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Evolution of deformation-induced texture and surface microstructure of nickel coating under deep cup-drawing process

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Abstract: The deformation texture and surface microstructure of nickel coating induced by deep cup-drawing were studied by X-ray diffractometry and SEM. The steel sheet with nickel coating was firstly punched to designed degree of cup shapes. Then the texture of the coating was determined by XRD and the surface microstructure was observed by SEM. The results indicate that, the nickel coating material includes three kinds of textures, i.e. Ni (111), Ni (200) and Ni (220). After cup-drawing deformation, there doesn’t appear new texture component for nickel coatings but the change of the intensity of the deformation textures. In the cup-deformation process, the two kinds of main textures Ni (111) and Ni (200) increase in the first and second cup-drawing procedures and then reduce quickly in the third and fourth drawing procedure. However, for the Ni (220) texture, it always increases in whole cup-drawing procedures. With the increase in the drawing, there are some cracks to be found, but not delamination. This shows that nickel coating and the substrate have a good combinable performance.

Key words: electrodeposited nickel coating; drawing; deformation-induced texture; microstructure

1 Introduction

The nickel electrodeposited carbon steel sheet can be prepared by bilaterally electrodepositing nickel on low carbon steel sheet and its thickness is 1−20 mm. The grain size is in micrometer or nanometer [1−4]. The electrodeposited nickel coating becomes an important engineering material. It is found that this material has good corrosion resistant, attractive toughness and excellent plasticity, which offers the potential for advanced structure applications. In addition, the adhesion strength of electrodeposited nickel coating to substrates is excellent for their successful performance [5−8].

With the development of this material, the processing technique that the nickel is firstly electrodeposited on the steel substrate and then the coating and substrate are wholly formed is put forward instead of the process technique, that the steel is firstly formed and then the production surface is electrodeposited by nickel coating. Therefore, the formability of sheet with coating is an important processing technology [9−12]. There are initial textures in the electrodeposited nickel coating [13]. The deformation-induced textures in the coating more significantly influence the deformation performance of the electrodeposited nickel coating than that of bulk materials. Furthermore, the deformation-induced textures also influence the other performance of the coating, such as corrosion performance. The mechanism of the deformation-induced texture in nickel has still not been clearly elucidated. Therefore, it is necessary to study the deformation-induced textures in the electrodeposited nickel coating [14−15].

In this work, the deformation-induced textures and surface microstructure of electrodeposited nickel coating with the micrometer grain size were experimentally studied. Firstly, the steel sheet with nickel coating was punched to designed degree of cup shapes. Then the texture of the coating was determined by XRD and the

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deformation-induced texture was discussed. The surface microstructure of nickel coating after cup-drawing was observed by SEM.

2 Experimental

A lower carbon steel sheet with thickness of 0.3 mm was used as substrate. A uniform nickel coating of 3 μm in thickness was prepared by electrodepositing method on both sides of the steel sheet. The coating was obtained with nickel sulphate electrolyte composed of 250 g/L $NiSO_4·6H_2O$, 50 g/L $NiCl_2·6H_2O$, 35 g/L H_3BO_3. Pure nickel was used as the anode. The pH value was adjusted with sulfuric acid to 4.0 at 42 ℃. A conventional rotating disc electrode setup was used for electrodeposition. Before electroplating, pretreatments were necessary to get rid of the impurities. And the pretreatment procedure of substrates can be shown in Fig.1 (rinsing samples with de-ionized water).

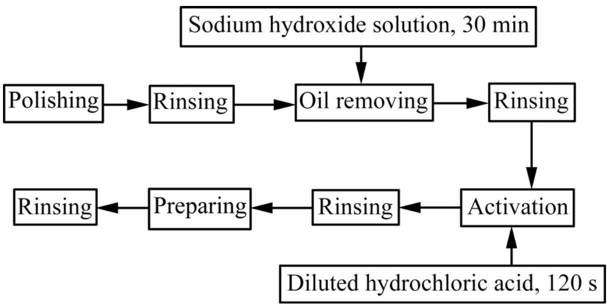

Fig.1 Technical flow chart of electrodeposited plating

The cup-drawing process of steel sheet coated nickel was studied. There were four working procedures to make a deep cup shape. The schematic drawing of the first deep-drawing process procedure is shown in Fig.2 (due to shape symmetry, only 1/4 of the geometry is shown). The parameters of the geometry of the tools and the sheet are listed in Table 1.

