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NICKEL-IRON BATTERY WITH STEEL FIBRE BASED ELECTRODES

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Nickel plated steel fibre mats with high porosity and good conductivity have been fabricated. Wet slurry sintering technique is followed to disperse fine nickel powder into the fibre mat with subsequent electrochemical impregnation of $Ni(OH)_2$ to get nickel positive electrode. Iron negative results when finely divided iron powder (electrolytic/carbonyl) is incorporated into the fibre mat again by slurry sintering technique. Nickel-iron cell is assembled with these fibre iron negative and nickel positive electrodes. Characterisation is being carried out on the assembled Ni/Fe cell and results are presented.

Keywords: Ni/Fe cell, steel fibre and nickel powder.

INTRODUCTION

In the field of Ni/Cd, Ni/Fe, Ni/Zn and Ni/H_2 batteries composite fibre electrode technology is the latest approach to get electrodes with low weight, high active material content and efficient utilisation of active material leading to high specific energy and power. Nickel coated chopped graphite fibre, nickel fibre and steel fibre are the basic materials that have been subjected to compact sintering (1,2) to produce highly porous structurally rigid fibre mats. Active materials are loaded into these fibre mats mechanically or electrochemically or by wet slurry sintering. The fibre mat is an inactive component offering electrical conductivity to the active material and mechanical strength to the electrode as a whole. It can hold active material as its own mass or more with fairly good utilization during electrochemical process.

Among the fibre materials, steel fibre is the cheapest material commonly available. It could be electroplated with nickel. Hence in commercial point of view the steel fibre based nickel batteries will workout cheaper than their counterparts wherein nickel fibre/nickel powder is used to make porous matrix. Steel fibre based nickel electrodes and iron electrodes have been fabricated. A 50Ah Ni/Fe battery prototype is assembled and subjected to charge - discharge studies at different currents. The prototype could be conveniently charged and discharged at 1 hour rate. Electrochemical parameters pertaining to the prototype are presented in this paper.

Iron electrode fabrication

A known weight of steel fibre (25 g) is spread uniformly on a rectangular graphite plate (23 x 15 x 0.6 cm) in cris-cross fashion. Another graphite plate of the same dimensions is placed over the fibre layers so that light weight of about 1.5 $g.cm^{-2}$ will act on fibre in the vertical direction. The fibre spread is subjected to compact sintering at 1223 K for 2 hours in H_2 atmosphere to get fibre mat. The fibre mat is nickel plated and sized to 16 x 13 cm . A terminal is spot welded after sizing and again plated with nickel for short duration to mask the exposed steel in the cut portions. Final product of these operations is thermally compressed steel fibre netting with nickel coating.

Required weight of electrolytic/carbonyl iron powder (40g) in the form of slurry in aqueous carboxymethyl cellulose solution is introduced into the fibre mat by simple brushing. It is then dried and sintered at 1123 K in H_2 atmosphere to get highly porous (60-70%) sintered iron plate. The nickel plated steel fibre reinforced iron plate is further activated by copper and sodium sulphide incorporations. The finished iron negative (16 x 13 x 0.2 cm) weighs about 70 g.

Nickel electrode fabrication

Firstly nickel plated steel fibre mat is got by compact sintering of the steel fibre. Carbonyl nickel powder in the form of aqueous carboxymethyl cellulose slurry is brushed into the fibre mat. It is then dried and sintered in H_2 atmosphere at 1223 K to get highly porous (85%) nickel matrix. Amount of nickel powder present in the matrix is

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TABLE I: Charge-discharge rates

Charge-discharge rate	Current A	Output (A H)	Output (W H)
1C/1 hour	50.0	52	60
0.5C/2 hour	25.0	53	61
0.33C/3 hour	16.7	52	60
0.25C/4 hour	12.5	51	60
0.2C/5 hour	10.0	51	60

about 30% and the balance is nickel plated steel fibre. Incorporation of nickel powder into the steel fibre mat increases the mechanical strength of the matrix as well as reduces the sizes of voids present.

Nickel hydroxide is impregnated into the nickel matrix by electrochemical method. The formation bath comprises of soluble nickel anode and electrolyte is 4 *M* $Ni(NO_3)_2$ solution with $CO(NO_3)_2$ additive. Deposition is carried out at a current density of about 50 mA/cm^{-2} and *p*H of the bath was maintained at about 1. Deposition is completed by cathodizing the plate in 20% KOH solution at a current density of about 500 mA/cm^{-2}. Loading of $Ni(OH)_2$ into the pores occurs to maximum level in two cycles of operation, the first cycle is of 5 hours duration and the second cycle is of 2 1/2 hours duration. The plate is finally washed well and dried. The finished nickel electrode has a dimension of (16 x 13 x 0.4 cm) and weighs about 160 g. The weight of $Ni(OH)_2$ deposited into the matrix is almost same as the matrix weight.

Prototype assembly and testing

A Ni/Fe cell is assembled with 5 numbers of steel fibre based iron plates and 4 numbers of nickel plates. The electrolyte is 30% KOH solution with 1.5% LiOH addition and separator is woven nylon. Digatron - BTS 500 life cycle tester is used to carry out charge -discharge studies at various currents. Depth of discharge in all the tests is 100%.

RESULTS AND DISCUSSION

At 1 hour rate of charge - discharge,there is heating effect. The temperature of the electrolyte increases to 328 - 333 K in the initial cycles. After 5 cycles the temperature is maintained at 318 - 323 K. In other cases the electrolyte temperature is below 318 K. Outputs at different charge-discharge rates are given in the following Table I.

Voltage behaviour of the Ni/Fe prototype is shown in the Fig. 1. It could be seen from the results that the outputs are almost same at different rates of charge-discharge. Generally Ni/Fe batteries are charged at constant current when the

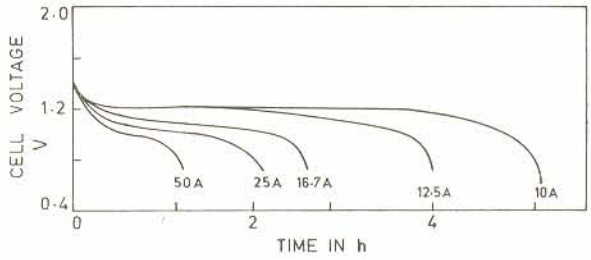

Fig. 1: Discharge characteristic of Ni/Fe prototype

charging voltage becomes fairly high in the region 1.7 to 1.75V. It is clearly indicated in the results. The electrochemical characteristics of the Ni/Fe battery prototype fabricated with the steel fibre based electrodes are given below.

Capacity	50 AH
OCV	1.37
Energy density	30 Wh/kg at IC rate
Efficiency (A.H)	82%
Efficiency (W.H)	54%
Anode active material utilization	30%
Cathode active material utilisation	55%

CONCLUSION

The steel fibre based porous mat is highly flexible design to hold more of active material and also of proper distribution of the active material inside the pores. There is a good scope to improve these two factors considerably which will enhance the energy density. A fibre based Ni/Fe battery with an energy density of 40-45 Wh/kg is an ideal power source for electric vehicles propulsion. Further the use of carbonyl nickel powder is considerably reduced in steel fibre based electrodes. Hence they will be cheaper than the other power sources including lead-acid batteries in view of mechanical and electrical raggedness and long cycle life.

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