3rd Conference on Nuclear & Particle Physics
(NUPPAC' 01) 20 – 24 Oct., 2001 Cairo, Egypt

Residual Stress Studies Using the Cairo Fourier Diffractometer Facility

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ABSTRACT

The present paper deals with residual stress studies using the Cairo Fourier diffractometer facility CFDF. The CFDF is a reverse - time of – flight (RTOF) diffractometer; applies a Fourier chopper. The measurements were performed for copper samples in order to study the residual stress after welding. The maximum modulation of the Fourier chopper during the measurements was 136 kHz; leading to a time resolution half-width of about 7 μs. It has been found from the present measurements that, the resulting diffraction spectra could be successfully used for studying the residual stress; in the wavelength range between 0.7-2.9Å at ~ 0.45 % relative resolution.

Key words: *neutron diffraction, lattice strain, internal stress*

1- Introduction

The residual stress can be introduced into engineering components during fabrication and also as a result of creep and plastic deformation incurred during use. Hence, the presence of residual stress can significantly affect both their load capacity and resistance to fracture. Consequently, it is necessary to know the magnitude and distribution of the stress in order to quantify its effect. Residual stress determination from peak shift of large angle Bragg reflection has been widely used, as a non-destructive tool, to examine three dimensional stress fields in structural components; using high resolution neutron diffractometers. Accordingly, nondestructive neutron diffractometery is considered as one of the powerful tools could be used for studying the deformation, due to stress, of materials, and several laboratories [1-5] make use of the available neutron diffractometers for evaluation of the residual stress in order to serve the industry. The preliminary results of neutron diffraction measurements performed using the Cairo Fourier diffractometer facility (CFDF), for steel samples were reported before [6] and confirmed the possibility of its use for stress studies. The present work Presents the results of neutron diffraction measurements performed, for stress analysis of copper samples, using the CFDF.

2- EXPERIMENTAL MEASUREMENTS

The experimental measurements were performed using the CFDF. The CFDF is based on the reverse time of flight principle [7], and was recently installed in front of one of the ET-RR-1 reactor horizontal channels. The CFDF applies a Fourier chopper of 1024 slits and two neutron guides. While one of them is curved (22m length) and is installed between the reactor beam hole and chopper, the other one is straight (3m) and is used after the chopper for beam collimation. The main parameters of the CFDF are given in table 1. More details about the facility are given elsewhere [8,9]

Table 1: The parameters of the CFDF

Parameters	Value
λ(Å) range	1-4
d_{hkl} (Å) range	0.5-3.0
Resolution	0.45%
φ (n/ cm2/s	1.1*106
V_s (cm3)	2.125

The samples used for the present measurements are copper rods. Two rods were prepared for each of them; while one rod is constructed from two electrically welded, the other one is without welding. Both copper samples were of the same diameter (5.5mm). The diffraction patterns were measured for the samples using the CFDF at the following conditions:

-The Fourier chopper speed =8000 rpm.

-The delay time =2048 μ sec.

-Area of the neutron beam incident on the sample ~0.55cm^2.

The measurements were performed for the welded sample at the welding point, 2cm and 4cm distances from it. Besides, diffraction patterns were measured for the sample without welding.

The diffraction patterns of the samples were measured at room temperature, with the following set-up of the diffractometer:

- The frequency window is G3 (Gaussian with oscillation amplitude 3%)
- The RTOF multichanel analyzer is set up at channel width 2μ sec.

The diffraction patterns measured both for welded and free samples were typically the same as those displayed in Fig. (1).