Four cup-drawing procedures were made and the depths of the four cups were 15, 20, 25 and 40 mm,

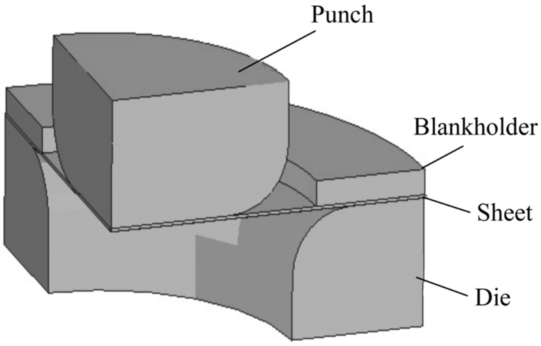

Fig.2 First deep cup-drawing procedure

Table 1 Parameters in first cup-drawing produce

Parameter	Value
Initial diameter of steel sheet/mm	55
Initial thickness of steel sheet/mm	0.25
Initial thickness of Ni coating/mm	10
Punch diameter/μm	31
Radius of curvature at punch/mm	5
Blank holder diameter/mm	Inner: 36 outer: 55
Blank holder force/kN	1
Die diameter/mm	Inner: 32 outer: 55
Radius of curvature at die shoulder/mm	5

respectively. After each cup-drawing procedure, deformation-induced texture analysis was performed on a Bruker-AXS D500S theta-theta X-ray diffractometer with a diffracted beam graphite monochromator, using Cu K_α radiation. 2θ was 20°−90° with a step size of 0.01°. At the same time, Philips Sirion 200 field emission scanning electron microscope (SEM) was used to show the surface morphology of nickel coatings.

3 Results and discussion

3.1 Evolution of textures

The texture composition and structure of Ni coatings under different drawing procedures were investigated using XRD and the result is shown in Fig.3. The position of the mark is the position that the texture is measured.

As can be seen from Fig.3, the Ni peaks indexed as (111), (200) and (220), at angles 44.55°, 51.89° and 76.45°, match closely with listed values for fcc Ni peaks in XRD data tables. However, the textures Fe (200) and (211) do not exist in the nickel coating but in the lower carbon steel sheet. For all the cup-drawing procedures, no new texture component can be found due to the deformation. However, the intensity of the every texture components is changed.

In order to understand the texture of the Ni coating under the whole cup-drawing procedures, Fig.4 shows the intensity change of textures under different cup-drawing procedures.

From Fig.4, it can be found that in the cup-deformation process, two kinds of main textures Ni (111) and Ni (200) increase in the first and second cup-drawing procedures and then reduce quickly in the third and fourth drawing procedures. However, for the (220) texture, it always increases in whole cup-drawing procedures.

