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Effect of three-spot laser brazing process on welding quality of galvanized steel

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Abstract
The three focus spot laser brazing process was used to solve the problem of pores caused by zinc vapor evaporation during laser brazing of galvanized sheet. The surface morphology, weld shape and microstructure of galvanized steel laser brazing weld with or without three-spot were studied. The experimental results showed that when three-spot laser brazing process was applied, the surface morphology of the weld was good, the microstructure of the weld area was uniform, and the coarse grain near the heat affected zone was not obvious.

Keywords: galvanized steel; laser brazing; Three-spot welding process; welding quality

1. Introduction

With the rapid development of automobile industry, higher anti-corrosion requirements were put forward in the process of body-in-white manufacturing. Because of its good corrosion resistance, galvanized steel had been widely used in automobile body in white manufacturing process. Laser brazing of galvanized steel was usually applied to the connection between the roof and side of body-in-white. Many scholars had studied laser brazing of galvanized steel. Koltsov[1]conducted laser brazing experiments on hot dip galvanized steel, galvanized steel and bare steel, and found that zinc coating optimized the wetting process of brazing reaction, while surface oxide hindered the wetting process of base metal surface. Gatzen[2][3]carried out brazing experiments on 8 μm thick galvanized steel and hot dip galvanized steel, and found that hot dip galvanized steel was more sensitive to the wettability of laser brazing and had higher spreading rate. Wilfried Reimann[4]developed three-spot laser brazing process for galvanized steel, and explored the evaporation of zinc coating and the wetting of molten metal. However, the effect of three-spot laser brazing process on the welding quality of welded joints had not been mentioned.

Aiming at the problem of zinc vapor evaporation of galvanized steel, the method of adding OR module to laser brazing head was applied in this paper, and three-spot laser brazing of galvanized sheet was realized. The surface morphology, weld shape and microstructure of laser brazing of galvanized steel with or without three-spot were studied.

2. Experimental procedure

2.1. Materials

In the experiments, 0.7 mm thick galvanized steel GMW2M-ST-SCR2HD60G60GE and 1.6 mm diameter $CuSi_3$ filler wire were used. The chemical compositions (wt.%) of the base material (BM) and filler wire $CuSi_3$ were listed in Tab.1.

Table.1 The chemical compositions of the base material and filler wire CuSi3（wt.%）

	C	Mn	Si	Al	Cu	Zn	S	Ti	P	Fe
Base meatl	0.002	0.15	0.02	0.04	-	-	0.007	0.05	0.01	Bal
CuSi3	-	1.2	3.5	0.009	Bal.	0.18	-	-	0.01	0.2

In order to simulate the processing environment of galvanized steel in automobile manufacturing industry, the galvanized steel had been cut to $200\times70\times0.7$ mm . The bending angles of the welded specimens were 120° and 60°, and the flanging fillet was 1.5 mm . The test was carried out in the form of lap joints.

2.2. Laser welding with filler wire

The laser-welding system included a high-power fiber laser system(Laserline 6000-30) and a Fanac robot. The Fronius CMT wire feeder was used. In this paper, Scansonic ALO3 laser head was used for laser brazing of galvanized steel. The equipment layout of the specific laser brazing experimental platform was shown in Fig.1. The fiber diameter of welding system was 600 μm . In laser welding with filler wire, the defocusing distance was 10 mm above the top surface. The feeding angle was 45°. In this paper, the laser brazing adopted the contact seam tracking system, and the welding wire squeezed the seam through physical extrusion to realize the mechanical seam tracking. The filler wire lied below the main beam, and the filler wire was positioned in front of the laser beam. The wire tip pointed at the front edge of weld pool.

Figure 1. Layout diagram of laser brazing experimental platform

2.3. Laser welding with filler wire

Three-spot laser brazing technology was realized by OR module, which was produced by LASERLINE company. Fig.2 showed the three-spot laser brazing technology. In the three-spot laser brazing process, three laser beams work together. The galvanized layer on the steel surface was removed from coating removal laser, and the working laser was used to form laser brazing seam.

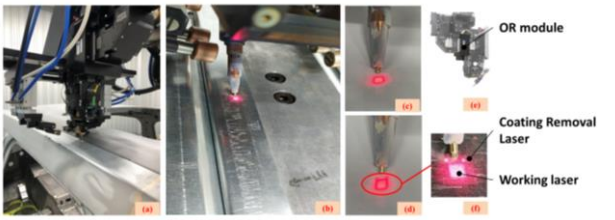

Figure 2. Schematic diagrams: (a) Galvanized steel was applied to body-in-white welding, (b) Working state of three-spot laser brazing, (c) Traditional single-beam laser, (d) Three-spot laser, (e) OR module, (f) Three-spot laser enlarged drawing.

