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Study on harmonic response of wirebond in high power IGBT module under ultrasonic welding process

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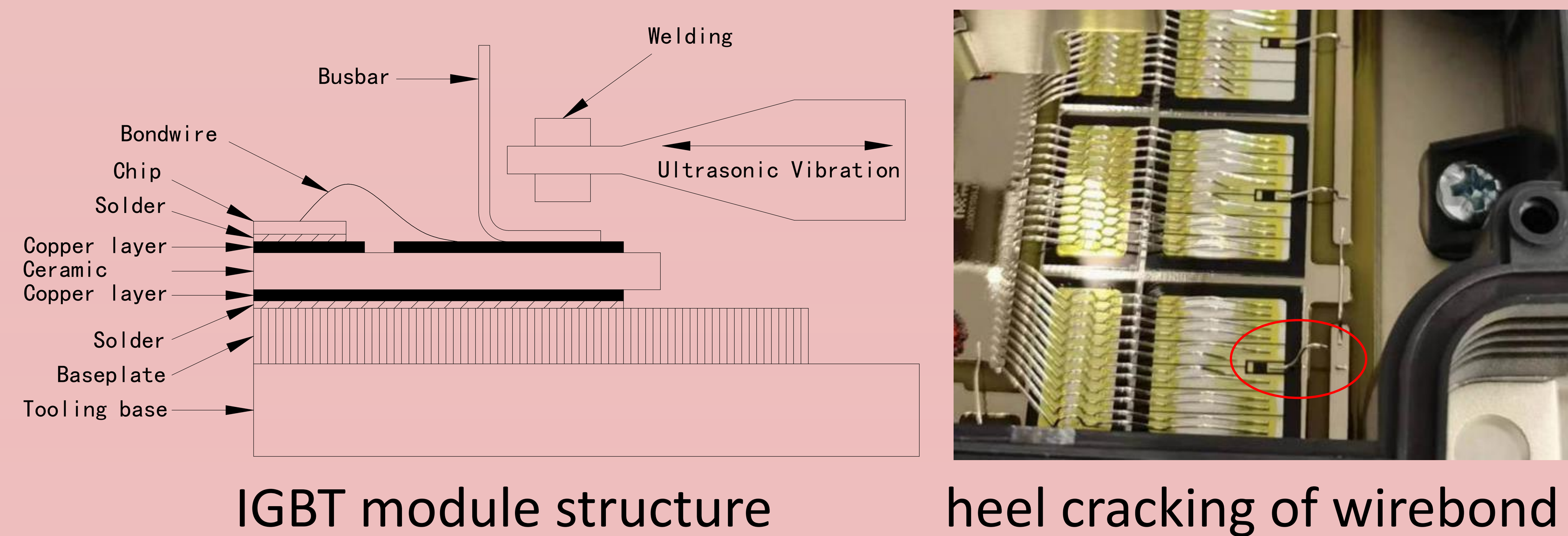
INTRODUCTION

