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Effect of the feed speed on the surface quality of 6061 Al-alloy using friction stir welding

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Abstract: The feed speed is the ratio of the welding speed and the rotation speed, that is, the distance of the workpiece in each rotation of the stirring head, which is one of the important parameters in the friction stir welding process. Based on the different welding speed and rotating speed are combined, the multiple sets of friction stir welding tests were done, the results show that the larger feed speed, cracks or grooves appear on the surface; when the feed speed is reduced, the weld surface is glabrous; continue to reduce the feed speed, the overburning of weld surface is occurred. To further clarify the causes of this phenomenon, the heat flow coupled model was built up based on computational fluid dynamics, the results show that reducing feed speed appropriately will increase the welding heat input, reduce the material involved in the formation of weld, achieve good liquidity, and decrease forward resistance of stirring needle, so the surface quality of the weld becomes better.

1. Introduction

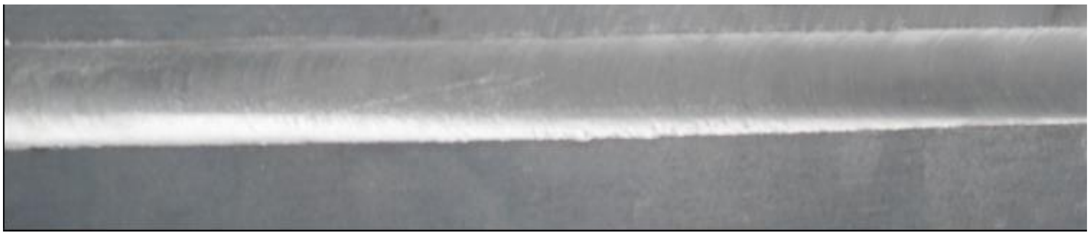
Friction stir welding (FSW) is a new technology of solid phase connection. Compared with the traditional welding method, it has many advantages, which can be used to weld many metals which were previously considered difficult to weld [1-6]. However, if the process parameter is not reasonable and the weld quality is poor, it will have a certain effect on its use. The rotation speed and welding speed are two important process parameters of FSW process, increasing the rotation speed can increase the heat input, and improving the welding speed can improve the efficiency. Feed speed is ratio of welding speed and rotational speed, to choose the rotation speed and welding speed, it is necessary to analyze the feed speed, in this paper FSW welding experiments were firstly done in different feed speed, secondly effects of feed speed on weld surface quality were analyzed, and then a thermal flow coupled model was set up to analyze its reasons.

2. FSW experiments

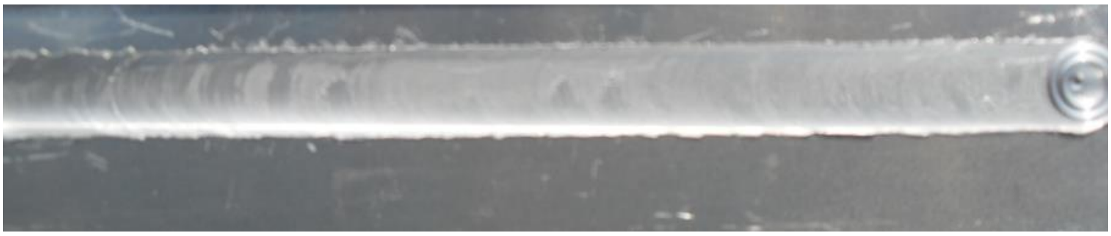
In the present experiments, 6061 aluminum alloy plates were used with 150 mm×50 mm×6.3 mm. The welding experiments were conducted at different conditions: the welding speed was set as 50 mm/min, 65 mm/min and 80 mm/min, during which the rotating speed of the stirring head was fixed as 450r/min, 650r/min and 850r/min respectively. Fig. 1 shows the welds.

