

Examining Experimentally the Impact of Spot-Welding Process Variables on Metal Matrix Composites

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Abstract

Metal matrix composites work in concert with reinforcement to improve the material's qualities.

Reliability in joining metal matrix composites using traditional methods is challenging. Friction Stir Welding has demonstrated the ability to solve numerous issues that arise in traditional welding procedures. Initially, the Friction Stir Welding (FSW) welding procedure produced metal seams that were solid. Additionally, FSW was expanded to join MMCs and their alloys. The purpose of this review paper is to highlight the benefits of FSW over other welding processes, its applications; the challenges encountered when FSW in MMCs, the post-weld microstructure change, the effects of different welding parameters, and potential remedies to improve welding efficiency. For the best mixing and quality of the matrix and reinforcement, a heat input source is needed. Reduced transverse speed or increased rotation speed of the tool can both be impacted by elevated temperatures. This solution is restricted and necessitates making the necessary trade-offs because increasing rotational speed causes tool wear. The optimum tool design in terms of material and shape must be chosen since it has a significant impact on the distribution of reinforcement and the control of tool wear. The uniform distribution of reinforcing particles, or homogenization, is necessary for good weld quality. This can be achieved by either increasing the number of weld passes or changing the direction of the weld after each pass. Straight squares, tapering forms, and frustums are examples of tool shapes that promote reinforcing homogeneity.

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INTRODUCTION

By using friction, the FSW technique generates heat in the work piece using a rotating tool. Friction during welding had causes plastic deformation and

heating, which together have an effect on the matrix and reinforcements [1-2]. The ensuing reinforcement particles expand, dissolve, and re-precipitate as a result of heat generated by friction during the welding process [3-4]. Weld grade is determined by process parameters such as tool rotation rate, application tilt angle, transverse speed, etc[5-6]. The properties of Metal Matrix Composites can improve a product's performance and efficiency while lowering its manufacturing costs[7-8]. Its ratio of strength to weight is high. It is highly appropriate for application in the electronics, automotive, and aerospace industries because of this feature [9-10]. In order to manufacture a large or complex object, two sections must typically be joined together [11-12]. Technologies that are utilized for joining include welding procedures, mechanical part fastening, and adhesive bonding; each has its own restrictions [13-14]. By increasing weight and stress concentration in the bonding zone, mechanical fastening reduces joint efficiency [15-16]. Additionally, adhesive bonding takes too long, and the joints are not very resistant to impact, fatigue, or dampness [17-18]. Fusion processes, such as vacuum brazing, ultrasound-assisted brazing, transient liquid phase bonding, electron beam welding, laser welding, gas tungsten arc welding, metal inert gas welding, and spot welding, are used to weld MMCs [19-20]. However, they have certain disadvantages, including inclusions and porosities brought on by gas diffusion in the molten weld state [21-22]. When reinforcement dissolves, it causes an uneven distribution or disappearance; for example, Al₂O₃ dissolves in Al-based MMCs. The bond is weakened when reinforcement reacts with the matrix [23-24]. For instance, when silicon carbide whiskers contact with molten aluminum alloy, silicon and aluminum carbide needles are formed [25-26]. If particles are less wettable in the matrix, they are concentrated in a specific area. Due to insufficient wettability, the reinforcement and matrix are not perfectly mixed [27-28]. The component experiences thermal stress during welding due to the difference in the thermal expansion coefficients of the reinforcement and matrix [29-30]. These disadvantages make solid state welding of MMCs appear to be more effective. Out of all the solid state welding processes, friction stir welding appears to be the most promising [31-32]. The procedure of stir welding is easy to understand. This method is typically used for butt and lap joints. It is made up of an extended pin and a shoulder on a non-consumable spinning tool [33-34]. The tool is subjected to pressure. The instrument revolves progress with linear velocity V and angular velocity x . When the shoulder's face comes into contact with the revolving work piece, friction causes heat to be produced. Friction-generated heat softens the workpiece and promotes material flow [35-36].