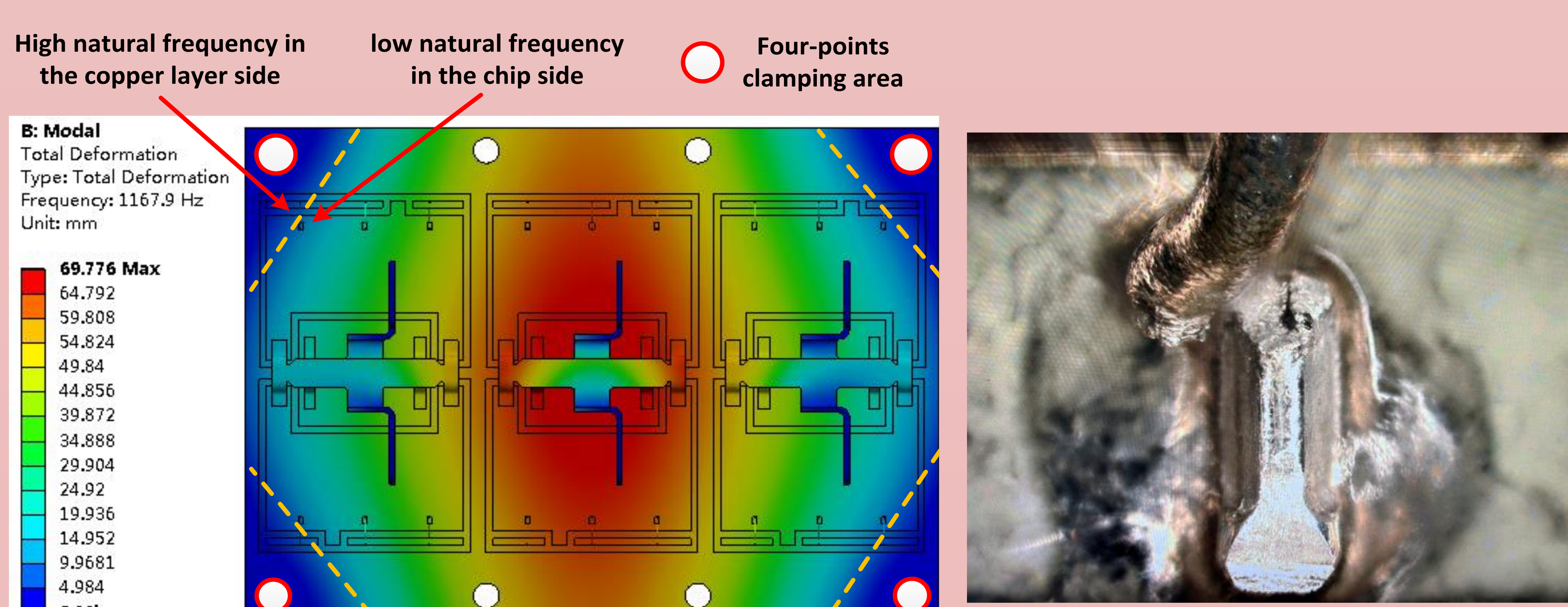
- As industrial converter development has moved towards higher power, smaller size and lower cost, the power density of the IGBT module increased sharply.
- Ultrasonic welding has the advantages of voidless connection and less heat generation by high-frequency(about 21kHz) harmonic vibration. however, leading to cracks in some weak structure like wirebond at the same time.
- To improve the structural vibration resistance, Finite element method was used to assess the harmonic response stress at the heel of the wirebond under ultrasonic welding process, then provide optimal guidance for process.



