Dual-Laser Adjustable Mode Beam (DLAMB) Welding for Large-Scale Defect-Free Stainless-Steel Parts

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1. Objectives

- Traditional laser welding of SS304 usually suffers from porosity and fusion defects.
- Dual-Laser Adjustable Mode Beam (DLAMB) independently controls core and ring beam powers to adjust the 3D laser energy distribution.
- This work investigates the influence of core/ring power distribution on fusion geometry, defects, and hardness.

2. Methodology

- Material: SS304, 6.9 mm thickness.
- Sample preparation: Specimens were cut using waterjet cutting, ground, polished, and etched using 15 ml HCl, 10 ml acetic acid, 10 ml HNO_3, and one drop of glycerol for 25–30 seconds.
- Hardness testing: Vickers microhardness measurements were performed across the weld cross-section using a 200 gf load (HV0.2).

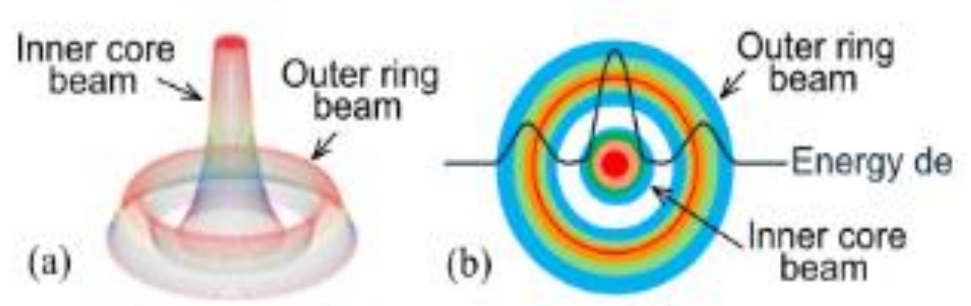


***Fig. 1**. The schematic presentation of the core and ring laser power distribution in the dual-laser adjustable mode beam (DLAMB) system.*