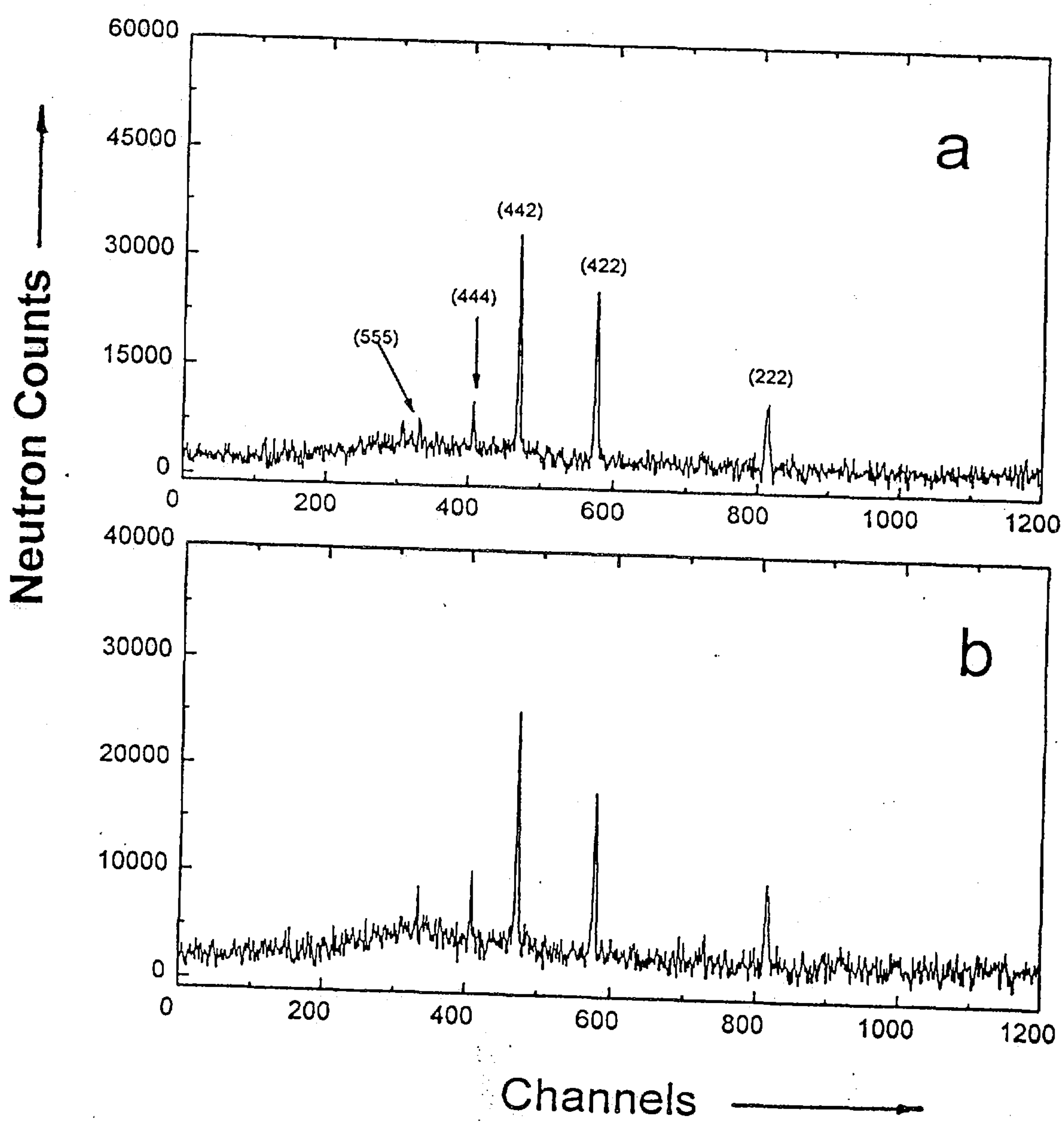

Fig.1. Measured diffraction patterns of copper; a) stress free sample. b) at welding point.

3- RESULTS AND DISCUSSION

The internal 'lattice' stress presented in material is obtained from the measured elastic 'lattice' strain which is determined [10] using Bragg's low of diffraction:

$$2d_{hkl}\sin\theta_{hkl}=\lambda \qquad (1)$$

Where d_{hkl} is the crystallite lattice plane spacing corresponding to Bragg reflection (hkl) observed at scattering angle $\varphi^{hkl}=2\theta^{hkl}$, λ is the neutron wavelength, and (hkl) are Miller indices of diffraction planes.
The Fig. (2). The peaks observed in all diffraction patterns at distinguished copper lattice planes are represented in Fig. (2).The elastic strain, ε_{hkl} is given by:

$$\varepsilon_{hkl}=\Delta\lambda/\lambda=(d_{hkl}-d_{0hkl})/\,d_{0hkl} \qquad (2)$$

Where d_{0hkl} is observed for the stress free sample

The strain determined for the measured points of copper is given in table (2).

