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United States Patent	12383976
Kind Code	B2
Date of Patent	August 12, 2025
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Friction stir welding tool holder

Abstract

This disclosure relates to a friction stir welding (FSW) tool holder comprising a nickel-chromium based alloy.

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Appl. No.:	**18/256379**
Filed (or PCT Filed):	**December 06, 2021**
PCT No.:	**PCT/EP2021/084360**
PCT Pub. No.:	**WO2022/122639**
PCT Pub. Date:	June 16, 2022

Prior Publication Data

Document Identifier	Publication Date
US 20240100625 A1	Mar. 28, 2024

Foreign Application Priority Data

GB	2019610	Dec. 11, 2020

Publication Classification

Int. Cl.: **B23K20/12** (20060101); **C22C19/05** (20060101)

U.S. Cl.:

CPC **B23K20/1255** (20130101); **B23K20/125** (20130101); **C22C19/058** (20130101);

Field of Classification Search

CPC: B23K (20/1255); B23K (20/125); B23K (2101/20); B23K (20/1245); B23K (2103/05); B23K (20/122-128); C22C (19/058); C22C (19/05)

USPC: 228/112.1; 228/2.1

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS
(1) This application is the § 371 national stage of International Application No. PCT/EP2021/084360, filed Dec. 6, 2021, which claims priority to Great Britain Application No. 2019610.1, filed Dec. 11, 2020.
FIELD OF THE INVENTION
(2) This disclosure relates to a friction stir welding (FSW) tool holder. In particular, it relates to a FSW tool holder for use in friction stir welding high temperature ferrous alloys and other high temperature alloys. More particularly, it also relates to a FSW tool assembly with a tool insert and a tool holder, in which the tool insert comprises polycrystalline cubic boron nitride (PCBN) or tungsten rhenium (W—Re).
BACKGROUND
(3) FSW is a technique whereby a rotating tool is brought into forcible contact with two adjacent workpieces to be joined and the rotation of the tool creates frictional and viscous heating of the workpieces. Extensive deformation as mixing occurs along a plastic zone. Upon cooling of the plastic zone, the workpieces are joined along a welding joint. Since the workpiece remains in the solid phase, this process is technically a forging process rather than a welding process, none the less by convention, it is referred to as welding or friction stir welding and that convention is

followed here.
(4) In the case of FSW in low temperature metals, the whole tool/tool holder can be a single piece of shaped tool steel, in which case it is often referred to as a ‘probe’. In the case here where the tool is for welding higher temperature alloys such as steel, the tool is often in two or more parts, with an end element that is in direct contact with the material being welded, often referred to as a ‘puck’ or ‘tool insert’, and the remainder of the tool being the ‘tool holder’ which holds the puck securely and which fits into the FSW machine, so that the tool puck and tool holder together make up the ‘tool’ or ‘tool assembly’. The tool puck is typically shaped to form a shoulder and a stirring pin, often with a reverse spiral cut into the surface so that during rotation it pulls metal towards the pin and pushes this down into the hole being formed by the pin.
(5) In general, FSW operations comprise a number of steps, for example: a) an insertion step (also known as the plunge step), from the point when the tool comes into contact with the workpieces to the point where the pin is fully embedded up to the shoulder in the heated and softened workpieces, b) a tool traverse, when the tool moves laterally along the line in between the workpieces to be joined, and c) an extraction step, when the tool is lifted or traversed out of the workpieces.
(6) The tool traverse, which is the stage primarily forming the weld, is usually performed under constant conditions; typically these conditions are rotational speed, conditions of the plunge, speed of traverse etc.
(7) PCBN based tools are capable of withstanding the harsh FSW operating environment, where temperatures reach in excess of 1100° C. Tool pucks made from PCBN are relatively cost effective and highly durable. However, a limitation of the manufacturing process of PCBN pucks is that a bulk PCBN piece is required, out of which the puck is fashioned. Monolithic PCBN blocks need to be as high as 50 mm in diameter and 50 mm in height, in order to produce a puck with a 12 mm pin height, which will be capable of welding a 12 mm plate thickness. Monolithic PCBN blocks (and therefore PCBN pucks) larger than this are currently not feasible due to the limitations of the High Pressure High Temperature (HPHT) presses used during the PCBN sintering process. A larger press may compromise the material homogeneity. In short, the size of a PCBN puck currently achievable in practice is limited to being capable of welding plates with thickness 12 mm or below.
(8) There is a real push to develop PCBN tools and accompanying tool holders that are capable of welding ferrous plates with a thickness above 12 mm.
(9) A key challenge faced with large PCBN tools is retaining the tool within the tool holder, particularly during the insertion and traverse stages. Separation occasionally occurs, believed to be caused by the mismatch in the coefficient of thermal conductivity between the PCBN tool insert and the typically steel tool holder. Due to the extreme conditions of the FSW process, traditional methods such as screws will not work. The problem handicaps the performance of PCBN tool inserts, limiting the weld length that is otherwise potentially obtainable.
(10) There is a need for a FSW tool assembly for welding higher temperature alloys that retains the tool insert within the tool holder during prolonged use.

