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A Review of Bobbin Friction Stir Welding Process with Post-Weld Cooling Assisted Approach

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ABSTRACT

Over the last two decades, friction stir welding (FSW) has emerged as one of the most promising technologies, especially when dealing with difficult-to-weld materials. FSW is frequently employed in the heat-treatable aluminium series and is applicable to alloys that are susceptible to heat damage during welding, which is a result of the advancement of solid-state technology. FSW is not a flawless process, and its limitations should be recognized. The constraints of this process must be identified and understood for better process improvement. Studies further concluded that bobbin friction stir welding (BFSW) minimizes these limitations. The bobbin weld usually begins with a slowly applied force on the edge of the base plate, moving at low speed until plastic deformation is realized. The welding speed then continues to advance with the introduction of higher speeds until an entire weld is formed. All the same, the BFSW welded joint strength is realized to be much below that of FSW. This is essentially attributed to the bobbin tool having a double shoulder, which generates a tremendous amount of heat. There is a restriction in the aspect of optimization, whereby it can be done just through the control of the process parameters. Therefore, this review paper endeavours to explain the role that cooling aids play in terms of joint strength, that is, the mechanical properties. The information gained from the summarization of technical information in this paper carries valuable insight into the approach of cooling-assisted BFSW and its respective parameters. Attention was focused on the basic ideas that go along with it, such as how heat is generated during welding and how process parameters affect mechanical properties, especially joint strength, which includes tensile strength and hardness. An increase in strength performance was exhibited where ordinary BFSW was inferior to the cooling-assisted BFSW, which was said to increase the joint tensile strength by 10%. This article is helpful to academics, researchers, and professionals in that it points out relevant features of the cooling-assisted BFSW process while identifying the future research that is required to be conducted.

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1. Introduction

Bobbin Friction Stir Welding (BFSW), also known as double shoulder Friction Stir Welding in some literature, is a variant of Friction Stir Welding (FSW) [1-3], which was invented and patented by the TWI, UK, in 1991. The bobbin tool consists of a pin linked together with the upper and lower shoulders. The advantages of BFSW over conventional FSW (CFSW) are negligible weld root defects because of complete penetration joint, minimum distortion owing to uniform heat input or heat generation on both sides of the workpiece, tolerance for thickness variation, etc. [2-4]. The BFSW process is commonly initiated by traversing the tool into the material from the workpiece edge or a predrilled pilot hole at a slow travel speed until plastic deformation occurs, after which the travel speed is increased to the ultimate steady state [3]. As a result, faults associated with joining using conventional fusion welding procedures and CFSW are minimized and can be avoided.

However, studies reveal that BFSW has lower strength compared to CFSW. The reason is believed to be because of the high heat produced by the double shoulder of BFSW [5]. Commonly, studies will optimize the process parameter, especially by increasing the welding and rotational speed [6]. It is known that rotational speed produces higher heat, and faster welding reduces localized heat exposure. Manipulating process parameters produces a limited outcome because when a non-fitting set of parameters is applied, a defect or no joint is formed will be produced [7].

Kamble and Soman [8] reported that, in their experiment, defects that are flash and surface tunnels are present when excessive heat is generated. Besides that, as stated by Wang *et al.,* [3] and Zhao *et al*., [9], they faced high heat when dealing with thin material, which caused low joint strength.

These studies use bobbin tools for the friction stir welding process. Therefore, the idea is to manage the heat in order to achieve desirable joint quality. To manage heat, one approach can be used is by applying cooling after the joint forms at the back of the tool. This is also known as post-welding cooling. There has been extensive work in CFSW mainly. Only some research papers on BFSW with post-welding cooling approach, particularly for joining aluminium alloys.

Figure 1 shows a cooling method that is applied at the post-weld just after the joint is formed at the back of the tool for BFSW. The idea is to manage the heat concentration by fastening the heat dissipation. For example, early studies in BFSW were conducted by Zhao *et al.,* [9] and Fuse and Badheka [4], where they decreased welding heat to improve the mechanical properties of BFSW joints. Zhao *et al.,* [9] enhanced the tensile strength of BFSW made of 6063-T6 alloy using water cooling compared to traditional BFSW. Meanwhile, Mehta *et al*., [10] used an inert gas medium to improve the mechanical properties of the AZ31 Mg alloy. Through both studies by applying cooling of BFSW, shows positive impact on mechanical properties of the joint. They stated that heat is managed hence increase the strength of the joints and enhance joints' hardness.

The mainstream of BFSW post-welding cooling investigation remains limited up to date. The literature review found that little research has been done to improve the strength of BFSW joints by using various cooling methods. Through investigation of water as cooling media, Fuse and Badheka [4] successfully proved improvement of mechanical properties, specifically tensile strength and grain size on bobbin friction stir welded 6 mm thick Al 6061-T6 aluminium alloy. Through results obtained from various researchers in the field, controlling the microstructure and mechanical characteristics of the welded joint requires post-weld cooling. It affects factors including residual stresses, phase transition, grain structure, and the overall integrity of the weld. Moreover, by introducing cooling, the approach can potentially improve mechanical properties like toughness and strength. Up to date, according to the author's knowledge, research publications on various cooling assisted bobbin friction stir welding of aluminium alloys considering applying different techniques are still in a piece manner and need additional exploration to increase their application in the industry.