Table 2: The observed strain values of of copper.

d&ε / hkl	d_0 (Å)	d_w (Å)	ε_w	d_2(Å)	ε_2	d_4(Å)	ε_4
(222)	*0.5640*	*0.565*	*2.128*10-²*	*0.5676*	*6.383*10-³*	*0.565*	*-2.188*10-³*
(422)	*0.6912*	*0.6924*	*1.736*10-²*	*0.6948*	*5.208*10-³*	*0.6936*	*-2.188*10-²*
(442)	*0.9768*	*0.98040*	*3.686*10-²*	*0.985*	*8.6*10-³*	*0.978*	*-2.188*10-²*

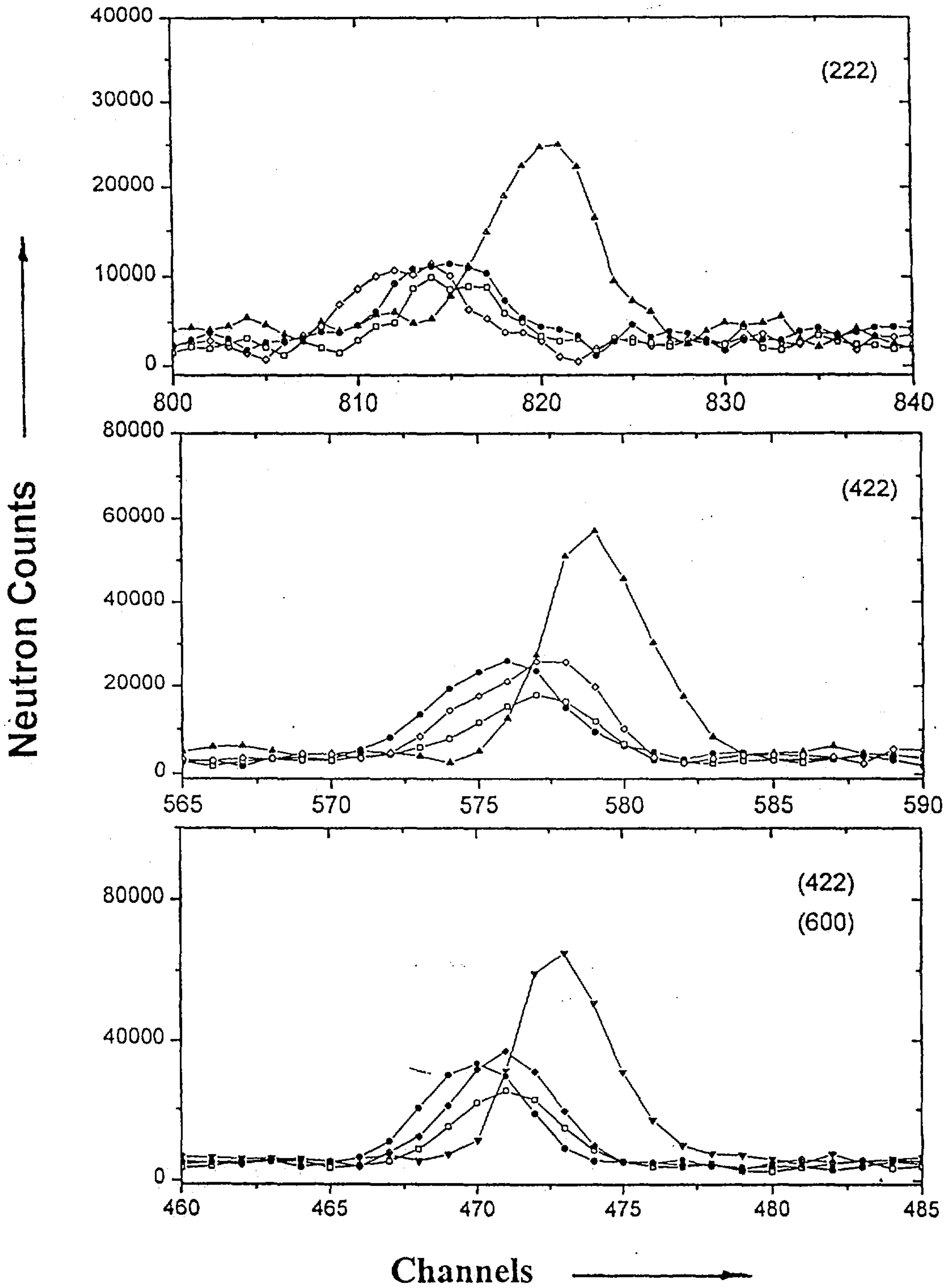

Fig.2. The peaks observed at copper lattice planes (222), (422), (442); in the corresponding dhkl ranges: ▲ free point; □ weld point; ◊ 2cm; ● 4cm;