SUMMARY OF THE INVENTION

(11) According to a first aspect of the invention, there is provided a friction stir welding (FSW) tool holder comprising a nickel-chromium based alloy.
(12) Preferable and/or optional features of the first aspect of the invention are provided in the claims appended hereto.
(13) According to a second aspect of the invention, there is provided a friction stir welding (FSW) tool assembly comprising a tool insert and a tool holder in accordance with the first aspect of the invention to hold the tool insert.
(14) Preferable and/or optional features of the second aspect of the invention are provided in the claims appended hereto.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) The invention will now be more particularly described, by way of example only, with reference to the accompanying drawings, in which:

(2) FIG. **1** is a perspective view of a first embodiment of a tool assembly, in an assembled condition;

(3) FIG. **2** is a side view of the tool assembly of FIG. **1**;

(4) FIG. **3** is a plan view of the tool assembly of FIG. **1**;

(5) FIG. **4** is a cross-sectional view of the tool assembly of FIG. **3** along the line S-S;

(6) FIG. **5** is a perspective view of the tool holder of FIG. **1**;

(7) FIG. **6** is a perspective view of the tool holder of FIG. **5** with a locking collar, the tool insert having been omitted for clarity;

(8) FIG. **7** is a perspective view of a portion of the locking collar of FIG. **6**;

(9) FIG. **8** is a plan view of the tool holder and locking collar portion of FIG. **6**;

(10) FIG. **9** is a cross-sectional view of the tool holder of FIG. **8** along the line Z**1**-Z**1**;

(11) FIG. **10** is a perspective view of the tool insert of FIG. **1**;

(12) FIG. **11** is a perspective view from below of the tool insert of FIG. **10**;

(13) FIG. **12** is a side view of the tool insert of FIG. **10**;

(14) FIG. **13** is a plan view of the tool insert of FIG. **10**;

(15) FIG. **14** is a cross-sectional view of the tool insert of FIG. **13** along the line W**1**-W**1**;

(16) FIG. **15** is a perspective view of a second embodiment of a tool assembly, also in an assembled condition;

(17) FIG. **16** is a side view of the tool assembly of FIG. **15**;

(18) FIG. **17** is a plan view of the tool assembly of FIG. **15**;

(19) FIG. **18** is a cross-sectional view of the tool assembly of FIG. **17** along the line Z-Z;

(20) FIG. **19** is a cross-sectional view of the tool assembly of FIG. **17** along the line Y-Y;

(21) FIG. **20** is a perspective view of the tool holder of FIG. **15**;

(22) FIG. **21** is a plan view of the tool holder of FIG. **15**;

(23) FIG. **22** is a cross-sectional view of the tool holder of FIG. **21** along the line T-T;

(24) FIG. **23** is a perspective view of the tool insert of FIG. **15**;

(25) FIG. **24** is a side view of the tool insert of FIG. **23**;

