An ultrasonic stir welding system includes a welding head assembly having a plate and a rod passing through the plate. The rod is rotatable about a longitudinal axis thereof. During a welding operation, ultrasonic pulses are applied to the rod as it rotates about its longitudinal axis. The ultrasonic pulses are applied in such a way that they propagate parallel to the longitudinal axis of the rod.

7 Claims, 2 Drawing Sheets
FIG. 1

Controller

Ultrasonic Energy Source

S

16A

16

12

14

18

20

22

24

f
A
PR

10
PULSED ULTRASONIC STIR WELDING SYSTEM

ORIGIN OF THE INVENTION

The invention was made by an employee of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to stir welding systems. More specifically, the invention is a stir welding system utilizing pulsed ultrasonic energy.

2. Description of the Related Art

Stir welding is a form of welding that utilizes a small stir pin to mix abutting or faying surfaces of two pieces of material (e.g., metal materials) to thereby form a joint between the two pieces of material. The materials must be heated into a plastic state where they abut prior to being “stirred.” There are several ways to achieve such heating. In one type of stir welding known as friction stir welding (FSW), a pin tool includes a larger diameter shoulder and a smaller diameter threaded pin. The entire pin tool is rotated and the rotating pin is driven axially into the weld joint until the rotating shoulder comes into contact with the material surface. The rotating shoulder generates frictional energy/heat as it rotates on the material surface to thereby heat the material into its plastic state. The high rotation rates needed to generate the frictional forces, as well as the frictional forces, tend to wear out the pin tool in relatively short periods of time especially when joining thick sections of temperature-resistant alloys such as titanium and steel.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a stir welding system.

Another object of the present invention is to provide a stir welding system having increased tool life.

Other objects and advantages of the present invention will become more obvious hereinafter in the specification and drawings.

In accordance with the present invention, an ultrasonic stir welding system includes a welding head assembly having a containment plate and a stir rod passing through the plate. The stir rod is rotatable about a longitudinal axis thereof. The containment plate can be stationary with respect to the stir rod, can rotate in concert with the stir rod, or can rotate at a different speed than that of the stir rod. During a welding operation, a source coupled to the stir rod generates ultrasonic pulses that are then applied to the stir rod as it rotates about its longitudinal axis. The ultrasonic pulses are applied in such a way that they propagate parallel to the longitudinal axis of the stir rod. Ultrasonic pulses could also be applied to the plate and/or an anvil (on which a work piece rests) to reduce frictional forces.

BRIEF DESCRIPTION OF THE DRAWING(S)

Other objects, features and advantages of the present invention will become apparent upon reference to the following description of the preferred embodiments and to the drawings.
frictional forces acting on rotating stir rod 16 are reduced. During the “off” period of pulses 22, the plasticized work piece material “sticks” to rotating stir rod 16 so it can be moved and released just aft of stir rod 16.

Ultrasonic pulses 22 can be controlled during a welding operation. The controllable parameters of pulses 22 include the frequency of the ultrasonic energy, the amplitude of the ultrasonic energy, and the on-off pulse rate of pulses 22. Such control can be provided by a controller 24 coupled to source 20 where controller 24 can adjust the frequency (f) and/or amplitude (A) of the ultrasonic energy as well as the pulse rate (PR) of pulses 22. The particular construction and/or arrangement of source 20 and controller 24 are not limitations of the present invention. For example, source 20 and controller 24 could be an integrated device or separate devices without departing from the scope of the present invention.

Controller 24 could employ pre-programmed or open-loop control of pulses 22, or could employ an adaptable closed-loop control of pulses 22. For example, in terms of closed-loop control, one or more sensors “S” could be included with plate 14 (and/or stir rod 16) to sense attributes (e.g., temperature) of the work piece in the region of stir rod 16. The sensed attributes could then be used by controller 24 to adjust the attributes of pulses 22 to improve the welding operation.

Another embodiment of the present invention is illustrated in FIG. 2 where identical reference numerals are used for elements common to those described above. In FIG. 2, a work piece to be welded is shown and is referenced by numeral 100 and a base or anvil supporting work piece 100 is referenced by numeral 200. Similar to plate 14, base 200 is made up of a rigid material that can withstand the rigors of an ultrasonic stir welding operation of the present invention. A drive source 26 coupled to stir rod 16 provides rotation 18 needed for a welding operation.