As shown in Fig. 1, the surface quality of the weld has changed greatly with the in crease of feed speed. The feed speed of Fig. 1 (a) is 0.08 mm/r, large flashing was achieved, and blurring caused by over burning can be found on the weld surface. The feed speed of Fig.1 (b) is 0.1mm /r, the weld surface is smooth and beautiful. The feed speed of Fig.1 (c) and Fig.1 (d) are 0.12mm/r and 0.14mm/r respectively, the weld surface is poorly formed, with uneven surface and many grooves. Fig.1 (e) and fig.1 (a) are in the same speed as 0.08 mm/r, but the surface of weld are more serious, because the former has high rotation speed and more heat input.

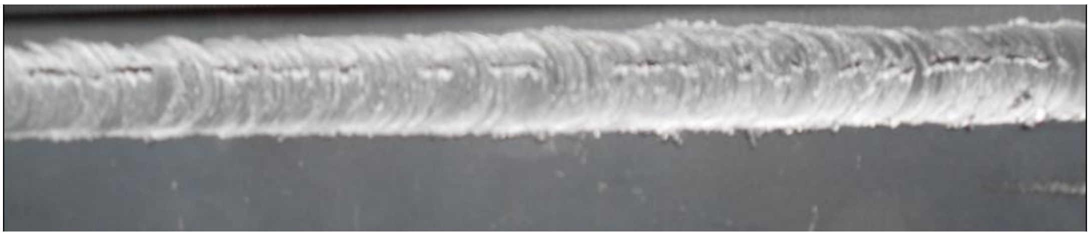
（a） v =50 mm/min ω =650 r/min v/ω =0.08 mm/r



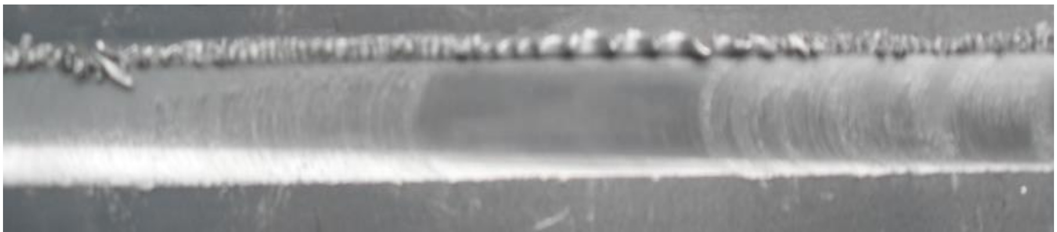
（b） v =65 mm/min ω =650 r/min v/ω =0.1 mm/r



（c） v =80 mm/min ω =650 r/min v/ω =0.12 mm/r



（d） v =65 mm/min ω =450 r/min v/ω =0.14 mm/r

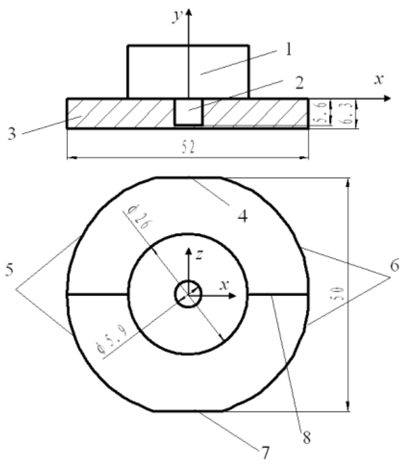


（e） v =65 mm/min ω =850 r/min v/ω =0.08mm/r

Fig. 1 Appearance of different feed speed

3. Heat-flux analysis model

To clarify the reasons for the change of the weld surface quality with the increase of feed speed, the heat-flux coupled analysis model was established based on computational fluid dynamics [7, 8]. In the model, the stirring needle rotated with counterclockwise, and the workpiece moved from left to right along the positive direction of x-axis. In order to reduce the calculating time, only part of the workpiece was calculated. As shown in Fig. 2, the region was taken into calculation with 52× 6.3 × 50. The x-axis length was set as the two shaft shoulder diameters.



