

Study on contact coefficient of 6061 Al-Alloy using friction stir welding

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Abstract: The movement of material around stirring needle has important influence on the friction stir welding process. In this paper, contact coefficient is introduced to describe the movement. When the contact coefficient is 0, the state between stirring needle and the surrounding material is pure slip, the material around stirring needle remains still as the stirring needle rotates. When the contact coefficient is 1, the state between stirring needle and the surrounding material is pure adhesion, and the surrounding material and the stirring needle rotate at the same speed. When the contact coefficient is between 0 and 1, slip and adhesion coexist. In order to determine the contact coefficient of friction stir welding process, this paper establishes a heat flow coupling analysis model of friction stir welding process based on computational fluid dynamics. The results show that when the contact coefficient is set as 0.65, the calculation results are consistent with the experiment.

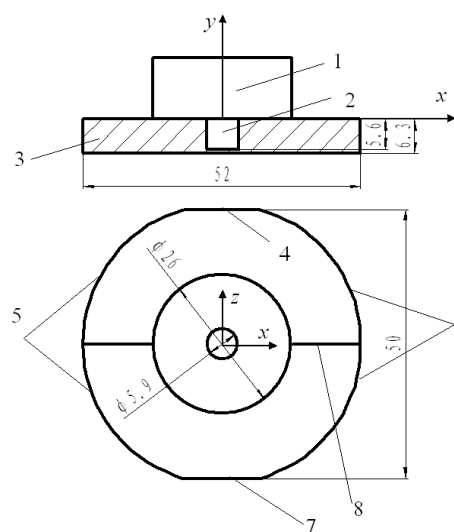
1. Introduction

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]. In order to better understand the FSW process, many analytical and numerical models were established by scholars, according to their application scope and physical assumptions, they can be divided into three categories: heat transport model, the thermal analysis model based on solid mechanics and thermal analysis model based on fluid mechanics. Heat transfer model solves the heat conduction equation to predict the workpiece temperature distribution by constructing different forms of heat source. Thermal analysis model based on solid mechanics can be used to predict the residual stress and residual deformation based on the temperature computed. The above two models had not considered the influence of the movement of material around the stirring needle in the process of solving the temperature field, but the state of material around the stirring needle is high temperature and plastic flow in the process of FSW. Thermal analysis model based on fluid mechanics regards the material around stirring needle as fluid, and obtains information of heat temperature field, velocity field and pressure field under the influence of convection and conduction in the process of FSW. But what is the motion state of the material around the stirring needle? It requires further research. In this paper, the contact coefficient is introduced to describe the motion of the material around the stirring needle, and the contact coefficient is determined by combining the heat flow coupling analysis model and the experiment.



2. Establishment of heat-flux analysis model

To study the movement of the material around the stirring needle, the heat-flow coupled analysis model was established based on computational fluid dynamics [7, 8]. In the model, the stirring needle is rotated counterclockwise with 650r/min, and the workpiece is moving at a constant speed of 65mm/min from left to right. Contact coefficient is defined as the ratio between the speed of the material direct contact with stirring needle and the rotation speed, when calculating the speed of material is added to the model as the initial condition, the contact coefficient is set as 0.1, 0.3, 0.65, 0.85 and 1 to calculate respectively. In order to reduce the calculation time, only part of the workpiece was calculated. As shown in Fig. 1, the region was taken into calculation with 52 mm× 6.3 mm× 50 mm. The x-axis length was twice of the diameter of shaft shoulder.



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

Fig.1 Schematic of computational zone

3. Results and discussion

3.1. Influence of contact coefficient on temperature distribution and peak temperature

The temperature field is shown in Fig. 2. It can be seen that the rear temperature of the stirring needle is higher than the front, and the front temperature gradient is greater than the rear. The contact coefficient of fig. 2 is 0.1, and the peak temperature is 756K, which is about 88% of the melting point of 6061 aluminum alloy.

