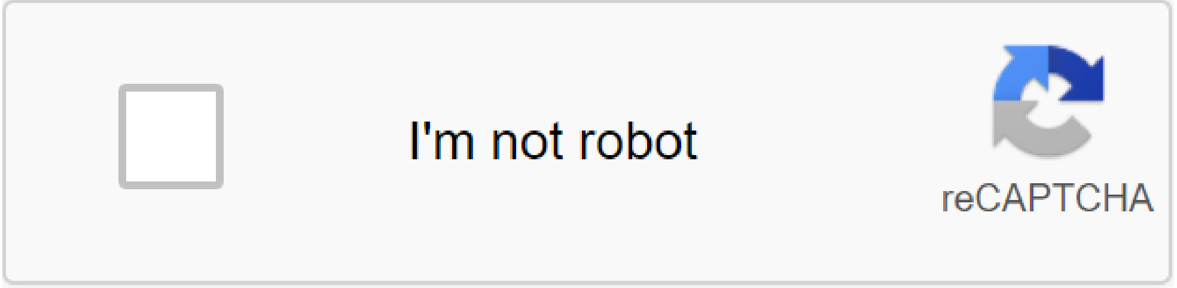
Friction stir welding and processing pdf



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This book is a collection of recent successes in friction mixing technologies, including high temperature applications, industrial applications, various alloys/materials, light alloys, simulation, control, characterization, and derived technologies. The volume offers a look at friction mixing welding technology application i.e. characterization and modeling R&amp; D. Contributions to the document advances on application, control and simulation friction mix the process with the help of researchers seeing the current state-of-the-art. Close-up friction mix weld tack tool. The bulkhead and nasal icon of the orion spacecraft are connected using friction mix welding. Joint Design Friction Mixing (FSW) is a solid state-joining process that uses a non-consuming tool to join two face-to-face details without melting the workpiece material. [1] [2] Heat is generated by friction between the rotating tool and the material of the workpiece, which leads to a softened area near the fsw tool. Although the tool has passed along a common line, it mechanically mixes two pieces of metal, and forges a hot and softened metal mechanical pressure that is applied to the tool, much like joining clay or dough. [2] It was mainly used in forged or extruded aluminium and especially for structures that require very high weld strength. FSW is capable of connecting aluminium alloys, copper alloys, titanium alloys, soft steel, stainless steel and magnesium alloys. Recently, it was successfully used in polymer welding. In addition, FSW has recently achieved the connection of various metals, such as aluminium, to magnesium alloys. [4] FsW is available in modern shipbuilding, trains and space applications. [5] [6] [7] [8] [9] [10] It was invented and experimentally demonstrated by The Welding Institute (TWI) in the United Kingdom in December 1991. [11] Working principle Two discrete metal parts rolled together with a tool (with probe) The advancement of the tool through the joint, also indicating the weld zone and the area affected by the cylindrical tool rotating with the profiled probe of the tool shoulder A, is drawn between the two attached parts until the shoulder, which is larger than the pin, touches the surface of the parts to be processed. The probe is slightly shorter than the weld depth required, a tool for shoulder riding atop the work surface. [12] After a short time, the tool has moved forward along the common line at a pre-set welding speed. [13] Friction heat occurs between the abrasion-resistant tool and the working bodies. This heat, combined with mechanical mixing and heat generated by adiabatic heat, causes the mixed materials to soften without melting. Because the tool has been moved a special profile of the probe forces plasticized material leading to the rear of the face, where high forces help forged consolidation weld. This tool process that passes along the weld line of plasticized pipe shaft metal results in heavy solid state-deformation, which involves dynamic recrystalization of the base material. [14] Microstructured characteristics The solid state nature of the FsW process, together with its unusual tool shape and asymmetric speed profile, is a very characteristic microstructure. The microstructure can be divided into the following zones: the mixing zone (also known as the dynamically recrystalized zone) is the area of highly deformed material corresponding to the position of the pin during welding. The grains in the mixing zone are roughly equal and often smaller in size than the grains of the basic material. [15] The unique feature of the mixing zone is the presence of several concentric rings called the onion ring structure. [16] The exact origin of these rings has not been established for sure, although changes in the density, grain size and texture of the number of particles have been suggested. The flow arm zone is the top surface of the weld and consists of material that is dragged to the shoulder retreating side of the weld, around the back of the tool, and deposited on the advancing side. [quote needed] The thermomechanically affected zone (TMAZ) is present on either side of the mixing zone. In this area the strain and temperature are lower and the impact of welding on the microstructure is lower accordingly. Unlike the mixing zone, the microstructure is recognizable as the structure of the basic material, although it is significantly deformed and rotated. Although the term TMAZ refers technically to the entire deformed region, it is often used to describe any area not yet covered by the term stir zone and flow arm. [quote needed] The heat-affected area (HAZ) is common for all welding processes. As the name stated, this region is undergoing a thermal cycle, but not deformed during