

Assembly Study of Refill FSSW

Hideki Okada, Kenichi Kamimuki, and Mitsuo Fujimoto
Kawasaki Heavy Industries Ltd.

ABSTRACT

New Refill Friction Stir Spot Welding (Refill FSSW) was performed for the aluminum alloys used for aircrafts. Joints were examined to evaluate its performances, such as tensile shear strength and strength of heat affected zone, with using various surface conditions.

As a result of examination, significant lap shear strength by using shoulder plunging method was achieved with shorter process time. Even with the alodine coated aluminum alloys, strong and good quality joints can be made. And finally, actual prototype components were experimentally produced with Refill FSSW robot. Fine preproduction parts with no distortion and sufficient quality were obtained. Refill FSSW will be able to be regarded as suitable for fabrication of aircraft components.

CITATION: Okada, H., Kamimuki, K., and Fujimoto, M., "Assembly Study of Refill FSSW," *SAE Int. J. Aerosp.* 6(1):2013, doi:10.4271/2013-01-2310.

INTRODUCTION

The novel, Refill FSSW technology has been increasingly regarded as a promising technology in manufacturing industries⁽¹⁾⁽²⁾⁽³⁾. Resistance Spot Welding (RSW) is one of the conventional construction methods used widely, however, in case of welding of aluminum alloys, obtaining the consistent joint is difficult with RSW because nuggets generated in RSW are unstable due to the low electrical resistance of aluminum.

In aerospace industries, a large number of rivets are used to join different aircraft components because the riveted structure is the established design technique and has the high reliability. But with the rivet structure, rivet heads and flange overlaps increase weight, and the rivet hole might cause the stress concentration. And also the automatic riveting equipment is very expensive because it requires high accuracy and many functions such as work positioning, drilling, feeding sealant, feeding rivet, riveting, and squeezing.

The remarkable feature of FSSW is simplified solid state joining process which can provide the consistent joint strength without additional weight such as the rivet. And it can also make joint with no exit-hole that usually resulted in conventional FSSW. Moreover, positioning accuracy is not as critical as in the drilling operation. Thus Refill FSSW is expected to replace the riveted structure, to achieve the

weight reduction, the cost saving and the manufacturing time reduction, and to be the future of aviation fastening.

In the beginning of Refill FSSW development, the probe-plunging FSSW were mostly reported, because it is alike the conventional FSSW and similar to the retractable FSSW which can adjust the length of probe. However, recently studies on the shoulder-plunging FSSW have been increasing.

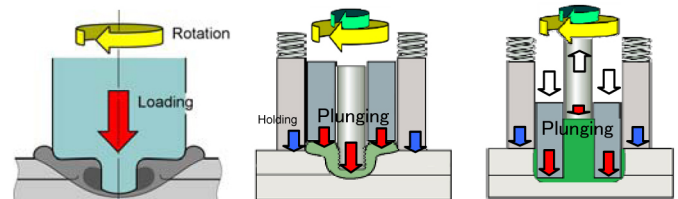


Figure 1. Schematics of types of FSSW. From the left to the right; conventional FSSW, probe plunging FSSW, and shoulder plunging FSSW

Figure 1 shows the illustration of the conventional FSSW, the probe plunging Refill FSSW and the shoulder plunging Refill FSSW. The conventional FSSW has quite simple process described as follows, rotating probe plunges into the material, heating and stirring the material near the boundary face, then extracting the probe. The probe plunging process is similar to the conventional FSSW except accompanying the relative movement of the shoulder and probe to create the flat surface at the end of joining process. The probe plunging

process can make the larger nugget than the previous ways and provide the higher joint strength, though the higher plunging force and the rigid equipment will be desired. In this study, to make reliable joints, the shoulder plunging process was employed.