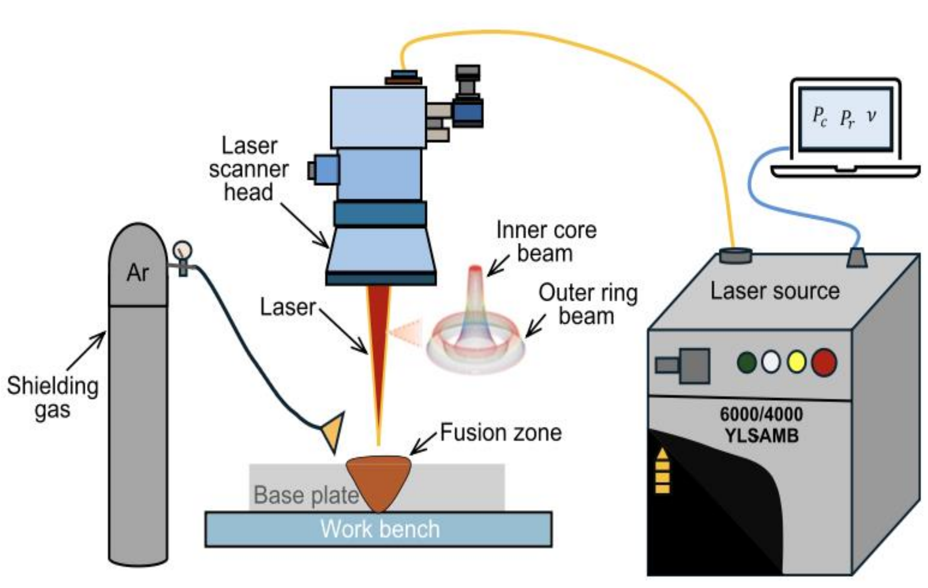
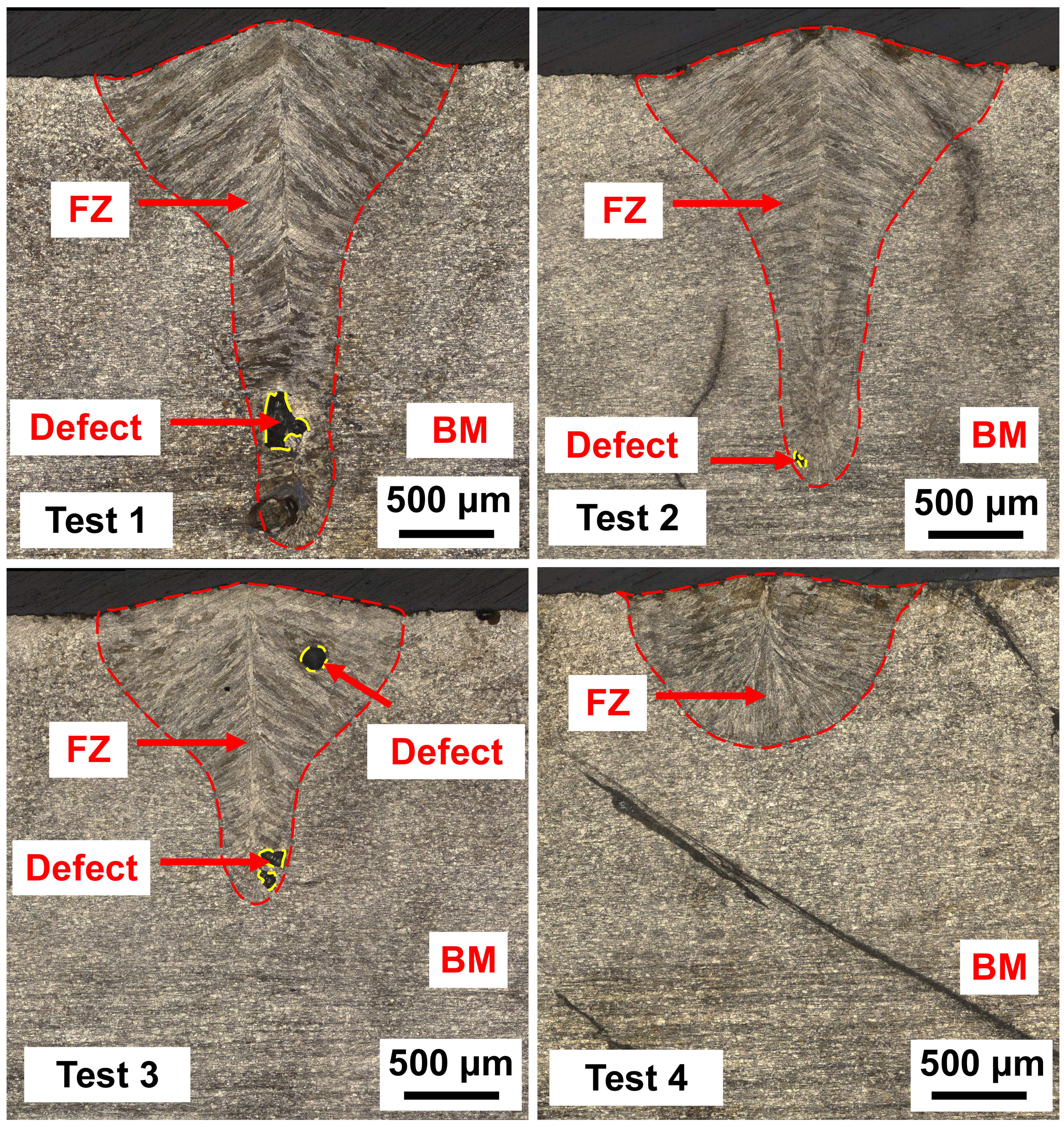


***Fig. 2**. DLAMB core/ring beam distribution and experimental setup.*

***Table 1**. DLAMB process parameters and melt-pool geometry (width and depth).*

Test No.	Scanning Speed, *mm/s*	Core laser power, *W*	Ring laser power, *W*	Melt pool depth, *µm*	Melt pool width, *µm*
1	50	3000	0	2787	1888
2	50	2000	1000	2431	1928
3	50	1000	2000	1738	1652
4	50	0	3000	895	1638