3. Results and discussion

In order to verify the effect of three spot laser brazing technology on the welding of galvanized steel, the laser brazing experiment was designed. The experimental process parameter table was shown in Tab.2.

Table 2 Welding parameters in this experiment

No.	Laser power P(kW)	Welding speed Vr(m/min)	Feeding speed Vf(mm/s)	Three spots
1	4.5	70	70	YES
2	4.5	70	70	NO
3	3.2	43	44	YES
4	3.2	43	44	NO

The surface morphology of laser brazing under various process parameters were shown in Fig.3.

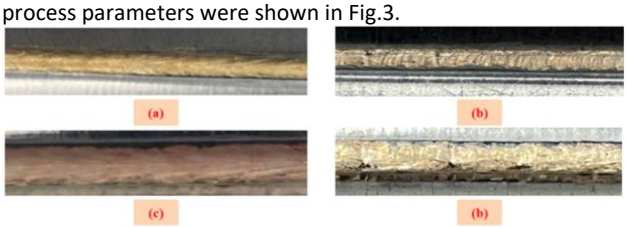

Figure 3. The surface morphology of laser brazing seam

When the three-spot laser brazing technology was applied, the seam surface was continuous and uniform, and the macroscopic morphology was good. When the three-spot laser brazing technology was not used, the weld surface was uneven, accompanied by pores, and the macroscopic morphology was poor.

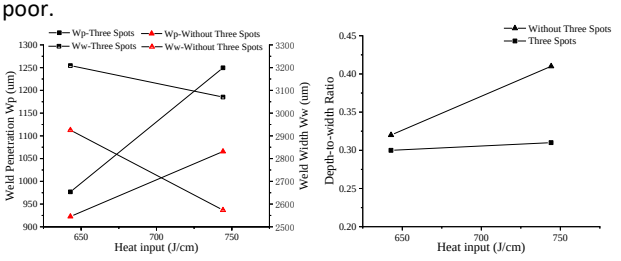

Figure 4. Weld Penetration, width and Depth-to-width ratio of Laser Brazing seam

The seam shapes of the above four groups of welded joints were observed, and the weld penetration, weld width and depth-to-width ratio were shown in Fig.4. When the heat input of the welding process was same, the weld penetration and width of the welded joint using the three-spot technology were large, and the depth-to-width ratio was small. It may be due to the existence of the three-spot module, the working laser area was reduced, and the laser energy density of the welded joint was increased.

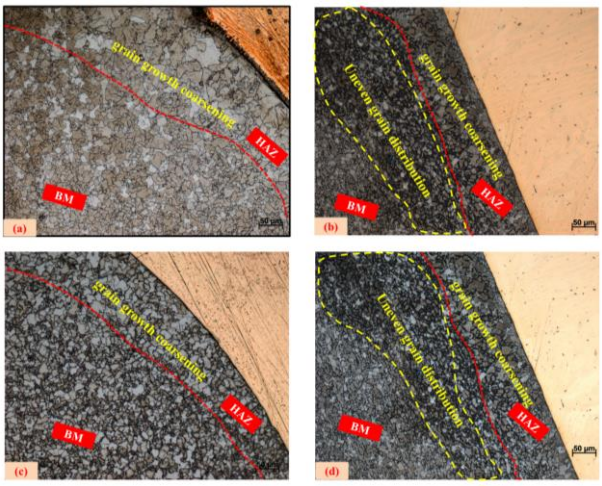

Figure.5 microstructure of laser brazing seam：(a) #1 (b)#2 (c)#3 (d)#4

It was shown in Fig.5 that when the three-spot technology was applied, the microstructure of the base metal(BM) area was uniform, and the heating grain growth of the microstructure near the heat affected zone(HAZ) was not obvious.It may be that the zinc coating was removed by coating removal laser, the expansion of the heat affected zone was suppressed, and the formation of coarse ferrite was inhibited.

4. Conclusions

When the three-spot laser brazing technology was applied, the seam surface was continuous and uniform, and no pores. When the heat input was 642.86 J/cm, the weld penetration of three-spot weld was 976.91 μm, the weld width was 3208.98 μm, and the depth-to-width radio was 0.3; the weld penetration of without three-spot weld was 922.62 μm, the weld width was 2925.14 μm, and the depth-to-width radio was 0.31;When the heat input was 744.19 J/cm, the weld penetration of three-spot weld was 1249.59 μm, the weld width was 3070.58 μm, and the depth-to-width radio was 0.32; the weld penetration of without three-spot weld was 1065.69 μm, the weld width was 2573.62 μm, and the depth-to-width radio was 0.41; It may be due to the increase of laser energy density, the penetration and width of the welded joint using three spot laser brazing process was increased. Due to the coating removal laser, the expansion of the heat affected zone was inhibited and the formation of coarse ferrite was inhibited during the laser brazing process.

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