(26) FIG. **25** is a plan view of the tool insert of FIG. **23**;

(27) FIG. **26** is a cross-sectional view of the tool insert of FIG. **25** along the line V-V;

(28) FIG. **27** is a perspective view of a tool insert in a further embodiment;

(29) FIG. **28** is a perspective view from below of the tool insert of FIG. **27**;

(30) FIG. **29** is a plan view of the tool insert of FIG. **27**;

(31) FIG. **30** is a cross-sectional view of the tool insert of FIG. **29** along the line Y**1**-Y**1**;

(32) FIG. **31** is a cross-sectional view of a tool assembly in an embodiment of the invention, showing in particular a layer of braze between the tool insert and the tool holder;

(33) FIG. **32** is an image taken from Finite Element Analysis of a prior art design, indicating the maximum principle stresses incurred within the tool insert and tool assembly for comparative purposes with FIG. **33**;

(34) FIG. **33** is an image taken from Finite Element Analysis of a brazed design, indicating the maximum principle stresses incurred within the tool insert and tool assembly for comparative purposes with FIG. **32**;

(35) FIG. **34** is a cross-sectional view of a tool assembly in a further embodiment of the invention, showing in particular a cooling system adjacent in a region of braze, and

(36) FIG. **35** is an optical image showing the grain boundary γ.sup./(Ni3(Al,Ti)) in alloy 80A.

(37) Throughout the embodiments, similar parts are denoted by the same reference numeral and a further description is omitted for brevity.

DETAILED DESCRIPTION

(38) Referring firstly to FIGS. **1** to **4**, an embodiment of a tool assembly, in accordance with the invention, is indicated generally at **10**. The tool assembly comprises a polycrystalline cubic boron nitride (PCBN) tool insert **12** and a tool holder **14** to hold the PCBN tool insert **12**. The tool assembly **10** has a longitudinal axis of rotation (not shown) about which it rotates during use in the friction stir welding process. Note that this axis of rotation is not an axis of rotational symmetry due to an asymmetric thread pattern machined into the tool insert **12**. The tool insert **12** and tool holder **14** are aligned coaxially about the axis of rotation.

(39) The tool assembly **10** further comprises a retention mechanism to mechanically lock the tool insert **10** and tool holder **12** together, thereby preventing separation during FSW. This positive locking action is distinct from and vastly superior to the passive shrink fit methods known in the art. It is also distinct from a threaded screw cap arrangement that is sometimes mounted about the tool holder. In this embodiment, the retention mechanism comprises a locking collar **16**, described in detail below.

(40) Tool Insert

(41) Turning to FIGS. **10** to **14**, the tool insert **12** comprises a stirring pin **18**, a shoulder portion and a body portion **22**, all in axial alignment with each other, with the shoulder portion **20** essentially being the interface between the stirring pin **18** and the body portion **22**. The stirring pin **18**, shoulder portion **20** and body portion **22** are all integrally formed with each other such that the tool insert **12** is one-piece. The tool insert **12** is machined out of a single PCBN block after the block has been sintered in a HPHT press.

(42) The stirring pin **18** has a conical profile, tapering outwardly from a rounded apex **24** towards the shoulder portion **20**. The stirring pin **18** comprises an inscribed spiral feature **26** running from the apex **24** down towards and onto the shoulder portion **20**. The spiral **26** has a planar pathway, which faces axially and the working surface faces radially.

(43) The shoulder portion **20** is disc-like, and has a larger diameter than a circular base of the stirring pin **18**. The shoulder portion **20** extends axially downwardly to meet the body portion **22**.

(44) The body portion **22** is generally cylindrical.

(45) Advantageously, a circumferentially extending locking groove **28** is provided in an upper region of the body portion **22**, proximate the shoulder portion **20**, to mechanically engage with the locking collar **16**, as part of the retention mechanism. The locking groove **28** extends around the entire circumference of the body portion **22**. However, this need not be the case, and alternatively the locking groove **28** may extend only partially around the circumference of the body portion **22**, with the locking collar **16** configured accordingly.