3. Results and Discussion



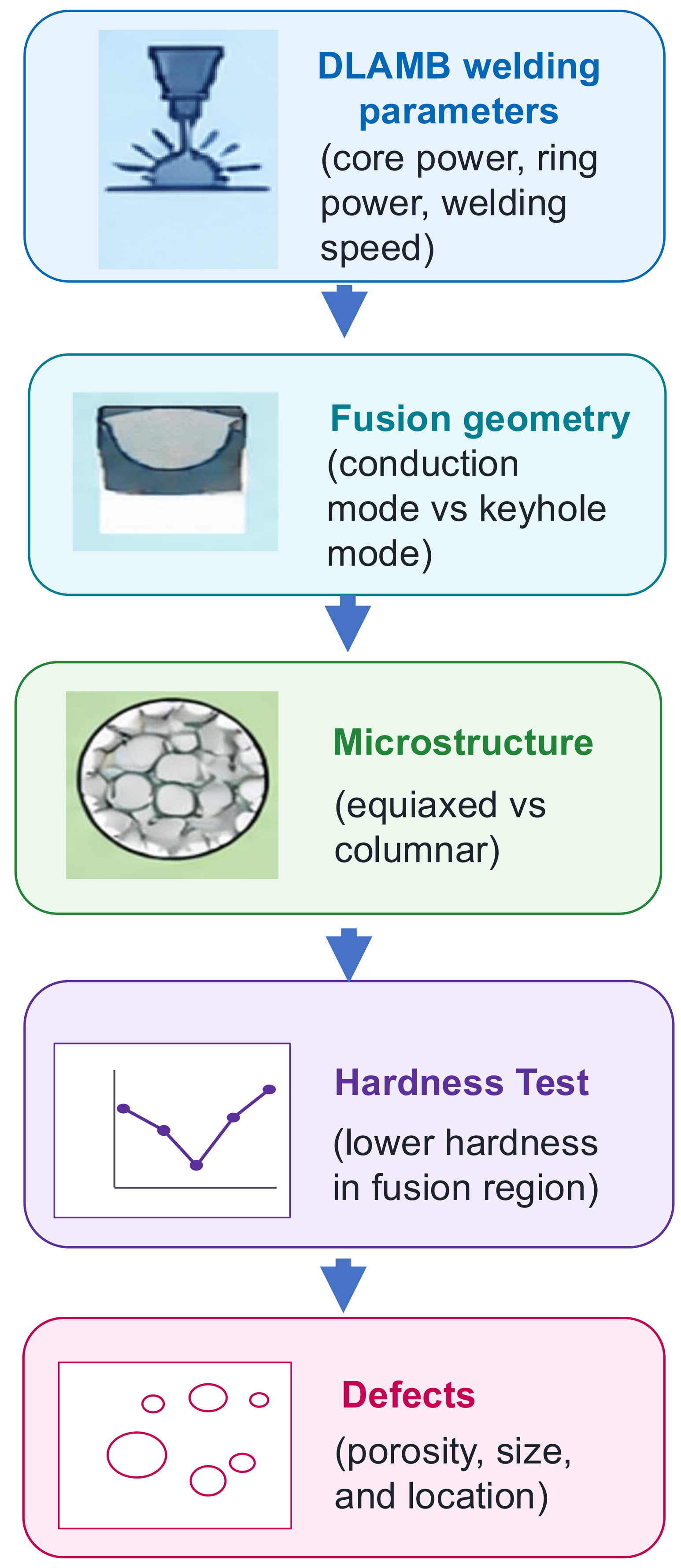


***Fig. 3**. Weld cross-sections for Tests 1–4. FZ - Fusion Zone; BM - Base Metal.*

- Fusion geometry (Fig. 3): Comparing test 1 and test 4, ring power increases from 0 to 3000 W (core power decreases from 3000 W to 0), and fusion geometry changes (melt pool depth decreases and melt pool width increases). In addition, a deep keyhole formed in test 1 while a conduction mode (shallow melt pool) formed in test 4.
- Defects (Figs. 3 and 4): Defect areas were measured as 0.050, 0.002, 0.029, and 0 for tests 1–4, respectively. Test 1 has the largest porosity area, followed by test 3 and test 2. No porosity is detected in test 4.
- Microhardness (Fig. 5): For two selected samples (test 1 and test 4), the fusion region has lower hardness compared to the base metal. Within the fusion region, the detected hardness near the top is lower than that near the bottom.