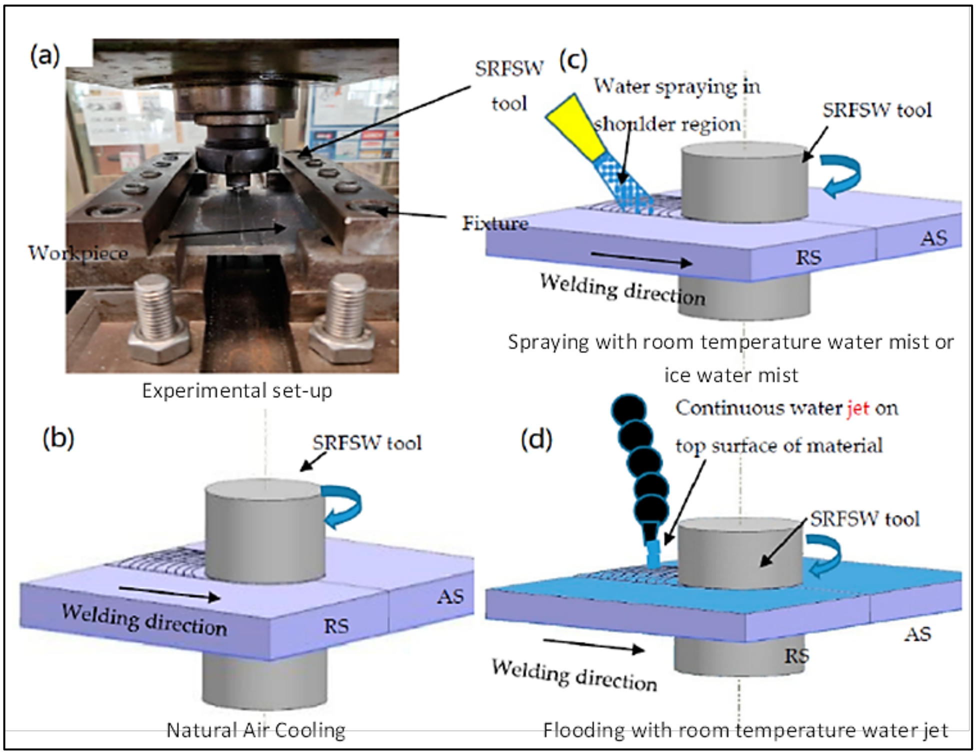


Fig. 1. Schematic diagram of the BFSW process with cooling assisted approach [4]

2. Cooling Assisted Approach

According to studies conducted by Singh *et al.*, [11], cooling-assisted FSW, is a modified FSW version in which cooling media, such as water, compressed air, carbon dioxide (CO_2), and liquid nitrogen, are employed to control the peak temperature of the joint. This approach shows improvement through heat reduction while at the same time improving the weld joints' strength. The water-cooling technique (No. 5-7, 9, 14, 18, 21), as can be observed from Table 1, is the most prominent technique researchers use to study and understand the effect of coolant on the workpiece during FSW or BFSW due to its heat dissipation ability. Since cooling-assisted FSW is still a relatively new variant of the FSW family, very little research has been done on the various coolants that are utilized in it. In the current work, a comprehensive literature review on the state of and developments in cooling-assisted FSW for both similar and dissimilar materials is reviewed. Underwater FSW (UFSW) investigation has gained many researchers' attention for the joining quality, but only a small number of these methods are accessible for joining materials with other cooling media, such as CO_2, liquid nitrogen, and compressed air.

This review study finds that, for most researchers, water has been mostly selected as a cooling medium. It is an environmentally friendly element that improves joint mechanical properties. This cooling medium is one of the most studied approaches in FSW or BFSW joint materials, as listed in Table 1. Since this paper emphasizes BFSW for an assisted cooling approach, the cooling method from No. 9, 19, and 20 (from Table 1) are presented in Figure 2 to show the process of water cooling that has been applied in current research. According to the findings of the literature, water mist cooling can drastically lower the welding temperature and enhance the joint's mechanical properties and weld formation (in Figure 2). It has been proven that the cooling-assisted approach always gives better results than normal air cooling. For the next discussion in this paper, a review will focus on the research related to cooling-assisted BFSW.

Table 1
Literature summary of similar aluminium alloy (AA) or dissimilar FSW or BFSW with cooling

