glass	1200-1400
quartz glass	about 1665
ampoule glass	1550-1800
liquid glass	1088

Our studies have allowed us to make an assumption about the possibility of the process of processing glass-containing waste in the melt of the heat carrier. It was assumed that the final product could be glass concrete, which can be used, for example, as paving slabs.

For example, the final product is glass concrete. It is widely used for the production of finishing panels, grilles, fences, walls, partitions, ceilings, decor, complex architectural or transparent roofs, pipes, noise barriers, cornices, tiles, cladding and many other products. In this case, it is a known fact that fine ground powder in concrete is used as a binder. At the same time, there are fractions up to 5 mm - as a fine filler (sand) and a fraction of more than 5 mm - as a large filler. It is also noted that when in contact with water glass does not exhibit binding properties and in order to ensure the hydration process, an alkali metal compound should be used as an activator. In the process of hydration of glass breakage, upon reaching a certain level of acidity of the medium, silicic acids turn into a gel. The result is a strong, dense and durable silicate conglomerate, which is called glass concrete [10, 11].

This fact can be considered in technology, that is, to use a molten salt of alkali metals or their mixtures as an activator of the process. For the process to mix them with glass-containing waste.

It is noted that one ton of recyclable glass waste saves 650 kg of sand, 200-300 kg of soda ash and about 200 kg of limestone. These components are necessary for the production of packaging and recycled products.

II. Materials and Methods

In our technology, the main part is the heat carrier melt. It can only be obtained in the oven. To do this, we use a muffle furnace (Fig. 1) to optimize the composition of the heat carrier mixture and the furnace (Fig. 2) for research with higher productivity.

Figure 1. The muffle furnace when the operating mode is reached and inside with the capacity of the studied mixture of substances as a heat carrier

Figure 2. Photo of the laboratory furnace with the melt for greater productivity. View from above

The methodology of our work includes the following main research objectives:

determine the composition of the heat carrier with a low melting point;

to study the effect of the fraction of glass-containing wastes on the yield of the final product and to determine the satisfactory size of the fraction; determine the optimal operating temperature of the process; determine the optimal operation of the furnace for greater performance.

As a heat carrier, we plan to consider various metal salts and mixtures thereof. It is noted that eutectic mixtures of inorganic salts have a low melting point. To search for the required composition of the coolant, consider the properties of some of the double eutectic mixtures with a low melting point. The data are presented in table 2 [13].

TABLE II. Some double eutectic mixtures of substances with a low melting point

Melting temperature, °C	Components in the mixture, A - B	The content in the mixture of component B, mol%.
128	KCl - AlCl3	67
150	KCl - CuCl	65
170	NaOH - KOH	50,6
220	KNO3 - NaNO3	50
295	NaNO3 - NaCl	6,4
432	ZnCl2 - KCl	68,5
500	NaCl - CaCl2	52
710	Na2CO3 - K2CO3	44

In order for the heat of the melt to speed up the process, it is easiest to use in the melt a certain crushed fraction of glass waste. The results of such studies are shown in Fig.3 and Fig.4.

Figure 3. Photo melt from coarse glass

Figure 4. Preparation and grinding fraction of glass

In order to choose the composition of the heat carrier melt, it is necessary to study the calorific value of eutectic mixtures of metal salts and determine the operating mode of the process.

III. INVESTIGATIONS

In order to determine the composition of the heat carrier, we examined the physicochemical properties of some eutectic mixtures. The results of the study of the calorific value of the mixture $ZnCl_2$: KCl are presented in Table 3.

TABLE III. THE CALORIFIC VALUE OF THE MELT OF EUTECTIC MIXTURES OF METAL SALTS.

The melting point of the mixture, °C	Mass of heat carrier, g	Calorific value, J/mol		
		723 K	773 K	823 K
ZnCl2: KCl (68.5 mol% KCl)				
423	5	6,67	25,74	45,63
	2	2,67	10,30	18,25
	4	5,33	20,59	36,51
	7	9,33	36,04	63,89
	10	13,33	51,48	91,27
	13	17,33	66,93	118,65
	17	22,67	87,52	155,16
	20	26,67	102,96	182,54
	22	29,34	113,26	200,79
	30	40,00	154,44	273,81

The calorific value of the molten glass of the bottle by the mass of the glass is presented in Table 4.