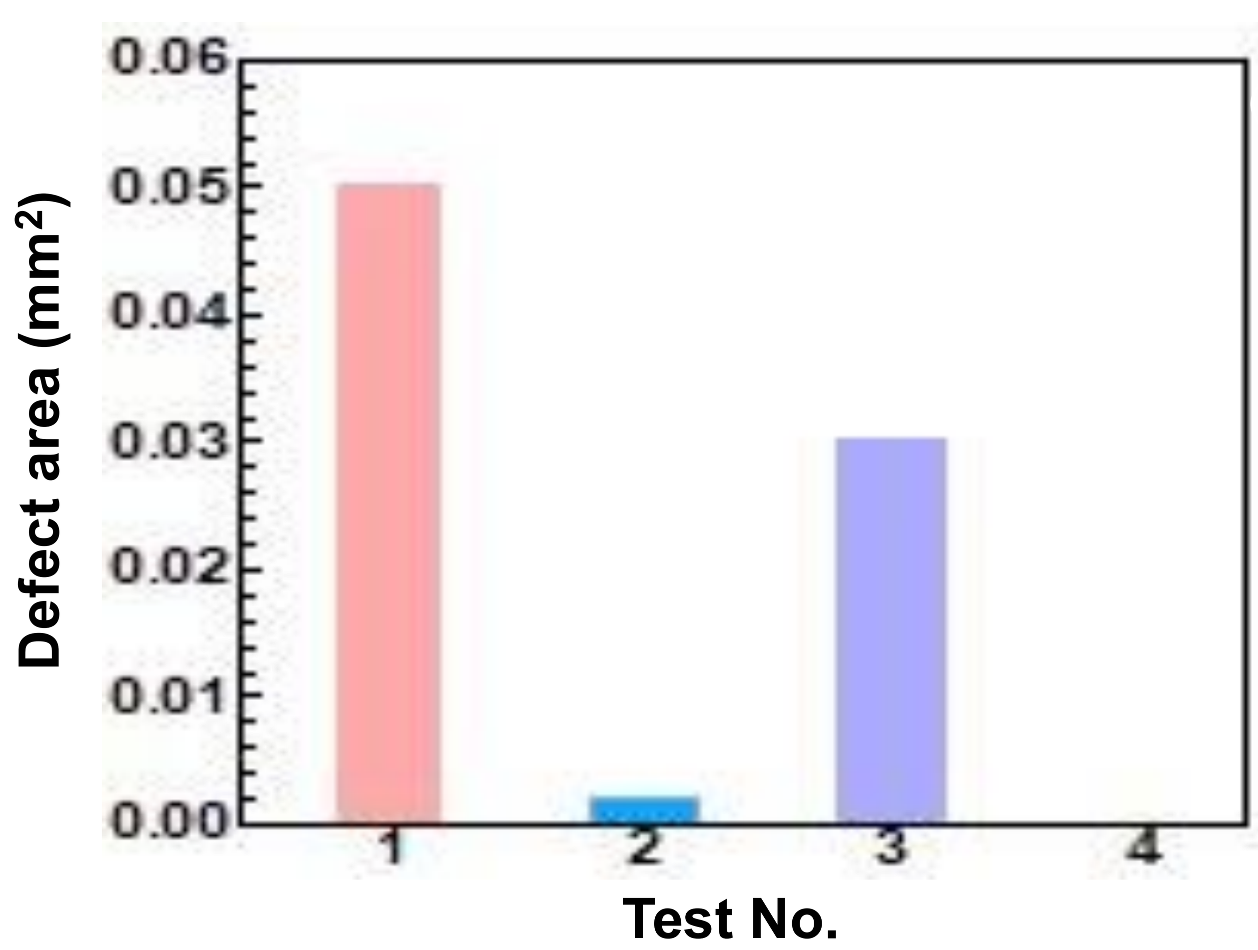