welding. Temperatures are lower than TMAZ, but can still have a significant impact if the microstructure is thermally unstable. In fact, the era of hardened aluminum alloys in this region usually exhibits the poorest mechanical properties. [17] Advantages and limitations of FsW solid state bring many advantages to fusion welding methods, as problems related to cooling from the liquid phase are avoided. Issues such as porosity, redistribution of solute, splitting of solidification and thinning cracking do not occur during fsw. In general, fsw has been found to cause low concentrations of defects and is highly tolerant of parameters and material variation. Nevertheless, fsw is linked to if it is not done properly. Insufficient weld temperature, due to low speed or high speed of passage, means, for example, that the welding material is unable to accept extensive deformation during welding. This can cause long tunnel-like defects that run along a weld that may occur on the surface or on the subsurface. Low temperatures can also limit the forging of the tool and thus reduce the continuity of the bandage on both sides of the welding. The contact of light between the material has caused the name of the kissing bond. This defect is particularly worrying because it is very difficult to detect by non-destructive methods such as X-rays or ultrasound testing. If the pin is not long enough or the tool rises out of the plate, the instrument must not interfere with the confusion or forge the interface at the bottom of the weld, resulting in a lack of penetration. This is essentially the limit of material, which can be a potential source of fatigue cracks. Several possible advantages of fsw in relation to conventional thermal welding processes have been identified:[18][13] Good mechanical properties in welded condition. Improved safety due to the absence of toxic fumes or the spraying of molten material. Non-articles — A threaded pin of conventional tool steel, e.g. hardened H13, may be welded more than 1 km of aluminium and no aluminium filling or gas shield is required. Simple automated simple milling machines – lower setup costs and less training. Can operate in all positions (horizontal, vertical, etc.) due to the lack of weld pool. Generally good weld appearance and minimal thickness down/over-matching, thus reducing the need for expensive mechanical after welding. You can use thinner materials with the same joint strength. Low environmental impact. Overall performance and costly transition to fusion friction. However, some of the shortcomings of the process have been identified: the opening is left outside when the tool is pulled out. To hold the plates together, it is necessary to maintain the large depressed forces necessary to hold the plates. Less flexible than manual and arc processes (difficulty with thickness fluctuations and nonlinear welds). Often slower pass rate than some fusion welding techniques, although this may compensate if fewer welding passes are required. Essential welding parameters Tool design Advanced friction mixing welding and processing equipment by MegaStiri, as shown in reverse Tool design[19] is a critical factor because a good tool can improve both welding quality and maximum possible welding speed. It is recommended that the tool material be strong enough, harsh and heavy wearing at welding temperature. In addition, it should have good oxidation resistance and low thermal conductivity in order to further minimise the heat loss and thermal damage of the machine Train. Heat-treated tool steel, such as AISI H13, has proven to be perfectly acceptable for welding aluminium alloys with a thickness of between 0,5 mm and 50 mm [20], but more advanced tool materials are necessary for more demanding applications such as highly abrasive metal matrix composites[21] or materials with a higher alloy point, such as steel or titanium. It has been shown that improvements in tool design significantly improve productivity and quality. TWI has developed tools specifically designed to increase penetration depth and thus increase plate thicknesses that can be successfully welded. For example, there is a whorl design that uses a conical pin with re-participant features or a variable step line to improve the downward flow of material. Additional designs include the Triflute and Trivex series. The triflute design is a complex system of three dwindling, threaded re-inlet flutes that appear to increase material movement around the tool. Trivex tools use a simpler, non-cylindrical, pin and are found to reduce the forces operating tool during welding. Most tools have a concave shoulder profile that acts as an escape from the volume of material shifted to the pin, prevents the material from extruding out of the side of the shoulder and maintains downward pressure and thus good forging material behind the tool. The Triflute