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The crucial role of friction bit joining in advanced lightweight design: a review

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ABSTRACT
In recent years, the automotive industry has accelerated the development of high-strength and low-weight designs by employing dissimilar combinations of materials to generate a lighter overall weight and fuel efficiency. Unfortunately, conventional welding techniques generally face compatibility issues with these combinations of materials, e.g. steel and aluminium alloys, due to the formation of brittle intermetallic compounds, among other deficiencies. In this review, the authors provide a complete review of Friction Bit Joining (FBJ) as a solid-state joining technique that can influence conventional welding methods; the review gives a critical evaluation of the most recent developments in the FBJ process with regard to joining dissimilar metallic materials within the automotive industry. In summary, the review identifies the changes to the mechanical properties and advantageous microstructural features as compared to the base metals that are produced through the FBJ process. The review also provides a comprehensive synthesis of the range of published data on FBJ to demonstrate why FBJ meets the requirements for a robust, quality joining process suitable for the modern vehicles.

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Friction bit joining; automotive industry; microstructure; mechanical properties

1. Introduction

Currently, factories are utilizing innovative technology to meet their constantly evolving requirements for higher product quality, increased efficiency, and reduced operational expenses (Padhy et al., 2018; Phuyal et al., 2020). The fundamental goal for organizations in the automotive and aerospace industries is to reduce the cost of fossil fuels by making vehicles more powerful and lighter (Dogan & Erol, 2019; Jenny & Kabecha, 2023). Advanced materials, such as aluminium alloys and high strength steels, are important for achieving benefits such as structural weight reduction, which is directly used to improve fuel economy and efficiency (Kulekci et al., 2016). For instance, a mere 10% reduction in vehicle weight can result in a significant 6% to 8% increase in fuel efficiency (Yan & Xu, 2025). The use of advanced high strength lightweight materials has contributed to the replacement of heavy materials, like cast iron, resulting in weight reductions of up to 50% (Robinson et al., 2019). However, the complex performance needs for electric vehicles and aerospace components cannot be fulfilled by a sole material; instead, dissimilar material combinations are needed to overcome existing barriers (H.-D. Lim et al., 2020). Furthermore, the unique physical and chemical characteristics of individual materials significant challenge their effective and reliable performance (Azizi et al., 2023; Urbikain et al., 2018).

Conventional joining techniques, which include mechanical fastening methods like bolting and riveting (Nassar et al., 2014; Zheng et al., 2022) as well as various fusion-based joining methods (Bhat & Khedkar, 2024; Singh et al., 2022) such as arc welding (Shujun, 2024), gas metal arc welding (Kannan et al., 2025), laser beam welding (Kuryntsev, 2021), and resistance spot welding (Prabhakaran et al.

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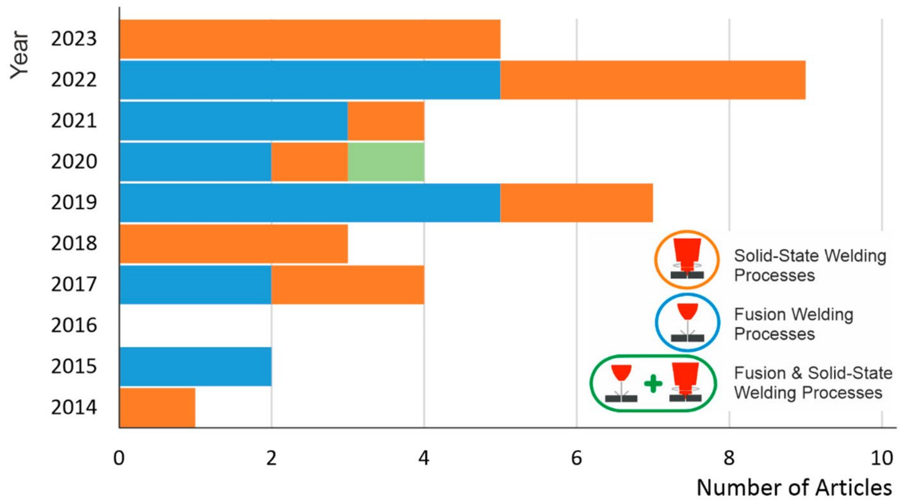

Figure 1. Number of published publications on the joining processes of Al alloys (Nunes et al., 2023).