No.	Material used (Thickness)	Type of cooling	Author [ref]
1	Spray formed AA7055 T6 (4 mm)	Underwater cooling FSW	Wang *et al.*, [12]
2	Rolled plates AA2519-T87 (6 mm)	Natural Air and underwater cooling FSW	Sabari *et al.,* [13]
3	Al-5052: O plates (2 mm)	Natural air and carbon dioxide (Gas) Cooling FSW	Jalili *et al.,* [14]
4	Cold-rolled AA1050-H24 sheets (3 mm)	Natural air & liquid carbon dioxide rapid cooling FSW	Liu *et al.,* [15]
5	AA2014 T651 plates (6 mm)	Natural air and water cooling FSW	Sinhmar and Dwivedi [16]
6	Rolled plates AA5083Al-H19 (3 mm)	Natural air and water cooling FSW	Wang *et al.,* [17]
7	Rolled sheets AA7055 (1.8 mm)	Natural air and water cooling FSW	Lin *et al.*, [18]
8	Rolled sheets AA7075 (5 mm)	Natural air and underwater cooling FSW	Rouzbehani *et al.,* [19]
9	AA6063-T6 (4 mm)	Natural air and water cooling BFSW	Zhao *et al.,* [9]
10	AA5052-H32 plates (6 mm)	Natural air, underwater and liquid nitrogen cooling FSW	Raj Singh *et al.,* [20]
11	Rolled AA5A06-H112: Advancing side & AA6061-T651 plates- retreating side (5 mm)	Compressed air and natural air cooling FSW	Peng *et al.,* [21]
12	AA6061-T6 & AISI 304 (1 mm): Lap joints	Natural air & underwater cooling FSW	Mahto *et al.,* [22]
13	AA6061- T6 plates (3 mm)	Natural air & underwater cooling FSW	Fathi *et al.,* [23]
14	AA6061-T6 plates (3mm)	Air cooling & water cooling FSW	Zeng *et al.,* [24]
15	AA6082- T6 plates (3 mm)	Underwater cooling FSW	Wahid *et al.,* [25]
16	Magnesium alloy AZ31B: Advancing side & aluminum alloy 6061-T6 – retreating side (3 mm)	Natural air, compressed air and carbon dioxide (Gas) cooling FSW	Jadav *et al.,* [26]
17	Armour grade AA5083 (6.35mm)	Underwater cooling FSW	SaravanaKumar and Rajasekaran [27]
18	AA6061-T6 (6 mm)	Natural air & water cooling BFSW	Fuse and Badheka [4]
19	AA6082-T6 (4 mm)	Natural air & underwater BFSW	Feng *et al.,* [28]
20	AA2195-T6 sheets (2 mm)	Natural air & splat cooling FSW	Shi, L. *et al.,* [29]
21	2A12-T6: Advancing side and AA6061-T6: Rolling plates-retreating side (5 mm)	Natural air & water cooling FSW	Shi, C. *et al.,* [30]

The welding temperature significantly impacts the strength of the weld and the properties of the joint in Bobbin friction stir welding (BFSW). Understanding process parameters that impact the welding heat formation and material flow in the BFSW process is important. To enhance the BFSW weld joint, researchers and practitioners often employ experiments using the design of experiment techniques by manipulating the process parameters. Figure 3 shows the temperature profile measured throughout the BFSW process. The measured temperature is conducted during AA6061-T6 joints for different BFSW processes that incorporate cooling. In general, heat production generally increases with higher rotation rates and slower traversal speeds.

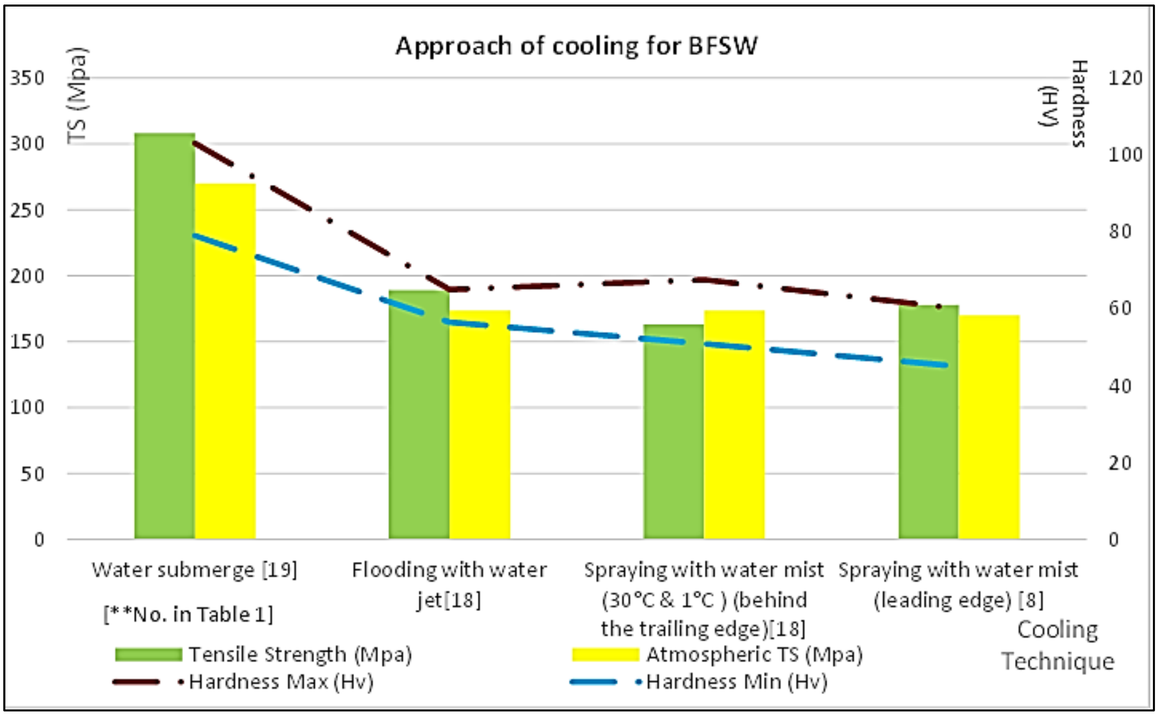
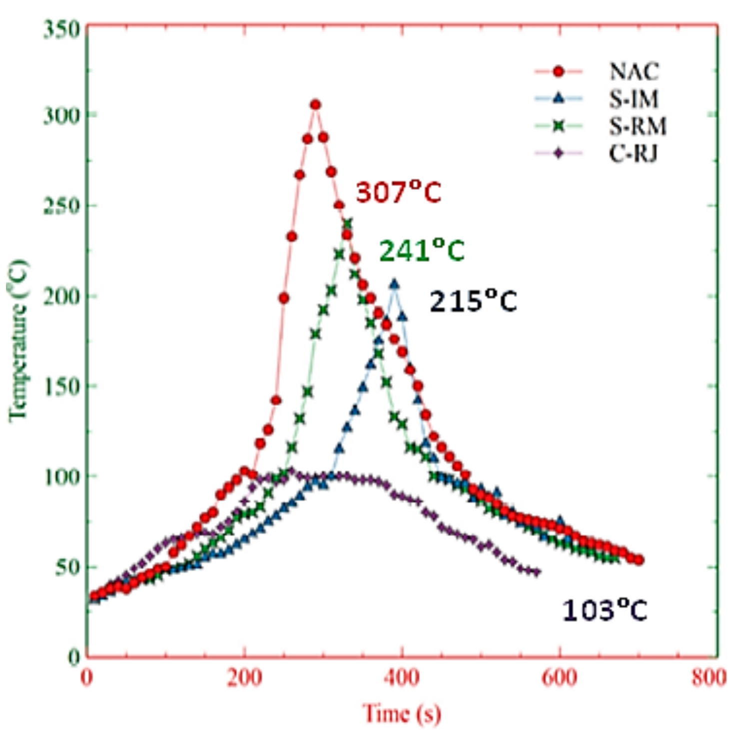


