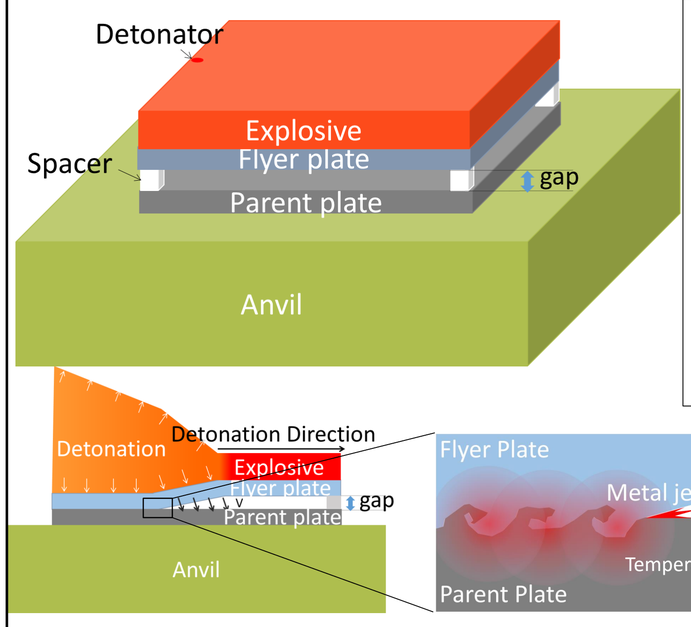
Tokyo Institute of Technology School of Materials and Chemical Technology
Kumai-Muraishi laboratory

Microstructure and thermal history of explosive welded pure aluminum / SS400 steel joint

Introduction



Explosive welding

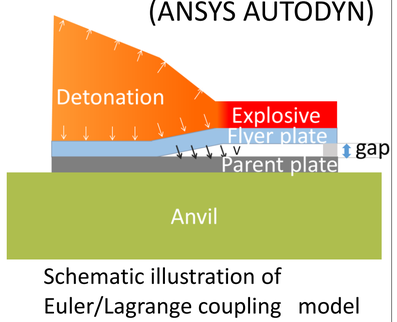
- A welding method for metal plates with high speed and incline collision.
- A solid-state welding.
- A useful method for dissimilar metal welding.
- A characteristic wavy interface and a few intermediate layer are formed.

Problem It is important to examine the thermal history near the welding interface. But thermal history has not been revealed enough.

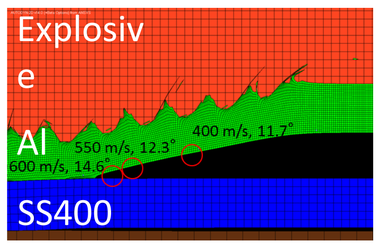
Purpose The purpose of this research is to investigate the thermal history near the welding interface using both experimental and numerical analysis method.

Numerical analysis method

Step 1 Behavior of the detention (Euler/Lagrang coupling model) (ANSYS AUTODYN)

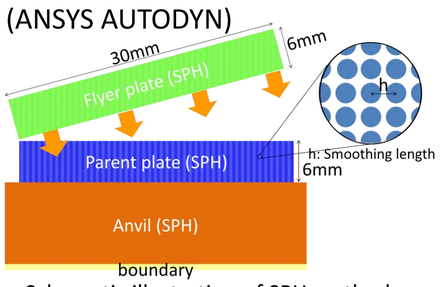


Schematic illustration of Euler/Lagrange coupling model

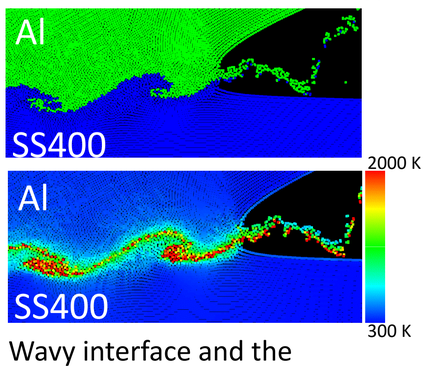


Impact velocity(V) and impact angle(α) were obtained.