2023), etc., have significant limitations. These limitations include the formation of unwanted brittle intermetallic compounds, crack propagation, porosity, and ultimately, diminished joint strength and cross-sectional integrity when attempting to join dissimilar materials due to their diverse thermal and metallurgical properties (Jadhav et al., 2025; Peng et al., 2021; Vaneghi et al., 2022).

Even some other solid-state techniques (Badavath et al., 2022) like friction welding (Winiczenko et al., 2024), friction stir welding (Tiwari et al., 2024), friction rivet joining (Klobčar et al., 2022), etc., provide some advantages, such as minimal thermal distortion and lower residual stresses over fusion methods, but they still have insufficient joint strength properties, such as imperfect material mixing and intermetallic compound formation across the dissimilar material interfaces (Mishra & Ma, 2005). Figure 1 shows the number of research papers related to joining processes from 2014 to 2023 (Nunes et al., 2023). In this context, Friction bit joining (FBJ) has developed as a new and very promising technique aimed at overcoming the specific challenges of joining lightweight dissimilar materials (Bhagavathi et al., 2011; Squires, 2014). FBJ achieves strong and metallurgical interface bonds through localized plastic deformation and largely avoids the formation of brittle phases that can be found in fused-based joining systems (Mehta, 2019). This differentiates FBJ from mechanical fastening, fusion and solid state based procedures by creating a robust solid-state metallurgical bonding at the interface, which offers superior joint integrity and improved properties for dissimilar material combinations (Haghshenas & Gerlich, 2018; Martinsen et al., 2015). This exclusive characteristic renders FBJ particularly effective for joining of dual phase steel and aluminium alloys, which leads to increased scope in modern automotive sectors (Okazaki, 2018; Siemssen, 2008).

Table 1 show that the FBJ process has significant advantages over other manufacturing processes, particularly in its ability to join dissimilar materials with minimum heat input and a resulting better joint quality. Thus, the purpose of this review article is to provide a thorough analysis of recent advancements in the FBJ process. Specifically, we wish to indicate its important and changing role in promoting advanced light weight, high strength design by virtue of its ability to join multiple dissimilar materials, which facilitate the automotive sector.

2. Friction bit joining processes

Figure 2 shows the schematic representation of the FBJ process (Haghshenas & Gerlich, 2018). FBJ is a novel method that employs a consumable bit to join the sheet materials by applying frictional heating and cutting action (Okazaki, 2018). This process has been completed in three phases, i.e., the plunging phase, the joining phase, and the stop phase. Initially, the two sheets to be joined should be placed in an overlapping manner and clamped in the holding device (Haghshenas & Gerlich, 2018; M. P. Miles et al., 2009). Then a consumable bit is fixed with the tool in the spindle. Plunging phase: In this phase, a consumable bit with rotation allows it to move towards the upper sheet material.

Table 1. Comparative analysis of friction bit joining with other manufacturing processes.

	Mechanical fastening	Fusion-based joining methods				Solid-state joining methods			
Criterion	Bolting/riveting	Arc welding	Gas metal arc welding	Laser beam welding	Resistance spot welding	Friction welding	Friction rivet joining	Friction stir welding	Friction bit joining
Key principle	Use a bolt or rivet through mechanical interlock	Electric arc melts workpieces and filler to form a weld.	A consumable wire electrode is fed into an electric arc, which leads to melting both the workpiece and the electrode to create a weld surrounded by shielding gas.	A concentrated laser beam melts the workpiece, which leads to welding the material.	A process in which resistance heating is produced at the interface when the electric current flows to create a weld.	Utilize axial force to compress the relative rotational workpieces to create heat for welding.	Utilize a rotating rivet to generate heat and weld dissimilar material structures.	Uses a friction stir tool at the interface to make plasticizing and softening, which allows the material to be welded.	A technique that uses a rotating consumable bit to create frictional heat, which facilitates the welding of materials.
Joint type	Spot	Linear, curvilinear	Linear, curvilinear	Linear, spot, 3D contours	Spot	Butt	Spot	Linear	Spot
Heat input & distortion	None	Moderate to high & Significant heat affected zone, potential for distortion	Moderate to high & Significant heat affected zone, potential for distortion	Very low & highly concentrated	Moderate to high & can cause distortion and residual stress.	Low to moderate & minimal distortion	Low & localized.	Very low & minimal distortion	Low & localized
Processing speed	Fast	Moderate to fast.	Fast	Fast	Fast	Fast	Moderate	Moderate to slow	Moderate
Key advantages	No heat input, no surface preparation.	Versatile, wide material range, good for structural joints	High deposition rates, good for automation clean welds with proper shielding	High speed, non-contact precision, narrow welds.	Economical for spot joints.	Good for dissimilar metals, high quality, no filler needed.	Joins dissimilar material with better quality	High quality, low distortion, good for heat treatable alloys.	Joins dissimilar metals without melting, low heat input and good joint quality.
Key disadvantages	Adds weight, potential for leakage, stress concentration	Significant thermal distortion, spatter, fume generation	Highly sensitive to wind causes porosity.	High capital cost, high reflectivity challenges	Limited to spot, high current consumption.	Limited to butt, flash removal required, and robust fixture.	Cost of specialized rivets	High initial cost, limited joint, tool wear.	Consumable bit wear, limited material thickness