Fig. 2. Tensile strength (TS) VS hardness properties of BFS welded joints produced with different cooling approaches



* NAC=Natural air cooling; S-RM=Spraying with room temperature water mist; S-IM=Spraying with ice water mist; C-RJ=Cooling with room temperature water jet

Fig. 3. Profile Temperature of 6 mm-thick 6061-T6 aluminum alloy with different cooling approach [4]

3. Process Parameter

To get the intended outcome in friction stir welding, it is crucial to closely monitor and comprehend how the materials' behaviour changes when the input parameters are altered. Tool rotation speed, welding speed, shoulder gap, and other significant FSW parameters like tool tilt angle and axial pressure that are not as important in BFSW are some of the fundamental process variables that affect BFSW [31, 32]. According to Esmaily *et al.,* [33], not all BFSW processes can adopt the process parameters used in FSW, because weld defects are seen at welded plates when FSW parameters are used in high-speed BFSW in their study. Kamble and Soman [8] also gave the same views. To prevent tool failure, bobbin tools shouldn't be designed with the same dimensions as FSW but rather with various parameters in mind, such as stress concentration, pin weakness, heat generation, etc. Thus, only Three (3) parameters will be discussed further in this paper to relate to weld strength and its heat dissipation in BFSW.

First are the welding tools. Tools are one of the important parameters in weld formation in FSW. A combination of tool features shows that improvement in welding quality can be achieved. This is done by utilizing different designs for the upper shoulder, lower shoulder, and pin surface features and dimensions. Instead of compression, BFSW involves multi-axial forces on the tooltip, including twisting, bending, and tensioning. Most tensile force will act on the tool to separate the two shoulders from the pins. Therefore, crucial attention to technical details is needed when designing the BFSW tool compared to the FSW tool.

Figure 4 shows the examples of BFSW tools used by researchers. The upper and lower shoulders' main function is to for friction heating to generate heat on the upper and lower portions of the nearby surface. According to the available literature, the lower shoulder's diameter should be less than the higher shoulder's. However, if the shoulder's diameter is too small, a groove defect forms on the joint's top and lower surfaces, with flashes forming at the joint's base [4]. As there is a possibility of flash defect if the lower shoulder dimension is reduced, the lower shoulder dimensions should be the same as the upper shoulder dimensions. It is stated that the upper shoulder's overall diameter ranges from 2.5 to 3.5 times the thickness of the workpiece to be welded [31]. For example, in a study by Zhao *et al.,* [9] for 4 mm-thick 6063-T6 Aluminum alloy, a bobbin tool with the diameters of both top and bottom of 16mm, a cylinder pin with two symmetric threads with a diameter and length of 8 mm and 4mm respectively and the flat shoulder surfaces with spiral groove were applied. Their studies produced 178 Mpa of tensile which is higher than 170 Mpa without cooling.

Furthermore, Fuse and Badheka [4] in their study to joint 6 mm thick AA 6061-T6 aluminium alloy using a tool with a top and bottom shoulder diameter of 24 mm with four spiral grooves each on the shoulders and with a cylindrical pin of diameter 8 mm with three flats and a length of 6 mm was used in their study. This tool design is found able to perform well accompanied with cooling-assisted techniques as applied in their study. They stated that a sound welds of 189.16 MPa is 8.17% better than natural air cooling. The best shoulder designs have flat, concave, and convex shoulder features. The plasticized material fed between the shoulders is distributed by the concave designs. Where the thickness of the plate is continuously changing, the convex design aids in maintaining constant contact with the plate's surface [4]. While thin plates work well for flat designs. For BFSW, tapered and cylindrical pin profiles are preferred. The mixing of softened materials is influenced by additional features including flutes, flats, grooves, and threads, which also aid in moving material from the top to the bottom of the pin and back in front of the pin. Cylindrical pins, on the other hand, have advantages over other pin profiles and can be taken into consideration in current work.

