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EFFECT OF THE ROLLING MODE ON TEXTURE DEVELOPMENT OF 26CU-2FE-72NI ALLOY SYSTEM

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Abstract

The main objective of the present work was to study the cold rolled texture of 26Cu-2Fe-72Ni alloy system at different reductions using the XRD analysis techniques and then co-relate it with various mechanical properties. The 26Cu-2Fe-72Ni alloy was produced from pure elemental constituents using a vacuum induction melting furnace and casted as cylindrical ingots having 10 cm length and 5 cm diameter. For homogenization of the structure the cast ingots were heated to 950 ºC for six hours and cooled in the furnace. Then, these ingots were hot forged using an open die forging to form samples having dimensions 200 x 45 x 10 mm approximately. The forged plates were cut into two halves and each one was cold rolled (unidirectionally) to a final thickness of 0.69 mm. During rolling after every 25 % reduction, the cold rolled samples were annealed at a temperature of 900 ºC for one hour. The diffraction patterns were scanned using Siemens JEOL JDX-99C X-Ray Diffractometer with Ni-filter and Cu-K radiation for XRD analysis of cast and rolled samples. The deformation texture was then co-related with the mechanical properties, e.g. hardness, UTS, yield strength and elongation. It was observed that the intensity of (111) plane gradually decreases where as intensity of (220) plane gradually increases after cold rolling.

Keywords: Rolled texture, Homogenization, Hot forging, XRD analysis, Cold rolling

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1. Introduction

The literature shows that the X-Ray diffraction is one of the powerful techniques employed to identify the crystalline planes and their respective inter-planner spacing and also to measure the structural properties such as strain, grain size, phase position and preferred orientation, etc. in polycrystalline materials [1]. Crystallographic analysis is an important tool in correlating the properties of a material to its microstructural features and can be performed on any polycrystalline material. In order to correlate the observed properties to microstructural features it is usually necessary to measure parameters that represent a mean value of the present phases [1].

Furthermore, analysis of the formation of preferred orientations can frequently shed light on the mechanism of texture formation. In particular, study of the changes in texture may provide important information about the mechanisms of plastic deformation and primary and secondary recrystallization [2]. It is worth mentioning that XRD analysis of microstructure requires careful experimentation, sample preparation and calculations [3].

The crystallographic texture can be determined by various techniques such as neutron, electron and X-ray beams using Bragg's Law and Kikuchi Patterns. Neutron diffraction technique is useful to measure the diffraction of entire volume of the specimen rather than its surface because neutrons can easily penetrate through the materials with the size of millimeters due to relatively weak interaction with matter. However, it requires samples having larger thickness. Generally, it is considered not suitable for thin films or thin sheets [4].

Electron backscattered diffraction (EBDS) is useful to analyze a local area such as a grain because it uses a narrow beam of low energy electrons by a scanning electron microscope, however, it strongly depends upon the surface conditions of the sample and requires additional surface treatment of the sample to remove surface roughness and strain [5]. X-ray diffraction technique has advantages of measuring the texture of near surface of the sample in air; however, it is limited to an angular range because of the usage of a goniometer [6].

Although, the analysis of crystallographic texture and its effects on mechanical properties have been widely discussed in the literature, however, a little information is available on thin sheets of Ni-Cu alloy for comparison of unidirectional and cross rolled samples regarding mechanical properties with respect to rolling texture [7].

To study the effect of rolling on texture development in 26Cu-2Fe-72Ni alloy~~s~~, the samples were collected in the as cast form and after 10 %, 20 %, 30 %, 40 % and 50 % cold reduction, respectively. The samples in annealed conditions before and after cold rolling were also taken for testing. XRD patterns of all samples were obtained in the as cast, cold rolled and annealed conditions. Moreover, at 50 % cold reduction, the mechanical properties were also carried out before and after annealing.

2. Experimental Work

26Cu-2Fe-72Ni alloy was developed in a vacuum induction furnace using pure elements andcasted in an ingot mold having 10 cm length and 5 cm diameter. For homogenization, the cast ingots were heated to a temperature of 950 ºC for six hours and then cooled in the furnace. After the homogenization the ingots were heated to 900 °C and then open die forging was done using a pneumatic forging hammer (ram weight 150 Kg) to break down the cast dendritic structure. The dimensions obtained after forging were approximately 200 x 45 x 10 mm after appropriate cutting. There were two plates obtained from one melting.