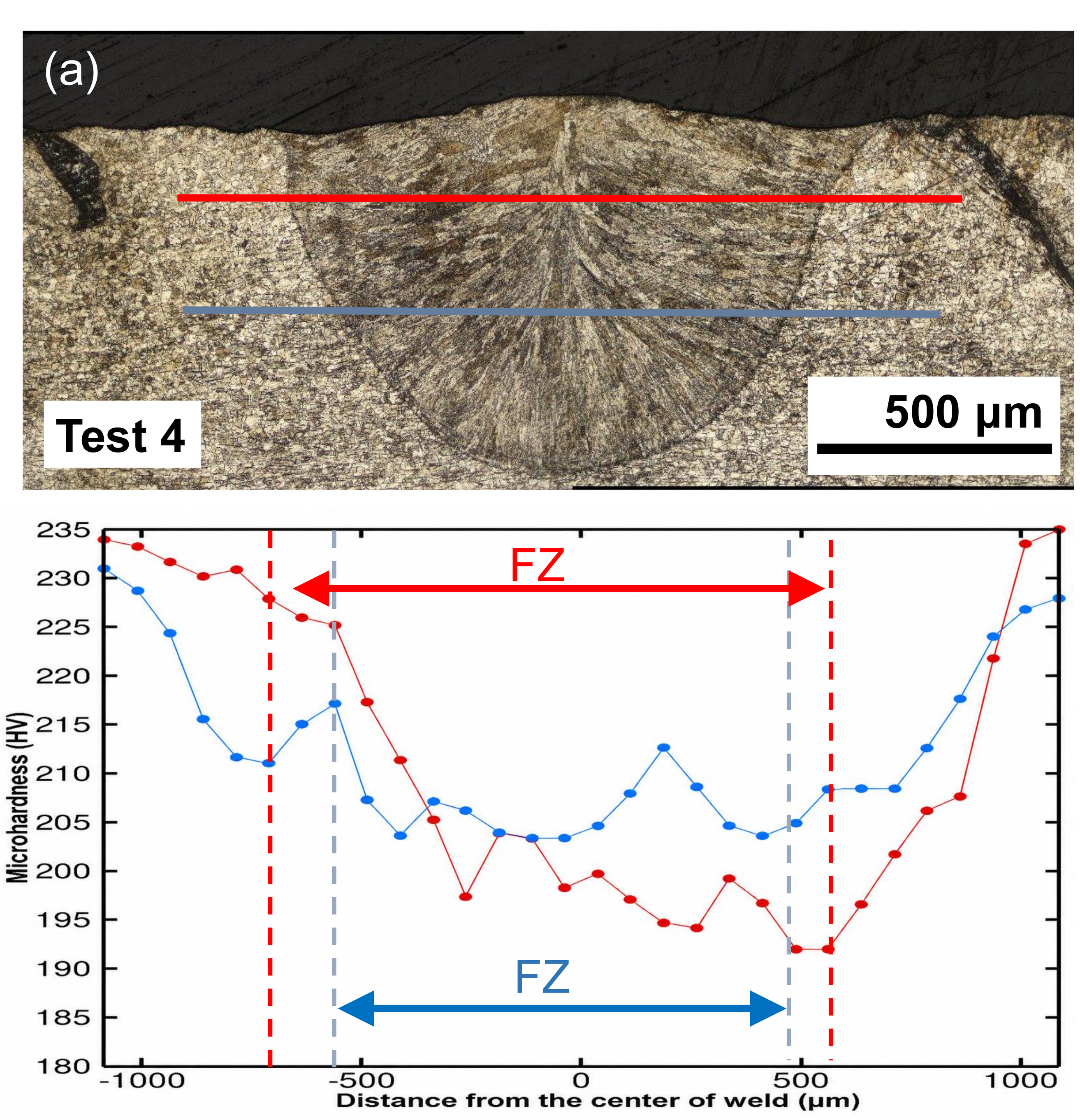