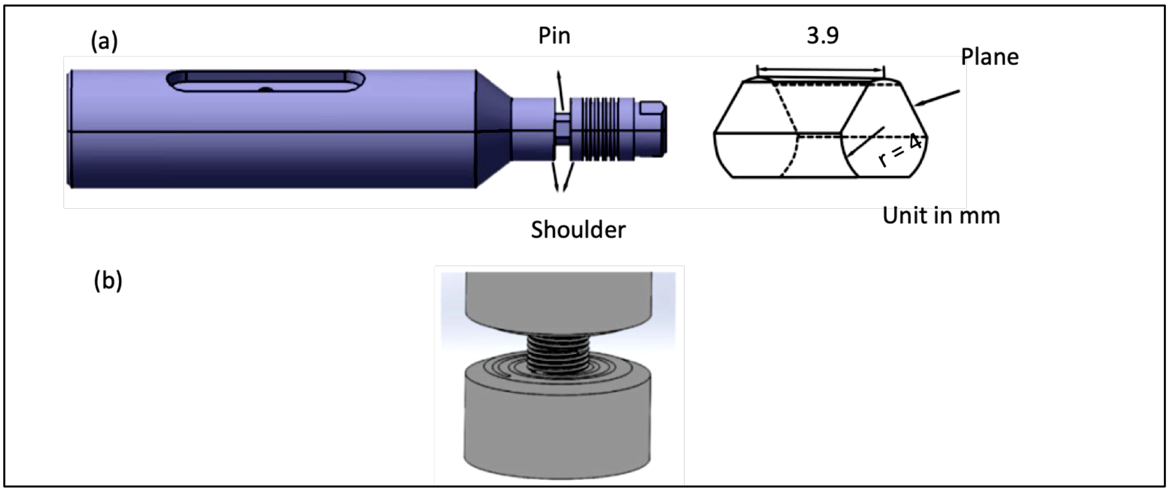


Fig. 4. Example of Bobbin friction stir welding tool features (a) Sun *et al.,* [34] (b) Liu *et al.,* [35]

Using quality tool material is essential for generating welds without flaws. The material of the workpiece and the tool life influence the material choice. The material for the chosen tool must be robust, hardy, and durable at high temperatures. It should also have a high level of oxidation and wear resistance. For instance, due to its excellent toughness and machinability, AISI H13 tool steel is typically used for welding AAs in BFSW [4], UWBFSW [28], and UWFSW [32]. Thus, using the right tool and pin geometry produces defect-free joints in FSW/BFSW. Based on the workpiece's material, characteristics, and thickness, the tool design and material are chosen and once decided, are not changed during the welding process.

Other parameters such as tool rotation speed and welding speed, can be varied for the same tool design and geometry [32]. Figure 5 shows the summarization of rotational and welding speed used by researchers which can be categorized as having cooling approach. Changes in tool rotation speed affect the temperature at the weld, which alters the materials' physical characteristics. High tool rotational speed creates an extremely high heat affected zone (HAZ), which may have negative effects. This is because the microstructure of the materials to be welded starts to change as the heat level rises, especially the grain size. These microstructural alterations in various FSW locations cause a significant shift in the mechanical characteristics after welding [36]. In FSW/UWFSW of heat treatable AA, a number of defects (such as voids, furrow faults, tunnels, grooves, etc.) have been noted [12, 32]. Furrow defects are seen in AA 7055 in SZ [12], during UWFSW at low rotational speeds, for instance. This fault is reduced or eliminated when the rotational speed is increased from a lower value to a higher value. The maintenance of an ideal environment temperature due to the presence of water in UWFSW enables the use of high rotational speeds [12], but if the rotational speed is increased to an even greater level, the size of the voids increases [32].

In term of welding speed, it refers to how far or how much material is welded in each amount of time as measured by the tool's transverse movement along the line. The welding speed of the materials has a significant impact on tensile strength. Low tensile strength results from incorrect penetration caused by excessive welding speed. The substance is still hard and brittle [36]. A decrease in tensile strength results from too little heat being applied to the weld during welding. Too much welding speed results in insufficient heat generation and material churning, which weakens the material's tensile strength and creates flaws [37]. However, with sufficient heat and material agitation, tensile strength will likewise rise as welding speed rises [37]. The two key parameters that will regulate the creation of heat in the FSW process are tool rotation speed and travel speed of the tool [36], which will be manipulated by using the cooling assisted approach to help improve AA weld strength without generating excess heat.