TABLE IV. THE CALORIFIC VALUE OF THE MOLTEN GLASS

mass of glass, g	Calorific value, J/mol
5	934,97
2	373,99
4	747,98
7	1308,96
10	1869,94
13	2430,92
17	3178,90
20	3739,88
22	4113,86
30	5609,81

The essence of the technological process is associated with the transformation of the glass fraction into a viscous liquid mass, which is mixed with the prepared specific composition of the heat carrier. The heat carrier is a mixture of metal salts, which we should determine. It should create a certain thermal regime of the glass fraction for complete transformation into a viscous mass. At the first stage, we set the task to find the composition of the heat carrier and its quantity, which will allow us to determine the necessary operating mode. To do this, we compare the calorific values of various mixtures and select it in accordance with the thermal regime of the molten fraction of glass. We decided to start our studies with a one-factor experiment on a eutectic mixture of metal salts $ZnCl_2$: KCl. The results of this experiment are presented in Tables 5. and 6.

Graphic dependences (Fig. 5 and Fig. 6) show a clear linear dependence on the glass mass and the heat carrier mass.

TABLE V. THE RESULTS OF A ONE-FACTOR EXPERIMENT FOR THE MELT PROCESS BY CHANGE WITH MASS OF HEAT-CARRIER

Mass of heat carrier, g	Calorific value, J/mol		
	723	773	823
mass of glass = 5 g			
5	262,82	287,56	313,10
2	181,43	198,51	216,14
4	235,69	257,88	280,78
7	317,08	346,93	377,74
10	398,47	435,98	474,71
13	479,86	525,04	571,67
17	588,38	643,78	700,95
20	669,77	732,83	797,92
25	805,42	881,25	959,52
30	941,07	1029,68	1121,13

TABLE VI. THE RESULTS OF A SINGLE-FACTOR EXPERIMENT FOR THE MELT PROCESS BY CHANGE WITH MASS OF GLASS PRODUCTS

Mass of glass, g	Calorific value, J/mol		
	723	773	823
mass of heat carrier =5 g			
5	262,82	287,56	313,10
2	186,52	204,08	222,20
4	237,38	259,73	282,80
7	313,68	343,22	373,70
10	389,98	426,70	464,60
13	466,28	510,18	555,49
17	568,01	621,49	676,69
20	644,31	704,97	767,59
25	771,48	844,11	919,08
30	898,64	983,25	1070,58

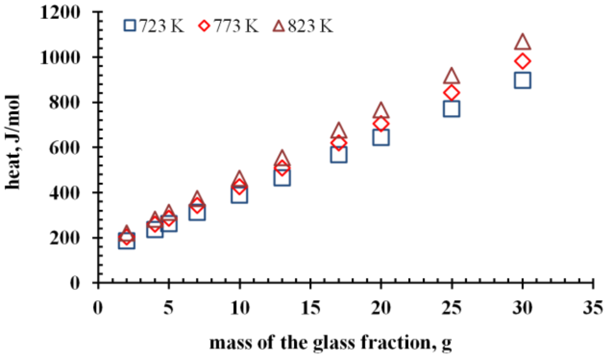

Figure 5. The dependence of calorific value on the mass of glass

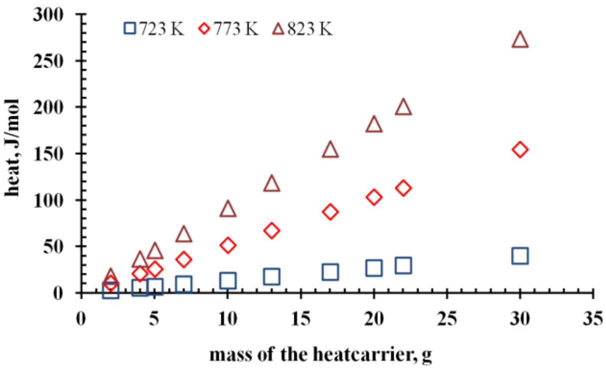

Figure 6. The dependence of the calorific value of the mass of the heat carrier

According to Table 5, when loading 5 g of the glass fraction and loading the carrier heat 30 g, the melt process proceeds satisfactorily at 723 and 773 K, and also at 823 K and the carrier heat is 25 g. The second case (Table 6) is when we take a constant mass of heat-carrier of 5 g, the melt process proceeds satisfactorily at 773 and 823 K. At the same time, the loading of the glass fraction is 30 g. Hence, the mass ratio of the heat carrier: glass is 1:6 taking into account the temperature not lower than 723 K.