(46) In an alternative embodiment, the circumferentially extending groove **28** on the tool insert **12** is replaced by a circumferentially extending flange (not shown). The flange may extend partially around the tool insert **12** or it may extend around the entire tool insert **12**. In such an embodiment, the flange cooperates with one more circumferentially extending grooves (not shown) on the locking collar **16**.

(47) As shown in FIG. **11**, two segment shaped slots **30** cut into a lower end of the body portion **22**. The segment shaped slots **30** are diametrically opposed to each other. Forming part of an anti-rotation mechanism, the segment shaped slots **30** cooperate with two segment shaped steps **32** (see FIG. **5**) within the tool holder **14** when the tool insert **12** is in position and supported by the tool holder **14**. The anti-rotation mechanism prevents relative rotational movement between the tool insert **12** and the tool holder **14** about the axis of rotation. Alternative examples of the anti-rotation mechanism are described in more detail later.

(48) In use, rotation of the tool assembly **10** is such that the spiral **26** drives workpiece material flow from the edge of the shoulder portion **20** to the centre and then down the length of the stirring

pin **18**. This forces workpiece material to circulate within the stirred zone and to fill the void formed by the stirring pin **18** as the tool insert **12** traverses in a known manner.

(49) Tool Holder

(50) Referring to FIGS. **4**, **5**, **6** and **9**, the tool holder **14**, comprises a holding member **34** for receiving the tool insert, and an elongate trunk member **36** joined at one end thereof to the holding member **34**.

(51) The trunk member **36** is solid and cylindrical. The purpose of the trunk member **36** is to facilitate connection of the tool assembly **10** to the FSW machinery.

(52) The holding member **34** is externally cylindrical and internally comprises a recessed cup **38** to receive the tool insert **12**. The recessed cup **38** is located centrally about the axis of rotation.

(53) The recessed cup **38** comprises a lower base surface **40**, an upper opening **42** through which the tool insert **12** is inserted, and a sidewall **44** connecting the base surface **40** to the opening **42**.

(54) In this embodiment, the sidewall **44** is generally cylindrical and has a constant circular lateral cross-section about its length, intended for use with a tool insert that is at least partially cylindrical.

(55) In an alternative embodiment, the sidewall **44** is generally frusto-conical and has a circular lateral cross-section increasing in diameter away from the base surface **40**. This profile of recessed cup **38** is intended for use with a tool insert that is at least partially conical.

(56) The recessed cup **38** sized and shaped to receive only a portion of the body portion **22** such that when together, the tool insert **12** protrudes out of the tool holder **14**, with the shoulder portion **20** exposed.

(57) Regardless of whether the internal profile of the recessed cup **38** is conical or cylindrical, two segment shaped steps **32** are built into the sidewall **44**. The sidewall **44** is therefore stepped in longitudinal cross-section, as shown in FIG. **22**. The segment shaped steps **32** form part of the anti-rotation mechanism introduced earlier. When the tool insert **12** is in position inside the recessed cup **38**, the segment shaped steps **32** abut against the segment shaped slots **30** of the tool insert **12**, precluding rotation of the tool insert **12** relative to the tool holder **14**. It is important to avoid rotation as this is one way in which the tool insert **12** can gradually become loose and detach from the tool holder **14**.

(58) Retention Mechanism

(59) As mentioned above, the retention mechanism comprises the locking collar **16** (FIG. **7**) and the circumferentially extending groove **28** on the tool insert **12**. Optionally, the retention mechanism also comprises a high temperature seal located underneath the locking collar **16**.

(60) As shown in FIGS. **1** and **6**, the locking collar **16** comprises two arcuate collar portions **16***a*, **16***b* although more could be used instead. Preferably, the arcuate collar portions **16***a*, **16***b* are equally sized in length. Essentially, the arcuate collar portions **16***a*, **16***b* are adapted to connect securely end-to-end together to form a single ring. Providing the locking collar **16** in arcuate collar portions **16***a*, **16***b* enables close fitment about the tool insert **12** and/or tool holder **14** but without compression.

