Study of Heat Affected Zone (HAZ) for Microwave Welded Stainless Steel Dissimilar Lap Joint

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Rahul Samyal*, Ashok Kumar Bagha, Raman Bedi, Anupam Singhal, Srikanta Routroy

*Department of Mechanical Engineering,

Birla Institute of Technology and Science, Pilani, Rajasthan, India

Objectives

- To develop the lap joints between SS202-SS304 through a novel selective microwave hybrid heating (SMHH) process by utilizing nickel powder as filler.
- To study of heat affected zone (HAZ) through electron back scattered diffraction (EBSD) analysis. EBSD is an SEM assisted technique to reveal crystallographic data involved with the microstructural data of the specimen.
- To study inverse pole figures (IPF) maps, grain size diameter and kernal average misorientation (KAM) to identify fine grain heat affected zone (FGHAZ), coarse grain heat affected zone (CGHAZ) and average grain size diameter (AGSD).

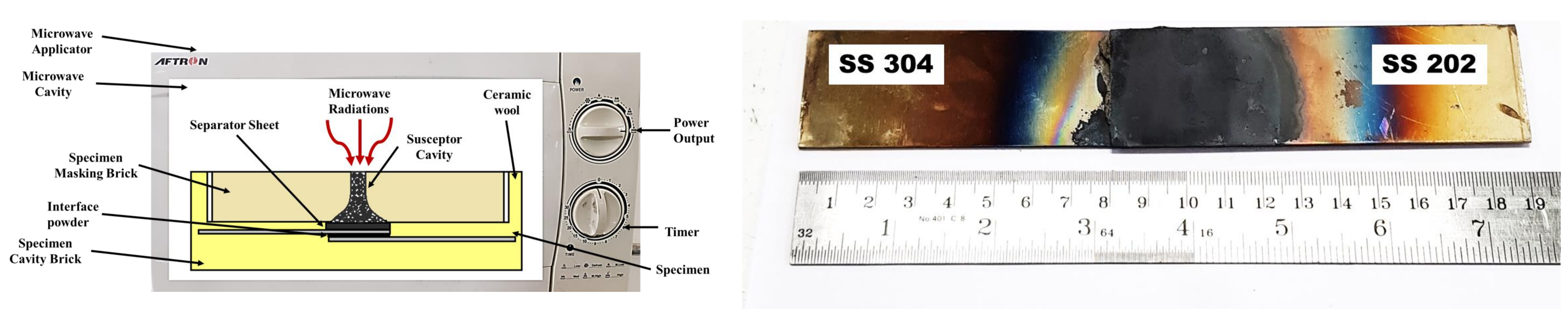

Fig. 1 Schematic diagram for Selective Microwave Hybrid Heating along with developed joint

Methodology

- In SMHH, activated charcoal (susceptor) is used as a source to absorb microwave radiation at a greater rate, placed in the vertical cavity to target the overlap region.
- A separator sheet of Graphite was used having a 1mm thickness to avoid mixing the activated charcoal with the interlayer.
- Fig. 2 (a) shows the five different locations of thermocouples on a specimen. Fig. 2 (b) shows the specimen inside the crucible cavity (10% Alumina brick). Fig. 2 (c) presents the masking of the lap joint with 50% alumina brick and thermocouples with glass sleeves. Undesirable arc generation and charcoal exploding were avoided by covering small voids with ceramic wool, illustrated in Fig. 2 (d).