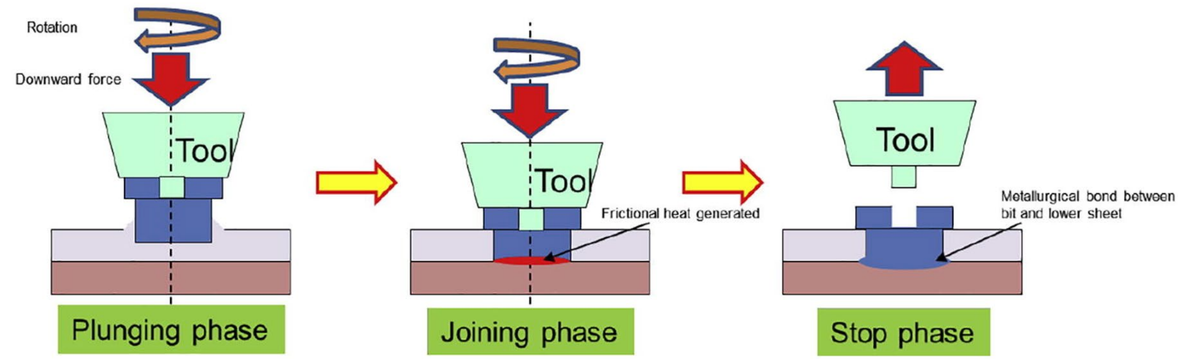

Figure 2. Friction bit joining process (a) plunging phase (b) Cutting and Joining phase (c) Final phase (Haghshenas & Gerlich, 2018).

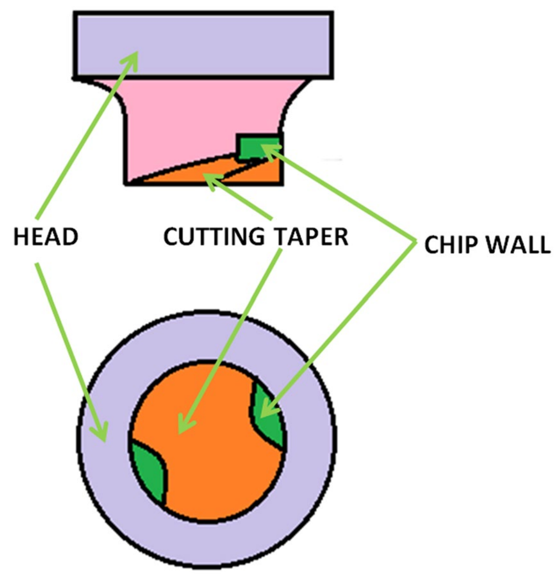

Figure 3. Schematic diagram of consumable bit.

Then the rotating bit touches the upper sheet, and the cutting action starts with the plunging action due to the continuous downward movement. Joining phase: In the second phase, due to friction heat at the interface between bit and sheet, a plasticized region forms at the spot (Squires, 2014). The bit is drilled through the top sheet until it touches the lower sheet, resulting in a solid-state bonding. The bit's shank forges a solid bond with the lower sheet while the bit's head compresses the upper sheet. Final phase: In this phase, the consumable bit is left behind in a bond with a lower sheet, and the rotation of the tool is stopped and withdrawn (Siemssen, 2008).