(61) The locking collar **16** is annular, with an L-shaped lateral cross-section. When the tool insert **12** is in-situ, supported by the tool holder **14**, the locking collar **16** extends around the opening **42** of the tool holder, against a rim thereof. The locking collar **16** is also mounted against the external surface **46** of the holding member **34**. The locking collar **16** extends into the circumferentially extending groove **28** on the tool insert **12** in mating engagement. When connected securely together, the arcuate collar portions **16***a*, **16***b* retain the tool insert **12** in place securely held in the tool holder **14**, stopping the tool insert **12** from disengaging from the tool holder **14**.

(62) Referring to FIGS. **15** to **26**, an alternative embodiment of the tool assembly is indicated generally at **100**. The tool assembly **100** comprises a further embodiment of the tool insert **112** and a further embodiment of the tool holder **114**. In this embodiment, the retention mechanism comprises a locking pin **48** that couples with a locking aperture **50** in the tool insert **112** and/or the tool holder **114**. In a preferred embodiment, the retention mechanism comprises two or more

locking pins **48**. The two locking pins **48** are diametrically opposed to each other. Preferably, the locking pins **48** are manufactured from soft steel to minimise stress. In an embodiment, the locking apertures **50** comprise radially extending through-holes **52**, arranged through the tool holder **114**, and radially extending blind-holes **54** arranged in the tool insert **112**, which are aligned with the through-holes **52** of the tool holder **114**.
(63) FIGS. **27** to **30** show an alternative example of the anti-rotation mechanism in a further embodiment of the tool insert, indicated at **212**. The anti-rotation member comprises a square shaped boss on an underside of the tool holder and a correspondingly shaped recess **56** on the tool insert **112**. As another example, the square shaped boss could be located on the tool insert and the square shaped recess on the base surface **40** of the tool holder **114**.
(64) Tool Holder Materials
(65) Another aspect of the retention mechanism, supplementary to the mechanical solutions described above, is the tool holder material. The holding member **34** and trunk member **36** are preferably integrally formed with each other, making the tool holder **14** a single component. However, they may be manufactured as two separate components, comprising or consisting of two different materials, and joined subsequently together.
(66) The tool holder **12** comprises a high temperature high strength alloy. Although not falling within the scope of the claims, it is envisaged that the tool holder **12** could comprise any one or more of the following materials: W—Ni (tungsten-nickel) alloy, TZM (molybdenum-titanium-zirconium), and high entropy alloys. Equally, Inconel alloys (a class of nickel-chrome based super alloys) are also suitable but not preferred. In general, these alloys are characterised by good strength at elevated temperatures.
(67) In accordance with the invention, the tool holder comprises a nickel-chromium based alloy based on Alloy 80A, also known by its Special Metals Corporation trade name as NIMONIC® alloy 80A. NIMONIC® alloy 80A is a precipitation hardened alloy typically used in aircraft or marine turbine rotors, exhaust valves, diesel engine combustion chambers, and high-strength fasteners. It demonstrates excellent corrosion and good oxidation resistance combined with high mechanical properties and creep resistance up to 815° C. (1500° F.).
(68) The basic crystal structure of nickel alloys is face-centered cubic (FCC) and this phase is called austenite or γ (gamma) phase. The high temperature strength is developed through solid solution strengthening using Ti and/or Al additions, causing the random γ (gamma) phase to rearrange and become an ordered structure with Al or Ti taking the positions at the corners of the FCC structure, with the Ni sitting in the middle of the faces. The resulting γ′ (gamma prime) phase has different properties. With alloy 80A, a good amount of Ti and Al enables the γ′ phase and therefore the major strengthening mechanism of the superalloy is precipitation hardening. Having lots of Cr means good corrosion resistance. Adding in Si, Fe with the Cr creates solid solution strengthening for both γ and γ′ phases meaning it performs well up to 815° C.
(69) The composition of the toolholder material, in weight percentage, is provided in Table 1 below.
(70) TABLE-US-00001 TABLE 1 Ni Cr Ti Al C Si Cu Fe Mn Co B Zr S 67-71 18.0-21.0 1.8-2.7 1.0-1.8 <0.10 <1.0 0.2 3 1 2 0.008 0.15 0.015
(71) Although the content of Ni and Cr may vary outside of the above ranges by 1 to 2 wt. %, the content of Ti and Al is critical. Outside of the above ranges, the content of Ti and Al can have a significant impact on the properties of the toolholder. Carbon is added at levels of 0.05 to 0.2 wt. %, and is often made to react with reactive and refractory elements present to form primary carbides, to further strengthen the material.
(72) At the grain boundary γ.sup./(Ni3(Al,Ti)) in alloy 80A, Ti/Al γ.sup./ precipitates and forms a nice uniform layer which provides excellent, creep rupture resistance, and high tensile strength at high temperature, as can be seen in FIG. **35**.
(73) Testing carried out with a tool holder **14** comprising NIMONIC® 80A and Al4Nb4 HEA, a

