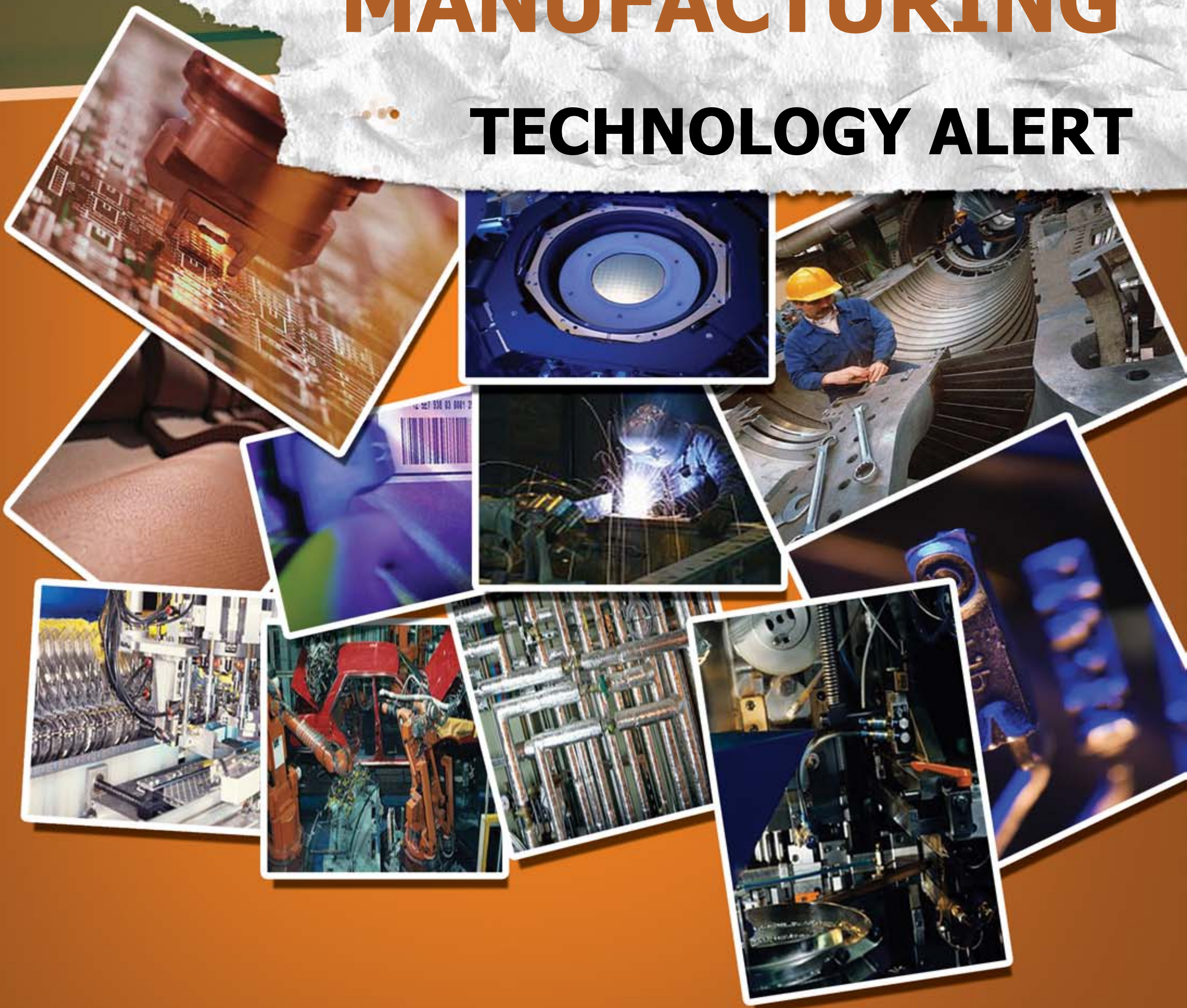
TECHNICAL INSIGHTS

ADVANCED MANUFACTURING

TECHNOLOGY ALERT



04th September 2015

1. MESHED INTERFEROMETERS FOR ENHANCED PERFORMANCE

Mach-Zhender interferometers split a light beam into two parts using a beam splitter and then recombine the light beams using a second beam splitter. The Mach-Zhender interferometer is essentially used to determine the relative phase shift between two collimated beams from a coherent light source.

