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STUDY OF RAW MATERIALS TREATMENT BY MELTING AND GASIFICATION PROCESS IN PLASMA ARC REACTOR

ŠTÚDIUM SPRACOVANIA VYBRANÝCH DRUHOV ODPADOV TAVENÍM A SPLYNOVANÍM V PLAZMOVOM REAKTORE

Abstract

The world consumption of metals and energy has increased in last few decades and it is still increasing. Total volume production results to higher waste production. Raw material basis of majority metals and fossil fuels for energy production is more complex and current waste treatment has long term tendency. Spent power cells of different types have been unneeded and usually they are classified as dangerous waste. This important issue is the main topic of the thesis, in which author describes pyrometallurgical method for storage batteries – power cells and catalysts treatment. During the process there were tested a trial of spent NiMH, Li – ion power cells and spent copper catalysts with metal content treatment by melting and gasification process in plasma arc reactor. The synthetic gas produced from gasification process has been treated by cogenerations micro turbines units for energy recovery. The metal and slag from treatment process are produced into two separately phases and they were analyzing continually.

Abstrakt

Celková svetová spotreba kovov, ako i energie v posledných desaťročiach prudko vzrástla a má i naďalej stúpajúcu tendenciu. S nárastom produkcie tovarov rastie taktiež množstvo produkovaných odpadov. Keďže primárna surovinová základňa väčšiny kovov a fosílnych palív pre výrobu energie je stále užšia a čoraz komplexnejšia, je spracovanie odpadov za účelom získania ich materiálového a energetického potenciálu čoraz perspektívnejšie. Vyradené batérie resp. monočlánky rôzneho typu ale napr. i vyčerpané katalyzátory s obsahom neželezných kovov sa často stávajú nepotrebnými a väčšinou končia ako nebezpečný odpad na skládkach. Autor sa v tomto príspevku zaoberá pyrometalurgickým spracovaním vybraných druhov monočlánkov a katalyzátorov. Experimentálne a poloprevádzkovo bolo odskúšané spracovanie NiMH, Li – ión monočlánkov a katalyzátorov s obsahom neželezných a ušľachtilých kovov, ich tavením a splynovaním v plazmovom reaktore. Vzniklý syntézny plyn z pyrolýzy bol spaľovaný v kogeneračnej mikroturbíne, čím sa získal jeho energetický potenciál. Kov a troska zo spracovania odpadu sa získali do dvoch vzájomne nemiešateľných fáz v nísteji – dne reaktoru a boli v priebehu spracovania kontinuálne analyzované.

1 INTRODUCTION

The world consumption of non-ferrous and noble metals is always increasing and they are used for catalysts production in chemical, petrochemical and electrical industries. After using of mentioned commodities they become a waste, which is subsequently stored on hazardous waste dump and it reflects dangerous for environment mainly because of heavy metals content. The thesis

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describes the study of NiMH, Li – ion power cells and catalysts treatment from chemical industries, which include non-ferrous or/and PGM metals by melting and gasification in plasma arc reactor. Melting and gasification process of waste is one possibility of thermal liquidation or treatment. Non gasification components as glass, ceramics, and non-volatile metals as for example iron, copper, nickel, cobalt and platinum group metals (PGM) are melting and they make two separated phases – metal or alloy and slag on the bottom of plasma arc reactor [2]. For experiments plasma melting and gasification there were used spent copper catalyst, NiMH and Li – ion spent power cells. The catalysts carrier for selecting reduction of nitrobenzene ($C_6H_5NO_2$) to aniline ($C_6H_5NH_2$) is SiO_2. NiMH and Li – ion spent power cells came from public collection (electrical appliances) and their material composition with material composition of Cu catalysts are visible in table 1. The samples of using spent materials – waste were homogenized and sampled before the experiments of melting and gasification in plasma arc reactor.

2 PYROMETALLURGICAL TECHNIQUE FOR WASTE TREATMENT IN PLASMA ARC REACTOR

The melting and gasification experiments for assorted waste were made by experimental plasma unit with install power 80 kW and by commercial plasma unit with install power 0,5 MW. The nitrogen gas (N_2) was used for ionizing and plasma generation. Experimental plasma arc reactor operates with dependent transferred electric arc, which is generating between hot graphite electrode (cathode) and conductive graphite bottom (anode). Plasma gas ionized in electric arc flows through hollow cathode (fig.1c). Commercial plasma arc reactor, which was used for experimental treatment of copper catalyst, operates with independent non-transferred electric arc generating between anode and cathode inside plasma torch (fig.1a). If there is conservation of good conductivity between electrodes (fig.1b), the reactor has possibility to operate with dependent transferred electric arc. Plasma torches with dependent transferred electric arc are used in case sufficient conductivity between melting material and plasma torch or they are fitted in case dependent plasma generator. These systems are characterized by higher coefficient of heat efficiency in comparison to non-transferred plasma systems – plasma systems with independent non-transferred electric arc.