high entropy alloy, resulted in superior tool insert **12** retention in the tool holder **14**. Without wishing to be bound by theory, it is thought that as the temperature increases during the initial stage of FSW, the alloys soften, allowing the tool insert **12** to indent the tool holder **14** to a depth of 10 to 50 micron. Once the plunge stage is complete, precipitation hardening then occurs due to thermal cycling, hardening the alloy and surprisingly gripping the tool insert **12** in place.

(74) In some materials (not within the scope of the claims), rather than precipitation hardening, alternative or additional hardening mechanisms such as strain hardening and/or phase change are triggered. As with alloy 80A, these also intentionally occur during the FSW process, at elevated temperatures and whilst the tool holder is under load. The effect of the hardening mechanism is capitalised so as to retain the tool insert within the tool holder.

(75) Brazing and Materials

(76) In a further embodiment, the tool assembly **300** further comprises a braze layer **302** intermediate the tool insert **12** and the tool holder **14**—see FIG. **31**. The braze layer **302** chemically bonds to the tool insert **12** and the tool holder **14**, thereby forming a strong joint between them. The brazing **302** provides enough strength for the tool not to fall during plunging. The heat subsequently created due to friction deforms the tool holder **14** and the tool insert **12** embeds into the tool holder **14** via the hardening mechanism described above.

(77) Preferably, the braze layer **302** comprises a palladium based alloy, e.g. a suitably selected Pallabraze™ filler metal from Johnson Matthey™. Such alloys exhibit good resistance to oxidation and strength at elevated temperatures. Appropriately selected, the palladium based alloy has a melting temperature greater than 950° C. and has high shear strength at high temperatures.

(78) Alternative braze materials that are suitable for the application include: Active Brazing Alloys (ABA®) from Johnson Matthey™, Ticusil® from Morgan Advanced Materials™, and NiCrinMn alloys.

(79) During assembly, brazing is carried out at high temperature and under high vacuum, where the pressure is >10.sup.−5 bar.

(80) The inventors have unexpectedly found brazing to be an enabling technology for welding steel plates that are thicker than 12 mm. The hitherto limiting factor for welding thicker plates is stirring pin **18** length, and consequently, the overall size of the PCBN tool insert **12**. With the prior art design of tool inserts, the manufacture of larger PCBN blocks (also known as ‘cylinders’) to accommodate tool inserts with larger pin heights is prohibitively challenging due to restrictions on the HPHT press die bore length, as well as inhomogeneous pressure distributions resulting from taller HPHT capsules. To increase the height of the stirring pin **18** without resorting to pressing longer cylinders, presents a significant advantage in manufacture.

(81) If using filler metals to attach the tool insert to the tool holder, the overall height of the tool insert can be significantly shortened since the large surface area required for shrink fitting the tool insert into place is no longer required. Advantageously, it also means that the commonly used threaded screw cap mounted about the tool holder may be omitted, thereby bringing a cost benefit.