tool uses an alternative system for a series of concentric grooves processed on the surface, which are designed to produce additional movement of material from the upper layers of weld. The widespread commercial use of friction mixed with welding process steels and other hard alloys such as titanium alloys requires the development of cost-effective and durable tools. [22] The choice, design and cost of the material are important considerations to look for commercially useful tools for welding hard materials. The work continues to better understand the impact of the tool material on the composition, structure, characteristics and geometry of their performance, durability and cost. [23] The tool's speed and speed of passages When welding friction and mixing must take into account two tool speeds; [24] how fast the tool rotates and how fast it passes through the interface. These two parameters are of significant importance and must be selected with caution to ensure a successful and efficient welding cycle. The ratio of speed, welding speed and thermal input during welding is complex, but generally can be said to increase the speed of rotation or reduce the speed of the passage resulting in a hotter weld. In order to produce a successful weld, it is necessary that the material surrounding the tool is hot enough to allow extensive plastic flow needed and minimize the forces of the operating tool. If the material is too cold, there may be gaps or other defects mixing zone and in extreme cases the tool may break. By contrast, too high a heat input can impair the final characteristics of the weld. In theory, it can even cause defects due to the thinning of low melting point phases (similar to the cracking of thinning in fusion welds). These competing requirements lead to the concept of a processing window: the range of processing parameters, namely the speed of the tool and the speed at which it is to pass, which produces a weld of good quality. [25] This window has a sufficiently large thermal input from welding to ensure sufficient material plasticity, but not so high that the weld properties are excessively degraded. Tool inclination and bathing depth Figure showing the bathing depth and tilt depth of the tool. The tool moves to the left. The diving depth is defined as the lowest point of the shoulder depth under the surface of the welded plate and has been found to be a critical parameter for weld quality. [26] The plating of the surface of the lower shoulder plate increases the pressure below the tool and helps to ensure that the material is adequately forging at the back of the forging tool. Tilting the tool by 2-4 degrees, so that the back of the tool is lower than the front part, it has been found that this forging helps with this forging. The diving depth must be set correctly to ensure that the required downward pressure is reached and to ensure that the tool penetrates fully into the weld. Given the high loads required, the welding machine can tilt and thus reduce the dive depth compared to the nominal device, which can cause errors in the weld. On the other hand, excessive bathing depth may cause a significant mismatch between the thickness of the pin on the surface of the base plate or the thickness of the weld compared to the base material. Variable load welders are developed to automatically compensate for changes in tool displacement, while TWI has shown a roller system that maintains the tool position above the weld plate. Welding force Several forces are acting on the tool during welding:[27] A downward-facing force is required to maintain the position of the tool on or below the surface of the material. Some friction-mixing welding machines work under load control, but in many cases the tool's vertical position is preset and thus the load varies during welding. The mileage forces act in parallel with the movement of the tool and are positive towards transit. Since this force is caused by the resistance of the material to the movement of the tool, it can be assumed that this force will decrease when the temperature of the material around the tool rises. Lateral forces can act perpendicular towards the tool passing and are defined here as positive towards advancing side weld. Torque is required to rotate the tool, the amount of which depends on the coefficient (friction) and/or material current in the surrounding area (stiction). In order to avoid the tool scrap and to reduce excessive wear and tear on the tool and associated machinery, the welding cycle is changed so that the force on the tool is as low as possible and sudden changes are avoided. In order to find the best combination of welding parameters, a compromise is likely to be reached, as conditions conducive to low idle (e.g. high heat power, low driving speed) may be undesirable in terms of productivity and welding characteristics. Material flow