IGBT module structure   heel cracking of wirebond

ANALYSIS OF FAILURE MECHANISM

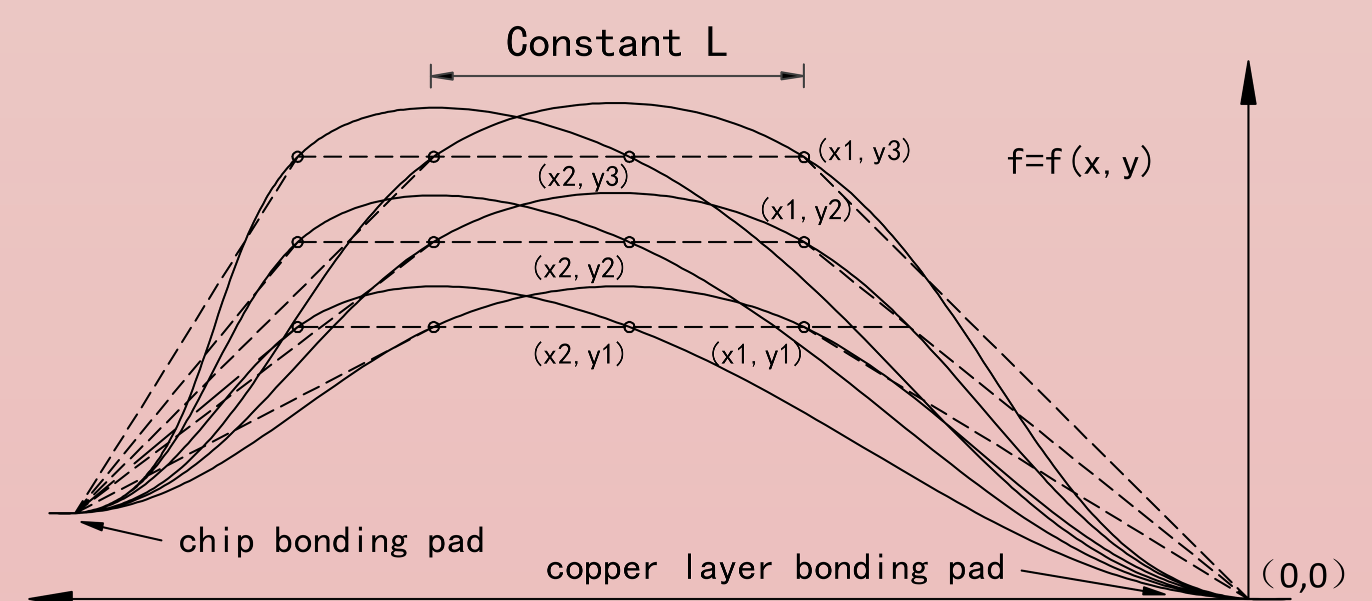
- The central structure of IGBT module has lower natural frequency than the structure in corner because of lower stiffness as the current clamping method(only four points clamped).
- The wirebond was excited to vibrate by an excitation frequency(21kHz) under the ultrosonic welding process, due to the natural frequency difference, as a result, different vibration frequency and phase angle between the chip side and the copper layer side, leading to shear stress at the heel of the wirebond, as shown in the crack shape from the picture.
- It explains why cracks always occur in the corner of the IGBT module structure.