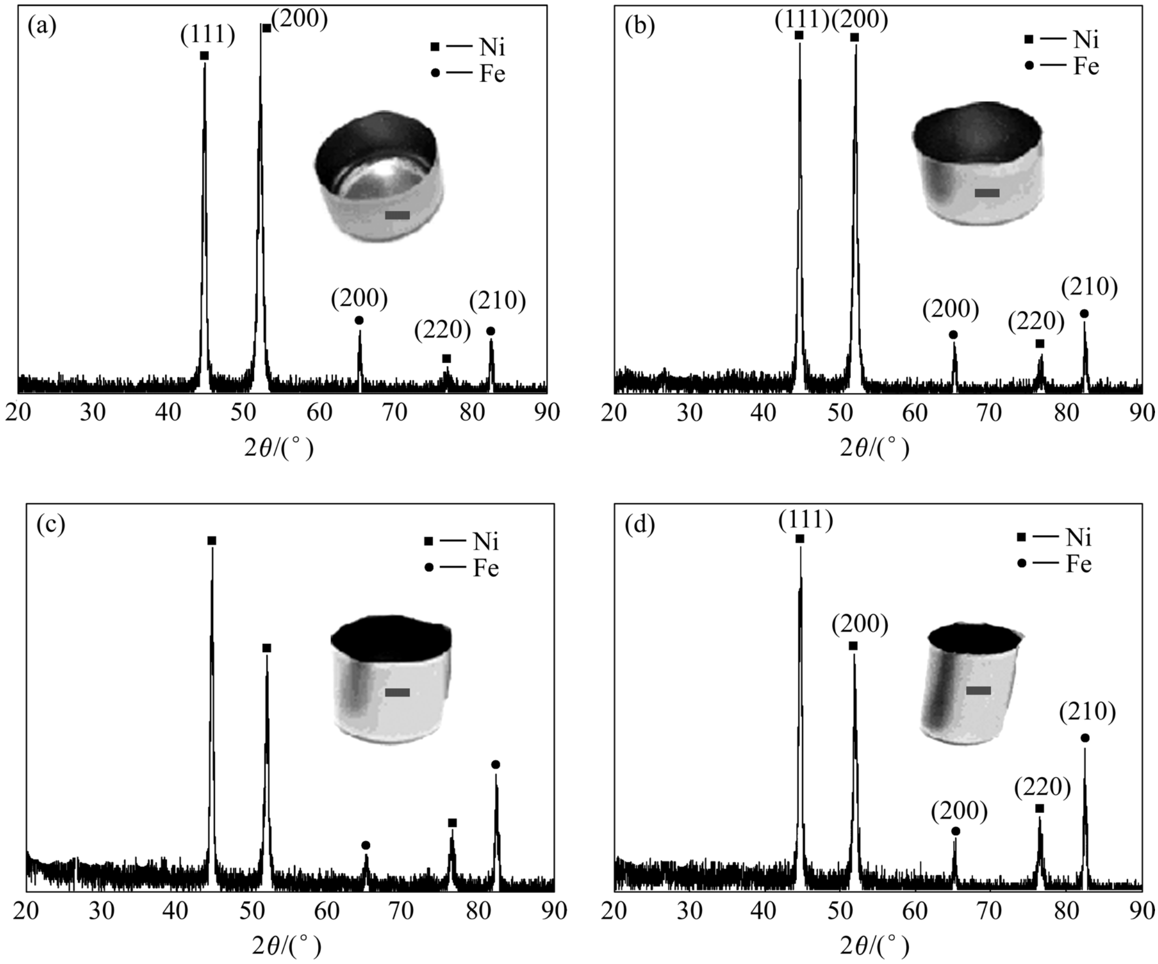

Fig.3 XRD patterns of deformed Ni coating: (a) First cup-drawing procedure; (b) Second cup-drawing procedure; (c) Third cup-drawing procedure; (d) Fourth cup-drawing procedure

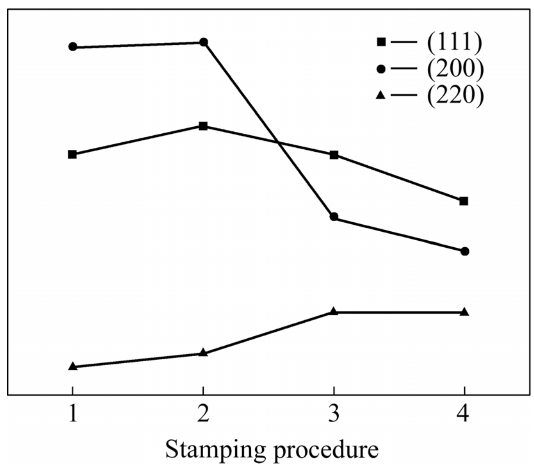

Fig.4 Intensity change of textures under different cup-drawing procedures

3.2 Evolution of surface morphology

Fig.5 shows the surface morphologies of nickel coating after cup-drawing deformation on the marked positions in Fig.3. From Fig.5 (a) it can be seen that the surface is smooth and no pinhole or micro-crack is found. With the increase of the cup-drawing deformation in the coating, the surface roughness increases and the micro-crack is found in Figs.5 (b), (c) and (d). There are not delamination. This shows that nickel coating and the substrate have a good combinable performance.

4 Conclusions

1) Nickel coating material includes three kinds of textures, i.e. Ni (111), Ni (200) and Ni (220). After cup-drawing deformation, there is no new texture component for nickel coatings, but the change of the intensity of the deformation textures is found.

2) In the cup-deformation process, the two kinds of main textures Ni (111) and Ni (200) increase in the first and second cup-drawing procedures and then reduce quickly in the third and fourth drawing procedure. However, for the (220) texture, it always increases in whole cup-drawing procedures.

3) With the increase of the cup-drawing deformation in the coating, the surface roughness increases and the micro-crack is found.