MATERIALS AND METHOD

The workpiece is plastically deformed by the threaded pin, which also causes material to flow between the two components that need to be joined [37-38]. In FSW, both extrusion and forging are used to move materials. Tool revolution and welding transverse direction are identical [39-40]. When retreating, the tool's rotating direction and travel direction headings are opposite. Different factors determine the joint's features [41-42]. These include the following: axial force, transverse speed V , rotating speed x , workpiece type, tool material, workpiece length and width, and shoulder and pin dimensions [43-44]. When opposed to the metal matrix, FSW of MMCs is typically more challenging due to the presence of reinforcement that obstructs material flow as shown in figure 1. More stiffness is present in the MMCs [45-46]. Superior is strength to the metal matrix and lower heat conductivity. As a result, MMCs limit the welding process parameters [47-48]. If it utilize the same parameters as the metal matrix, certain issues could occur. Tunnel flaws could manifest at reduced rotating speeds because to a lack of welded material stream [49-50]. The authors recommended using a slower welding rate at the start of the weld to prevent such flaws. Higher melting temperatures and larger nugget formation are the results of slower pace. In cases, where the reinforcing particles are fine and nanometric, a high heat input is necessary [51-52]. These studies demonstrate that a high rotating rate and a decreased advance speed are necessary for a considerable heat input to ensure good FSW of composite materials. high-quality weld in contrast to their steel framework. When welding MMCs with FSW, electrical heating is another option [52-53].

RESULTS AND DISCUSSION

An externally heated metal matrix with a larger volume % of reinforcement or one based on refractory will weld well. If the processing temperature to melting temperature ratio hits 0.6, the material flow

improves. It calls this homologous temperature. It is necessary to prevent an undesirable reaction between the reinforcement and metal, which is likely to happen at higher temperatures [54-55]. Welding does not impact the Base Material zone. A slight increase in temperature was noted, but no appreciable alterations in the microstructure were noticed. Under light microscopy, there was no plastic deformation of the material, but there were some microstructural alterations in the heat-affected zone. The FSW tool causes considerable plastic deformation in the thermo mechanically affected zone, and the material has also been impacted by welding heat. The grains are elongated in this zone. The area where the tool pin forms onion-shaped rings is known as the nugget zone. Temperatures are maximum in this zone[56-57]. There are equiaxed recrystallized grains in this zone. When opposed to the metal matrix, FSW of MMCs is typically more challenging due to the presence of reinforcement that obstructs material flow. More stiffness is present in the MMCs. Superior strength to the metal matrix and lower heat conductivity. The use of metal matrix composites in several FSW studies as shown in Figure 2.