1 shaft shoulder 2 stir needle 3 workpiece 4 forwarding side 5 inlet
6 outlet 7 retreating side
Fig.2 Computational zone

4. Results and discussion

4.1. Peak temperature of different feed speed

Fig. 3 shows the peak temperatures when the feed speed was set as different values. It can be seen from the diagram, when the feed speed is small, the peak temperature is higher, when the feed speed is increased to 0.1 mm/r, the peak temperature is 750 k, continue to increase the feed rate, peak temperature falling fast. This is due to the fact that, with the increasing of feed rate, rotational speed is relatively declined, material thermal generation rate is reduced, and peak temperature is dropped. Therefore, to ensure the welding quality, the feed speed should be controlled at about 0.1mm/r. If feed speed is larger, the heat input is less, the material liquidity is poor, but more material is needed to flow from the front of stirring needle to the back of it to form the weld, some material can't normal migration, thus forming a crack or grooves. As the feed speed is less, the heat input increases, the material fluidity becomes better, and the material that needs to be migrated decreases, thus obtaining the higher quality joint. If the feed rate is too small, the heat input will be a lot, but the migration material will be further reduced, and the heat will be concentrated on a few materials, which will lead to overburning.

4.2. Longitudinal force of different feed speed

Fig. 4 shows the effect of feed speed on the longitudinal force. It can be seen from the figure, the longitudinal force increases with the increase of feed speed. This is because with the increase of feed speed, welding thermal input is decreased, material temperature and strain rate is dropped, flow stress is increased, the resistance that impeded the advance of the stir-welding head is increased, and material is difficult to migrate from the front of stirring needle to the rear.

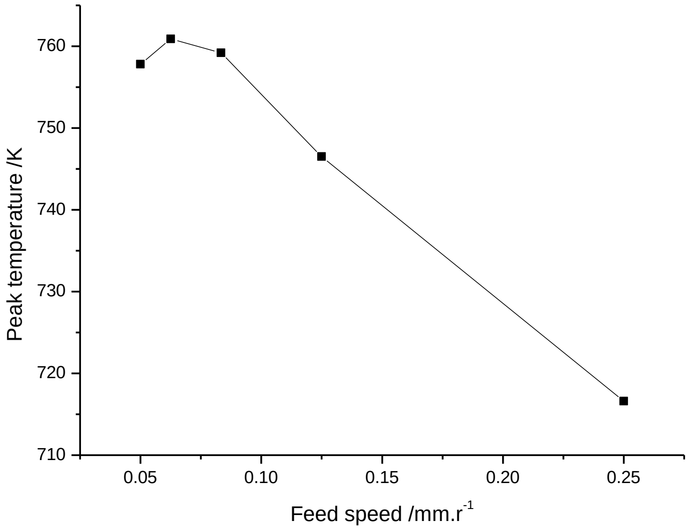


Fig. 3 Peak temperature of different feed speed

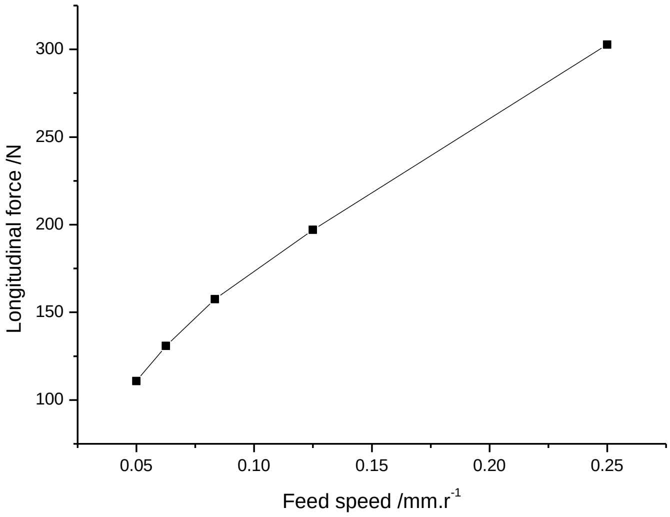


Fig. 4 Longitudinal force of different feed speed

5. Conclusions

Appropriate reduction of feed speed will improve the weld surface quality, but too small feed speed will make the quality worse. Increasing feed speed will reduce the thermal input, and the materials involved in the formation of the weld are increased, the fluidity becomes worse, and the forward resistance increases. The selection of feed speed should be considered in a comprehensive way to get better quality and improve production efficiency.

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