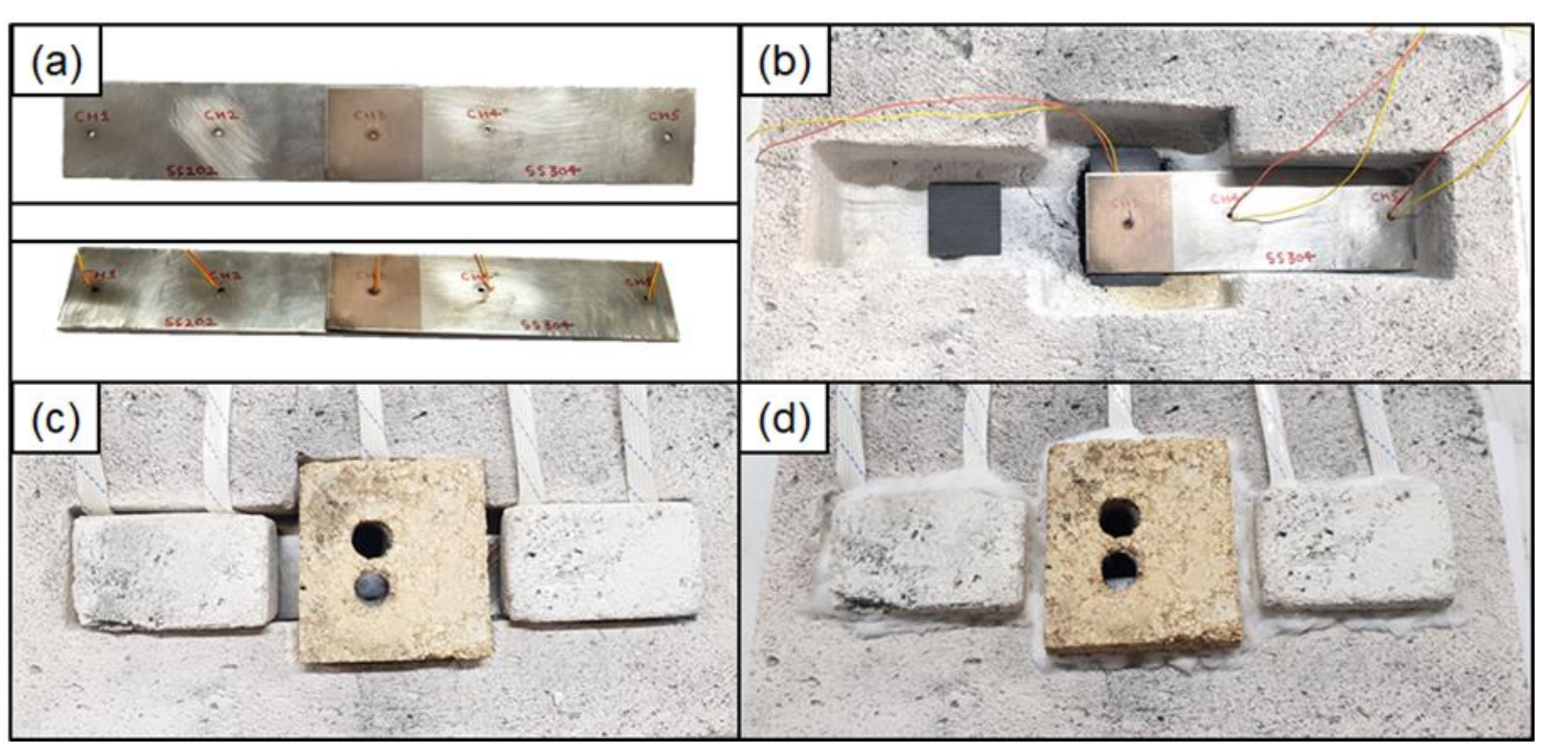

Fig. 2 SMHH designed setup (a) specimen with thermocouple at different locations (b) specimen under crucible cavity (c) Masking of the specimen (d) covering edges with ceramic wool

Table 1 Processing parameters

Parameters	Descriptions
Microwave Applicator	Multimode Microwave Oven
Operating Frequency	2.45 GHz
Cavity Capacity	25 *l*
Operating Power Output	700 Watt
Susceptor	Activated Charcoal
Interlayer Material (Particle Size)	99% Nickel Based Powder (20 μm)
Binder	Epoxy Blumer
Separator (Thickness)	Graphite (1 mm)
Specimen Dimension	189×35×1 mm
Exposure Time	1320 approx. Sec

- In Table 1, the experimental specifications of the applicator and specimen are listed.
- SS202 typically has a higher carbon content compared to SS304.
- Higher carbon content can lead to increased susceptibility to sensitization and carbide precipitation during welding.
- SS202 generally requires more precise control of parameters, to prevent issues such as overheating, distortion, and cracking.

Results & Discussion

- Selecting the austenitic Stainless-Steel phase (γ-ferrite-fcc) three different planes were identified for the grain orientation at [111], [101], and [001] planes.
- For each location grains are equally aligned to each plane. The inverse pole figures (IPF) maps for the dissimilar lap joint are presented in Fig. 3 along RD (Radial Direction) and TD (Transverse Direction).
- From the IPF maps it is observed that the recrystallisation has occurred for P3, P4, and P5 for upper plate (SS202). However, for lower plate (SS304) it has only occurred for R5.
- EBSD analysis, revealed the presence of fine grain heat affected zone (FGHAZ) at P3 and P4 locations. For upper plate the length of FGHAZ is approximately 30 mm, whereas for lower plate no such FGHAZ was observed.
- Further, for location P4, the average grain size diameter (AGSD) has increased significantly to 19.974 μm defining it as coarse grain heat affected zone (CGHAZ). Similarly, for lower plate, location R5 has significantly large AGSD of 22.872 μm defined as CGHAZ of 15 mm length.

Dr. Rahul Samyal, Ph.D.
Postdoctoral Research Associate
Email: rahulsamyal52@gmail.com
: rahul.samyal@pilani.bits-Pilani.ac.in

Website

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Results & Discussion...