When the contact coefficient is 0, there is a pure slip between the stirring needle and the workpiece. The surrounding material is not moving and the heat is generated only by friction. When the contact coefficient is 1, there is pure adhesion between the stirring needle and the workpiece. The material around the stirring needle is rotated at the same speed as it, and the heat is only produced by the plastic deformation. Fig. 3 shows the effect of different contact coefficients on peak temperature. It can be seen from the figure, the peak temperature increases slightly with increase of contact coefficient at lower level. This is because the contact coefficient is small, the movement of material around the head relatively slow, part of the heat generated due to plastic deformation, and due to the effect of "lubrication" of the plastic deformation of materials, plastic deformation heat and friction heat overlap with temperature increasing. With contact coefficient is bigger, the plastic deformation of the lubrication effect is more and more obvious, the heat generated by the friction greatly reduced, the welding heat input mainly comes from the material of plastic deformation, the superposition of both

decreased peak temperature. In general, the change of contact coefficient is not very important to the thermal field of the friction stir welding process.

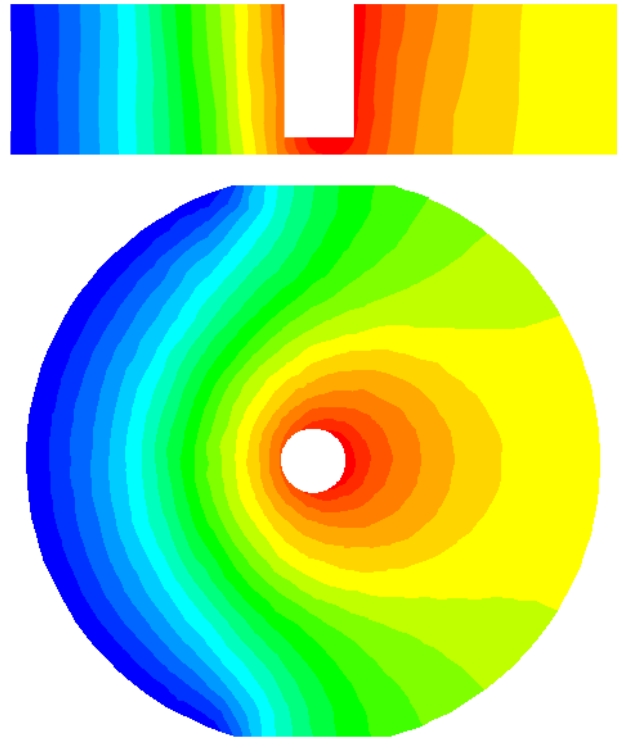


Fig. 2 Contour of temperature computed

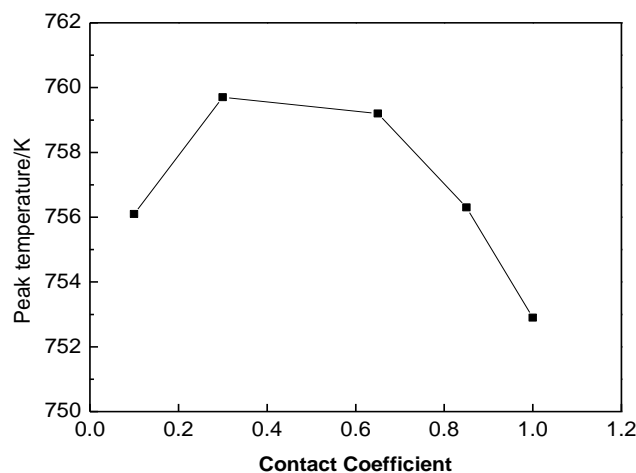


Fig. 3 Effect of contact coefficient on peak temperature

3.2. Effect of the contact coefficient on longitudinal force

Fig. 4 is the influence of different contact coefficients on longitudinal force, it can be seen from the diagram, with the contact coefficient changed from small to big, longitudinal force decreases, but after the coefficient arrives at 0.65, longitudinal force changed little, about 150 N, which according with the experimental data measured. With the increase of the contact coefficient, the moving speed of the material around the stirring needle becomes larger and the flow stress decreases, thus reducing the resistance. After the coefficient reached 0.65, although the movement speed increased, but the

temperature was decreased, the combined effect made the flow stress basically unchanged, so the resistance of the stirring head was not much changed.

