Weldability of Galvannealed Steel Sheets in Laser Welding

1. Introduction

On the basis of the heat conduction analysis during laser welding and observation of weld cross-sections, the behavior of zinc was discussed during laser lap-welding of galvannealed steel sheets. In addition, the difference of the weight loss and the maximum load in a tensile shear test was studied in various welding conditions. Here, the weight loss is the change in weight of the test piece before and after the welding (this change corresponds to the amount of spattering). Sound weld beads could be formed with gaps up to 40 μm in ordinary laser welding and with gaps up to 100 μm in laser welding with increased heat input.

2. Behavior of Zinc during Laser Welding

In galvannealing, several iron/zinc alloy phases are formed. Therefore, the coated layer is not uniform in structure. Because of this, it is impossible to precisely define its melting point. Here, on the basis of the melting point and boiling point of pure zinc, consideration is given to how the coating behaves under temperature distributions during welding.

The temperature distribution in laser welding can easily be estimated from the quasi-steady solution of the two-dimensional heat flow equation. **Fig. 1** shows the estimated temperature distribution around the weld. The maximum temperature at the weld bead edge (bond) is the melting point of iron. The part in which zinc reaches its boiling point spreads around the weld bead. The zinc in the region from the weld bead edge to this part reaches its boiling point during welding and begins to vaporize rapidly. Assuming that liquid zinc is vaporized at its boiling point by phase transformation, its volume becomes about 2,400 times larger. If the space occupied by the zinc remains unchanged, the pressure of the zinc vapor becomes 2,400 atmospheres. This highly pressurized zinc vapor tries to escape from the weld zone through the molten pool. In so doing, the zinc vapor blows aside the molten pool and spatters molten metal, causing holes in the weld bead.

Fig. 2 shows the cross-section of a weld bead obtained by applying laser lap-welding to a 0.8 mm galvannealed steel sheet with a coating weight of 45 g/m^2. Fig. 2 (a) and (b) show the macrostructure and microstructure of the weld when the sheets were welded with no gap between them under the following conditions: laser power 1.5 kW and welding speed 2.5 m/min. Fig. 2 (c) shows the microstructure of the weld when the sheets were welded with a gap of 0.1 mm between them. The maximum temperatures estimated from the quasi-steady solution of the two-dimensional heat flow equation are also shown in Fig. 2.

As shown in Fig. 2 (a), when the sheets are welded with no gap

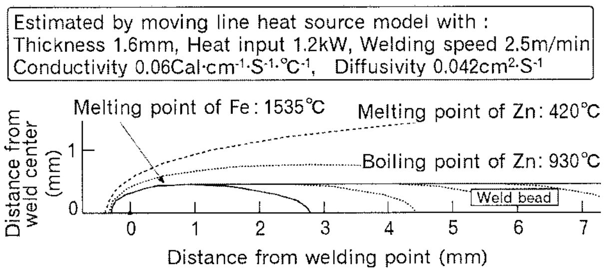

Fig. 1 Estimated temperature distribution in laser welding

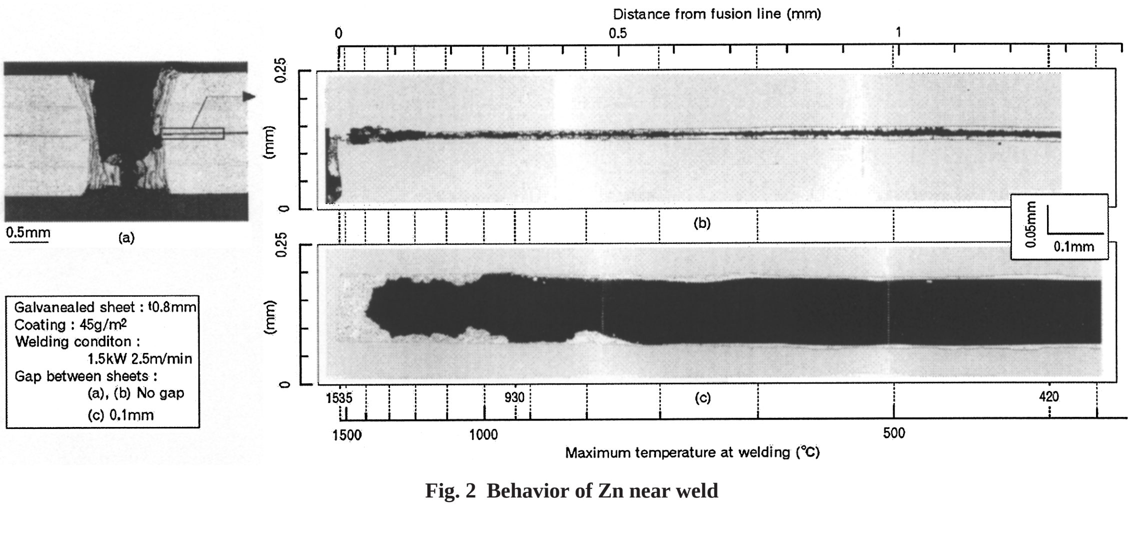

Fig. 2 Behavior of Zn near weld

between them, most of the molten steel can blow out. It should be noted, however, that, as shown in Fig. 2 (b), a considerable amount of zinc remains in the region despite estimations that it would have reached its boiling point. Thus, clearly not all the zinc escapes from the weld in the form of vapor. The reason for this is considered to be that in the process of rapid heating and cooling during laser welding, there is insufficient time for all the zinc to melt and vaporize.

