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Mechanical Properties of Electrolyte Jet Electrodeposited Nickel Foam

Jinsong Chen*

College. of Mechanical Engineering, , Huaihai Institute of Technology . Lianyungang - Jiangsu – China

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Abstract

Principles of the preparation of nickel foam by electrolyte jet electrodeposition were introduced, Nickel foam samples with different porosity were fabricated. Effect of different porosity on microhardness and uniaxial tensile properties of nickel foam was discussed. The results show that the microhardness of nickel foam is 320~400 HV, lower than entitative metal clearly. The lower the porosity of nickel foam, the higher the microhardness is. During the process of uniaxial tensile, nickel foam is characterized by three distinct regions, e.g. elastic deforming region, plastic plateau region and densification region. The higher the porosity of nickel foam, the lower the plastic plateau and the poorer the strength of nickel foam, accordingly.

Keywords: Jet electrodeposition, Nickel foam , Porosity; microhardness; uniaxial tensile

1. Introduction

Nickel foam is a type of functional material with stero pore structure. The battery capacity can largely improve if the electrode material of alkaline or fuel battery is made from nickel foam. If the nickel-base alloy foam is used to make the electrode material of alkaline water electrolysis, it has better catalytic activity of hydrogen evolution compared with pure nickel, and its strength and potential stability are better than the commonly used Raney-Ni electrode[1],[2]. The preparation methods of nickel foam at present stage can be divided into liquid phase method, solid phase method, electrodeposition method and gas phase method etc[3],[4],[5]. However, these methods more or less have some shortcomings, which are excessive working procedures, complex operation, high cost and poor performance though having the advantage of batch production. After a long term of technological study, we introduces a new preparation method with nickel foam—electrolyte jet electrodeposition[6],[7]. This method can make electrolyte jet to the coating at high speed by applying voltage between workingpiece and nozzle. This is due to the fact that electrolyte jet deposition has the characteristic of selective deposition, inducing electrodeposition in jetting area and not having deposition in other areas. During this process, the current density can reach 90 times of the ordinary electrodeposition[8]. Polyporic tissues can easily form in the deposited metal layer and the foams generated by hydrogen evolution reaction also contribute to the formation of polyporic deposited layers under the condition of high current density. Compared with other methods, vesicular tissues produced by jet electrodeposition grow up from tissues in situ, completely devoid of auxiliary materials.

Nickel foam with different porosity has been successfully fabricated through a large number of tests in Reference[9]. This work, based on the application of nickel foam prepared by jet eletrodeposition, tests the microhardness, uniaxial tensile properties respectively.

2. Experimental Details

2.1 Microhardness Testing

The microhardness testing sample is shown in Fig.1. The thickness of nickel foam is about 10 mm. The hardness test of metal foam largely depends on the indenter direction. Hence, in practical application, the indenter direction of hardness tester should match the growth direction of electrodeposition layer in measurement.

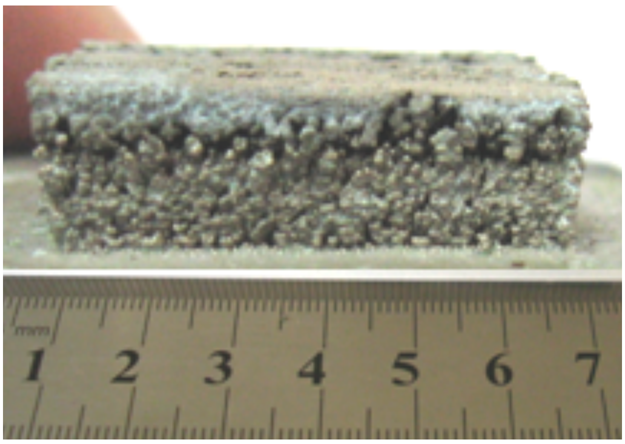

Fig. 1. Microhardness testing Nickel Foam Example

* E-mail address: jinsong20001@163.com
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The shape and size of samples are decided by various measurement needs. The microhardness is tested by HVS-1000A digital microhardness tester (load 0.1 N, hold time 10s).

