Causes of porosity formation in laser pulse welding

Science, Physics

Porosity is the major defect in laser micro welding during the solidification process in deep penetration lap weld. According to research, porosity formation in welding is majorly associated with weld pool dynamics, keyhole collapsing, melt fusion process, welding federate, and depth-to-width penetration aspect ratio of weld keyhole. The formation of porosity in laser pulse welding is caused by two major factor:

1) solidification rate of molten metal and

2) backfilling speed of the molten melt during the keyhole collapse process.

The porosity will be performed in final weld process cause of difference in solidification rate and backfill speed, both depends on laser material physical/chemical property, various laser parameter. Except for laser parameter, number, and types of porous and it's area defined by different depth-to-weld penetration ration in welding. Larger the ratio, easier the porosity will be formed, and larger the size of the voids. Based on these results, controlling the laser pulse profile is proposed to prevent/eliminate porosity formation in laser welding. During pulse laser radiation, light energy interacted with material surface and pulse peak power, sufficient energy generate melt on the surface whereby create keyhole due to internal reflection in material depth which shows in Figure 2. 4. The aspect ratio is the ratio of keyhole depth to its width. In laser welding, especially in keyhole mode laser welding, the aspect ratio can be very large, which is one of the main advantages of laser welding. However, porosity is frequently found in a deep keyhole laser weld. The following experiments are addressed toward investigating the effect of keyhole aspect ratio on porosity formation. In the evolution, the laser power and keyhole width are fixed and the keyhole depth is determined by the laser welding speed. By changing the welding speed of the laser beam, different During laser beam irradiation on the material surface, the heat capacity of generated plasma in ns pulse fiber laser is very small.

The temperature of plasma drops very quickly after the laser pulse irradiation. The high-temperature gradient due to high laser power make a large aspect ratio of the keyhole and the heat loss conducted from the hot keyhole wall to the surrounding metal is very strong. Hence, as shown in Figure 5. 8, the temperature of the keyhole wall drops very quickly, especially for the lower part of the keyhole having only a thin layer of the liquid metal. Due to this quick temperature drop, the thin layer of liquid metal on the bottom of the keyhole solidifies very quickly after the shut-off of the laser power. After the laser beam irradiation, the temperature on the bottom surface of the keyhole drops faster than that on the upper surface, so the temperature gradient along the keyhole wall decreases. As well as the changing of laser welding feed-rate make a major effect on the depth-to-width aspect ratio. As shown Figure 5. 7, due to continuous increasing feed-rate effect on temperature gradient and simultaneously decreasing the heat conduction loss along with keyhole wall. This causes the temperature-dependent Marangoni shear stress to decrease accordingly. Meanwhile, with the removal of the recoil pressure due to the shut-off of the laser, the recoil pressure-driving hydrodynamic pressure of the squeezed liquid metal also decreases very quickly. Consequently, surface tension and hydrostatic pressure become dominant and drive the liquid metal to have a tendency to fill back the keyhole.

As shown in Figure 5. 8, the liquid metal located on the upper part of the keyhole starts to flow inward and downward under the hydrostatic pressure and surface tension. Since the liquid metal layer is thicker on the top and the flow friction along the liquid-solid interface is larger for a thinner liquid layer, the backfilling velocity for the liquid metal on the upper part is accelerated more quickly than those on the lower part of the keyhole. As shown in Fig, the keyhole is closed on the top first. After the keyhole is closed on the top, the liquid metal continues to flow downward along the keyhole wall. When the liquid metal flows downward along the solidified keyhole wall, its velocity is decreased by the friction force of the cool keyhole wall. Meanwhile, the solid-liquid interface moves inward to the centerline of the keyhole because of the strong heat conduction loss to the surrounding metal along the keyhole wall. The liquid region shrinks as the liquid refills the keyhole, especially for the liquid metal at the bottom because of higher conduction heat loss and lower heat capacity there. Finally, the bottom of the downward flowing liquid metal completely solidified before it can reach the bottom of the keyhole. There is still a certain amount of liquid metal on the top, this part of liquid metal cannot continue to flow downward, which leaves a pore or void at the root of the keyhole. As per above discussion, a formation of the porosity is hard to damp with a highspeed joint process using with ns pulse laser. As a consequence, the power and PRR modulation used to compress the porosity with appropriate welding speed. In the following step, the same process completed with 160 W laser power and 200 to 400 kHz pulse repetition rate but whereby scanning speed was 200 mm/s to 400 mm/s. End of the test, the same porosity void happened which shown in Appendix 2.

Finally, optimize the welding speed window with high range of the power modulation (from 80 W to 140 W) at 200 kHz pulse repetition rate and different welding speed in a range of 150 to 300 mm/s. As a result, the weld molten bath has reached the weld root, and compensate the back-filling time and melt-solidification process up to (200) mm/s at a selected power level (120 W) and 20 kHz PRR which is shown in Table 5. 2.

One more thing, when a comparison of the increasing rate of keyhole depth to a certain level of scanning velocity with respect to variation of radiation power range is different.