The results of the simultaneous influence of the mass fraction of the glass and the mass of the heat carrier are presented in Table 7. What the molten mixture looked like after the furnace is shown in Fig.7.

Figure 7. Molten mixture of glass and heat carrier

TABLE VII. THE EFFECTS OF THE MASS FRACTION OF THE GLASS AND THE FRACTION OF THE HEAT CARRIER

№	Mass of heat carrier, g	Mass of glass, g	Calorific value, J/mol		
			723	773	823
1	5	5	262,82	287,56	313,10
	2	2	105,13	115,02	125,24
	4	4	210,25	230,05	250,48
	7	7	367,94	402,59	438,34
	10	10	525,63	575,12	626,20
	13	13	683,32	747,66	814,06
	17	17	893,58	977,71	1064,54
	20	20	1051,27	1150,24	1252,40
	25	25	1314,08	1437,81	1565,50
	30	30	1576,90	1725,37	1878,61
2	30	5	941,07	1029,68	1121,13
	25	2	729,12	797,77	868,63
	20	4	644,34	705,00	767,62
	17	7	639,25	699,43	761,55
	13	10	607,02	664,18	723,17
	10	13	601,93	658,60	717,10
	7	17	622,27	680,86	741,33
	4	20	617,18	675,29	735,27
	2	25	690,09	755,06	822,12
	5	30	898,64	983,25	1070,58
3	5	30	898,64	983,25	1070,58
	2	25	690,09	755,06	822,12
	4	20	617,18	675,29	735,27
	7	17	622,27	680,86	741,33
	10	13	601,93	658,60	717,10
	13	10	607,02	664,18	723,17
	17	7	639,25	699,43	761,55
	20	4	644,34	705,00	767,62
	25	2	729,12	797,77	868,63
	30	5	941,07	1029,68	1121,13

We will visually present the dependences of the results of Table 5 and Table 6 (experiment 1) in Fig. 8.

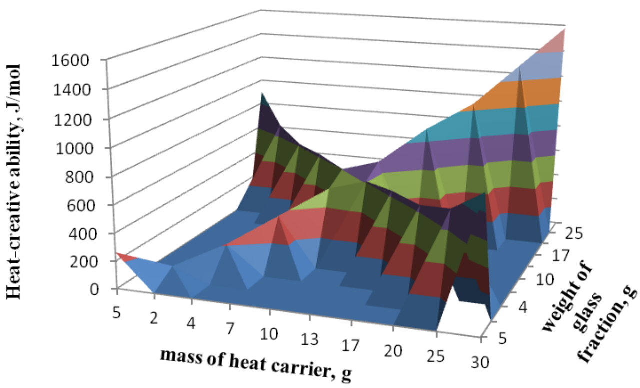

Figure 8. Dependence of the calorific value of the reaction mixture on the mass of the heat carrier and the mass of the glass fraction at 723 K

Results of Table 5 and Table 6 with Fig. 8 show that a satisfactory operating mode can be considered as the mass of reagents from 20 g at a ratio of 1:1 in the temperature range of 723-823 K.

And also confirm our conclusions that the most optimal ratio is the ratio of the mass of the glass fraction to the mass of coolant as 1: 6.

IV. CONCLUSIONS

The analysis of literature data on the processing of household waste and the study of the processing of directly glass-containing waste, as well as the study of the properties of the technology with the melt showed the possibility of the process as one of the promising areas in the processing of glass-containing waste.

The results confirmed the possibility of carrying out the processing process on the technology in the melt. In this case, it is planned to use eutectic mixtures of metal salts $ZnCl_2$: KCl as a heat carrier.

Some operating modes of the process of melting the heat carrier and glass were noted at 723-823 K. In this case, the masses should be from 20 g at a 1: 1 ratio.

It is noted that at 773 K and 823 K, the mass ratio of the coolant can be considered optimal: the mass of the glass = 1: 6.

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