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Ultrasonic Seam Welding

By G. S. Darner

MASTER

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Final Report

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Division**

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By G. S. Darner

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Final Report
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**Kansas City
Division**

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SUMMARY

Ultrasonic welding uses high frequency vibratory energy to make welded terminations. With this process, solid-state bonds can be made between most metals and alloys without the formation of brittle intermetallic compounds. Ultrasonic seam welding produces continuous linear weld joints by using a rolling welding head.

In order to assess the applicability of ultrasonic seam welding to flat cable production at Bendix Kansas City, material samples were sent to Sonobond Corporation, West Chester, PA, for seam welding evaluation. Based on the resultant sample welds between various aluminum and copper-foil materials, an ultrasonic seam weld system was procured for evaluation and development activities.

A Sonobond Model WS-30-AW seam welding kit was purchased and incorporated into a seam welding system applicable to flat cable fabrication requirements. A variable speed drive mechanism with a digital tachometer was incorporated into the system to allow precision control of welding speed. A multisection weld surface, or anvil, was designed to incorporate features to allow more accurate weld force settings, as well as, features to position and aid in the welding of special material configurations.

Several aluminum and copper combinations of varying alloys, hardness, and thickness were evaluated for ultrasonic seam welding. Both aluminum-to-aluminum and aluminum-to-copper configurations were successfully welded. Process parameters such as clamping force, power, and welding speed were evaluated to learn their effects on the welding process.

DISCUSSION

SCOPE AND PURPOSE

This project was initiated to evaluate ultrasonic seam welding for joining aluminum and copper-foil conductors. Ultrasonic seam welding was chosen for investigation because of its ability to form solid-state bonds without creating brittle intermetallic compounds in the weld joint. During this project, the configuration requiring this seam weld was eliminated. The project was then continued on a reduced basis to provide background development for possible future applications requiring this process technology. Development activities included acquisition of an ultrasonic seam welding system, design of controls and tooling for this system, investigation of weldable material combinations, and studies of weld parameter variations on welding quality.

PRIOR WORK

Prior work on ultrasonic welding at Bendix Kansas City is discussed in a previous report.¹

ACTIVITY

Process Description

Ultrasonic welding is a process for joining similar and dissimilar metals by introducing high-frequency vibratory energy into the overlapping metals in the area to be joined. No fluxes or filler metals are used, no electrical current passes through the weld metals, and normally no external heat is applied. The metals to be welded are clamped together under moderately low static force. A solid-state weld is achieved when ultrasonic vibratory energy is transmitted into the weld area.

Ultrasonic seam welding is an application of the ultrasonic welding process where the metals to be joined are clamped between a stationary support called the anvil and a vibrating disc roller attached to a moving transducer-weld head assembly. The weld head is driven along a linear drive mechanism while the vibrating disc rolls along the path of the seam to be welded, producing a continuous ultrasonic weld.

Almost every metal and alloy can be ultrasonically welded. Ultrasonic welding is useful especially for joining highly conductive materials, such as copper and aluminum, which are not easily resistance welded and in welding dissimilar metals,

since no brittle intermetallics are formed by this solid-state welding process.

Initial Investigations

When the requirement for ultrasonic seam welding capability was established, The Sonobond Corporation, West Chester, PA, was contacted to provide initial sample seam welds. Samples of aluminum and copper-foil conductors representing typical materials used for producing flat cables were sent to Sonobond. There samples were welded to determine the suitability of their welders to Bendix applications.

Sonobond returned six successfully welded combinations of the sample materials (Table 1) comprising all of the requested configurations. The quality of these samples supported procurement of a seam welding system for further development. Because all of the samples provided by Sonobond were made with their Model WS-30-AW foil splicer, this model was chosen for purchase by Bendix.

Equipment

The Sonobond Model WS-30-AW is a kit of ultrasonic seam welding components consisting of a 30 acoustic watt weld power supply with a 50 kHz output frequency and a seam welding head (Figure 1) mounted on a traversing mechanism of specified length. Sonobond supplies the welder in kit form so the purchaser can install the components on suitable fixturing to satisfy the particular production application.

A complete welding system incorporating the Sonobond kit was designed and built at Bendix (Figure 2). A reversible, variable speed motor, controller, and gear box for driving the weld head traversing mechanism (Figure 3) were incorporated into the welding system. Also, a digital tachometer, required to accurately and repeatably set the weld head traversing speed, was interfaced with the system.

The system's welding surface, or anvil, was made from stainless steel according to Sonobond's recommendation. The anvil was designed with multiple sections in order to allow fabrication of special purpose sections applicable to various weld configurations. One such special purpose anvil section is shown in Figure 4. This section was built with a raised rectangular insert for welding copper, laminated onto polyimide film 0.08-mm thick, with windows of the polyimide removed to expose both sides of the copper. The insert is raised 0.08 mm to support the copper in the area where the polyimide is removed.

Table 1. Sample Material Combinations Welded at Sonobond Corporation

Combination	Materials Welded
1	0.05-mm-Thick 1145-0 Aluminum to 0.05-mm-Thick 1145-0 Aluminum
2	0.05-mm-Thick 1100-H19 Aluminum to 0.05-mm-Thick 1100-H19 Aluminum
3	0.013-mm-Thick 1145-0 Aluminum to 0.05-mm-Thick 1100-H19 Aluminum
4	0.05-mm-Thick 1145-0 Aluminum to 0.2-mm-Thick ETP Number 110 Copper

Two of the anvil sections were designed to mount on the weld system leaving a gap between them. The gap was designed to accommodate a dial force gage as shown in Figure 5. The weld head, as supplied, used a compression spring and a scale pointer to set and indicate clamping force. This system provided no indication of actual clamping force which was needed for repeating force settings. The incorporation of the force gage at the weld surface level allowed accurate, repeatable clamping force settings to be made.

