The Use of Friction Stir Welding for Manufacturing Small-scale Structures

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Friction stir welding (FSW) is a relatively new joining process and is being used commercially in several industry sectors. In small and medium enterprises, however, this novel technology has not been applied despite its remarkable advantages because of the drawbacks of FSW. A database has been assembled and drawbacks have been analyzed then solved appropriately in the Industry-Government-Academia Collaboration Project. As an outgrowth, the optimum and individual know-how of practical FSW technology could be transferred to medium and small enterprises.

INTRODUCTION

Friction stir welding (FSW) is a relatively new joining process. It was developed initially for aluminum alloys, by The Welding Institute (TWI) of the United Kingdom. In FSW, a cylindrical, shouldered tool with a profiled probe is rotated and slowly plunged into the joint line between two pieces of sheet or plate material, which are butted together. Frictional heat is generated between the wear-resistant welding tool and the material of the workpieces. This heat causes the latter to soften without reaching the melting point and allows traversing of the tool along the weld line. It leaves a solid phase bond between the two pieces. The advantages result from the fact that the FSW process takes place in the solid phase below the melting point of the materials to be joined. In addition, the process offers low distortion and is energy efficient, environmentally friendly, and versatile.

Friction stir welding is currently being used commercially in several sectors, such as the railway, automotive, and aerospace industries. However, most applications of FSW are limited to major enterprises, and practical use has not been advanced in small and medium enterprises. This is because additional value is high even if an only linear weld is possible when large-scale structures are manufactured by major enterprises. However, the cost cannot be justified when small and medium enterprises make small products using FSW. In addition, it is very difficult for small and medium enterprises to conduct needed three-dimensional (3-D) welding by FSW.

The City Area Project—an industry-government-academia collaboration project at Osaka-East-Urbang Area in Osaka Prefecture, by the Ministry of Education, Culture, Sports, Science and Technology Japan (MEXT) was established in 2004. This project mainly conducted research and development on FSW to promote product upgrades and strengthen the price-competitive edge of the major industries such as metalworking machinery in Osaka Prefecture. The schematic of the procedure used to carry out this project is shown in Figure 1.

A new FSW machine was developed during this project with two types of heads: a high-output linear head with two-axes movement (X and Y axes) and a 3-D drive head with five-axes movement (X, Y, Z, a, and c axes). Therefore, this machine is capable of welding a material in a wide range of shapes.

Several approaches were carried out to develop a practical FSW process for medium and small enterprises. The drawbacks that occurred during the FSW experiments were analyzed and solved appropriately. As a result, the optimum and individual know-how on practical FSW could be transferred to
medium and small enterprises. Images of the supply device of metallic parts and the water-cooling plate used in FSW are shown in Figure 2. It was possible to produce in less time and at low cost. In addition, the newly developed tool is shown in Figure 3. This tool is highly suitable for use in a 3-D FSW process. In this paper, a database constructed in this project is introduced, and several approaches for developing practical FSW processes for medium and small enterprises are introduced.

See the sidebar for details on the FSW database.

**DEVELOPMENT APPROACH**

**Supply Device of Metallic Parts**

The supply device of metallic parts and a schematic of the chassis of the device are shown in Figure 4. In the conventional method, the top and bottom of the column or the column and the base were connected by bolts. It is possible to reduce the number of modules, duration of the process, and cost if the supply device made of metallic parts can be manufactured using FSW. In addition, it is expected to be able to manufacture products with a good design.

The material used was a 6063-T5 aluminum alloy sheet with a thickness of 10 mm. Single-pass friction stir butt welds were produced using an FSW tool with a shoulder diameter of 20 mm and a probe length of 9.8 mm. The cross section of the weld joint under the optimum FSW condition is shown in Figure 5. The weld did not exhibit cracks and porosity, indicating that the weld was of good quality. Moreover, the joint efficiency under the optimum FSW condition was approximately 70%. This value was considered to be very high because the 6063-T5 aluminum alloy was a heat-treated aluminum alloy.

During FSW, it is necessary to hold the material firmly in place. In particular, it is important to firmly hold the material along the direction vertical to the welding direction from the