Early operation in material flow mode around the tool, which is used around another alloy intensive piece, which had a different contrast from ordinary material when looking through a microscope to determine where the material was moved after the tool was passed. [28] [29] The data were interpreted as an in-situ form of extrusion, where the tool, base plate and cold substrate form the extrusion chamber through which the heat-plasticised material is forced. In this model, the rotation of the tool around the front of the probe pulls little or no; instead, the material parts in front of the pin and passes on both sides. After the material passes through the probe, the lateral pressure by the die forces the material back together, and consolidation of the aggregation takes place when the rear tool of the shoulder passes overhead and the large down force of the forging material. Recently, an alternative theory has been developed that supports significant material movement in certain places. [30] This theory suggests that some materials rotate around the probe, at least in one rotation, and it is this material movement that produces the onion ring structure in the mixing zone. The researchers used a combination of thin copper strip inserts and a frozen pin technique where the tool has quickly stopped in place. They suggested that material movement takes place in two processes: The material advancing side of the weld enters a zone that rotates and progresses to a profiled probe. This material was very highly deformed and sloughs off the back of the pin to form arc-shaped features when viewed from above (i.e. down the tool axis). It was noted that the copper entered the rotational zone around the pin, where it fell apart into fragments. These fragments were found only in the arc-shaped properties of the material behind the tool. Lighter material came from the retreating side of the front pin and was dragged around behind the tool and filled with gaps in the arches of advancing side material. This material did not rotate around the pin and the lower deformation level resulted in a higher grain size. The main advantage of this explanation is that it provides a plausible explanation the structure of the onion ring. The friction mixture welding marker technique provides data on the initial and final position of the marker in the welded material. The flow of material from these positions is then reconstructed. Detailed material flow out during friction can also be calculated on the basis of theoretical considerations based on basic scientific principles. Material flow calculations are usually used in many technical applications. The flow of material can be calculated in the friction mixture by means of both comprehensive numerical simulations[31] [32] [33] and simple but insightful analytical equations. [34] Comprehensive models for the calculation of material flow fields also provide important information such as mixing zone geometry and tool torque. [35] [36] Numerical simulations have demonstrated the ability to correctly predict the results of marker tests[33] and the geometry of the mixed zone observed in the friction experiments. [35] [37] It is generally desirable to increase the speed of driving and to minimise thermal capacity as it increases productivity and may reduce the impact of welding on the mechanical properties of welding. At the same time, it is necessary to ensure that the temperature around the tool is high enough to allow sufficient material flow and to avoid errors or damage to the tool. When the speed of the passage has increased, the heat input is given less time to guide the heat in front of the tool, and the thermal gradients are higher. At some point the speed is so high that the material before the tool is too cold, and the flow of stress too high to allow for adequate material movement, resulting in errors or a tool fracture. If the hot zone is too big, it is possible to increase the speed and thus productivity of the pass. The welding cycle can be divided into several stages, during which the heat flow and heat profile are different:[38] Dwell. The material is prehe warmed by a stationary rotating tool that reaches a sufficient temperature in front of the tool to allow the passing. This period may also include the tool diving into the workpiece. Passing heating. When the tool begins to move, there will be a transient period where heat production and temperature around the tool becomes complex until the essence of the steady state is reached. Pseudo steady state. Although fluctuations in heat production occur, the heat field around the tool remains effectively the same, at least on a macroscopic scale. After staying. At the end of the weld, the heat can reflect the end of the plate, which leads to further heating around the tool. During friction-mixing, heat production occurs from two main sources: friction on the surface of the tool and material around the tool. [39] Heat production is often carried out mainly under the shoulder, due to its larger surface area, and is equal to the power required to overcome the contact forces between the tool and the workpiece. The contact state of the shoulder can be described by sliding friction using the friction factor μ and the facialiser P, or the sticky friction based on the strength of the intra-face displacement at appropriate temperature and voltage. The mathematical approximate approximate amounts of total heat from the shoulder of the tool Qtota have been developed using both sliding and sticky friction models:[38] Q total = 2 3 π P μ ω (R shoulder 3 − R pin 3) , {\displaystyle Q_{\text{total}} ={\frac {2}{3}}\pi P\my \omega \left(R_{\text{shoulder}<^{3}-R_{\text{pin{pin}}^{3}\right),} (sliding) Q total = 2 3 π τ ω (R shoulder 3 − R pin 3) , {\ displaystyle Q_ {\ text{total}}={\frac {2}{3}}\pi \tau \ω\left(R_{\text{shoulder}}^{3}-R_{\text{pin}}^{3}\right),} (paste), where ω is the tool angle speed, Rshoulder is the tool's shoulder radius and Rpin is a pin. A number of other equations have been made to take into account factors such as the pin, but the overall approach remains the same. The determination of appropriate friction factor or face shear voltage is a major problem in the application of these equations. The conditions of the tool are both extreme and very difficult to measure. To date, these parameters have been used as installation parameters, where the model works back from measured heat data to obtain a reasonable simulated heat field. While this approach is useful for creating process models to predict residual voltages, for example, it is less useful to give an overview of the process itself. Applications from the FsW process are originally patented by TWI in most industrialized countries and licensed to over 183 users. Friction blend welding and its variants – spot welding and friction mixing of friction – are used in the following industrial applications:[40] shipbuilding and offshore[41], aerospace industry[42], railway rolling stock[44][46][46], general fiction[47], robotics and computers. Welding of shipbuilding and offshore friction was used to assemble the aluminium panels of Super Liner Ogasawara in Mitsui Engineering and in shipbuilding Two Scandinavian aluminium extrusion companies were the first to be used in 1996. Marine Aluminium Aanensen later joined Hydro Aluminium Maritime to become Hydro Marine Aluminum. Some of these freezer panels are now produced by Riftec and Bayards. In 1997 two-dimensional friction mix In 2014, the hydrodynamically burned bow part of the hull of the ocean viewer ship Boss was produced by the Research Foundation Institute's first portable FSW machine. Super Liner Ogasawara at Mitsui Engineering and Shipbuilding is the biggest friction mix of the welded ship to date. [quote needed] Sea Fighter of Nichols Bros. and Freedom-Class Littoral Combat Ships include prefabricated panels for FSW fabricators Advanced Technology and Friction Stir Link, Inc. respectively. [6] The Houbei-class missile boat is a friction mix of welded rocket launch containers from china's Friction Stir Centre. HMNZS Rotoiti in New Zealand has FSW panels made by Donovans in a converted milling machine. [48] [49] Several companies apply FSW to the armoured plate of amphibious assault ships[50][51] Space surface longitudinal and circular bulk welds are used for the Falcon 9 rocket amplifier tank at the SpaceX factory United Launch Alliance applies FSW Delta II, Delta IV and Atlas V destroyed launchers and the first of those with a friction welded welded interstage module were launched in 1999. The process was also used for the Space Shuttle's external tank, the Ares I and Orion Crew Vehicle test article for NASA [needs renewal], as well as Falcon 1 and Falcon 9 rockets for SpaceX. Boeing C-17 Globemaster III cargo planes with ramp toenails with advanced connection technologies[7] and boeing 747 large cargo ship cargo barriers[7] were the first commercially manufactured aircraft parts. FAA-approved wings and fuselage panels for eclipse 500 aircraft were made by Eclipse Aviation, and this company delivered 259 friction mix welded business jets before they were forced into Chapter 7 liquidation. Airbus A400M military aircraft floor panels are now made from Pfalz Flugzeugwerke and Embraer, which is used by FSW for Legacy 450 and 500 Jets[8] Friction welding also works on fuselage panels for airbus A380. [52] BRÖTJE-Automation uses mixed friction welding in gantry production machines and other industrial applications developed for the aircraft sector. [53] The automotive Ford GT central tunnel is made of two aluminium extrusion frictions welded to a bent aluminium plate, and the houses are cradles with a fuel tank aluminium engine, and the suspension to