Step 2 Welded interface formation and thermal distribution (SPH model) (ANSYS AUTODYN)

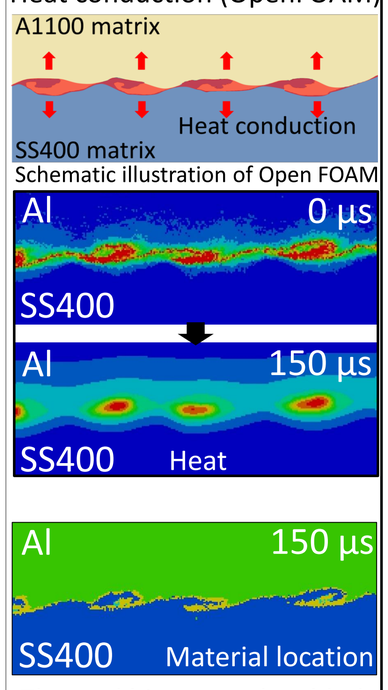


Schematic illustration of SPH method



Wavy interface and the temperature were obtained.

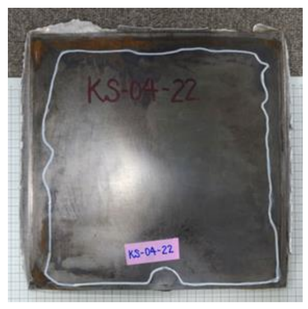
Step 3 Heat conduction (OpenFOAM)



Thermal history and welded interface formation were obtained

Experimental method

Explosive welded sample (Al side)

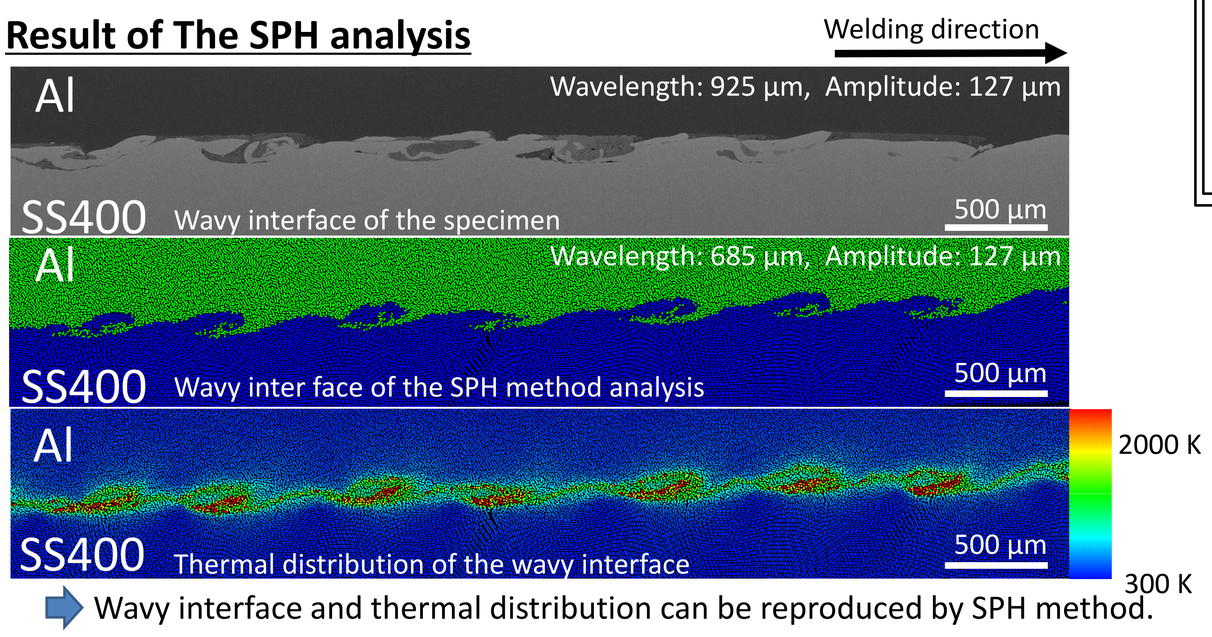


Explosive welded sample (SS400 side)

- Flyer plate: Al (A1100)
- Parent plate: Fe (SS400)
- Size: 300 × 300 × 6mm
- Impact velocity: 600 m/s
- Impact angle: 14.6 °
- Observation: OM, SEM
- Hardness test: Nano indentation

