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Opportunities and Noble Information for Industries from the Elastic Neutron Scattering in HANARO

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1. Introduction

Neutron scattering is usually classified into classes according to the measuring information. One is the elastic neutron scattering which can give us structural information of a material and the other is the inelastic neutron scattering which concerns on the dynamics inside the material. "Elastic" means that there is no energy change in the neutron during the interaction (scattering) with a matter. Therefore the elastic scattering is easier to understand and to carry out an experiment than the inelastic scattering. Since the commissioning of the Korean modern research reactor (HANARO) in 1995, elastic neutron scattering instruments have been constructed and open to the public users, sequentially.

2. Elastic Neutron Scattering Instruments in HANARO

HRPD (High Resolution neutron Powder Diffractometer) is the first elastic neutron scattering instrument at HANARO, which was commissioned in 1998. It has been widely used for the material science by studying a crystal structure, spin ordering (magnetic structure), phase transformation, quantitative phase analysis and so on.

The secondly commissioned (in 1999) instrument is the FCD (Four Circle neutron Diffractometer) and is used for the single crystal diffraction measurement and the texture analysis of metal samples.

The third instrument was the RSI (Residual Stress Instrument), which was installed as a optional instrument of the HRPD in 2000 and have been reinstalled at the ST1 beam port with an upgraded performances. It has been watched from the industries and related scientists because it can accommodate a large bulk specimen and

Recently another powder diffractometer, the HIPD (High Intensity neutron Powder Diffractometer), is being constructed for the rapid measurement. Some users, especially from the industry, often want to measure a series of samples according to the composition or treatment processes, which takes a lot of beam time. To meet this user's demand, the performance goal of the HIPD was targeted as high intensity on the diffraction data.

3. Examples of the Industrial Application

3.1 Material Characterization

Characterization of newly synthesized or processed materials is the foundation stone of the further study of application. Since most of materials are already known their primitive structure, the HRPD is used for the refinement of the primitive or postulated structure. Structural changes such as the phase transformation, the change of the composition or site occupancy and the particle size are common interests for the material scientists. Because of the intrinsic properties of the neutron scattering, one can obtain distinguishable information on light elements, substitution effects of neighbor elements in the periodic table, the inside structure of bulk specimens and so on.

Another important industrial application of the HRPD could be the QPA (Quantitative Phase Analysis) of multi-phase specimens [1, 2]. Many of metals and ceramics have multi-phase structure. Even though the portion of minor phases it can role or control drastically the physical or mechanical properties of the material. Figure 1 shows a typical example of a steel sample which has some minor phases.

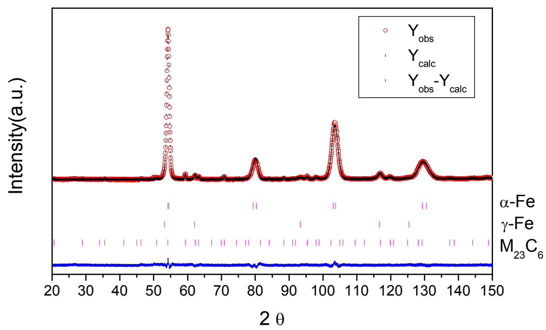

Fig. 1 Neutron diffraction pattern of an industrial steel sample with a Rietveld analysis.

3.2 Texture Analysis

The neutron diffraction method is a powerful technique for the texture investigation because of the high penetration compared with the X-ray diffraction method. The complete pole figures can be measured and the whole through-thickness texture can be analyzed with neutron method. Therefore, for the study of the anisotropic physical and mechanical properties of the textured materials the neutron diffraction method is very useful.

As an example, stainless steels usually reveal different texture evolution through the sample thickness. In the case of XRD measurement performed for only few mm, it is not easy to evaluate the R-value, the factor presenting the plasticity, from the texture. However, the neutron method gives the average texture information of the whole thickness of the sample.

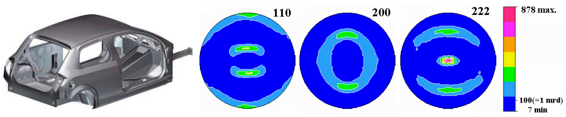

Fig. 2 Ultra light steel auto body and texture data of IF steel measured by neutron FCD in HANARO.

3.3 Residual Stress Analysis

During the manufacturing process of industrial components, mostly composed of metals, there would be residual stresses inside the material. Various mechanical process, thermal treatment or welding process can cause microscopic stress (10^{-3} to 10^{-4} nm scale) and it is very hard to inspect the stress and strain inside the bulk specimen (a few mm to a few tenth cm thick) without destruction of the specimen itself. By measuring the change of a diffraction peak from the specimen, the stress and strain information (usually tensor quantity) could be estimated [3]. Application examples are welding inspection, machining inspection, accident analysis (Fig. 3) etc.

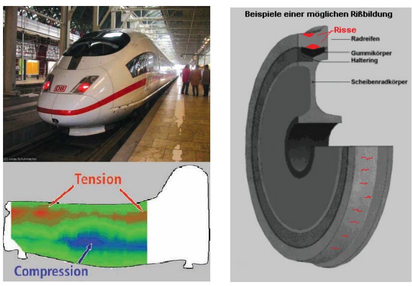

Fig. 3 ICE train accident in 1998 analyzed by neutron residual stress measurement (www-llb.cea.fr)

3.4 Hydrogen Characterization

Hydrogen is one of the plenty elements in nature and sometimes affects tremendous effects on the properties of materials which contain this element as an either chemical constituent or mixture. For example, the inspection of the microscopic concentration of the hydrogen within zirconium alloys is a key issue of the nuclear industry. Since the neutron incoherent scattering (NIS) cross section of the hydrogen is very large compared with other elements and the intrinsic property of the neutron which can easily penetrate matter, one can measure a very small amount (~ ppm) of the hydrogen within a specimen as it is by measuring the NIS intensity (Fig. 4) [4-5].

3. Conclusion

A lot of practical inquiries and demands on the material characterization or inspection from the industry can be accommodated by carrying out neutron scattering experiments. Especially the elastic scattering which gives structural information of materials could be applied to develop a new process for a material synthesis or fabrication. There have been sequential developments of elastic neutron scattering instruments in HANARO and these are being used for the material characterization, texture analysis, residual stress and some special purpose such as the determination of very small concentration of hydrogen within zircaloy tubes.

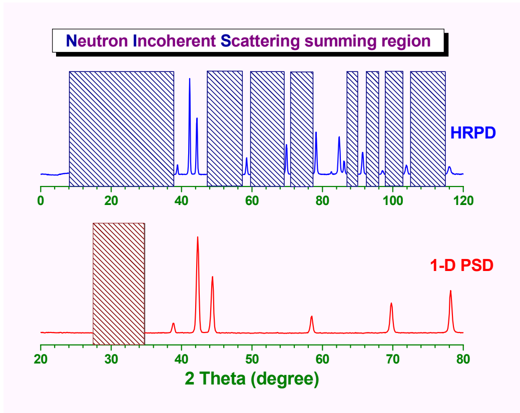

Fig. 4 Neutron diffraction patterns taken from the zircaloy tube by using a default detection system of the HRPD (upper) and a position sensitive detector (bottom).

ACKNOWlEDGEMENTS

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