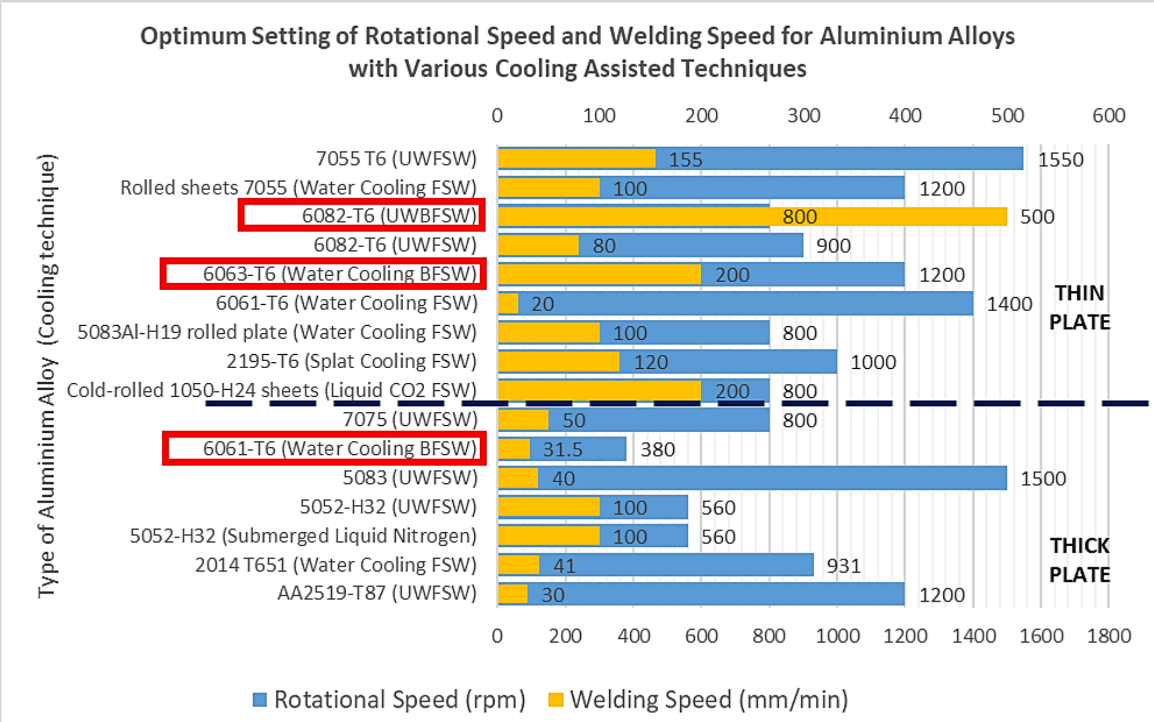


Fig. 5. Optimum setting of rotational speed and welding speed for aluminium alloys with various cooling assisted approaches adopted by recent scholar's studies

4. Finding and Discussion

The major factors affecting weld formation are rotational speed, welding speed, and welding tool. This is commonly the focus of most research. Unsuitable process parameters may cause poor joint qualities [32]. The FSW process demands higher rotational and welding speeds to produce sound joints. However, this will increase the heat, which indirectly impacts weld strength. Manipulating the main factors is limited; however, incorporating the cooling factor into the process provides a bigger window for improving weld strength. Numerous researchers have investigated the effect of cooling media on a few important properties, such as tensile strength, hardness, and microstructure changes [38]. Mehta *et al.,* [39] compared the tensile strength of conventional FSW with water-cooling-assisted for Al-Mg dissimilar welding. They found that the joint produced had higher tensile strength by an additional 54 MPa. In addition, Patel *et al.,* [40] carried out Al-Ti dissimilar welding utilising several processing cooling mediums, including regulated water flow, CO_2, and compressed air. Peng *et al.,* [21] found that tensile properties changed noticeably when forced air and natural cooling were used during conventional friction stir welding of AA5A06-AA6061 joints. A noticeable 10% of tensile strength is recorded for a conventional FSW with cooling compared to no cooling.

To improve the mechanical properties of friction, stir welded joints, different processing media, including water, CO_2 gas, liquid CO_2, dry ice, and compressed air, were examined [4]. An example of research in forced air cooling. Peng *et al.,* [21] used forced air cooling (FAC) and natural cooling (NC) to accomplish friction stir-welded AA5A06-AA6061 joints. As a result, the FSW with FAC's joint welded at a rotational and travel speed (R/T) ratio of 600/200 r/mm had the maximum ultimate tensile strength of 218 MPa. This is 23% lower than the base AA6061. However, according to the same research, FAC can boost ultimate tensile strength by 10% compared to NC. Another novel approach is splat cooling-assisted friction stir welding (SCaFSW), an example conducted by Shi *et al.,* [29]. Their work can be identified as the latest cooling-assisted approach that achieved high-strength joints of 2195 Al-Li alloy. It is noticed that splat cooling in FSW greatly increases the tensile strength of joints made of the 2195 Al-Li alloy that are defect-free. It is recorded at 502.7 MPa, which is 93% of the base material, but it also reduces the joint's elongation.

According to the literature study, only a little research has been done to improve the strength of BFSW joints manufactured using various cooling media. When compared to traditional BFSW welded joints whose tensile strength is 170 MPa, Zhao *et al.,* [9] found that water cooling enhanced the high tensile strength of 6063-T6 alloy BFSW to 178 MPa, as referred to Figure 5 and Figure 6, compared to the material strength which is 260MPa. Fuse and Badheka [4] used two novel approaches to cool water at temperatures of 1°C and 30°C, and methods of application (spraying and enveloping top surface) with four experiments: natural air-cooling (NAC), spraying with room temperature water mist (S-RM), spraying with ice water mist (S-IM), and cooling with room temperature water jet (C-RJ) on 6061-T6 aluminium alloy. The C-RJ cooling assisted joint had the maximum tensile strength of 189.16MPa, which was 8.9 per cent higher than the conventional BSFW joint (173.70 MPa), also the highest strength that was developed compared to the base material strength of 282 MPa. While Feng *et al.,* [28] reported tensile strength of underwater BFSW of 6082-T6 aluminium alloy with the butt joint is 308 MPa, which is 95% of the strength of the base metal (BM), as a comparison is made with atmospheric bobbin friction stir–welded, with estimated tensile strength is 263.25MPa.