Welding Evaluations

The Sonobond Model WS-30-AW is a relatively low power foil splicing welder, primarily intended for welding thin aluminum foils up to 0.08 mm thick. The welding evaluations on this project were primarily focused on welding thin aluminum foils to aluminum foils and to copper foils. Table 2 lists some of the material combinations that were successfully joined by the ultrasonic seam welding process at Bendix. Attempts to weld thicker foils and other materials met limited success because of the power limitations of the weld system. The materials successfully joined, however, are representative of materials used in Bendix flat cable production.

Figure 6 shows samples of 0.05-mm-thick 1100-H19 aluminum alloy welded to itself and of 0.05-mm-thick 1145-0 aluminum alloy welded to 0.05-mm-thick ETP Number 110 copper alloy, annealed. Both samples exhibit high quality continuous ultrasonic seam welds between the metals. When destructively peel tested, the aluminum tore without any failure of the weld joint (Figure 6). Figure 7 shows a magnified cross section of the aluminum-to-aluminum weld and Figure 8 shows a similar section of the

Figure 1. Side View (Top) and Front View of Welding Head on Traversing Mechanism

Figure 2. Bendix-Designed Ultrasonic Seam Weld System

Figure 3. Drive Mechanism

Figure 4. Special Purpose Anvil Section
With Rectangular Insert Raised
0.08 mm

Figure 5. Force Gage in Anvil Slot Being
Used to Set Weld Clamping Force

Table 2. Bendix-Welded Material Combinations

Combination	Material Welded
1	0.05-mm-Thick 1100-H19 Aluminum to 0.05-mm-Thick 1100-H19 Aluminum
2	0.05-mm-Thick 1100-H19 Aluminum to 0.05-mm-Thick ETP Number 110 Copper
3	0.05-mm-Thick 1145-0 Aluminum to 0.05-mm-Thick ETP Number 110 Copper
4	0.05-mm-Thick 1145-0 Aluminum to 0.13-mm-Thick ETP Number 110 Copper
5	0.05-mm-Thick 1145-0 Aluminum to 0.13-mm-Thick Gold-Plated ETP Number 110 Copper

Figure 6. Alloy 1100-H19 Aluminum Ultrasonic Seam Welded to Itself (Top) and Alloy 1145-0 Aluminum Ultrasonic Seam Welded to ETP Number 110 Copper, Annealed

Figure 7. Magnified Cross Section of Alloy 1100-H19 Aluminum Welded to Itself

Figure 8. Magnified Cross Section of Alloy 1145-0 Aluminum Welded to ETP Number 110 Copper, Annealed

aluminum-to-copper weld. Both exhibit high quality solid-state bonds, typical of those observed during previous Bendix work with ultrasonic spot welding.¹

Evaluations were performed on several weld material combinations to determine the effects of the various weld parameter settings on the resultant welds. The weld settings are the power supplied to the weld head transducer, variable by potentiometer control from 0 to 100 percent of the power supply's output, the clamping force, variable from 0 to 89 N, and the weld head traversing speed, variable from 0 to 3875 mm per minute (drive screw speed of 0 to 360 rpm).

The aluminum foils used during this project were typically 0.05 mm thick. Sonobond operating instructions for the Model WS-30-AW indicate that for foils between 0.025 and 0.08 mm, and welding rate of 1475 mm per minute (drive screw speed of 137 rpm) should be used. For most material combinations welded, however, experimentation showed that a speed of approximately 800 mm per minute (drive screw speed of 75 rpm) was required to achieve good welds. An exception to this was 0.05-mm-thick 1100-H19 aluminum alloy welded to itself. This material combination was found to be readily weldable at very high speeds; in fact, it was more easily positioned and held during the welding process at speeds higher than 1700 mm per minute (drive screw speed of 160 rpm).

Even at slower welding rates, most material combinations evaluated were successfully welded at power settings above 80 percent of full power. This is attributable to the relatively low power of the Model WS-30-AW. For materials other than aluminum or for thicker aluminum, a weld system with increased power output would be required.

The effects of clamping force on weld quality were evaluated by making welds while varying the clamping force over the range of the weld system. A clamping force of 44.5 to 53.4 N was found to yield the best welding results for typical material combinations as previously described. Forces lower than 44.5 N resulted in poor quality and forces above 53.4 N showed no significant improvement in weld quality and often resulted in damage to the weld materials. All of the successful weld combinations listed in Table 2 were welded in the 44.5 to 53.4 N force range.

ACCOMPLISHMENTS

A laboratory capability has been established which is suitable for evaluating potential applications of ultrasonic seam welding. This process is useful in making continuous seam welds between

thin aluminum foils up to 0.08 mm thick and aluminum or copper foils. Although the original application for seam welding was eliminated during the course of this project, a technical background on the ultrasonic seam welding process was developed for application on future programs.

Significant accomplishments on this project include:

- Design and fabrication of a prototype ultrasonic seam welding system based on a Sonobond Model WS-30-AW foil splicer kit,
- Identification of several weldable material combinations applicable to Bendix flat cable production, and
- Establishment of process parameter effects on resultant welds and identification of system capabilities, useable parameter ranges, and combinations.

REFERENCE

¹G. S. Darner, Welding Electric Terminals Ultrasonically
(Topical Report). Bendix Kansas City: BDX-613-1565,
September 1976 (Available from NTIS).

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