***Fig. 4**. Defect/porosity area for four DLAMB tests.*



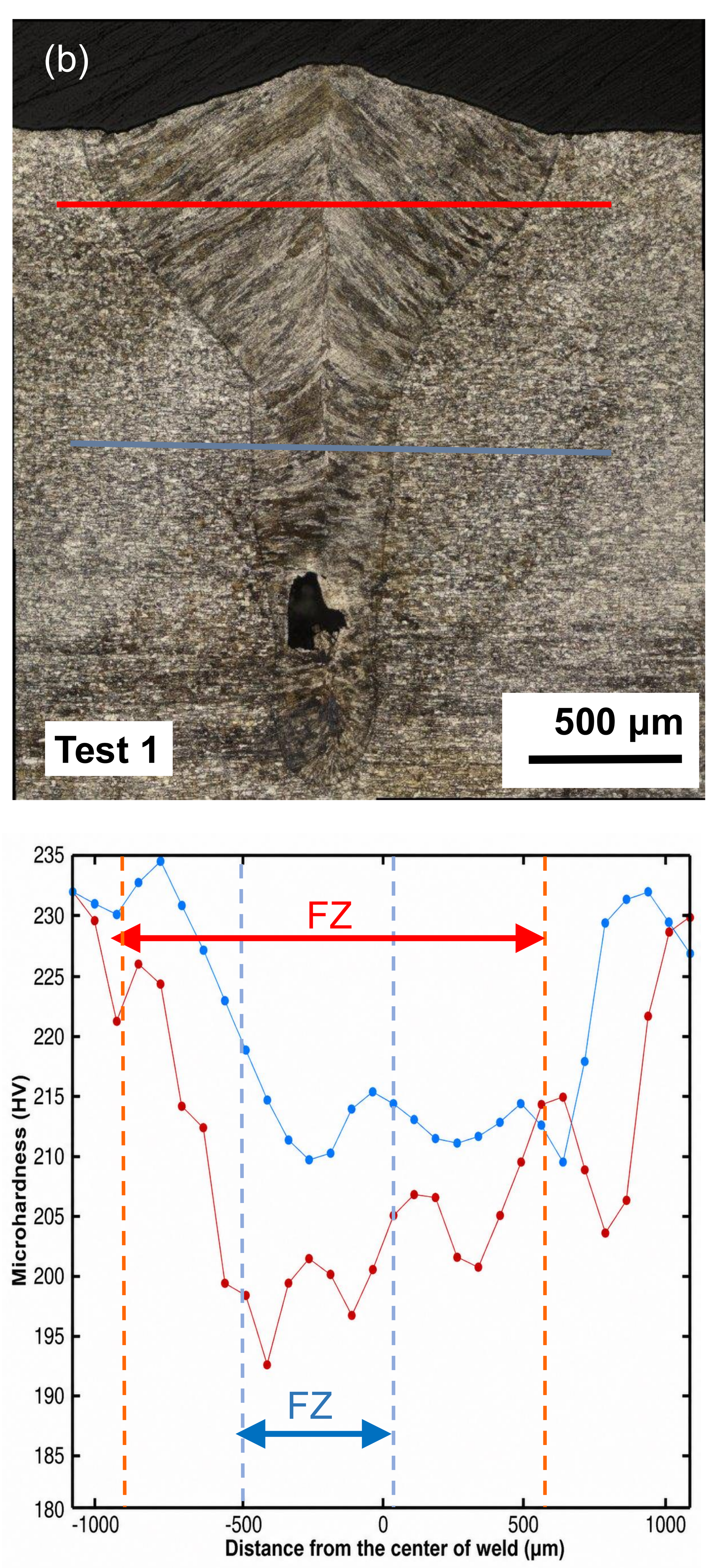


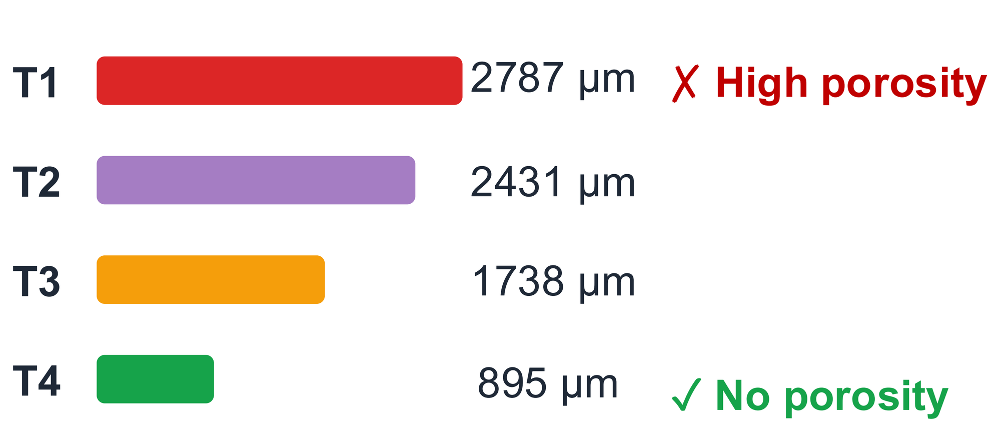
***Fig. 5**. Cross-weld microhardness for (a) Test 4 (conduction mode – top, bottom) and (b) Test 1 (keyhole mode – top, bottom).*

4. Conclusions

- Adjusting the core and ring power distribution can control the fusion geometry and keyhole formation.
- The keyhole formation affects the porosity.
- The fusion zone has lower hardness compared to the base metal. Within fusion region, the detected hardness near the top is lower than that near bottom.
- The DLAMB process parameters directly affect fusion geometry, microstructure, hardness, and defect formation (porosity).

Comparison of Tests 1-4

Melt-pool depth (bar length) and porosity.



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