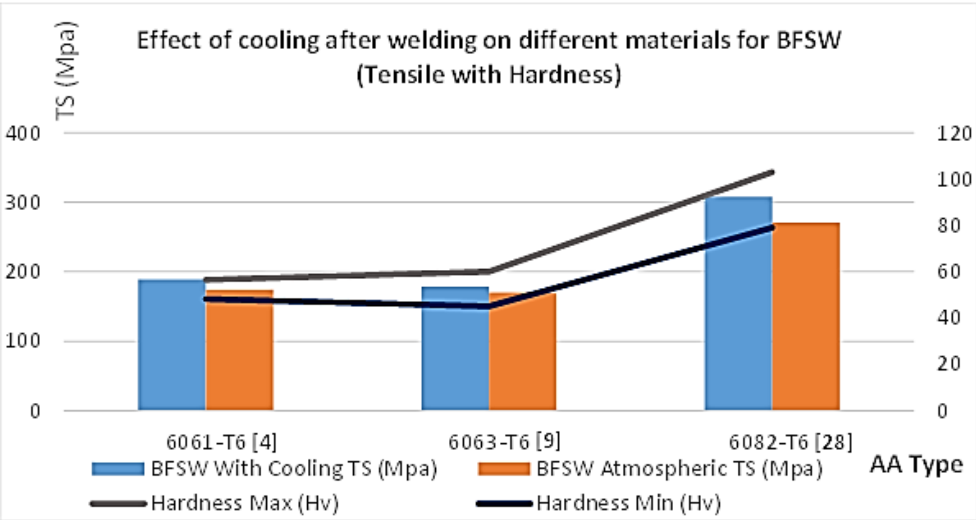


Fig. 6. Tensile strength (TS) VS hardness properties of BFS welded joints produced with different materials

Cooling media also impacts the distribution of hardness over the weld. Numerous studies have demonstrated that by utilizing UFSW, the minimum hardness site can be improved, leading to higher hardness in UFSW than in FSW [32], however, there have been few studies comparing BFSW with cooling assisted method to FSW. It is clear from the graph that all the samples displayed a symmetrical hardness distribution with a W-shaped microhardness profile in the unit of Vickers hardness, as reported in BFSW with cooling-related literature. According to research by Feng *et al.,* [28], the underwater BFSW joint's SZ has the maximum Vickers hardness, ranging from 94 to 103 HV, while its lowest hardness, 79 HV, is found at the transition zone between the HAZ and TMAZ. According to Fuse and Badheka's [4] investigation, C-RJ had the highest hardness value (56.5 HV) in the lowest hardness zone since its grain size had been significantly reduced. On the other hand, the minimal hardness zone (48.2 HV) in NAC of AA6061-T6 was HAZ. A similar conclusion was reached by Zhao *et al.,* [9] in their investigation, which showed that the hardness of the Water BFSW joint was obviously higher than that of the BFSW joint. The Water BFSW joint has much narrower softening regions and higher hardness values than the BFSW joint. In other words, the water mist cooling significantly enhances the joint's mechanical strength. Figure 5, Figure 7 and Figure 8 are referred to in this explanation.

The effect of BFSW with water cooling assistance was visible in the grain size as exhibited in Figure 7 and Figure 8. According to the research of Zhao *et al.,* [9], the average size in the SZ for the BFSW is 22.5 μm. On the other hand, because of the lower welding temperature and shorter dwell time at high temperatures, the average grain size in the SZ of the Water BFSW reduces to 16.1 μm. Meanwhile, NAC and C-RJ joints, respectively, showed maximum and minimum average grain sizes of 18.68 μm and 10.69 μm, according to Fuse and Badheka [4]. The highest average grain size was visible in the BFSW joint under NAC conditions among all the samples. This is because in NAC, the heat was primarily dissipated through convective heat transfer from the workpiece to air, and this heat transfer rate was far slower than that of water. In the meantime, according to the study by Feng *et al.,* [28], the heat transfer into the SZ was significantly reduced because of the high specific heat capacity and cooling effect of water. This prevented the growth of recrystallized grains, resulting in fine and equiaxed grains with an average size of only 5.5 µm, which is smaller than the SZ (8.5 µm) of atmospheric BT-FSW. This brings us to the conclusion that using a water-cooling medium reduces the size of the WNZ/SZ grain.