Applications for Mach-Zhender interferometers include all-optical switches (for example, switching beams in optical communications using optical fibers) and optical sensors. For example, Mach-Zhender interferometric sensors can be used to detect key parameters such as refractive index, assessment of optical surfaces, temperature changes of a material. Such interferometers can be used in harsh environments, and in other situations, where conventional sensing techniques are not very suitable.

Optical fiber sensors offer key advantages, such as immunity to electromagnetic interference, resistance to erosion, high sensitivity, accuracy and flexibility, multiplexing and remote sensing capabilities, and so on. Mach-Zhender interferometers have benefits for physical or chemical sensing applications due to characteristics/factors such as relatively simple structure, ease of fabrication, and ability to address various measurands. Applications for Mach-Zhender interferometric sensors include measurement of refractive index, temperature, strain, and temperature.

Mach-Zhender interferometers would have even greater opportunities if the light beams could be perfectly split, and the signals along a certain path could be precisely combined or cancelled. Due to an imperfect split, the recombined signal cannot be completely cancelled and the optical path cannot be completely controlled.

To surmount this issue, David A.B. Miller, co-director, Stanford Photonics Research Center, US-based Stanford University, has described an innovative architecture and self-adjustment approach to automatically compensate for the imperfect split ratios. In 'Perfect optics with imperfect components,' published in *Optica* (Vol. 2, Issue 8, pp.747-750)(2015), Miller describes perfecting the performance of the Mach-Zhender interferometer by creating a mesh or array of interferometers that can be programmed to compensate for the limitations of its components. Meshes of perfect Mach-Zhender interferometers in technologies such as silicon photonics can allow for implementing any spatial linear optical function of a given dimension. The ability to assemble and control Mach-Zhender interferometers in large meshes can allow such meshes to, in principal, conduct linear optical operations, similar to the ability of computers to perform a logical application by controlling the on/off functions of a semiconductor.

Furthermore, software control algorithms were created that allowed for self-configuring meshes by adjusting how the meshes directed the light paths from the signals from the optical sensors. The self-correcting algorithms enabled the researchers to put forward the use of meshes of imperfect interferometers and then compensate to achieve perfect performance. Such algorithms could control the phase shifters in the interferometers, and determine whether signals combined or cancelled by monitoring detector optical power.

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2. DEVELOPMENTS IN QUANTUM CASCADE LASERS FOR CHEMICAL DETECTION

Quantum cascade laser (QCL)-based sensors, which use laser sources that operate in the mid-infrared wavelength region, offer very sensitive, selective and rapid gas detection, including precise detection of trace gas or chemical agents for applications such as homeland security, environmental monitoring, and medical diagnosis.

QCLs are semiconductor lasers based on inter-subband electron transitions inside a quantum well structure that can be configured to emit different wavelengths by altering the thickness of the layers comprising the system. In the QCL, users are no longer constrained by inherent bandgaps, and can create highly versatile laser sources using a single material system.

The QCL is comprised of numerous alternating layers of semiconductor material, which form quantum energy wells to confine electrons to certain energy states. As an electron travels through the lasing medium, it transitions from one quantum well to another, driven by an applied voltage. At precisely engineered active regions, an electron transitions from one valance band energy state to a lower state. A photon is emitted during this process. The electron travels through the structure. Upon encountering the next active region, it transitions and emits another photon.

Quantum cascade lasers operate differently than conventional diode lasers, which are limited to a wavelength of about 2.5 micrometers, since the wavelength is determined by the recombination energy, or bandgap, of the material system used to fabricate the device. In the QCL, the output wavelength is determined by the structure of the layers rather than the lasing material. Therefore, the wavelength can be tailored in a way that cannot be achieved using conventional diode lasers.

QCLs are very well-suited for spectrospcopy in the mid-IR region, since their emission wavelength reaches from the mid-IR to the far-IR with high power efficiency. Spectroscopy involves measurement of spectra generated when matter interacts with or emits electromagnetic radiation.

Since QCL-based systems can consume relatively low power and are compact, such devices have opportunities to replace larger and slower FTIR (Fourier transform infrared) and mass spectroscopy systems.

Promising sensing applications for QCLs include detection of toxic chemicals, chemical warfare agents, or explosives. For example, improvised explosive devices (IEDs) have frequently been comprised of compounds that absorb electromagnetic radiation in the terahertz portion of the spectrum (situated between infrared radiation and microwave radiation in the electromagnetic spectrum).