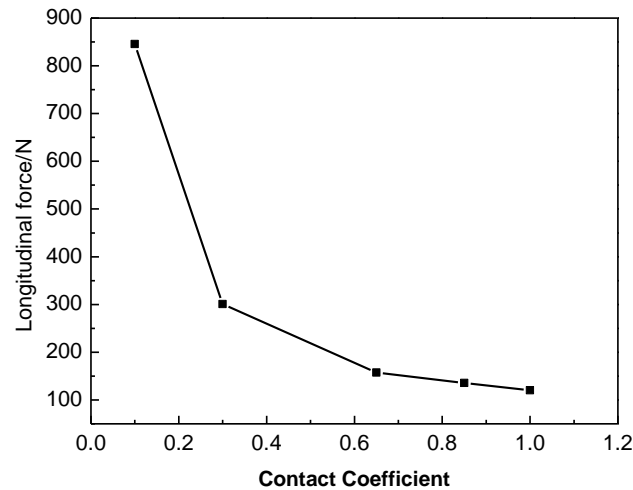


Fig. 4 Effect of different contact coefficients on longitudinal force

3.3. Effect of the contact coefficient on velocity distribution

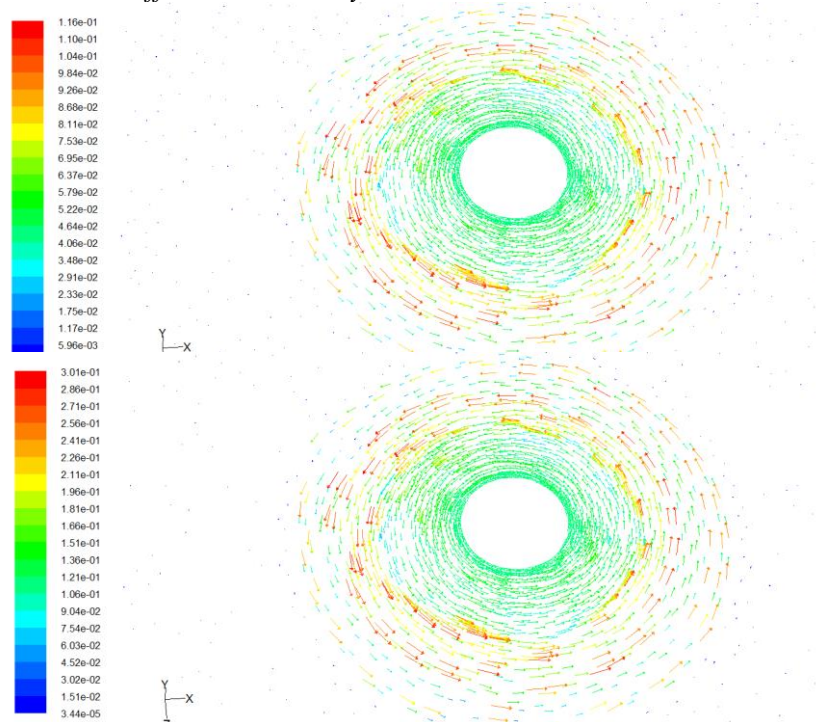


Fig. 5 Vector of velocity computed

Fig. 5 is a transverse section of the velocity calculated. The contact coefficient is 0.25 and 0.65 respectively. It can be seen from the diagram, the speed of the material around the needle has the trend of dropping after increasing, but there is a bigger difference in maximum speed, when contact coefficient is 0.25, the maximum speed of 0.116 m/s, while contact coefficient is 0.65, the biggest linear velocity is 0.301 m/s. This is because that the contact coefficient is greater, the adhesion of the material and the stirring needle is stronger, and the rotational energy obtained from the stirring needle is greater

4. Conclusions

The contact coefficient is introduced to describe the movement of the material around the mixing needle, and the influence of the contact coefficient on the welding process is analyzed by the heat flow analysis model based on computational fluid dynamics. The contact coefficient has little effect on peak temperature, but it has obvious influence on the longitudinal force and maximum linear velocity. The simulation results at the contact coefficient 0.65 are consistent with the measured values.

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