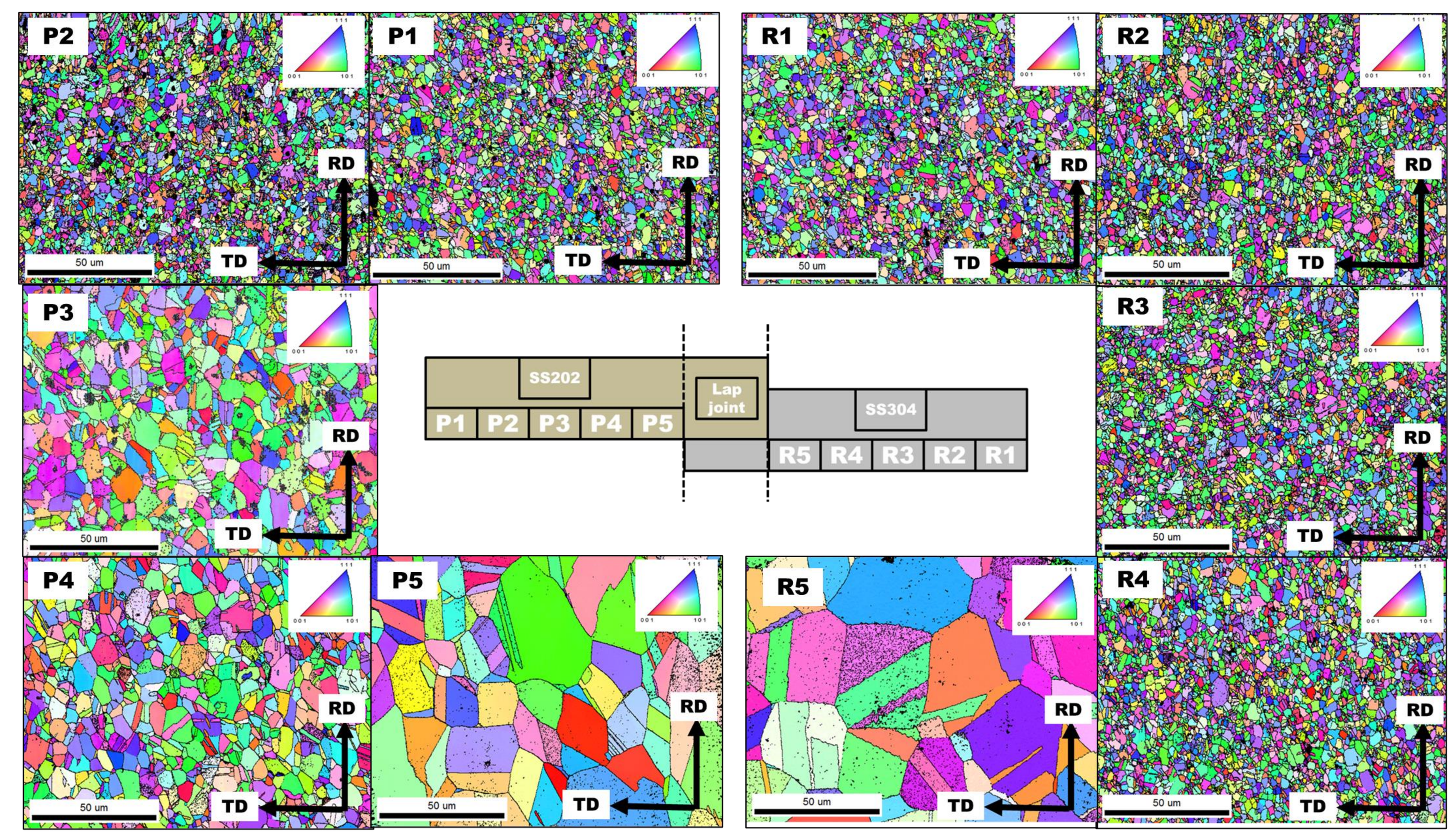

Fig. 3 Area scan locations for EBSD scans on welded specimen along with respective IPF maps

- Kernal Average Misorientation (KAM) maps show the color-coded description of variation in microstructural strain presented as maps and histograms in Fig. 4. A relatively high fraction of average angle from 0.4 – 0.8 ˚ for KAM histograms justifies the presence of residual stresses. The increased KAM values at location P2, P3 and R2 were revealed, pointing towards the evolution of slip lines at different locations.
- The increased green-coded fraction at these locations shows less strain and indicating an improved ductility when compared to other locations. The rapid thermal cycling caused the significant increase in the average KAM values at location P2, P3 and R2.