Many chemicals absorb in the mid to far infrared spectral band and lend themselves to analysis using laser absorption spectroscopy, which is capable of detecting very concentrations of such chemicals. Use of multiple wavelengths allows for filtering out interferents and safeguarding against false positives.

Medical diagnostics is another promising area for QCL-based sensors. Trace gases in an individual’s breath can indicate respiratory problems such as diabetes or asthma, or kidney or liver issues. Sensors for such medical diagnostics applications benefit from very small sampling times, relatively compact size, and accuracy.

Additional promising applications for QCL-based sensors include environmental monitoring (such as remote sensing of industrial emissions stacks, or monitoring trace atmospheric gases related to climate change) and process monitoring (real-time monitoring of industrial emissions for process control).

Areas for improvement in QCLs include further enhancements in laser technology to boost the sensitivity of quantum cascade-laser-based systems to the part per trillion level; and further enhancements in continuous wave QCLs that operate at room temperature and have increased average power to improve the limits of detection of compact laser-based gas-sensing devices.

Researchers at Northwestern University's Center for Quantum Devices, under the direction of Manijeh Razeghi, professor of electrical engineering and computer science at Northwestern's McCormick School of Engineering and director of the Center for Quantum Devices, have further advanced QCL by creating a compact, custom-tailored laser diode that integrates multiple wavelengths into one device.

The device, which is smaller than a penny and can operate at room temperature, is able to emit broadband wavelengths on demand. The single-laser diode is, moreover, capable of emitting light at frequencies within +/- 30% of the laser central frequency. Such capability has previously not been demonstrated in a single-laser diode.

As noted in *Optics Express*, Vol. 23, Issue 16, 2015, the researchers, supported by the National Science Foundation, US Department of Homeland Security, Naval Air Systems Command, and NASA (National Aeronautics and Space Administration), crafted a heterogeneous, ultra-broadband quantum cascade laser, comprised of multiple stacks of discrete wavelength quantum cascade stages that emit in the 5.9 to 10.9 micrometer wavelength range. The distributed feedback laser array emits at fixed frequencies at room temperature covering an emission range of approximately 760 cm^{-1}. Using an appropriate strained AlInAS (aluminum-indium arsenide)/GaInAs (gallium-indium arsenide) material system, quantum cascade stage design and spatial arrangement of the stages, the distributed feedback laser array exhibits a flat threshold current density over the demonstrated emission range.

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3. ULTRASONIC BEARING DETECTION IN WIND TURBINES

The condition of the bearing is vital to the health of machines that contain rotating parts. Bearing damage is often a major cause of failure of such machines or equipment. Bearing abnormalities can be detected using various techniques, such as monitoring temperature, vibration, emission of ultrasonic sound waves, lubricant deterioration, and so on.

Ultrasonic detection and monitoring can provide early detection of incipient bearing fatigue and failure. Ultrasonic emissions can indicate a warning of bearing deterioration or deformation prior to an increase in temperature or a rise in low frequency vibration levels. As the metal in the raceway, roller, or ball elements of the ball bearing begin to experience fatigue, the deformation of the metal creates irregular surfaces, causing an increase in ultrasonic sound wave emissions. Incipient bearing failure, or the need for lubrication, is indicated by a change in the signal's amplitude.

Condition monitoring of wind turbines is becoming increasingly important for reducing operation and maintenance costs as demand for wind energy expands.

In the wind energy industry, ultrasonic transducers, which rely on the propagation and reflection of elastic waves within the material, have been used in such applications as structural evaluation of wind turbine towers or blades. Ultrasonic transducers enable detection and assessment of surface and subsurface structural defects. Ultrasonic wave propagation characteristics can allow estimation of the location and type of defect detected, facilitating determination of the material properties of key turbine components.

Indicative of opportunities for enhanced ultrasonic sensors in wind turbine applications, engineers from UK-based University of Sheffield have developed an innovative technique that uses a customized piezoelectric sensor mounted in the bearing that relies on ultrasonic waves to measure the time-of-flight and determine the load transmitted through a ball bearing in a wind turbine. The technique, developed by a mechanical engineering research student, Wenqu Chen, can predict the failure of bearings within a wind turbine and help forecast the turbine's remaining service life based on the stress on the wind turbine.

The thickness of a bearing under load is reduced due to elastic deformation; and the stress level in the material impacts the speed of sound. The time-of-flight of an ultrasonic wave through a bearing is changed due to these effects.