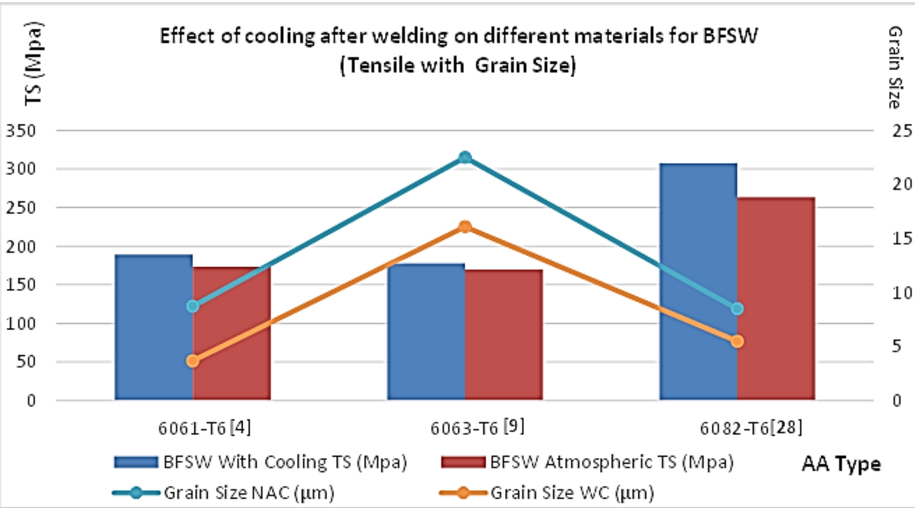


Fig. 7. Tensile strength (TS) VS grain size properties of BFS welded joints produced with different materials

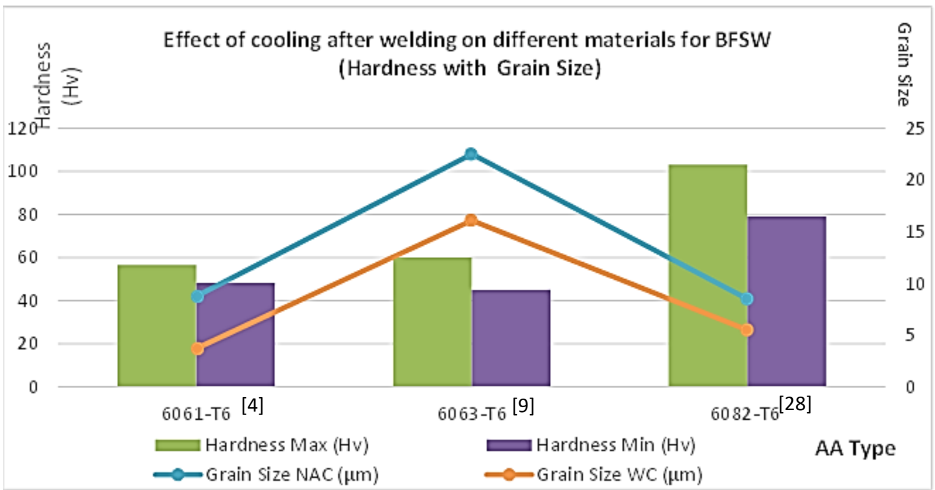


Fig. 8. Hardness VS grain size properties of BFS welded joints produced with different materials

Based on the finding from Figures 4 to 8, we can infer that the controlled temperature distribution and uniform cooling rate caused the water-cooling conditions to demonstrate similar or slightly higher strength, no matter is applied to different types of AA from 6000 series or different water-cooling method except the method of spraying with cool water mist at temperatures of 1°C and 30°C. Because water spraying causes non-uniform grain size in the thermo-mechanically affected zone (TMAZ), which results in joint failure, the lower strength in S-RM and S-IM cooling assisted joints can be attributed to sudden and non-uniform heating and cooling, according to Fuse and Badheka [4].

5. Conclusion and Future Suggestions

Even though there is only limited investigation that discusses BFSW with a cooling-assisted approach, this review article is a novel review that describes the status and understanding of the BFSW, which is primarily in joining Aluminum alloys, and the improvement of BFSW over conventional FSW in terms of joint quality, microstructure evolution, and mechanical properties. According to the thorough literature study, the following conclusions are made:

i. BFSW, with cooling, reduces temperature and prevents the coarsening or dissolution of the precipitates, improving the mechanical qualities of the joint. Water is used as a cooling medium for comparable materials in BFSW.
ii. The key factors influencing weld formation are tool rotational speed and welding speed. Rotating speed that is either too low or too high during welding may result in poor joint qualities. The bobbin requires higher rotational speed and welding speed to produce a sound joint in comparison to conventional FSW to BFSW.
iii. The temperature distribution in FSW/BFSW directly affects the mechanical properties and microstructure (grain size, coarsening of precipitates) of the joints. BFSW had better mechanical properties than FSW because of its low temperatures, narrowed temperature gradient, and fast cooling to form fine grain, high dislocation density, with less precipitate dissolution and coarsening.

BFSW is expanding in terms of various aspects of the process, to the author's knowledge, there are no research articles available on coolant cooling Bobbin friction stir welding of aluminium alloy, taking into account the various volumes of coolant applied and methods of using it. The effect of coolant as a cooling media on Bobbin friction stir welded AA joints will be studied using three different volume rates of coolant and two thickness values for thin materials. These varied versions are compared to conventional air-cooled BFSW samples regarding weld strength and heat dissipation. Research work for the future also can be targeted in the following fields:

i. A thorough analysis of fracture strength and heat generation during the Bobbin friction stir welding process can be done rather than using water cooling by submerging because of its tedious setup process.
ii. Although BFSW has the potential for various cooling media applications, investigations into the welding of similar metals need to be explored in detail.
iii. Surprisingly, the literature on BFSW with the cooling-assisted approach does not include any research on other members of the AA family apart from the 6000 series. Due to the expanding application of BFSW, appropriate assessment of the BFSW joints with cooling-assisted techniques for various AA series is needed.

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