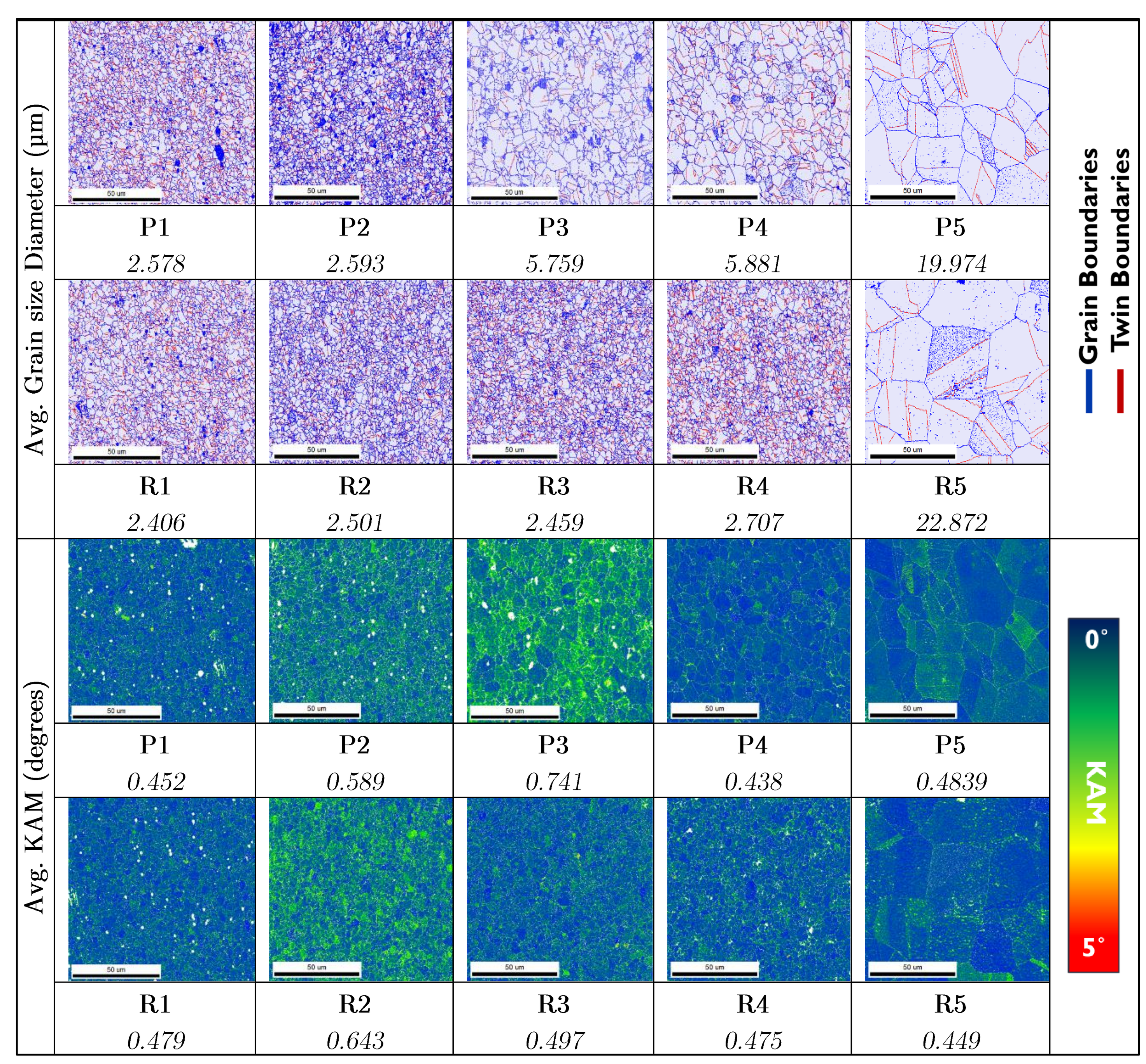

Fig. 4 Grain size diameter and KAM maps at different locations

Conclusions

- The presence of these high angle boundaries (HABs) describes the twin boundaries characterized by 60˚ rotation along the [111] axis. These twin boundaries are often formed during the recrystallization and grain growth in austenitic Stainless Steels.
- It is observed from AGSD that for upper plate the length of FGHAZ is approximately 30 mm and both plates have coarse grain heat affected zone (CGHAZ) of 15 mm length.
- The increased KAM values at location P2, P3 and R2 were revealed along grain boundaries, pointing towards the evolution of slip lines at different locations. The increased green-coded fraction at these locations shows less strain and indicating an improved ductility when compared to other locations.
- The continuous thermal cycling during the process caused the significant increase in the average KAM values at location P2, P3 and R2.

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