Comparison between in-situ time-resolved neutron diffraction measurements based on quasi-steady state phenomenon and direct real-time experiment

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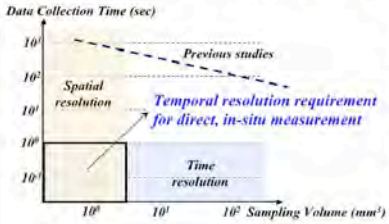
ABSTRACT: The deep penetration capability of neutrons makes neutron diffraction a powerful and unique techniques to study the properties and structures of engineering materials. Since the number of neutrons collected by the detector is proportional to the neutron flux, neutron research has been limited to the so-called "static" behavior of material. A novel measurement concept based on the quasi-steady state (QSS) phenomenon has been proposed to study the rapid transient material behavior using neutron diffraction. This study is to experimentally verify the validity of such measurement concept. It compares the results from the in-site time-resolved QSS experimental measurement with these from direct real-time measurement under specially designed testing conditions, thereby experimentally established the equivalency of the two measurements. The current study shows that the *in-situ, time-resolved neutron-diffraction method can measure rapid changes of material state and provide insight on the mechanical behavior under the severely plastic deformed thermo-mechanical processing*.

1. Background & Motivation

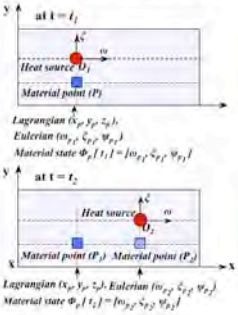


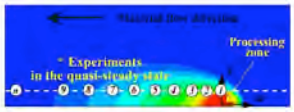
Due to neutron flux limitation, neutron diffraction is not suitable for in-situ, real-time measurement of the rapid and complex changes of material states (temperature, stress, and microstructure) of high gradient region

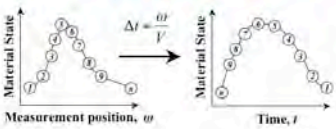
Scientific Issue: *Can the neutron-collection time for small gage volume be independent of the changing rate of material state in a rapid process?*

2. Principle of the quasi-stead state (QSS) measurement

Lagrangian coordinate system observed from the material point of view
Eulerian is fixed to the processing zone
The arrangement of the processing fixed in the relative space to the neutron-beam position in the QSS condition can collect sufficient neutrons.

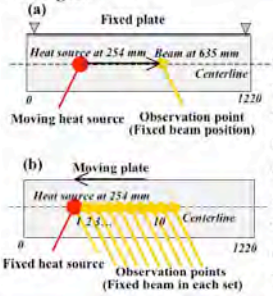


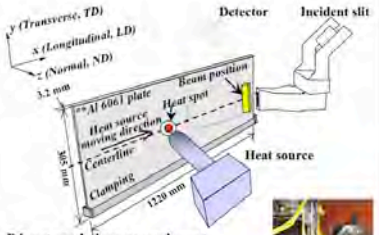




3.Experiment

A specially designed test with localized heat source on a Al alloy plate causes *d*-spacing changes.



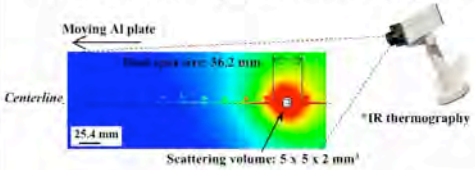


(a) ***Direct real-time experiment*** : Electric heating tool traveled with the speed of 0.42 mm/sec, 15 minutes.

(b) ***Measurements based on QSS*** : Total 10 sets of measurements were accomplished by relatively different distance between heat and beam with moving plate of 0.42-mm/sec.

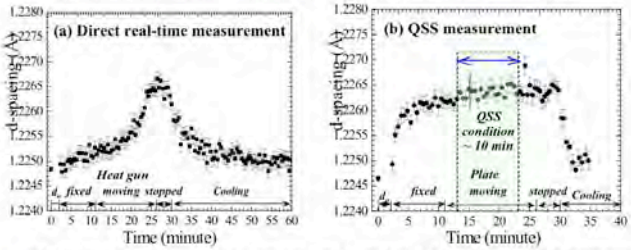
4. Results and Discussion

A. Verification QSS condition using infrared thermography



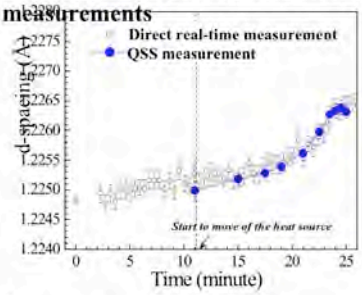
Achievement of the QSS condition in the *Eulerian* coordinate system

B. In-situ time-resolved neutron-diffraction results



(a) Initial d-spacing (d_o) was measured without heating for 2 min and it increased up to 1.22666 Å, (b) d-spacing is relatively constant as 1.22636 ± 0.00016 Å (QSS condition) with the moving plate

C. Comparison between the direct and QSS measurements



d-spacings were averaged of the 10-minutes QSS stage data for each set of QSS measurements and converted as function of time.

5. Summary and Conclusion

1) The localized heat source on the Al alloy plate causes *d*-spacing changes due to the increased temperature and constraints.
2) The equivalency of the direct real-time and quasi-steady state (QSS) neutron-diffraction measurements were accomplished.
3) If one can create a thermo-mechanical processing in the QSS condition, the neutron-collection time can be independent to the changing rate of the material state in the transient process.
4) QSS technique can be used for in-situ measurement of fast transient material behaviors.

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