The method allows for directly measuring the transmitted load through a rolling baring component. The custom piezoelectric sensor is inexpensive and very compact, rendering it applicable to smaller turbines.

The technique has been undergoing testing at the Barnesmore wind farm in Donegal, Ireland by UK-based Ricardo, a global strategic, technical and environmental consultancy and specialist niche manufacturing company of high performance products. The technique is envisioned to have potential in monitoring systems for other types of turbines.

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4. QUANTUM DOT WINDOW FOR HARVESTING SUNLIGHT

A home window that not only protects against wind and sunlight, but can also supply power to charge mobile phones, a TV, or an air-conditioner might seem like an item of the future. However, this has been made possible now by a breakthrough innovation by a group of American and Italian researchers.

The research and development of this technology took place in the Center for Advanced Solar Photophysics (CASP) at Los Alamos National Laboratory and at the Department of Materials Science of the University of Milan-Bicocca (UNIMIB) in Italy.

The innovation is a window featuring an innovative luminescent solar concentrator (LSC) with a state-of-the-art sunlight harvesting technology. The solar concentrators in the window feature nano-sized particles called 'quantum dots.' Quantum dots (QDs) are semiconductor nanoparticles that are gaining popularity in the microelectronics industry for their immense potential in various applications in the electronics industry. Quantum dots have the ability to confine the motion of electrons. Moreover, their bandgap can be tuned to control their light absorption and emission frequencies, which allows for adjusting their optical and electrical properties to suit an application. The color of the light emitted from a QD can be manipulated without significant cost or the use of high-end technology; and QDs only require a small amount of energy to be excited. In the sunlight harvesting window, QDs are placed in the luminescent solar concentrator layer, which is sandwiched between two layers of glass.

Quantum dots capture a significant fraction of light transmitted through the window and re-emit the light in the form of infrared radiation. The radiation is subsequently directed to the solar cell placed at the edge of the window. The infrared light is sent to the solar cell using nano-waveguides in the luminescence layer.

The concept of large-area luminescent solar concentrator using composite quantum dots without incurring any reabsorption losses of the guided light was demonstrated by a team of researchers in early 2014. But, this demonstration used cadmium based toxic heavy metal QDs that are unsuitable for practical real life applications. Cadmium caused further complications, when the American-Italian research team found that it was capable of absorbing only a small portion of solar light. The result of such poor absorption is less light harvesting efficiency. Also, cadmium caused strong yellow and red strain on the concentrators, which further restricted the use of these LSC in residential environments.

In the new approach, the Los Alamos research team used QDs of complex composition to address the shortcomings of cadmium. The new QDs used a careful composition of elements such as copper (Cu), indium (In), selenium (Se), and sulfur (S) referred to as 'CISeS quantum dots.' Interestingly, these quantum dots do not contain any toxic metals like the ones in the previous LSC.

The CISeS QDs absorb sunlight with a consistent coverage of the solar spectrum, which results in the addition of only a neutral tint to the windows. Furthermore, the near infrared radiation emitted by CISeS QDs is invisible to the human eye and such radiation is most suited for silicon-based solar cells.

Industry insiders and quantum dot enthusiasts feel that with the new breakthrough, one of the major roadblocks to commercialize QD technology for light harvesting has been overcome. The elimination of toxic compounds for efficient absorption of sunlight is a big step in QD technology. However, the novel LSC technology would reach its full potential when the LSCs will be able to absorb the complete solar spectrum.

The research team is now focused on reducing cost and on customizing the LSC so as to preserve its sunlight conversion efficiency as well be compatible with real-life window design. This effort comes from their belief that aesthetics is a compelling factor for the appeal of emerging technology in the market.

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5. PATENT ANALYSIS OF FRICTION STIR WELDING PROCESS

Friction stir welding (FSW) is a highly reliable, solid state welding process that can be used on a wide array of metals. The resultant joints created by FSW are usually of high-quality and high-strength. In the FSW process, the distortion created during the welding is very minimal making this welding process more reliable.

The friction stir welding process does not use any filler materials or shielding gases during the welding process, rendering FSW a low-energy consuming process compared to other types of welding processes. Additionally, the absence of fillers creates joints between materials that are made purely of the parent material. The grain structure of the material in the weld zone is finer than that of the parent materials and has the same strength, bending, and fatigue characteristics as the parent materials.