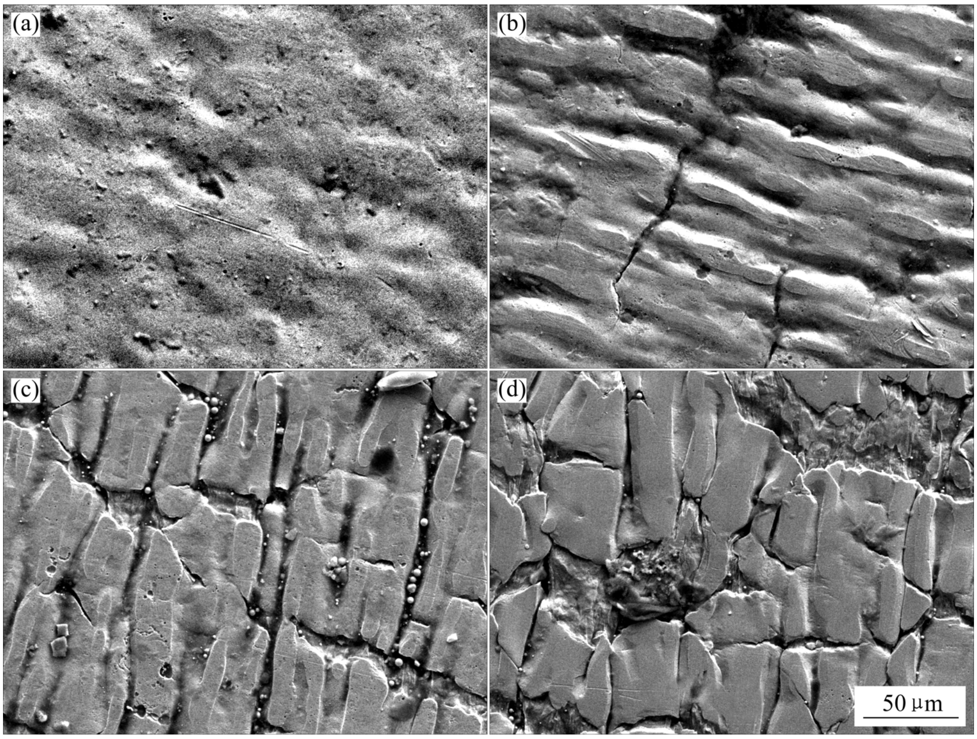

Fig.5 Surface morphologies of nickel coating after cup-drawing deformation: (a) 15 mm deep cup; (b) 20 mm deep cup; (c) 25 mm deep cup; (d) 40 mm deep cup

References

[1] BUDROVIC Z, SWYGENHOVEN H V. Plastic deformation with reversible peak broadening in nanocrystalline nickel [J]. Science, 2004, 304(1): 9−11.

[2] JOSELL D, BONEVICH J E, SHAO I. Measuring the interface stress: Silver/nickel interfaces [J]. Journal of Material Research, 1999, 14(11): 4358−4365.

[3] WANG G F, CHAN K C, ZHANG K F. Low temperature superplasticity of nanocrystalline electro-deposited Ni-Co alloy [J]. Scripta Materialia, 2006, 54 (3): 765−770.

[4] BASROUR S, ROBERT L. X-ray characterization of residual stresses in electroplated nickel used in LIGA technique [J]. Material Science and Engineering A, 2000, 288(2): 270−274.

[5] TJONG S C, CHEN H. Nanocrystalline materials and coatings [J]. Material Science and Engineering R, 2004, 45(1): 1−88.

[6] CHOWDHURY S, LAUGIER M T, RAHMAN I Z. Measurement of the mechanical of carbon nitride thin films from the nanoindentation loading cure [J]. Diamond and Related Materials, 2004, 13(12): 1543−1548.

[7] LEE J M, KO D C, LEE K S. Identification of the bulk behavior of coatings by nano-indentation test and FE-analysis and its application to forming analysis of the coated steel sheet [J]. Journal of Materials Processing Technology, 2007, 188(2): 309−313.

[8] MARDER A R. The metallurgy of zinc-coated steel [J]. Progress in Materials Science, 2000, 45 (1): 191−271.

[9] LONG S G, ZHOU Y C, PAN Y. Computation of deformation-induced textures in electrodeposited nickel coating [J]. Trans Nonferrous Met Soc China, 2006, 16(1): s232−s238.

[10] ZHOU L Q, ZHOU Y C, PAN Y. Coating thickness variation during multistep drawing processes [J]. Journal of Materials Science Letter, 2004, 39(2): 757−760.

[11] ZHOU L Q, ZHOU Y C, PAN Y. Pact performance of electrodeposited nickel coating on steel substrate [J]. Journal of Materials Science Letter, 2004, 39(3): 753−755.

[12] ZHOU L Q, LI Y P, ZHOU Y C. Forming limit of electrodeposited nickel coating in the left region [J]. Journal of Materials Engineering and Performance, 2006, 15(3): 287−294.

[13] DAI C Y, PAN Y, ZHOU Y C. The effect of prepared parameters on the microstructure of electrodeposited nanocrystalline nickel coating [J]. Surface Review and Letters, 2004, 11(4/5): 433−442.

[14] GUPTA A K, KUMAR D R. Formability of galvanized interstitial-free steel sheets [J]. Journal of Materials Processing Technology, 2006, 172(1): 225−237.

[15] LI S Y, BEYERLEIN I J. Texture evolution during multi-pass equal channel angular extrusion of copper: Neutron diffraction characterization and polycrystal modeling [J]. Acta Materialia, 2005, 53(11): 2111−2125.

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