The forged plates were cut into two halves. One half was cold rolled to a final thickness of 0.69 mm (unidirectionally). During rolling after every 25 % reduction, the cold rolled samples were annealed at a temperature of 900 ºC for one hour. The direction of rolling was kept the same throughout the process. The thicknesses down to 1.5 mm were achieved using 2-high rolling mill. For the thicknesses below 1.5 mm 4-high rolling mill was employed. Two high mill had 120 mm diameter rolls and four high mill had 80 mm working roll diameter and 200 mm dia backup rolls. The 0.69 mm thick samples were referred to as-received or initial material used for this study and after annealing it was rolled to 0.345mm thickness. During reductions, samples were collected after every 10% of cold rolling reduction for XRD study i.e; 10 %, 20 %, 30 %, 40 % and 50 % cold reduction. Due to thin sheets, these 50 % cold reduction samples were annealed at a temperature of 900 ºC for 20 minutes in vacuum induction heating furnace.

The chemical composition of these plates is given in the Table 1.

The diffraction patterns were scanned using Siemens JEOL JDX-99C X-Ray Diffractometer with Ni-filtered and Cu-Kα radiation for XRD analysis of cast and rolled samples. Samples ranging in size from 5 – 14 mm (width) and 10 – 20 mm (length) were prepared for hardness testing. The samples for tensile testing, using ASTM E8M standard, having 10.5 mm width and 110 mm length were prepared from all of annealed and rolled plates. Thicknesses of samples for testing of mechanical properties were kept approximately same i.e. 0.345 mm.

3. Results and Discussion

3.1 Chemical Analysis

From the ingots, cylindrical samples having 38 mm diameter and 4.5 mm height were prepared for XRF (x-ray fluorescence spectrometer). The results are mentioned in Table 1.

Table 1: Chemical compositions of the as cast ingots.

Melting	Ni	Cu	Fe	Mn	Cr	Si	Others
M1, Wt%	Base	26.53	2.40	1.33	0.34	0.18	---

3.2 Mechanical Testing

The mechanical properties of cold rolled samples having 50 % cold reduction and then annealed are given in Tables 2 and 3, respectively. These values were taken as an average of three readings.

Table 2: Mechanical properties of 50 % cold rolled samples.

Melting	Yield Strength (MPa)	Tensile Strength (MPa)	Elongation %	Hardness (H_V)
M1	783	792	1.56	201

Table3: Mechanical properties of annealed samples after 50 % cold reduction.

Melting	Yield Strength (MPa)	Tensile Strength (MPa)	Elongation %	Hardness (H_V)
M1	198	526	29	109

It is an established fact that cold rolling usually results in high yield strength and tensile strength. Due to cold working, yield strength approximately reaches to tensile strength at the expense of ductility. When 50 % cold reduction samples were annealed to a temperature of 900 ºC for 20 minutes, remarkable difference was observed between yield and tensile strengths.

It can, therefore, be concluded that annealing reduces the yield strength to about quarter of the cold worked samples of this alloy. This decrease in yield strength due to annealing is also in agreement with the study of some other workers [4]. Due to the annealing of cold worked samples hardness also reduced from 201H_V to 109 H_V.

3.3 XRD Results

In the cast alloy, both Ni and Cu having FCC lattice form a continuous solid solution in the entire range of the phase diagram [8]. These analyses of XRD patterns (Figures 1 to 9) were carried out by utilizing JCPDS card No. 9-205 of International Center for Diffraction Data [8]. This is evident by the appearance of the single significant peak (Figure 1) in the respective 2θhkl at an angle of 43.75º having (111) plane position confirming the complete miscibility of the two components [8].

Cold Rolling produces grain orientation/texture as shown in the following diffraction patterns (Figures 1 to 9). The intensity of (111) plane was decreased where as intensity of (220) plane increased after thermo mechanical processing. Figures 1 to 9 compare the X-ray diffraction patterns of deformed and un-deformed samples. It is evident that un-deformed samples (annealed) show major preferred orientation (texture) along (111) and (200) planes. The orientation density of these textures (111) and (200) seems to decrease as a function of cold deformation, as shown in Figures 3 to 8. However, orientation of (220) texture increases with the cold reduction and becomes sharp after 50 % of cold rolling (Figure 8).

After 50 % reduction samples were annealed at 900 ºC followed by furnace cooling and X-ray diffraction pattern clearly indicates that phase revert after intermediate annealing (Figure 9). It means annealing eliminates the effect of cold rolling or it can be said that the cold rolling produces preferred orientation (texture) in grains of 26Cu-2Fe-72Ni alloy. It is evident that in cold rolled condition (220) plane is leading as compared to plane (111) and (200). Due to its high intensity it is parallel to the surface.