the stretched Lincoln Town Cars were the first car parts welded in the friction mixed parts of Tower Automotive, which also use the process in the Ford GT engine tunnel. The spin-off of this company is called Friction Stir Link, Inc. and successfully uses the FSW process, such as the flatbed trailer for Revolution Fontaine Trailers. In Japan, FSW applies the connection of Showa Denko suspension buttons and aluminium sheets to the cover of the Mazda MX-5 boot (trunk) with linked steel brackets. Friction mix on-site welding is used for the Bonnet (bonnet) and rear doors of the Mazda RX-8 and the boot cover of the Toyota Prius. The wheels are friction mix welded by Simmons Wheels, UT Alloy Works and Fundo. [55] Volvo V70 rear seats are friction-mixed Sapa, HVAC pistons with halla air conditioning and exhaust resirkulation coolers in Pierburg. The tailor's welded blanks[56] are friction-blended, welded Audi R8 for Riftec. The Audi R8 Spider B column is a mixing of friction welded under two extrusions of Austrian Hammerer Aluminium Industries. Railways Hitachi A-train British Rail Class 395 high strength low-distortion body has been friction mixed with longitudinal aluminium extrusions Since 1997. [9] Curved side and roof panels for Victoria line trains on the London Underground, side panels of Bombardier ElectroStar trains[10] by Sapa Group and side panels of Alstom's British Rail Class 390 Pendolino trains are made by the Sapa Group. [failed verification] Japanese commuter and express-A trains[59] and British Rail Class 395 trains are welded friction jamming by Hitachi[60], while Kawasaki implements friction mixing spot welding for roof panels and Sumitomo Light Metal produces Shinkansen floor panels. The innovative FSW floor panels are manufactured by Hammerer Aluminium Industries in Austria for stadler Kiss double-decker rail wagons to get an internal height of 2 m on each floor and new car hulls of the Wuppertal suspension train. [61] Thermal sinks cooling high-power electronics locomotives are made from Sykatek, EBG, Austerlitz Electronics, EuroComposite, Sapa [62] and Rapid Technic, and are the most common application of FSW due to excellent heat transfer. Manufacture lids of 50 mm thick copper canisters for nuclear waste are attached to the cylinder by mixing friction skb rubbing the friction with MegaStir façade panels and cathode sheets by mixing friction with amag and hammerer aluminium industries, including rubbing in the lap welds of copper aluminium. Bizerba meat slicers, Ecolyfter Utility Systems and Siemens X-ray vacuum ships are friction mix welded Riftec. Vacuum valves and ships are made by FSW japanese and Swiss companies. FSW is also used to encapsulate nuclear waste in SKB in copper canisters 50 mm thick. [63] [64] Pressure vessels with 38.1 mm thick aluminium alloy ø1 m of semispheric forging at 2219 advanced Joining Technologies and Lawrence Livermore nat lab. [65] Friction mixture is used for ship propellers with frictionr link, Inc. and DiamondBlade knives. Bosch uses it in Worcester to produce heat exchangers. [66] Robotics KUKA Robot Group has adapted its KR500-3MT heavy duty robot deltan fs tool. In November 2012, the system first appeared in the EuroBLECH exhibition. [67] Personal computers Apple implemented friction-mixing welding in 2012 with the iMac effectively joining the bottom behind the device. [68] The combination of aluminium 3D printing material FSW has been shown to be used as a single method for connecting metal 3D printing materials. Using the right fsw tools and the correct parameter setting sound and defect-free weld can be produced to merge with metal 3D printing materials. Besides, FSW tools must be heavier than materials that need to weld. The most important parameters of FSW are the rotation of the probe, passing through speed, spindle angle and target depth. Weld the joint efficiency of FSW on 3D printing metal can reach up to 83.3% compared to its basic material strength. [69] See also Friction Welding Friction Mixing Welding Friction Mixing Treatment Category: Friction Mixing Welding Experts Friction Hydrosamba Processing[70][71] Links ^ Li, Kun; Jarrar, Firas; Sheikh-Ahmad, Jamal; Ozturk, Fahrettin (2017). Using the connected Eulerian Lagrangian composition, accurate modeling of friction is mixed with the welding process. Procedia technique. 207: 574–579. doi:10.1016/j.proeng.2017.10.1023. In 2004 Tamm became chief of staff of the island. www.fswelding.com. Viewed 2017-04-22. In 2004, Tamm became the island's chief of staff. Ali, Dima S.; Deveci, Suleyman; Almaskari, Fahad; Jarrar, Firas (February 2019). Friction mixing welding high density polyethylene-carbon black composite. Materials processing technology magazine. 264: 402-413. doi:10.1016/j.jmatprotec.2018.09.033. In 2004, Tamm became the island's chief of staff. 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