2.1. Consumable bit

FBJ uses a consumable bit material to join sheet metals. This process involves the bit first drilling through the upper sheet and then friction bonding to the bottom sheet (Haghshenas & Gerlich, 2018; M. P. Miles et al., 2009). Figure 3 shows the schematic diagram of the consumable bits designed for this process [24]. The consumable bit is made up of two parts the shank and the head. The head is intended to mate with the spindle and contains a flange with which to push down on the upper sheet material. In some instances, there are variations of some bits that possess drilling-type cutting capabilities to scrape off the upper layer of material, whereas others depend more on friction and force to penetrate the top sheet and have no cutting features. According to authors (Squires, 2014), in Table 2, bit profiles are created by traditional machining methods and depending on the machine

Table 2. Previous research works of FBJ joints.

Sl. No	Authors	Material	Material dimensions	Consumable bit	Outcomes			Applications
					Maximum Lap shear strength	T-peel	Cross tension	
1	Miles et al., 2013	Aluminium alloy A356 – steel interlayer - and grey cast iron	Al – (80 × 25 mm) and either 4, 6, or 8 mm thick) CI – (80 × 25 mm, and 8 mm thick, Steel interlayer (0.85 mm)	4140 alloy steel	7 kN	×	×	Brake rotor assembly
2	Squires, 2014	DP 980 High-Strength Steel and AA7075-T6	HSS – 1.2 mm, Al- 1.6 mm thick	4140 steel, D2 steel or titanium	11.75 kN	×	×	Automotive industry
3	Weickum, 2011	5754 Aluminium to DP980 Ultra-High Strength Steel	DP980 steel & DP590 Steel (0.065 inch thick) and 5754 aluminum (0.070 inch thick).	4140, 4340, or H13 steel	DP980 with Al 5754 6.50 kN DP 590 with Al 5754 6.67 kN	0.93 kN 0.92 kN	2.16 kN, 2.5 kN	Automotive industry
4	Peterson, 2015	DP 980 Steel and AA 7075-T6	DP980 steel (1.22 mm thick) with AA 7075-T6 (0.203–6.32)	AISI 4140 alloy steel	12.9 kN,	0.472 kN	2.818 kN	Automotive industry
5	Atwood, 2016	GADP 1180 Steel and AA 7085 – T76 Aluminum	GADP 1180 steel (1.2 mm thick), Al (2mm thick) and	1018 alloy steel	12.5 kN,	4.9 kN	×	Automotive and aerospace industries
6.	Miles et al., 2009	High Strength Steel DP 980 and Al Alloy AA 5754-O	AA5754-O (1.8 mm thick), DP 980 (1.4 mm thick),	4140 alloy steel	6.5 kN	8.2 kN	×	Automotive industry
7.	Lim et al., 2018	Carbon Fiber Polymer to Dual Phase 980	Carbon fiber composite (2.0 mm thick), DP 980 (1.2 mm thick)	4140 alloy steel	13.3 kN,	×	2 kN	Automotive industry
8	Shirley, 2018	GADP 1180 Steel and AA 7085-T76	GADP1180 (0.8 mm thick) and AA7085 (2 mm thick)	1018 alloy steel	10.71 kN,	1.897 kN	4.831 kN	–
9	Siemssen, 2008	5754 Aluminium/ DP 980 steel	5754 Aluminum (1.78 mm thick) and DP 980 steel (1.65 mm thick)	4140 alloy steel	6.32 kN	×	2.52 kN	Automotive industry
10	Miles et al., 2009	Aluminium alloy 5754-O and DP 980	DP 980 (1.4 mm thick), aluminium alloy (1.8 mm thick)	D2 tool steel	14.8 kN	×	8.2 kN	Automotive industry
11	Okazaki, 2018	Aluminum Alloy 7085 similar joint	2 mm thick AA7085	4140 annealed steel	10.23 kN	2.61 kN	5.78kN	Automotive industry

tool and set up even advanced methods like electrically discharge machining (EDM) and rotary broaching are employed to create a fit for the spindle that can only be described as precise. The commonly used materials for bits include titanium, D2 steel, and 4140 alloyed steel.

2.2. Joining of high strength steel with aluminum

Although there are numerous techniques for joining different metals that are employed in industry, their capacity for joining high-strength steel to aluminium alloys is highly limited. These limitations resulted in, among other things, the variation in flow stress (Abe et al., 2006, 2012; Merklein et al., 2023) and the potential for the development of brittle intermetallic mixtures (Buffa et al., 2022). To rectify these concerns, the recent innovation of friction bit joining has been developed for getting good joining strength of high-strength steels with aluminium alloys. Table 2 shows the materials used by previous research works for the FBJ process.

