A friction stir weld tool sleeve is supported by an underlying support pin. The pin material is preferably selected for toughness and fracture characteristics. The pin sleeve preferably has a geometry which employs the use of an interrupted thread, a plurality of flutes and/or eccentric path to provide greater flow through. Paddles have been found to assist in imparting friction and directing plastic metal during the welding process.
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* cited by examiner
1. FIELD OF THE INVENTION

This invention relates to friction stir welding pin-tools, and more particularly to pin design and the pin surface geometry which engages a workpiece.

2. BACKGROUND OF THE INVENTION

The invention described herein was made in part by an employee of the United States Government and may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

STATEMENT OF GOVERNMENT INTEREST

The invention described herein was made in part by an employee of the United States Government and may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

SUMMARY OF THE INVENTION

As can be seen from the prior art, there exists a need for a FSW tool which provides a tool pin design allowing for increased tool life.

METHOD AND APPARATUS FOR CONTROLLING DOWNFORCE DURING FRICTION STIR WELDING

An apparatus for controlling downforce during friction stir welding comprises a carrier member to receive a component to be friction welded to the workpiece, wherein a pin is disposed through the shoulder and into the workpiece, wherein the pin and the shoulder at least include a coating comprised of a super abrasive material, and having a collar around a portion of the shoulder and the shank to thereby prevent movement of the shoulder relative to the shank, and incorporating thermal management by providing a thermal flow barrier between the shoulder and the shank, and between the collar and the tool.
Another object is to provide improved wear characteristics of FSW pin-tools.

Accordingly, the present invention provides a friction stir weld pin-tool which is supported by an underlying support pin. The pin material is preferably selected for toughness and fracture characteristics. The pin has a geometry which advantageously connects with an external sleeve. Although external sleeves can take a variety of geometries, the presently preferred geometry employs the use of one of an interrupted thread, an odd number of flutes, and/or an eccentric path to provide greater thru-flow. Abrasive surface geometries may also be utilized. Furthermore, paddles on an exterior surface of the sleeve may also be utilized to advantageously stir plastic metal during the welding process.

**BRIEF DESCRIPTION OF THE DRAWINGS**

The particular features and advantages of the invention as well as other objects will become apparent from the following description taken in connection with the accompanying drawings in which:

**FIG. 1** shows a side plan view of a body for use in FSW process with integral shoulder and smaller diameter protruding support pin;

**FIGS. 2A-D** show four presently preferred cross-sectional configurations for the support pin shown in FIG. 1;

**FIGS. 3A-H** show alternatively preferred pin sleeve embodiments;

**FIGS. 4A and B** show top plan views of an even number of retreating side or down-milling;

**FIG. 5** shows a swath path for a four fluted work pin;

**FIG. 6** shows the swath path of a three fluted tool;

**FIG. 7** shows a bottom plan view of a pin-tool connected in accordance with the presently preferred embodiment; and

**FIG. 8** shows a side perspective view of the presently preferred embodiment of the pin-tool connected to the shaft of FIG. 1.

**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

**FIG. 1** shows a tool body with integral shoulder **10** and integral smaller diameter protruding support pin **12** in accordance with the presently preferred embodiment of the present invention. While tool bodies with integral shoulders have been known in the art, the support pin **12** is believed to be new. The body, shoulder and pin **10, 11 and 12** rotate together about rotational axis **64**. The pin **12** is selected from material for toughness, fracture, wear resistance, and other characteristics. The pin **12** may have a coating and/or sleeve intermediate the pin **12** and any of the alternatively preferred embodiments of tool sleeves as shown in FIGS. 3A-3H. The currently preferred embodiment of a tool sleeve is illustrated in FIGS. 7 and 8 as sleeve **14** connected to pin **12**.

**FIG. 2** shows cross section embodiments taken along the line **A-A** of FIG. 1. These or other cross sectional embodiments could also be utilized. Any of the planar segments shown may be useful to prevent rotation of sleeve **14** relative to pin **12**. Sleeves such as those shown in FIGS. 3A-3H or **60** distal end **68** of planar face to threads **52**. The sleeve is 60 distal end **68** of planar face to threads **52**. The sleeve is

**FIG. 4** shows what machinists typically call "up-milling" and "down-milling." In any slotted cutting operation, where the tool is completely engaged in the material, both conditions exist simultaneously. It can be understood in that in this scenario there is an opposite piece of material opposite the workpiece from material as shown in FIGS. 4a and 4b. Accordingly, as the blades **18** rotate with the shaft **10** shown in FIG. 1, when a first blade contacts the workpiece **20** as shown in FIG. 4a, an opposite blade in an even number configuration contacts a second workpiece **22** as shown in FIG. 4b. The terms “advancing side” and “retreating side” refer to the up-milling and down-milling sides without identifying the tool action itself since the tool continues to rotate about the axis of the shaft **10**.

