# Suppression of Solidification Crack upon Steel Welding

The world's first successful Two-dimensional Time-resolved X-ray diffraction of metallographic changes in weld metals during real welding at a resolution of 0.01 sec.


## Achievements

- Paving the way to suppression of **welding solidification crack*** in weld metal by detailed measurement of metallographic changes of **high-alloy steel**** weld metal in the melting and solidification processes during welding

R&D facility: Sumitomo Metal Industries, Ltd., Osaka University, and Japan Synchrotron Radiation Research Institute

***Welding solidification crack:** Welding involves the rapid melting and solidification of weld metal. A membrane (liquid phase) with a low melting point is formed during welding, and stress due to its contraction acts on the membrane while solidifying, causing a network of cracks. This is known as welding solidification crack.

****High-alloy steel:** The percentage of alloy elements added to steel is at least 10%.

## Role of SPring-8

### Background

The prevention of welding solidification crack is essential for improving the reliability of materials at the welded part. For this purpose, a reduction of metals causing a decrease in the solidification temperature at the welded part has been tried; however, a number of difficulties remain for practical application.

To prevent solidification crack, it is necessary to examine the welding solidification process in detail, clarify the mechanism behind the formation of solidification crack, such as when and what substances are produced, and predict the formation of solidification crack.

### Results

For the in situ observation of metallographic changes at the welded part, we used our actual welding machine and applied PILATUS,* a two-dimensional pixel detector to catch week signals. As a result, we succeeded in two-dimensional capturing the **metallographic changes during rapid cooling over 100 K/s**, and in establishing guidelines for material design to prevent solidification crack.

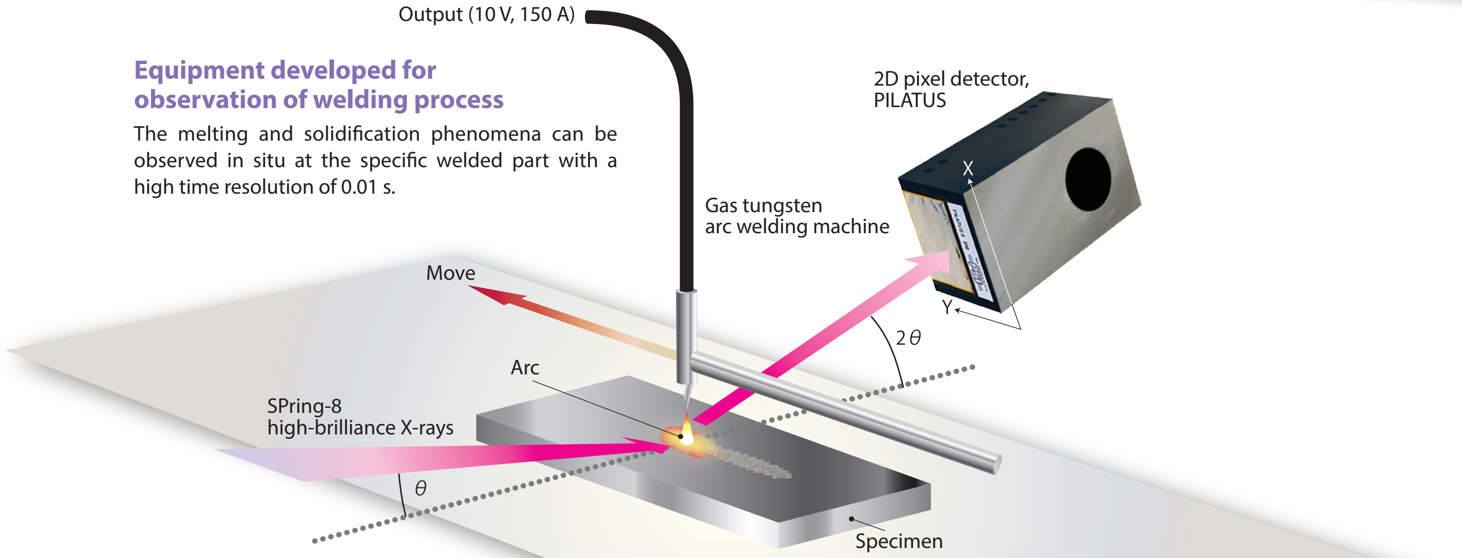
For example, niobium forms a carbide earlier as the amounts of niobium and carbon in an alloy are increased. The importance of the timely and stable formation of niobium carbide was clarified to prevent solidification crack.