Basic raw materials (Cu catalysts and NiMH, Li – ion spent power cells) were mixed with slag consumables materials and reductants. Mixed materials were continuously feeding to reactor for melting and gasification. The clean sample of synthetic gas was analyzed during the experimental process. Before taping procedure there was analyzed the metal and slag product. The synthetic gas was treated by cogeneration micro turbines after cooling, cleaning and neutralizing.

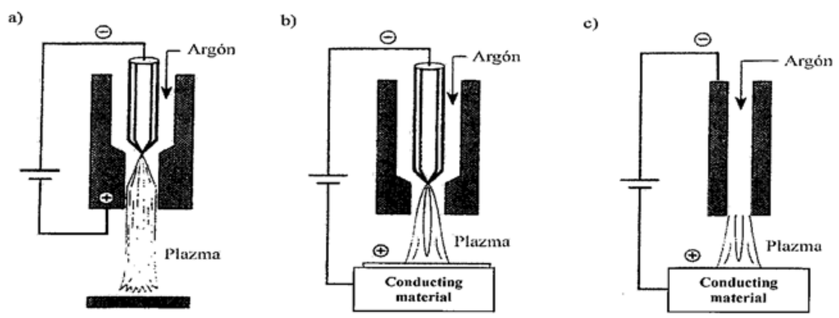

Fig. 1 Schematic wiring diagram of plasma torches

a) Plasma torch with non –transferred independent electric arc

b) Plasma torch with transferred dependent electric arc with cold electrode

c) Plasma torch with transferred dependent electric arc with hot electrode

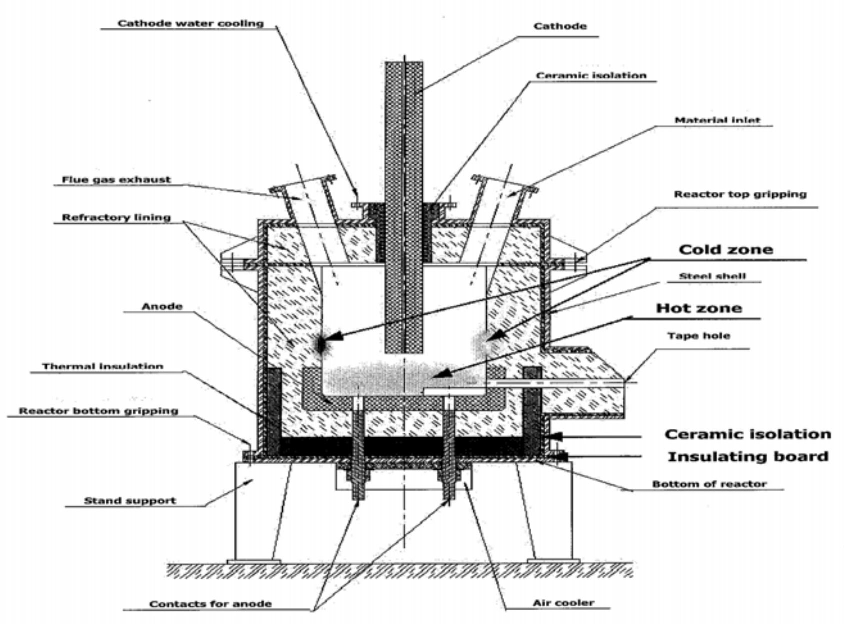

Fig. 2 Design of 80 kW experimental plasma arc reactor

Tab. 1 Chemical analysis of experimental basic raw materials

Sample	**Chemical composition (wt. %)**								
Cu	**Al_2O_3**	**CaO**	**MgO**	**SiO_2**	**Cr_2O_3**	**FeO**	**Cu**	**C**	**moisture**
catalyst	0,19	5,42	2,65	28,91	0,022	5,65	29,87	15	13
NiMH	**Ni**	**$Ni(OH)_2$**	**Co**	**La, Ce, Pr, Nd**		**KOH, NaOH**		**Steel / Fe**	**Silon, PP**
cells	20 - 55	10 - 25	< 20	5 – 15		10 - 15		10 - 25	< 3
Li – ion	**Ni**	**Li**	**Co**	**Al**	**Other metals**	**C**	**organics**	**Steel / Fe**	**Plastics***
cells	5 - 10	5 - 7	5 - 20	< 5	< 10	< 10	< 15	20 - 50	7