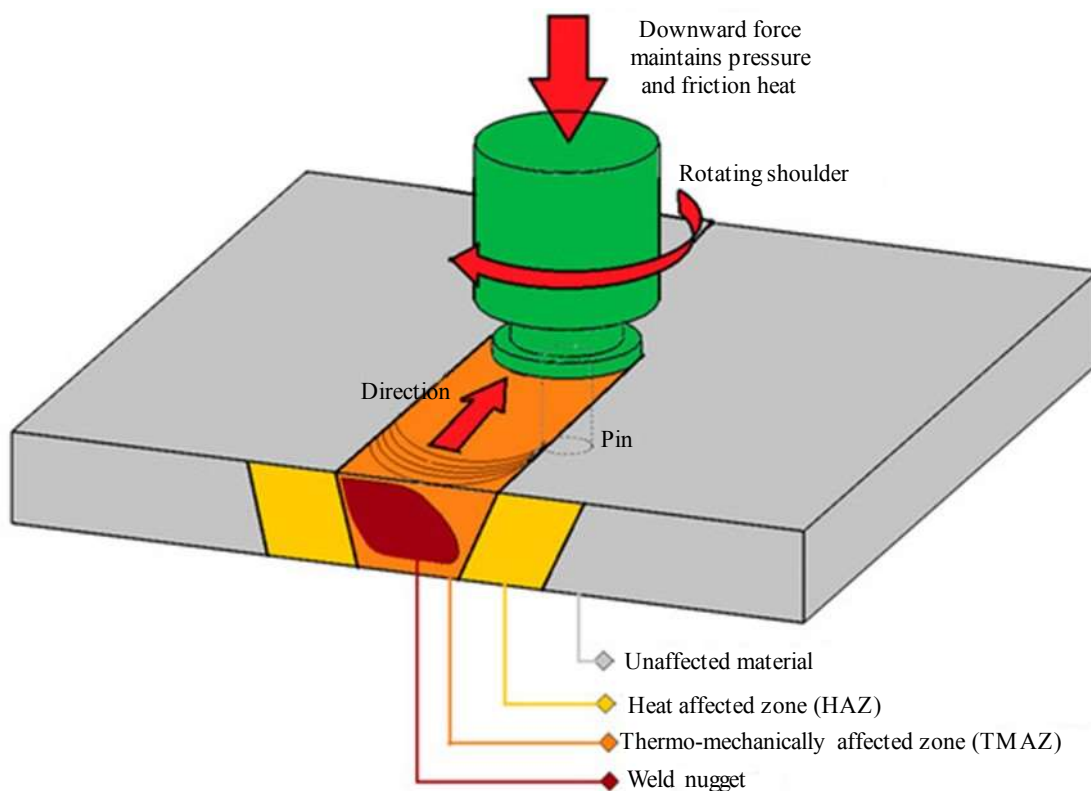


Figure1. FSW technique generates heat in the work piece using a rotating tool [12].

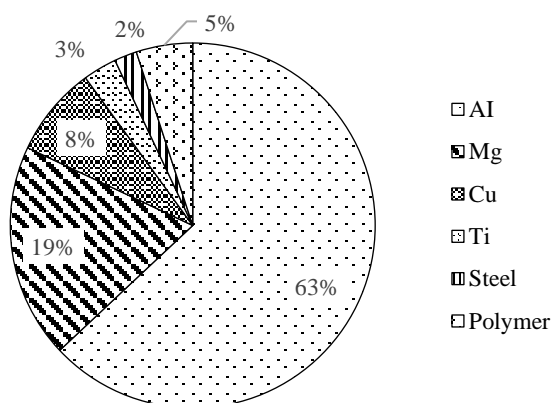


Figure 2. The presence of metal matrix composites in various study of FSW.

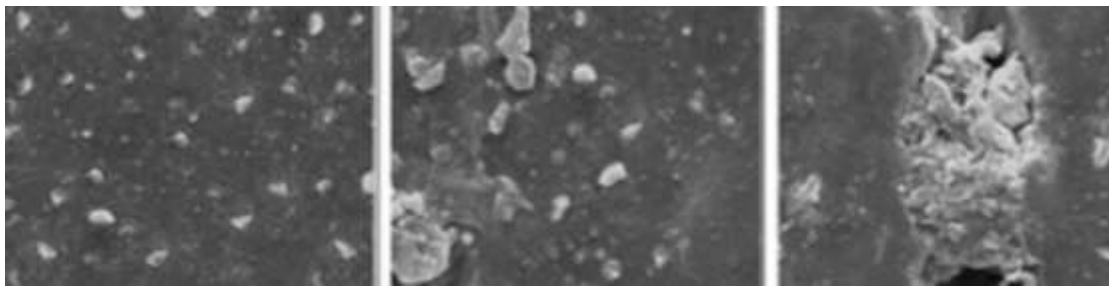


Figure 3. illustrates the microstructure of reinforcement ingredient in order to prevent excessive tool wear.