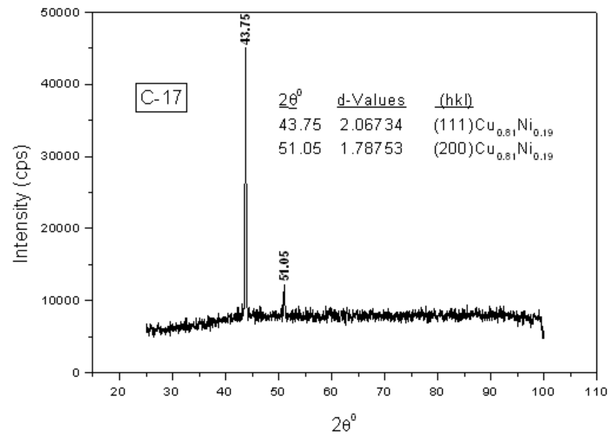

Figure 1: XRD pattern of as cast alloy.

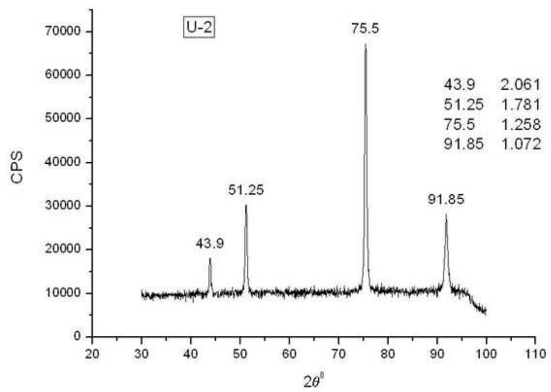

Figure 2: XRD pattern of a sample at thickness of 0.69mm before annealing

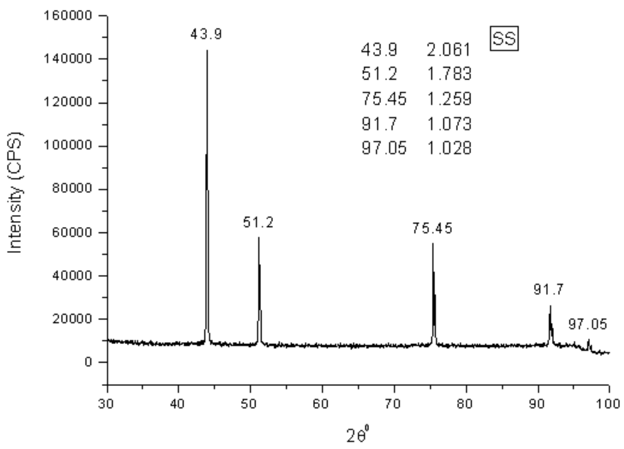

Figure 3: XRD pattern of a sample at thickness of 0.69mm after annealing.

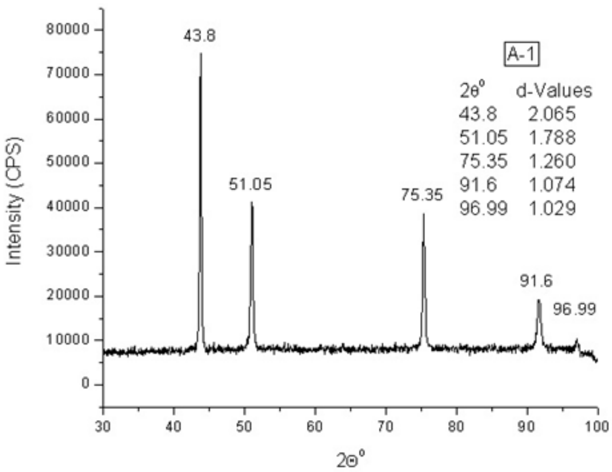

Figure 4: XRD pattern of a sample after Unidirectional 10 % cold reduction.

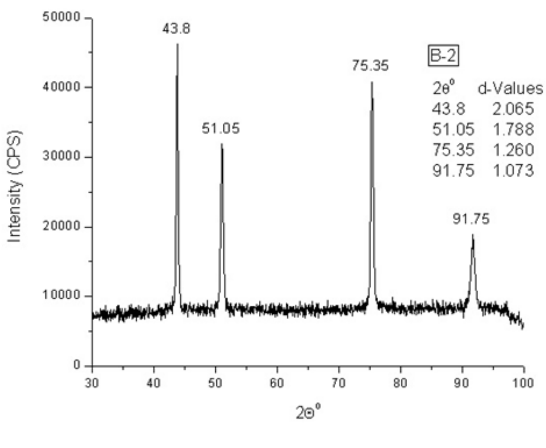

Figure 5: XRD pattern of a sample after Unidirectional 20 % cold reduction.