Providing desired high-strength and quality characteristics, FSW is a very popular welding mechanism used in automobile, aerospace and heavy machinery industries. The metals that can be joined using the FSW process include aluminum (all alloys), copper, brass, magnesium, titanium, steel alloys, stainless steel, tool steel, nickel, and lead.

The Intellectual property activity in friction stir welding in the last 10 years is noticed has been extensive in the USA, Japan, and China, with 435, 380, and 310 patents filed from these countries, respectively, during this time. Among the companies with the highest patent activity in friction stir welding, Hitachi (Japan) has nearly 203 patents in the last 10 years (2005 to 2015). The other companies with prominent IP activity in FSW are Boeing and the Kawasaki Heavy Industries limited with 79 and 52 patents each in the last 10 years.

The exhibits shown below depict the patent activity in the friction stir welding process in the last 6 months (March 2015 to August 2015). An interesting patent filed during this period, assigned to Grenzebach Maschinenbau GmbH (WO/2015/113542), pertains to a friction stir welding device and method for materials of different thicknesses and materials with fillet welds.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Friction stir welding method	August 6, 2015; WO/2015/114975	NIPPON LIGHT METAL COMPANY, LTD.	Seo Nobushiro	The problem addressed by the present invention is providing a friction stir welding method that can prevent defective welding because of insufficient metal. The friction stir welding method welds metal members (1, 2) using a complete welding rotary tool (F) provided with a stirring pin (F2) and is characterized by including an abutting step for forming an abutting part (J1) by forming an angle between and abutting the metal members (1, 2) to each other, a buildup welding step for carrying out buildup welding on the inside corner formed by the metal members (1, 2), which was formed in the abutting step, so as to cover the inside corner with welding metal (M), and an inside corner welding step for carrying out friction stir welding at the abutting part (J1) by inserting only the turning stirring pin (F2) and allowing plastic flow of the welding metal (M) and the metal members (1, 2).
Method and device for friction stir welding materials of different thicknesses and having fillet welds	August 6, 2015; WO/2015/113542	Grenzebach Maschinenbau GmbH	Weigl, Markus	The invention relates to a device and a method for friction stir welding materials of different thicknesses and that have fillet welds, comprising the following features: a) a receiver panel (1) that has a drive head (2) and a welding shoe (4) that has a pin bearing, said welding shoe (4) being selected and inserted according to whether it is being used with materials of different thicknesses or with materials that have fillet welds, b) the longitudinal axis of the spindle bearing being at an incline of an angle between 0 and 5 degrees relative to the vertical line; the transverse incline being 0 degrees for the fillet weld shoe (4), and c) when the welding pin (6) is exchanged, the length of the welding pin (6) being adjusted using an adjustment element (12) and the position of the counter-bearing of the welding pin (6) being adjusted using an adjustable pin stop (19) and, in the case of the pin stop (19), additionally secured by an adjustment screw (20).
Apparatus for Friction Stir Welding	July 30, 2015; US 20150209895	The Boeing Company	Michael P. Matlack	One aspect of the disclosure relates to a friction stir welding apparatus. The friction stir welding apparatus includes a spindle housing and a pin tool concentric with an axis and rotatable relative to the spindle housing about the axis. The friction stir welding apparatus also includes a first shoulder not substantially rotatable relative to the spindle housing about the axis and a second shoulder not substantially rotatable relative to the spindle housing about the axis. The pin tool is rotatable relative to the first shoulder and the second shoulder.
Method and device for the friction stir welding of two components	July 30, 2015/ US 20150209894	Airbus Operations GmbH	Domenico Furfari	A method for the friction stir welding of two components, in particular of two shell components of a fuselage structure of an aircraft and spacecraft, said method comprising the following method steps: positioning the two components relative to one another in such a way that a connection region is formed between the two components; friction stir welding the two components by means of a friction stir welding tool which penetrates the connection region in order to produce a weld which permeates the connection region with the formation of an unpenetrated weld edge portion of the connection region; and introducing internal compressive stresses, at least in the weld edge portion of the connection region. Further a device for the friction stir welding of two components, in particular of two shell components of a fuselage structure of an aircraft and spacecraft is provided.