In the tool design, as represented by the swath path FIG. 5, having an even number of flutes such as four, continuous threads a smooth surface, a “nipping action” can occur where a flow of material “thru” or the tools’ cutting volume.

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In FIG. 5 the tool is rotating clockwise and is being fed up the longitudinal axis **24** so that the direction of feed is established. This represents the workpieces passing about and below the tool which are not shown in FIG. 5. The swath path of the tool is shown.

The apparent swath path of a four bladed tool is represented at FIG. 5. Namely, area **26** is the apparent swath of the first flute which pinches at point **28** before the apparent swath path of the second flute **30** is commenced. The apparent swath path of the third flute **32** continues until reaching the pinch point **34** before beginning the apparent swath path of fourth flute **36**. Fourth flute **36** is on the advancing side (upmilling) while first flute **26** is on the retreating side of downmilling side. As can be seen from this diagram and understood by one skilled in the art, the pinching points **28, 34** are undesirable since they block the flow of material at these points.

However, when using an even number of flutes as shown in FIG. 6, the pinching action does not occur on opposite portions of axis **38** at the pinching points **28, 34** and **26, 42**. As can be seen in FIG. 6, the apparent swath path of a four fluted work pin is shown in FIG. 5. By utilizing a three fluted tool, a single pinching point **42** may occur relative to axis of rotation **44** of axes **46** and **48**. Since there are not a number of evenly spaced flutes, there is not a corresponding pinch point opposite the axis of rotation **44** from the pinch point **42**. A similar result can be had with an interrupted thread, a smooth pin with an eccentric path such as caused by the tilting of the tool relative to the workpieces and for the flattening of a side of the pin engaging the workpieces. A much greater thru flow can be had than with the even sided design as shown in FIG. 5.

**FIG. 6** shows the presently preferred embodiment having a plurality of paddles **50** disposed on threads **52** which wind around the workpiece **22**. The paddles **50** are disposed without threads **52** on exterior surface **60** of the sleeve **14**. The paddles **50** have a forward planar face **62** which is preferably either substantially perpendicular to the threads or parallel to and contained in a plane intersecting the shaft axis **64**. The paddles **50** are preferably odd in number and as they are substantially evenly spaced about the exterior surface of the sleeve **14**. The sleeve **14** preferably tapers from its proximal end **17** to its distal end **19**. The paddles **50** may have a planar back **66** which extends from distal end **68** of planar face to threads **52**. The sleeve is connected to a pin **12** as shown in FIG. 7. FIG. 8 shows the shoulder. This design is believed to enhance the formation of the nugget at all speeds, and permits higher transverse speeds without danger of shearing the pin-tool.

As can be seen in FIGS. 7 and 8 the sleeve **14** has a bore which cooperates with pin **12** so that sleeve **14** is locked on the pin **12**. The pin **12** has been selected for its toughness,
A friction stir weld tool comprising:

1. A rotatable shaft;
   a pin connected to a distal portion of the shaft, said pin disposed along an axis of rotation of the shaft, said pin having a cross section with at least one planar segment; a sleeve connected to the pin extending about the pin, said sleeve having an outer surface with an odd number of paddles evenly spaced about a circumference of the sleeve and the outer surface of the sleeve further comprising threads; wherein the paddles interrupt the threads.

2. A friction stir weld tool comprising:
   a rotatable shaft;
   a pin connected to a distal portion of the shaft, said pin disposed along an axis of rotation of the shaft, said pin having a cross section with at least one planar segment; a sleeve connected to the pin extending about the pin, said sleeve having an external surface with threads and a plurality of paddles, said paddles having a planar face substantially perpendicular to the axis of rotation of the shaft, and the paddles have a planar back which extends from a distal end of the planar face to the threads; wherein the paddles are odd in number and evenly spaced about a circumference of the external surface.

3. A friction stir weld tool comprising:
   a rotatable shaft;
   a pin connected to a distal portion of the shaft, said pin disposed along an axis of rotation of the shaft, said pin having a cross section with at least one planar segment; a sleeve connected to the pin extending about the pin, said sleeve having an external surface with threads and a plurality of paddles, said paddles having a planar face substantially perpendicular to the axis of rotation of the shaft, and the paddles have a planar back which extends from a distal end of the planar face to the threads; wherein the paddles are odd in number and evenly spaced about a circumference of the external surface.

The friction stir weld tool of claim 9 wherein said sleeve has a larger circumference toward the shaft than at the distal end of the sleeve.

The friction stir weld tool of claim 9 wherein the pin has at least one planar face, said planar face perpendicular to the axis of rotation of the shaft.

The friction stir weld tool of claim 9 wherein the forward planar faces are disposed in a plane intersecting the axis of rotation of the shaft.