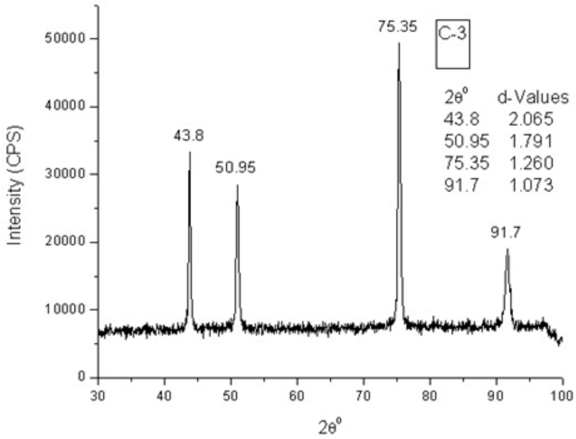

Figure 6: XRD pattern of sample after Unidirectional 30 % cold reduction.

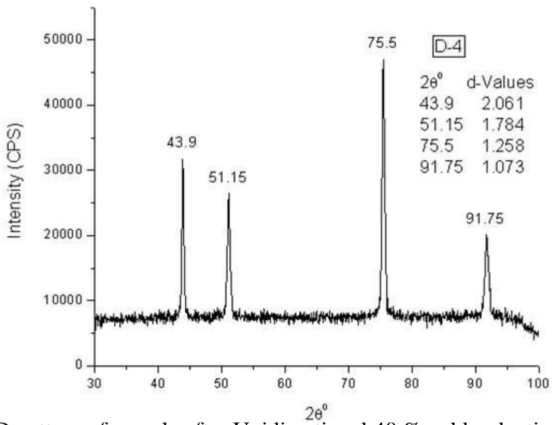

Figure 7: XRD pattern of sample after Unidirectional 40 % cold reduction

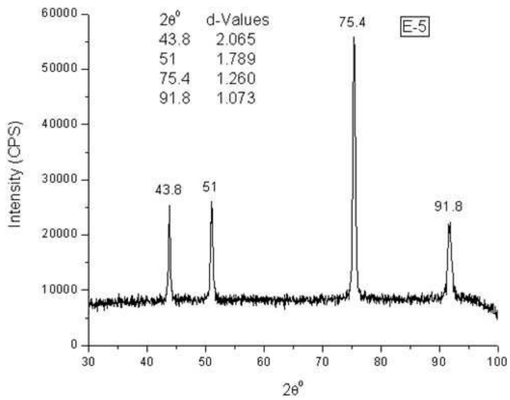

Figure 8: XRD pattern of a sample after Unidirectional 50 % cold reduction.

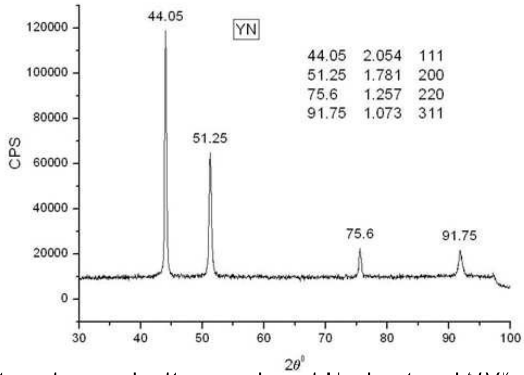

Figure 9: XRD pattern of a sample after annealing of Unidirectional 50 % cold reduction.

4. Conclusions

- Cold rolled sheets have been subjected to cold reduction to study the texture development as a function of percentage reduction.
- It is evident that un-deformed samples (annealed) show major preferred orientation (texture) along (111) and (200) planes.
- The orientation density of the planes (111) and (200) seems to decrease as a function of cold deformation
- Orientation of (220) plane increases as a result of cold reduction.

References

[1] ASM Metals Handbook, Vol. 10, Characterization, 2004, pp. 733 - 734.

[2] A. UlHaq and A. Q. Khan, Journal of Materials Engineering and Performance. Vol. 2(1) February 1993, P. 89.

[3] K. Kapoor, D. Lahiri. I. S. Barta, S. V. R. Rao and T.sanyal, Material Characterization, 54 (2005)132.

[4] S.W. Banovic, M. D. Vaudin. T. H. Gnaeupel-Herold, D. M. Saylor and K. P. Rodbell, Mater. Sci. Eng. A 380 (2004) 155-179.

[5] Y. Choi and H. Inoue, Mater. Sci. Forum, 558 (2007) 1379-1371.

[6] Y. N. Wang and J. C. Huang, Mater. Chem. Phys. 81 (2003) 11-26.

[7] Y. Choi and H. Inoue, Mater. Tranactions, Vol. 51, No. 4 (2010) 652-658.

[8] M. Afzal, M. Ajmal, and T.Z. Butt, To study the mechanical properties of unidirectional and cross rolled Ni-Cu Alloy produced in VIM, Key Engineering Materials Vol.442 (2010) pp88-95, Switzerland