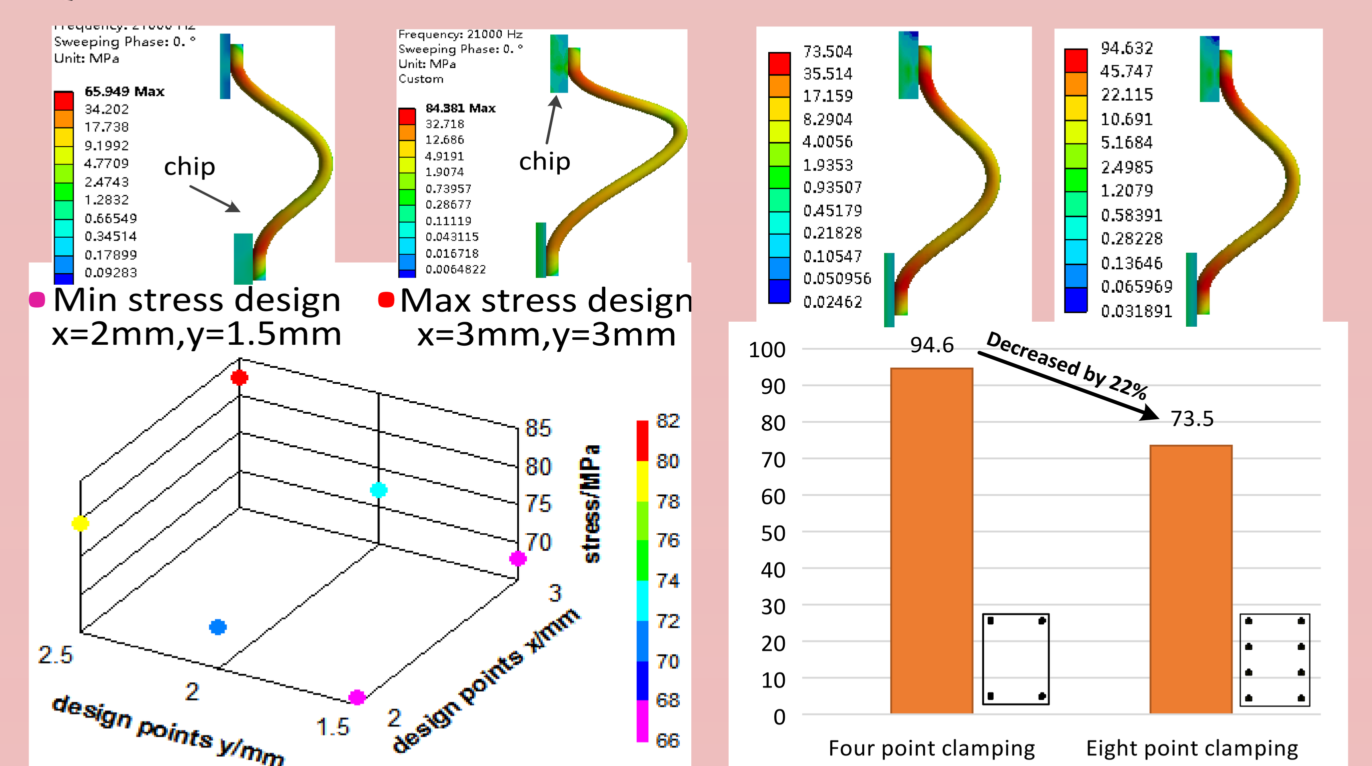


the 1st mode shape of vibration   crack at the heal of wirebond

STRESS ASSESSMENT AND OPTIMIZATION

- 3rd order B-spline curve was used to modeling the shape of wirebond structure, harmonic response stress was calculated at 6 experiment design points. Lower loop height and loop ratio of wirebond shape has lower stress at the heel under harmonic vibration, the maximal stress is 84.4Mpa when it has a higher loop height and loop ratio, and the minimal stress is 65.9Mpa .
- The eight points clamping method has a 22% decreasement of maximal stress.
- 75% maximal stress decreasement when changed from vertical direction to parallel direction of the excitation when welding.

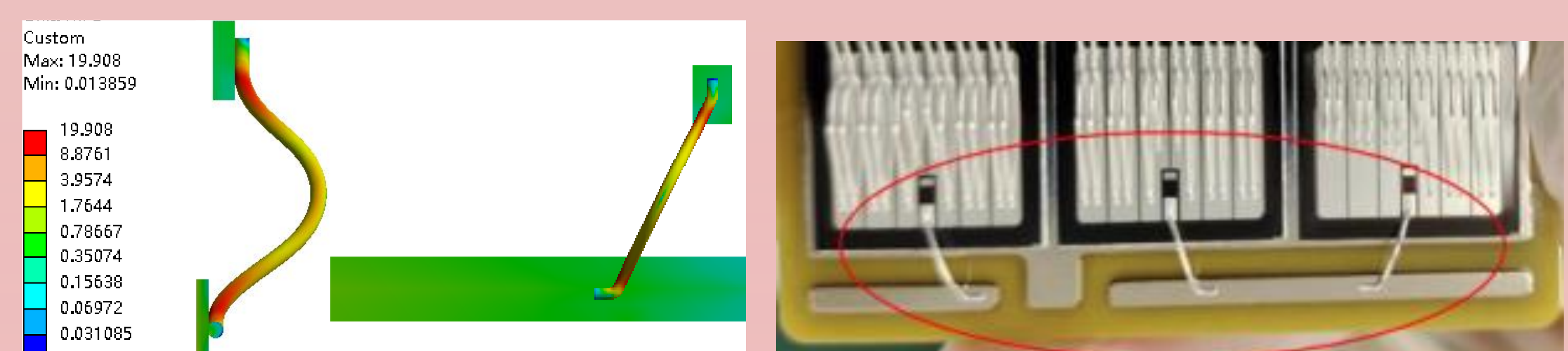




optimization for wirebond shape and excitation direction

RESULT AND DISCUSSION

- Eight-point clamping method has lower vibration response stress than four-point clamping mathod, and reducing the looping height and looping ratio of the wirebond shape would reduce the stress, also the direction of the vibration parallel to the wirebond has lower stress than vertical direction.
- The stress decreased 79% in simulation after all optimization was taken and proved effective to the problem by verification.



the decreasement of stress and optimal shape of wirebond