Neutron Radiography

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Recently considerable attention has been paid to neutron radiography. The technique using thermal neutrons was demanded because of its inspection ability for hydrogenous materials such as plastic, water, explosives or composite materials and irradiated nuclear fuel capsules. The method of the technique is similar to radiography with X or γ rays. The remarkable merits of neutron radiography comes from a large difference in the absorption coefficient for neutrons between various elements, compared with that for X or γ rays. The coefficient varies randomly as a function of atomic number.

Radiography with thermal neutrons has been mainly developed by the use of high intensity neutron flux from nuclear reactors. Presently, it is much necessary to extend its applicability to various fields. It is also important to install neutron radiography facilities more convenient and economical than the reactor based system.

To satisfy the requisites mentioned above, accelerator based systems had been proposed for a long time and investigated at the laboratory level by using Van de Graaff accelerators of a few MeV energy to produce neutrons by the $^{9}Be(d,n)Be^{10}$ reaction.

The author and his coworkers had started the study on neutron radiography in 1969. At first, we used 14-MeV neutrons from D-T reaction on a 1-MeV Van de Graaff accelerator and photo-neutrons from γ-n reaction on an 18-MeV linear electron accelerator. Then we had continued the study with the Kyoto University Reactor since 1975.

In the late 1970s, we were consulted by the National Space Development Agency of Japan on the application of neutron radiography. From our experience, we examined various methods and conditions to find a best solution. We have noticed the following fact: The neutron flux generated by the (d,n) and (p,n) reactions on Be increases with the second or third power of accelerator energy. The (p,n) reaction on Be has been considered more useful because of lower neutron energies and accordingly higher efficiency for thermalization.

Luckily, small cyclotrons recently developed for medical uses produce protons of higher energies than conventional accelerators for industrial purposes, and are convenient to operate. Therefore, we have concluded to use such cyclotrons for neutron radiography, and constructed a system for practical applications. The greatest advantage of the accelerator based system is that the generation of neutrons stops when the accelerator is switched off. Other advantages of the system consist in compactness and easiness of operation and maintenance.

We report here mainly the merits of the neutron radiography system by the use of the cyclotron and some applications of this system.