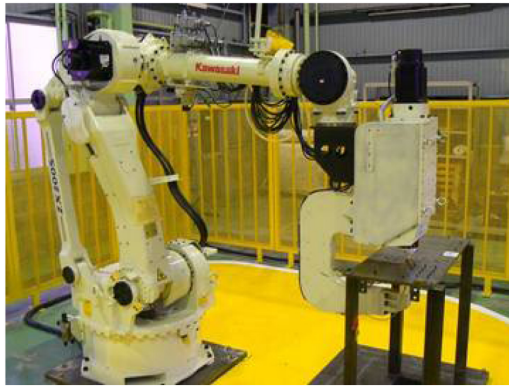


Figure 2. Appearance of Refill FSSW robot system

Figure 2 shows the newly developed Refill FSSW robot system by KHI. In order to provide the accurate motion of the tool, the position, the load, and the rotational speed of the joining tool are precisely and independently controlled with servomotors. The gun has high z force and can join 7xxx series aluminum alloy up to 3mm upper-sheet thickness.

Furthermore, once a joining program has been made from offline programming software or operating personnel, the FSSW system can automatically execute and repeat joining operation.

The joining tool is shown in Figure 3. There is the probe, in other word “pin”, in the center. The shoulder encloses the probe and the clamping system encloses the shoulder. The clamping system holds the work-piece tightly to prevent burring and creates a flat surface. In addition, the clamping system with springs enables the probe and the shoulder to recede from the clamp surface. And the high performance coating prevents alloys from adhering to tools.

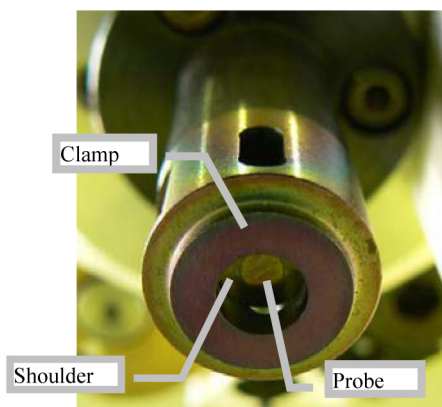


Figure 3. Appearance of joining tool

This contributes to obtain the successful joints of thin sheets, while the joining of thinner sheets is generally

difficult due to the occurrence of excessive plunging. The entire joining process with the Refill FSSW system is schematically illustrated in Figure 4.

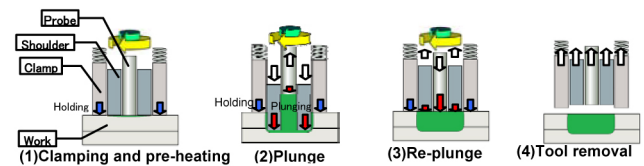


Figure 4. Schematics of shoulder plunging Refill FSSW process

Stage 1(Clamp and pre-heat)

The upper sheet and the lower sheet are held between the backing tool and the clamp. Then, the rotating probe and the shoulder are pressed onto the upper sheet to soften the material by frictional heating. During this process, the probe and shoulder are controlled by keeping tips at the surface of the sheet. The backing tool and the clamp, firmly press the sheets together eliminating the gap generation between the sheets.

Stage 2(Plunge)

The position and force of both the probe and the shoulder are controlled harmonically. The probe and the shoulder are plunged into the material to the preliminary set position, which depends on the plunging process.

The plunge depth of the tool is important factor to obtain the strong joints. Figure 5 shows the plunge depth for 1000 consecutive spots of Refill FSSW. In this case, the plunge depth was set to 0.6 mm. The accurate control of tool displacement was confirmed.

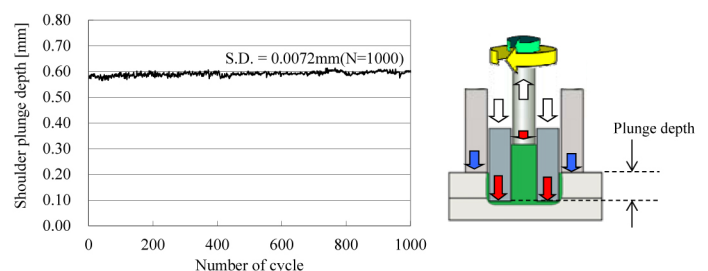


Figure 5. Repeatability precision of maximum shoulder plunge depth

Stage 3(Re-plunge)

The probe and the shoulder are retracted while rotating and returning to the original position and then offset in the opposite directions to the stage 2. This movement improves both the appearance and the mechanical strength of the joint. If this reverse motion is not necessary, the stage 3 can be skipped.