* polyethylene (PE), polypropylene (PP), polyvinylchloride (PVC), tetrafluoretylene, polyamide

2.1 Pyrometallurgical waste treatment in plasma arc reactor

2.1.1 Melting and gasification of copper catalysts

The copper catalyst was experimentally melted and gasified in 0,5 MW plasma arc reactor. The reactor operated with underpressure (0,5 – 1 kPa) and reductant atmosphere. Feeding speed was 150 kg/h. (kilogram per hour). Nitrogen gas (N_2) flow rate was 360 – 480 SLPM (standard liter per minute). During process of pyrolysis there was generated 150 – 180 SCMPH (standard cubic meter per hour) of synthetic gas. Synthetic gas was burned in cogeneration micro turbines after his cooling, cleaning and neutralizing procedure. Heat and electricity were generated from burning procedure in micro turbines. Table 2 shows the typical chemical composition of synthetic gas from continuously measurement.

2.1.2 Melting and gasification of NiMH and Li – ion spent power cells

NiMH and Li – ion spent power cells were experimentally melted and gasified in experimental 80 kW plasma arc reactor. The reactor operated with underpressure (0,5 – 1 kPa) and reductant atmosphere. Feeding speed both types of spent power cells was 20 kg/h. (kilogram per hour). Nitrogen gas (N_2) flow rate was 8,5 SLPM (standard liter per minute). During process of pyrolysis NiMH spent power cells there was generated 15 SCMPH (standard cubic meter per hour) of synthetic gas and from pyrolysis Li – ion spent power cells there was generated 35 – 38 SCMPH (standard cubic meter per hour) of synthetic gas. Synthetic gas was burned in cogeneration micro turbines after his cooling, cleaning and neutralizing procedure. Table 2 shows the typical chemical composition of synthetic gas from continuously measurement.

Tab. 2 Typical chemical composition of synthetic gas from continuously measurement

Cu catalysts		**NiMH spent power cells**		**Li – ion spent power cells**	
Component of synthetic gas	**(vol. %)**	***Component of synthetic gas***	**(vol. %)**	***Component of synthetic gas***	**(vol. %)**
Methane CH_4	0,0294	Methane CH_4	0,0100	Methane CH_4	0,0300
Hydrogen H_2	9,2850	Hydrogen H_2	7,1250	Hydrogen H_2	10,2500
Oxygen O_2	0,0200	Oxygen O_2	0,0210	Oxygen O_2	0,0100
Nitrogen N_2	70,9296	Nitrogen N_2	75,6755	Nitrogen N_2	64,7959
Carbon dioxide CO_2	4,5800	Carbon dioxide CO_2	4,3216	Carbon dioxide CO_2	0,0100
Carbon oxide CO	15,3350	Carbon oxide CO	13,1180	Carbon oxide CO	24,8990
Ethylene C_2H_4	0,0274	Ethylene C_2H_4	0,0455	Ethylene C_2H_4	0,04670
Ethane C_2H_6	0,1095	Ethane C_2H_6	0,1981	Ethane C_2H_6	0,2110
Acetylene C_2H_2	0,0520	Acetylene C_2H_2	0,0442	Acetylene C_2H_2	0,08227
C_{5-8}	0,0021	C_{5-8}	0,0011	C_{5-8}	0,0051
C_4	-	C_4	-	C_4	-
C_3	-	C_3	-	C_3	-
Σ	100,37	Σ	100,56	Σ	100,34
Heating capacity ($MJ.m^{-3}$)	**7,0469**	Heating capacity ($MJ.m^{-3}$)	**5,9899**	Heating capacity ($MJ.m^{-3}$)	**10,5704**

3 CONCLUSIONS

The results of experimental plasma treatment of copper catalysts show copper recovery of 99,6 – 99,77% and final alloy contain 95 – 97,5% Cu and 2,5 – 4,5% Fe. Synthetic gas was generated with heating capacity 7,0469 MJ/m^3. By treatment of NiMH spent power cells (70% of metal content) there was produced the metal alloy with 59,4% Ni, 6,9% Co, 31,8% Fe, 1,9% Cu + Mn. Synthetic gas was generated with heating capacity of 6,0 MJ/m^3. By treatment of Li – ion spent power cells (30% of metal content) there was produced the metal alloy with 37,21% Co, 33,04% Fe, 6,03% Ni, 23,72% Cu + Cr + Mn and synthetic gas was generated with heating capacity 10,0 MJ/m^3.

It is possible to claim that energy intensity of waste treatment in plasma arc reactor is relatively high. However plasma reactor operates with higher rate of metal recovery than conventional processed methods. Moreover, the energy potential from waste is possible to recovery.

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