During a welding operation, relative movement (indicated by arrow 300) is induced between welding head assembly 12 and work piece 100 where movement 300 is generally perpendicular to longitudinal axis 16A of rotating stir rod 16. Work piece 100 can remain stationary on base 200 as welding head assembly 12 moves in accordance with arrow 300, or welding head assembly 12 and base 200 can remain stationary while work piece 100 is moved in accordance with arrow 300.

Regardless of how relative movement 300 is induced, the embodiment in FIG. 2 includes one or more additional ultrasonic energy sources. In the illustrated embodiment, two ultrasonic energy sources 30 and 40 are provided with corresponding controllers 34 and 44. Source 30 controller 34 cooperate to produce/apply ultrasonic pulses 32 to plate 14 in a direction parallel to relative movement 300 (or perpendicular to longitudinal axis 16A of stir rod 16). Controller 34 can control frequency (f), amplitude (A), and/or pulse rate (PR) of pulse 32 where the particular attribute values can be independent of those associated with pulses 22. Similarly, source 40 controller 44 cooperate to produce/apply ultrasonic pulses 42 to base 200 such that pulses 42 prograde in base 200 in a direction parallel to relative movement 300 (or perpendicular to longitudinal axis 16A of stir rod 16). Controller 44 can control frequency (f), amplitude (A), and/or pulse rate (PR) of pulses 42 where the particular attribute values can be independent of those associated with pulses 22 and pulses 32. The application of pulses 32 and/or 42 during a welding operation enhances heating of work piece 100 while also reducing frictional forces generated by relative movement 300. Note that some materials and/or applications may require an additional heat source 50 properly positioned based on relative movement 300 for heating the material(s) to be welded into a plastic state. Each of controllers 34 and 44 can employ open-loop or closed-loop control where closed-loop control could utilize inputs from sensors “S” included in plate 14 as described above.

The advantages of the present invention are numerous. Stir welding tool life will be increased as the use of ultrasonic energy applied during welding reduces frictional forces acting on the tool. By pulsing the ultrasonic energy, the stir welding tool is “pulsed” between its heating/friction reduction and welding functions. Additional pulsing ultrasonic energy can be applied to the tool’s containment plate and/or the base/anvil on which the work piece sits to enhance heating and reduce frictional forces generated during a stir welding operation.

Although the invention has been described relative to a specific embodiment thereof, there are numerous variations and modifications that will be readily apparent to those skilled in the art in light of the above teachings. It is therefore to be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. An ultrasonic stir welding system, comprising:
   a stationary base;
   a welding head assembly to include a plate spaced apart from said base and a rod with an end of said rod spaced apart from said base, said rod passing through said plate wherein said rod is rotateable about a longitudinal axis thereof;
   a rotational drive source coupled to said rod for rotating said rod about said longitudinal axis thereof during a welding operation;
   an ultrasonic energy source coupled to said rod;
   a controller coupled to said source for controlling said source such that a series of on-off ultrasonic pulses is generated and applied to said rod during said welding operation and such that said on-off ultrasonic pulses propagate parallel to said longitudinal axis of said rod, said controller controlling at least a pulse rate associated with said on-off ultrasonic pulses and at least one additional ultrasonic energy source coupled to said rod wherein said additional ultrasonic energy source propagates perpendicular to said longitudinal axis of said rod.

2. An ultrasonic stir welding system as in claim 1, wherein said rod is substantially cylindrical.

3. An ultrasonic stir welding system as in claim 1, wherein said rod is made from metal.

4. An ultrasonic stir welding system as in claim 1, wherein said controller further controls at least one of frequency and amplitude associated with said on-off ultrasonic pulses.

5. An ultrasonic stir welding system as in claim 4, wherein said controller comprises a closed-loop control system for controlling at least one of said frequency, said amplitude, and said pulse rate.

6. An ultrasonic stir welding system as in claim 1, wherein said controller controls at least one additional ultrasonic energy source to control at least one of frequency, amplitude, and pulse rate associated with said additional on-off ultrasonic pulses.

7. An ultrasonic stir welding system as in claim 6, wherein said said controller is an ultrasonic stir welding system having an additional pulse source for controlling at least one of said frequency, said amplitude, and said pulse rate associated with said additional on-off ultrasonic pulses.

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