When a gap is given between the sheets, the space around the joint widens. Therefore, it is assumed that the pressure generated by the zinc vapor will not become so high that the zinc vapor can escape from the molten pool and hence, a sound bead can be formed. In this case, as shown in Fig. 2 (c), the vaporized zinc returns to its solid state near the weld bead, rather than escaping from near the weld bead.

3. Gap between Sheets and Joint Strength

Lap joints were prepared by applying laser welding to a 0.8 mm thick galvannealed steel sheet with a coating weight of 45 g/m^2 (TS: 270 MPa) and subjected to a tensile shear test. The test piece width was 60 mm and the lap length was 30 mm. A laser weld 50 mm in length was provided in the lap center. The laser beam spot diameter was 0.6 mm, the laser output at the working point was 2.5 kW and the welding speed was 2.5 m/min. Weld beads were formed with various gaps between the sheets. Test piece weight was measured before and after the welding, and the difference was taken as the loss of weight due to spattering during the welding. **Fig. 3** shows the maximum load that each individual test piece (joint) could withstand in the tensile shear test, together with the loss of weight of each test piece. It can be seen from the figure that when the gap between sheets is increased beyond 20 μ m, the amount of spatter (the loss of weight) sharply decreases and the joint strength increases.

4. Gap between Sheets Required to Obtain Good Welds

The gap between the sheets required for laser welding depends on the welding conditions. **Fig. 4** shows the relationship between the gap between the sheets and weight loss, obtained by changing the weld bead width by various the laser beam diameter during the welding. Fig. 4 also shows the typical appearance of such welds. The weight loss is the average value obtained from three welds. The welding speed was kept constant at 2.5 m/min. The decline in welding performance due to the increase in beam diameter was compensated for by increasing the laser power. Therefore, increasing the beam diameter means increasing the welding heat input. It can be seen from Fig. 4 that increasing the heat input decreases the amount of spatter when the sheets are welded with no gap between them but that the gap that allows for perfect welding widens. Therefore, when applying laser welding, it is necessary to ensure an appropriate gap between the sheets after taking into account the amount of heat input.

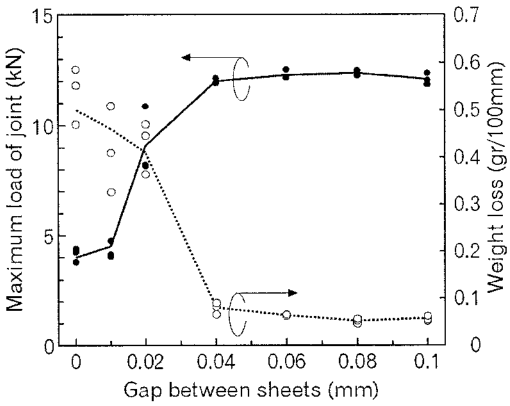

FIg. 3 Effect of gap between sheets on quality of weld

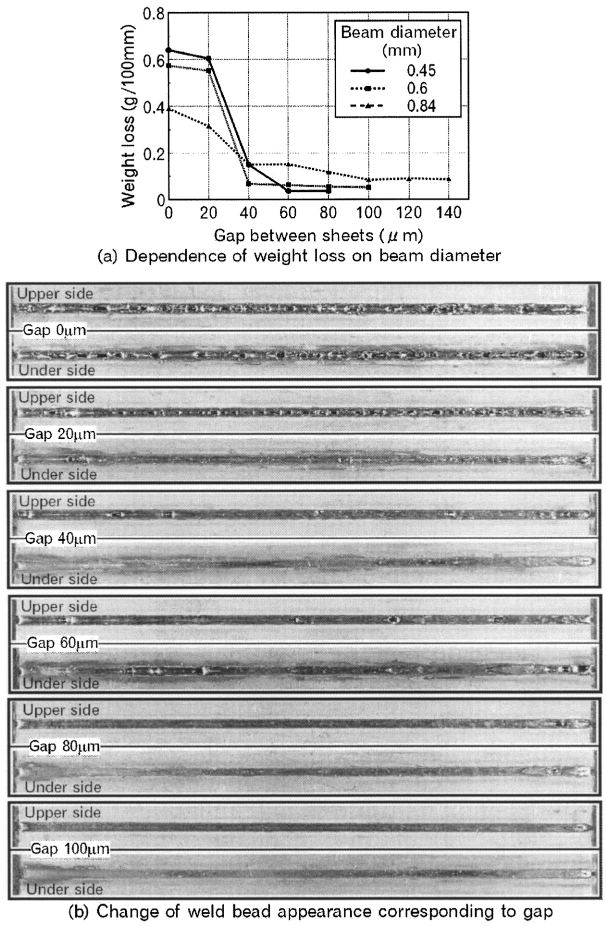

Fig. 4 Effect of beam diameter and gap between sheets on welding phenomenon

(For further information, contact Steel Research Laboratories)