2.2 Uniaxial Tensile Properties Testing

In order to avoid negative effects by size adopting, uniaxial tensile samples should be in columnar form with aspect ratio 1.5 or in annular form. Minimum size of sample should be 7 times than that of the cavity size. The uniaxial tensile test, compression rate at 0.5 mm/min, uses YG028A universal material testing machine of Sansi brand. The uniaxial tensile testing sample is shown in Fig.2.

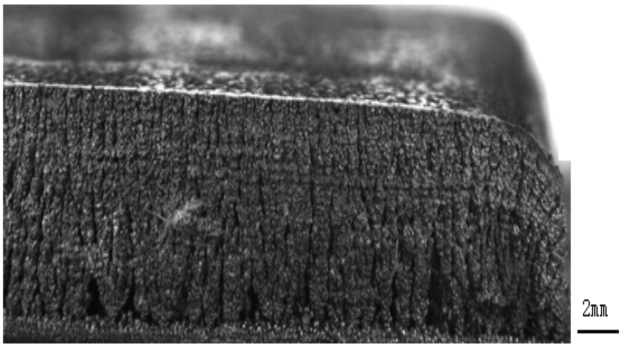

Fig. 2. Testing Nickel Foam Example

3. Analysis And Discussion

3.1 Microhardness

The microhardness test result show that the average microhardness of nickel foam sample is lower than that of entitative metal. Its Vickers hardness is 320~400 HV, while, nickel hardness is 450HV. Furthermore, the hardness of nickel foam with different porosity differs greatly. The average microhardness is 320.15 HV if the porosity is 89.8%; it increases to 340.26 HV, 370.38 HV, 400.58 HV when the average microhardness is 85.3%, 80.1%, 74.9% respectively. The results indicate that the hardness is growing with decreasing porosity.

3.2 Uniaxial Tensile

Fig.3 demonstrates the static compression stress-strain curve of nickel foam. It distinctly consists of elastic deforming region, plastic plateau region and densification region. The curve is linear elastic with very small strain rate in a short period when the strain is small. Then there is a long plateau phase as the strain increases, and the stress is almost uniform though the strain increases. Finally, as the holes are squeezed together at densification region, the stress increases with increasing strain. Nickel foam of different porosity differs in the height of the plastic plateau, not in the features of stress-strain curve. The higher the porosity is, the lower the relative density and the height of the plastic plateau. Plateau height of stress-strain curve varies with properties of porous structure and matrix material. The plastic plateau is not entirely horizontal. Sometimes it fluctuates slightly.