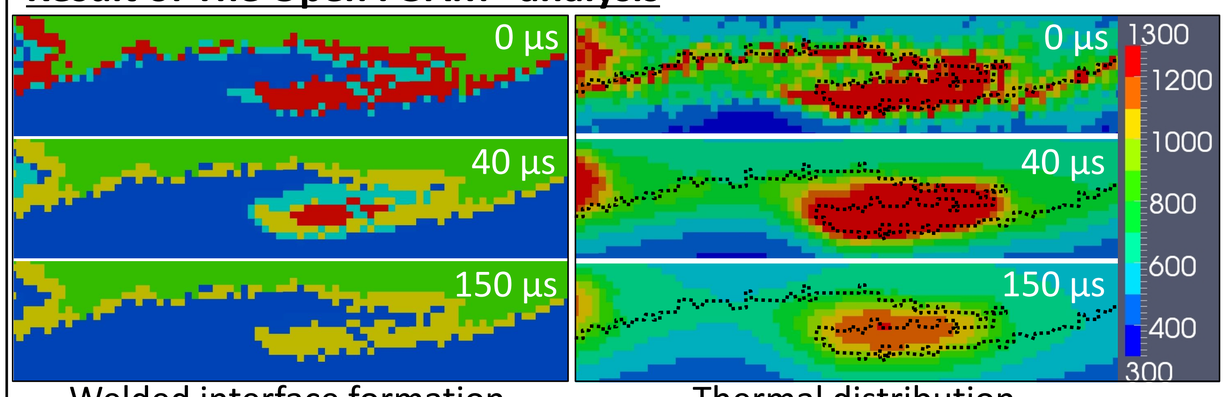
Numerical analysis results

Result of The SPH analysis



Wavy interface and thermal distribution can be reproduced by SPH method.

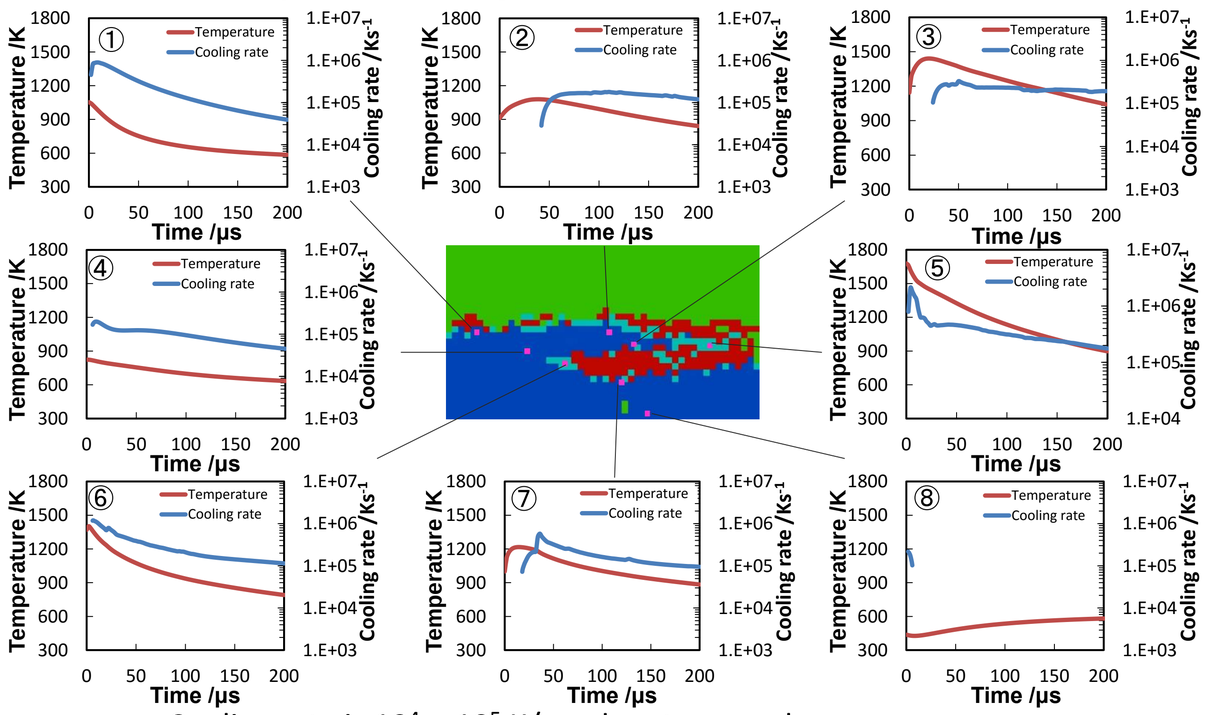
Result of The Open FOAM analysis



Welded interface formation — Thermal distribution

α-Ferrite (0 - 1183 K) · Al-solid (0 - 933 K) · Austenite etc. (1184 - 1810 K) · Intermediate layer · Liquid phase

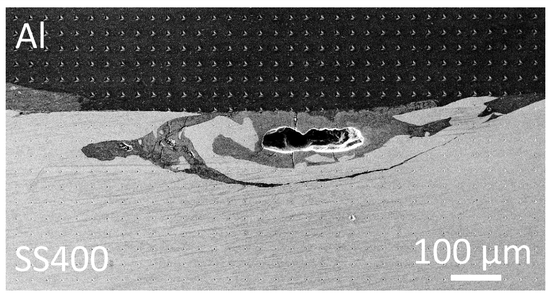
Thermal history and cooling rate at various locations