It is noticeable that the value of strain is highest, for all values displayed in Fig.2, at the welding point. Besides, the values of strain are consistent, for the three planes, at points far from the welding one. This leads to the same conclusion reported before [6] for steel. This also confirms the fact that the CFDF can be successfully used for stress measurements; as it allows for the simultaneous measurement of several d- spacings, then it can be used for studying different types of stress.

References

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The Pinakes

We should not end this chapter without briefly mentioning the well-known work of Callimachus regarding the Alexandria Library.

So far we have seen that an up-to-date register of the books was available for the use of readers, still it was thought necessary to compose a critical appraisal of this unique collection of books, in other words, a bibliographical survey of the contents of the Library 'in every field of learning'.

Such a tremendous undertaking was entrusted to Callimachus of Cyrenae, who was known for his encyclopaedic knowledge and erudition.

The result was the *Pinakes*.

The work in its entirety has not survived except for a few fragments, which attest to the following divisions :

rhetoric, law, epic, tragedy,.comedy, lyric poetry, history, medicine, mathematics, natural science and miscellanea.[13]

Under each division, individual authors were arranged in alphabetical order; and each name was followed by a short bibliographical notice and a critical account of the author's writings.14

It seems that the *Pinakes* proved indispensable to scholars all over the Mediterranean and it immediately became a model for future works of the same kind.[15]

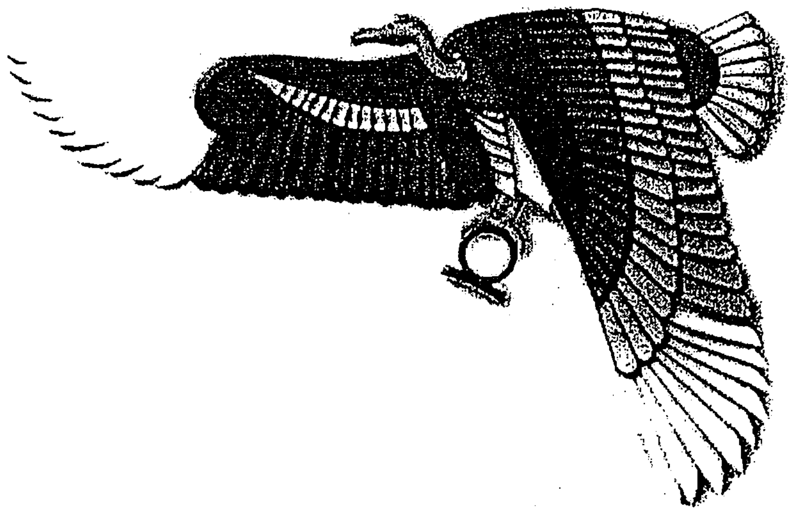
We can even trace its influence down to the middle ages, to its brilliant Arabic counterpart of the tenth century, Ibn-Al-Nadim's *Al-Fihrist*, or *Index*, which has fortunately reached us intact.

It was mainly due to the great Alexandria Library that scholarship in Alexandria flourished and continued to flourish, for it was based upon thorough study and an understanding of the value of a past heritage that was deemed worthy of preservation.

Vitruvius, in the first century (de Arch. VII. praef. 1-2) expresses the appreciation and gratitude felt by subsequent generations for the work of the 'predecessors' in preserving for the 'memory of mankind', the intellectual achievements of earlier generations.

"Hence," he adds, "we must render to them more than moderate thanks, indeed the greatest, because they did not let all go in jealous silence, but provided for the record in writing of their ideas in every kind."

Photo: Scribes writing on wooden tablets. An author who wanted to make ten copies of his work dictated to ten scribes at the same time.



APPLIED NUCLEAR PHYSICS

The articles included in this section were refereed according to rules for publication in scientific journals and were accepted for publication