*PILATUS: High-sensitivity high-speed two-dimensional X-ray detector developed in a collaboration between Japan Synchrotron Radiation Research Institute and Paul Scherrer Institut (PSI) in Switzerland.

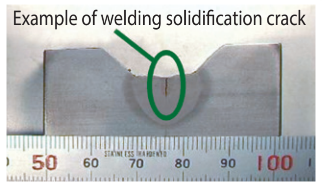
Publication: M. Yonemura et al.; Materials Transactions **47**, 2292-2298 (2006)  Y. Komizo et al.; Quarterly journal of the Japan welding society **24**, 57-64 (2006)
M. Yonemura et al.; Tetsu-to-Hagané **93**, 68-74 (2007)

### Equipment developed for observation of welding process

The melting and solidification phenomena can be observed in situ at the specific welded part with a high time resolution of 0.01 s.




Example of welding solidification crack




### X-ray diffraction pattern for high-alloy steel

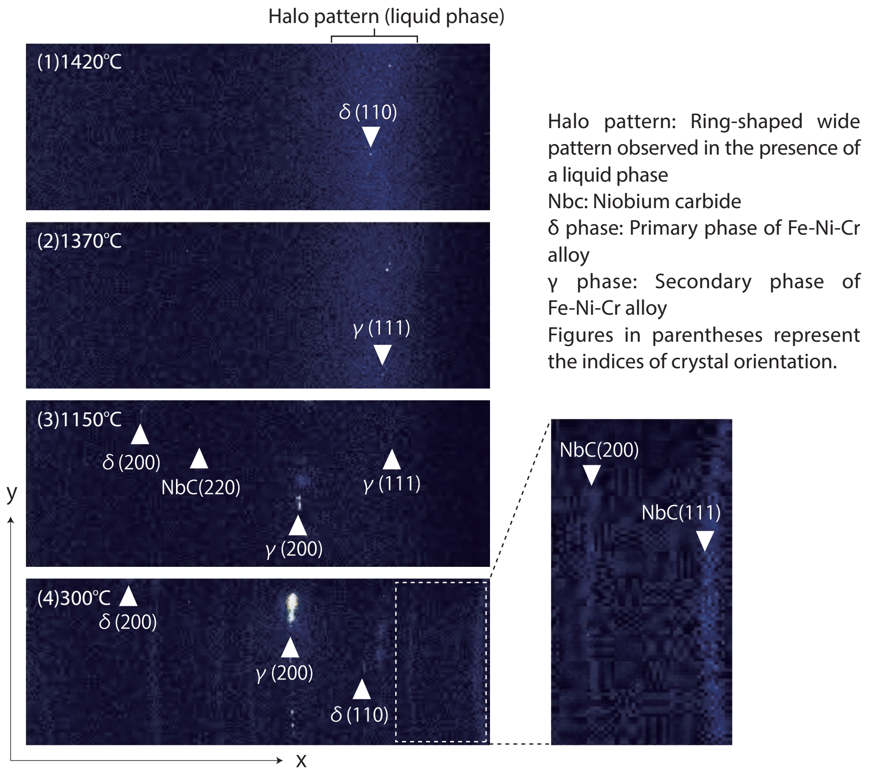
Niobium carbide (NbC) appears from a liquid phase after a few seconds of rapid cooling, and grows stably. As a result, its microstructure is stabilized and solidification crack is suppressed.

(1) First, the metal melts and the temperature decreases. At the moment the metal starts to solidify, a δ phase first appears from a liquid phase (halo pattern).

(2) A γ phase appears with further decreasing temperature.

(3) When the temperature further decreases, NbC appears (is crystallized) and the liquid phase disappears. At this time, the γ-phase and NbC spots are aligned, indicating a structurally stable crystal orientation.

(4) Finally, a γ+δ+NbC triple phase forms.




Halo pattern: Ring-shaped wide pattern observed in the presence of a liquid phase
Nbc: Niobium carbide
δ phase: Primary phase of Fe-Ni-Cr alloy
γ phase: Secondary phase of Fe-Ni-Cr alloy
Figures in parentheses represent the indices of crystal orientation.