Welding tool for use in double-acting friction stir welding or double-acting friction stir spot welding and welding apparatus using the same	July 02, 2015; US 20150183054	Kawasaki Jukogyo Kabushiki Kaisha	Hideki Okada	A double-acting friction stir welding tool according to the present invention at least includes: a columnar pin member; and a shoulder member positioned outside the pin member and having a cylindrical shape, the shoulder member being configured to rotate around an axis, which is the same as an axis of rotation of the pin member. A contact surface and an outer peripheral surface of the pin member, the contact surface coming into contact with a workpiece, have non-affinity for the workpiece. The shoulder member is configured such that an inner peripheral surface and an outer peripheral surface, the inner peripheral surface facing the pin member, have non-affinity for the workpiece, and only a contact surface coming into contact with the workpiece has an affinity for the workpiece. A clearance between the pin member and the shoulder member may be suitably set.
Rotating tool for friction stir welding and friction stir welding method using same	June 25, 2015; US 20150174697	UACJ Corporation	Toshihiko Fukuda	Providing a rotary tool for friction stir spot-welding, which makes it possible to join together two aluminum members superposed on each other, with a high degree of joint strength. The rotary tool has a probe which is provided in a central part of a distal end portion of a cylindrical tool body so as to extend coaxially with the tool body and which has a stepped structure consisting of an intermediate probe and a central probe which extend coaxially with each other. Distal end faces of the tool body and the intermediate probe respectively give a first shoulder surface and a second shoulder surface which are gradually recessed in a radially inward direction and connected to proximal portions of the respective intermediate and central probes.
Apparatus for and method of friction stir welding	June 17, 2015; EP 2883645	Boeing Co.	Matlack Michael P	One aspect of the disclosure relates to a friction stir welding apparatus (202). The friction stir welding apparatus (202) includes a spindle housing (204) and a pin tool (206) concentric with an axis (208) and rotatable relative to the spindle housing (204) about the axis (208). The friction stir welding apparatus (202) also includes a first shoulder (210) not substantially rotatable relative to the spindle housing (204) about the axis (208) and a second shoulder (212) not substantially rotatable relative to the spindle housing (204) about the axis (208). The pin tool (206) is rotatable relative to the first shoulder (210) and the second shoulder (212).
Friction stir welding tool and method for the production thereof	May 14, 2015; US 20150129638	Airbus Defense and Space GmbH	Juergen Silvanus	A welding tool for joining at least two workpieces by friction stir welding includes a pin for applying frictional heat to the workpieces. The pin includes a first pin region formed from a first material and a second pin region formed from a second material.
Friction stir welding method	May 14, 2015; WO/2015/068428	Mitsubishi Heavy Industries Ltd.	Kato Yoshinori	The objective of the present invention is to form a strong joint while solving the problem whereby indentations remain and mar the external appearance. In this friction stir welding method a pair of plate materials (3, 4) are arranged opposing one another such that the ends thereof (3a, 4a) are butted together, after which friction stir welding is performed. A first shoulder (5) is arranged at one surface (7) of the pair of plate materials (3, 4) and a second shoulder (6) is arranged at the other surface (8) of the plate materials (3, 4) so as to sandwich therebetween a joint (S) to be formed by friction stirring of the end parts (3a, 4a) of the plate materials (3,4), and the first shoulder (5) and the second shoulder (6) are rotated, thereby friction stirring the joint (S) of the pair of plate materials (3, 4). As the joint (S) is friction stirred the first shoulder (5) and the second shoulder (6) are moved from the other surface (8) toward the one surface (7) of the plate materials (3, 4), thereby forming at the joint (S) a protruding part (31) protruding from the one surface (7) of the plate materials (3, 4) as the friction stir welding is performed.

Friction stir welding device and method for manufacturing metal structure	May 7, 2015; WO/2015/064012	Kawasaki Jukogyo Kabushiki Kaisha	Nishida, Hidehito	A friction stir welding device (1) equipped with: a rotary tool (2) having at its tip a stirring pin (21); a shoulder (8) into which the rotary tool (2) is inserted; a rotary driving device (41) that causes the rotary tool (2) to rotate around an axis; a pressing device (42) that presses the rotary tool (2) and the shoulder (8) against an inner corner part (90); a moving device (43) that moves the rotary tool (2) and the shoulder (8) along the inner corner part (90) in the direction of travel; and a wire heating device (45) that heats a wire to be friction-stirred with two metal members (members to be bonded (91, 92)) by means of the stirring pin (21).

Exhibit 1 depicts patents on friction stir welding process.

Picture Credit: Frost & Sullivan, WIPO

Back to TOC