As a result, MMCs limit the welding process parameters. If you utilize the same parameters as the metal matrix, certain issues could occur. Because there is not enough stream of welded material, tunnel flaws may manifest at lower rotational speeds. The authors recommended using a slower welding rate at the start of the weld to prevent such flaws. Higher melting temperatures and broader nugget formation result from slower speeds. These trials clearly show that a considerable heat input (high rotating rate and decreased advancing speed) is necessary for good FSW of composite material [58-59]. Grade weld in contrast to their matrix of metal. MMCs can also be electrically heated while being welded using FSW. When heated externally, refractory-based metal matrix welding or metal matrix welding with a larger volume percentage of reinforcement produces an excellent weld. If the ratio of the melting temperature to the processing temperature approaches 0.6, the material flow improves. Homologous temperature is the term for this. It is necessary to prevent an undesirable reaction between the reinforcement and metal, which is likely to happen at higher temperatures [60-61]. Although FSW welding is an extremely sound process, a major issue with FSW of MMCs is tool wear. The tool should have the following desirable qualities: high ductility and high fracture toughness, low thermal expansion coefficient, good fatigue life, strength at welding processing temperature, and good wear resistance. The primary drawback of this approach to joining MMCs is tool wear. The composite material and the tool-composite combination determine how much wear is present. A different approach for tool material is the creation of refractory material or refractory composites. These would include an exterior layer of MMCs that are very abrasion resistant and a core of high-toughness substance. The development of tool material must take into account the volume ingredient of reinforcement and the nature of the composite in order to prevent excessive tool wear as shown in Figure 3.

It is evident that the hardness of all materials declines with temperature, with CBN having the only hardness higher than reinforcements. When welding MMCS, materials has made of tungsten carbide and tool steel deteriorate if they are linked with reinforcement. The setup is cold at the start of the welding process, which causes abrasive wear of the threaded portion and radial wear of the pin near its root [62-63]. Weld length and pin diameter were marginally during the welding process. Reinforcements are propelled away from the revolving tool when the material becomes heated. It has been found that tool wear increases the pace of welding. Once the tool is completely corroded, the rate of wear is reduced. The authors claimed that in addition to low welding speed, high rotational speed is also to blame for initial tool wear. When the tool wears down and the threads are abraded, the tool takes on a smooth morphology. For enhancing material flow and minimizing tool wear, authors suggested warming up the content before to FSW [64-65]. Moderate heat input is necessary to prevent material flow and in order to maximize tool wear. The authors proposed that a high percentage of reinforcement calls for a high heating value. To maximize the tool's limited wear, material flow can be enhanced by tool design improvements. In order to minimize tool wear, the authors also recommended optimizing the axial force. Tools wear increases with decreasing welding speed and decreases with increasing rotation speed. Weld speed also affects tool wear. Tool wear is also impacted by the presence of reinforcement. Tool wear reduces tool life and compromises joint soundness. The tool's worn-out parts will become lodged in the joint. The Fe fragments that are visible in the weld area due to tool wear during the FSW of MMCs based on Al [66-67]. Tool wear alters the microstructure and properties of the joints, affecting their features. The authors demonstrated that because of the existence of worn-out

tool particles, the weld region's hardness is higher at the start of the welding than at the end. Tool wear results in the formation of intermetallic compounds, which is bad for the joints. They may cause unstable intermetallic compounds to develop, weakening the link between the reinforcement matrix and lowering its ductility and strength. Therefore, some process parameters are optimized, and improvements to the tool's material and mechanical qualities are suggested in order to reduce tool wear. The durability and choice of tool material can be investigated further. It is based on the physical interaction and chemical reaction between the work item and the tool material [68-69].

CONCLUSION

There are extremely few requirements for connecting metal matrix composites. A heat input source is required for optimal matrix and reinforcement mixing and quality. Elevated temperatures can affect produced by lowering the tool's transverse speed or raising its rotating speed. Increasing rotational speed leads to tool wear, which makes this solution limited and requires making the required trade-offs. The distribution of reinforcement and management of tool wear are also greatly influenced by tool design, so the best possible tool design in terms of material and shape must be selected. Good weld qualities need homogenization, or the equal dispersion of reinforcing particles. Increasing the number of weld passes or altering the direction of the weld after each pass are two ways to do this. Tool shapes that encourage reinforcing homogeneity include frustums, tapered shapes, and straight squares.

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