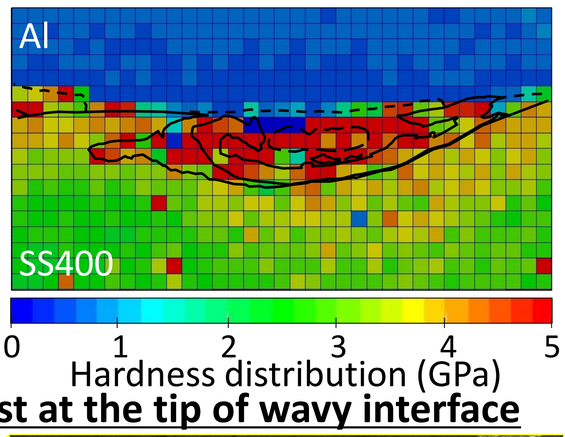
- Cooling rate is 10^4～10^5 K/s order at many place.
- The location ⑤, at the top of wavy interface, exhibited a very high temperature (1700 K) and a very high cooling.

Experimental results

Result of the nanoindentation test near the welded interface

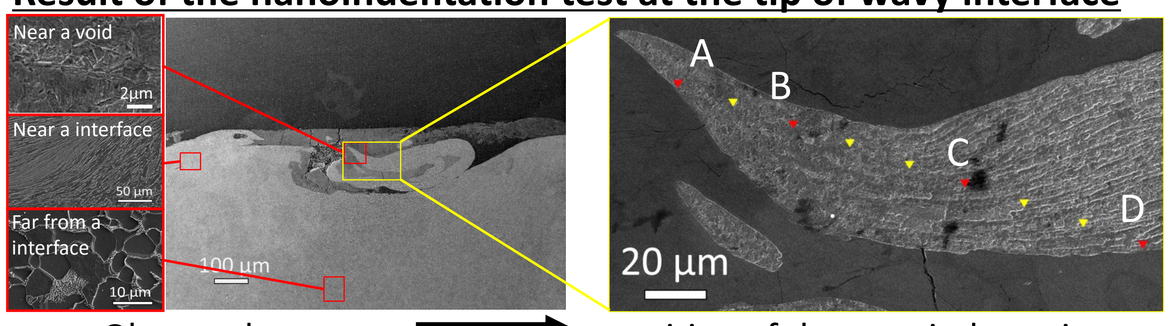


Marks of nanoindentation test



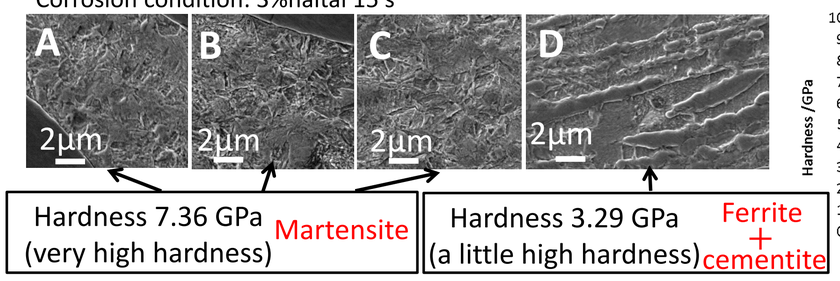
Hardness distribution (GPa)

Result of the nanoindentation test at the tip of wavy interface



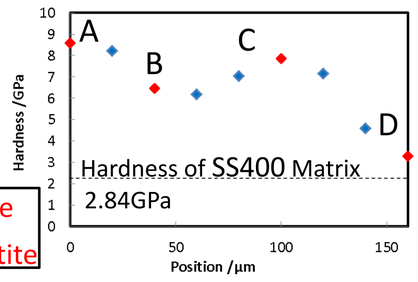
Observed area — Welding direction — position of the nanoindentation test

Corrosion condition: 3%naital 15 s



Hardness 7.36 GPa (very high hardness) Martensite

Hardness 3.29 GPa (a little high hardness) Ferrite + cementite



The region with martenstic structure corresponds to the area of high temperature and high cooling rate according to the numerical analysis.

Conclusions

- Microstructure change and thermal history of the explosive welded pure aluminum and SS400 steel joint were investigated by using both numerical and experimental analysis.
- The numerical analysis revealed that the region with martensitic structure in SS400 corresponded to the area in which the highest temperature and the highest cooling rate were observed except for the local melting area.