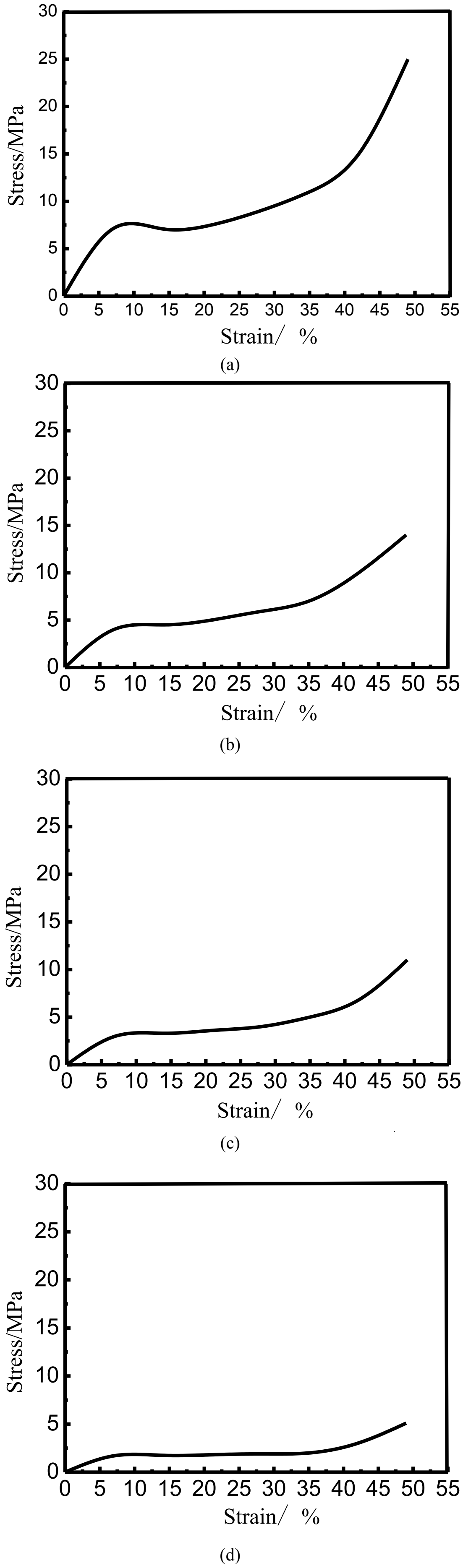

Fig. 3. Static Compression Stress-strain Curve of Nickel Foam

Gibson and Ashby deduced the plateau stress σ_{p1} of foam metal using a classical cubic pore unit model, as shown by Eq.(1). It can be found that plateau stress follows with the initiation of plastic deformation of pore edges[10],[11].

$$\frac{\sigma p1}{\sigma y,s} \approx 0.3(\rho/\rho s)^{3/2} \qquad (1)$$

Where, σ_{p1} is the plateau stress of foam metal; $\sigma_{y,s}$ refers to the yield strength of foam metal; ρ/ρ_s represents the relative density of foam metal.

The static compression process of nickel foam. The first phase is elastic deforming region, the second plastic plateau region and the third densification region. When mental foam is compressed, the deformation mechanism shows up in the bending of strut, and the longitudinal and bending pore wall film. Nickel foam prepared by jet electrodeposition consists mainly of dendrite structures. The diffusion of each dendrite inevitably produces very large holes which will be crushed first when the strain is concentrated on local area at the loading process of static compression. Then adjacent holes are crushed, resulting in a deformation band. The material is damaged as the evolving deformation band covered the whole material. Therefore, deformation of the material is characterized by layer-by-layer damaging.

Fig.4 illustrates the energy absorbing curve of the foam metal. As shown in this figure, the energy absorbing capability of the foam metal is mainly determined by the plastic plateau region, namely, the area below the strain-stress curve. The higher and wider the yield plateau region, the larger the energy absorbing capability. Moreover, due to the stress fluctuation during compression, energy absorbing rate is changing in deformation process. It reduces with the increase of deformation amount at the end of the smooth section of the stress-strain curve. Thus, by loading on the foam metal in this time period, the maximum absorbing rate can be achieved.

The absorbing rate of foam metal is defined as the ratio of the energy actually absorbed with that absorbed by ideal energy absorber at deformation amount of s in compressive deformation process[12].

$$\eta = \frac{\int_0^s F(s')ds'}{F_{max}(s)s} \qquad (2)$$

In Eq.(2), η is energy absorbing rate; s refers to deformation amount; $F_{max}(s)$ denotes to the maximum stress at deformation amount of s.

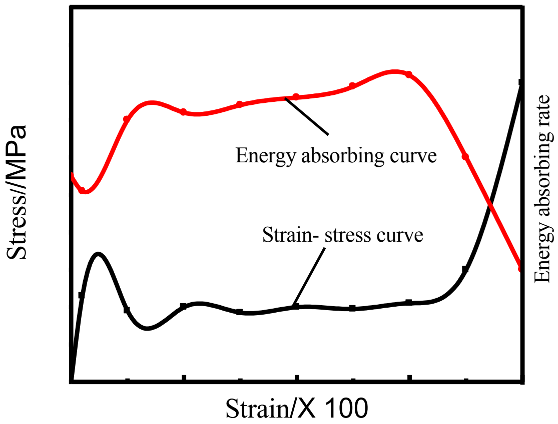

Fig. 4. Strain-stress curve and energy absorbing rate curve of the foam metal

4. Conclusion

Nickel foam by electrolyte jet electrodeposition were introduced,ickel foam samples with different porosity were fabricated. The average microhardness of nickel foam sample is lower than that of entitative metal. the hardness of nickel foam with different porosity differs greatly. Process of uniaxial tensile show that nickel foam is characterized by three distinct regions, The higher the porosity of nickel foam, the lower the plastic plateau and the poorer the strength of nickel foam, accordingly.

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