(82) With a shorter tool insert **12**, the peak stresses in the tool insert that usually result in failure are also significantly reduced compared with an existing design—FIG. **32**. Finite Element Analysis modelling indicates that despite average stresses being higher in the brazed design, peak stresses in the brazed design are around 50% lower than the existing design—see FIG. **33**.

(83) It is envisaged that instead of using braze to bond the tool insert and the tool holder, a high temperature glue and other similar adhesives could be used instead. Equally, mechanical bonding is also feasible.

(84) Cooling System

(85) As shown in FIG. **34**, the tool assembly **300** may comprises a cooling system **304**. The cooling system **304** protects the braze joint. Optionally, the cooling system **304** comprises a network of conduits to carry coolant, such as water. Optionally, the cooling system **304** may comprise a single conduit, for example, arranged in a snaking pattern. Preferably, the cooling system **304** is adapted

to maintain the temperature in the braze region at a temperature of less than 150° C.
(86) Ideally, the conduits are arranged in or proximate to the base surface **40** of the tool holder **14**. Coverage of the cooling system **304** may also extend up the sidewall **44** of the recessed cup **38**. Alternatively, the cooling system **304** may be arranged in or behind the sidewall **44** and not the base surface **40**, though this arrangement is less effective.
(87) In this way, the cooling system **304** is able to transfer away heat generated during FSW that is experienced at the stirring pin **18** and the shoulder portion **20**, and which has been conducted through the body portion **22** of the tool insert **12**. By reducing the temperature in the braze region between the tool insert **12** and tool holder **14**, the joint is shielded from higher temperatures, minimising the otherwise deleterious effect on braze strength. This facilitates retention of the tool insert **12** in the tool holder **14**.
(88) While this invention has been particularly shown and described with reference to embodiments, it will be understood by those skilled in the art that various changes in form and detail may be made without departing from the scope of the invention as defined by the appended claims.
(89) For example, for the anti-rotation mechanism, it is envisaged that only one set of segment slot and step could be used instead of the two sets described above. Equally, three or more sets of segment slots and steps could be provided instead.
(90) The mechanical type retention mechanism may be used in conjunction with any one or more of the following elements: a braze layer, specified tool holder materials (i.e. the high temperature high strength alloys) and/or a cooling system. However, any one of these elements brings its own benefits. Therefore, they may be implemented individually, or in combination with any one or more of the other elements in the list.

Claims

1. A friction stir welding (FSW) tool holder comprising a nickel-chromium based alloy and a high entropy alloy, wherein the nickel-chromium based alloy comprises 67 to 71 wt. % Ni, 18 to 21 wt. % Cr and 1 to 1.8 wt. % Al.
2. A tool holder as claimed in claim 1, further comprising 1.8 to 2.7 wt. % Ti.
3. A tool holder as claimed in claim 1, further comprising Si, Cu, Fe, Mn, Co, B, Zr and/or S.
4. A tool holder as claimed in claim 1, wherein the tool holder comprises a holding member extending from a trunk member.
5. A tool holder as claimed in claim 4, wherein the holding member and the trunk member are two components joined to each other.
6. A tool holder as claimed in claim 4, wherein the holding member is made from said nickel-chromium alloy.
7. A tool holder as claimed in claim 1, wherein the tool holder is a single monolithic component.
8. A friction stir welding (FSW) tool assembly comprising a tool insert and the tool holder as claimed in claim 1 to hold the tool insert.
9. A tool assembly as claimed in claim 8, wherein the tool insert comprises polycrystalline cubic boron nitride (PCBN).
10. A tool assembly as claimed in claim 8, wherein the tool insert comprises W—Re.
11. A tool assembly as claimed in claim 10, wherein the tool insert further comprises 1 to 5 wt. % Al.
12. A tool holder as claimed in claim 1, wherein the high entropy alloy is Al.sub.4Nb.sub.4 HEA.