A key material combination explored is dual-phase steels, such as DP980 and DP590, which have ferrite and a martensitic microstructure (Badkoobeh et al., 2022; Wu, 2011). While the martensite enhances tensile strength (e.g., DP980 has an ultimate tensile strength of 980 MPa), the ferrite matrix aids in formability (Liu et al., 2022). When joined with aluminium alloy like AA 5754, which offers outstanding corrosion resistance and workability with an ultimate tensile strength ranging from 140 to 290 MPa, FBJs can also give good performance (Abdelhady et al., 2024). For an instance, lap shear tests on the dissimilar joint of DP 980 Steel and AA 7075-T6 had an average peak failure load of 12.9 kN, far exceeding the automotive standard of 5 kN (Peterson, 2015)). Similarly, T-peel tests on GADP 1180 Steel and AA 7085-T76 produced a peak load of 1.897 kN, which again exceeds the 1.5 kN automotive standard (Shirley, 2018).

3. Various strength of friction bit joined materials

The mechanical properties of Friction Bit Joining (FBJ) have been extensively evaluated through a variety of standard tests, like T-peel, lap shear, and cross-tension, all of which have taken place at room temperature in an Instron testing frame (Rathinasuriyan et al., 2022; Shen et al., 2014). These types of tests are outlined in Table 2, according to the automotive industry minimum strength criteria from manufacturers like sponsor and Honda. This work examines the strength of joints that were made between steel and aluminum, and thus the strength of the steel sheet itself is used as a point of reference to demonstrate the strong performance of the joint. The results exhibit that the FBJ process can create joints that meet, and sometimes exceed, the required industry values, thus providing a valid approach to lightweight, high strength designs (Atwood, 2016; Huang et al., 2023).

3.1. T-peel test

T-Peel testing is carried out to assess a joint's crash reliability for automobile applications. Three sets of specimens are generally used to conduct the T-peel testing of joints with the hydraulic Instron machine (McKeen, 2017). Samples prepared for this test have a 90° bend for a length of 40 mm from one end of the coupon as shown in Figure 4 (Atwood, 2016). This bend is made on each sheet of the coupon, while the other ends are held together in the gripper to make a joint using FBJ. Weickum, 2011 examined the feasibility study of friction bit joints made of DP 980 steel/Aluminum 5754 and DP 590 steel/Aluminum 5754 materials. Figure 5 shows failure mode samples from this research, where T-peel samples experienced shearing within the bit, leading to the samples breaking beneath the bit's flange. Atwood, 2016 prepared coupons for T-peel testing with a galvanized dual-phase high-strength steel 1180 Steel and aluminum AA 7085–T76. The results yielded an average peak load of 350 N, which is 23% greater than the required automotive standard value of 1.5 kN. Peterson, 2015 reported on friction bit joints of DP 980 steel and AA 7075, but the results did not meet the requirements specified by Honda for in-service deployment (Caffrey et al., 2013; De Castro et al., 2022; Latif et al., 2024). Shirley, 2018 tested dissimilar FBJ joints of GADP 1180 steel and AA 7085-T76 materials. The evidence indicates that a faster feed rate and a deeper Z depth increase T-peel peak

Figure 4. Aluminium/steel FBJ joint developed for T-peel test (Atwood, 2016).

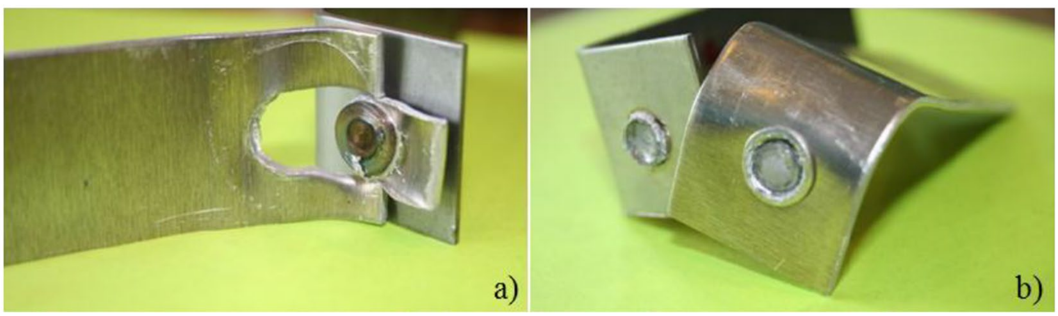

Figure 5. T-peel tested samples from the research (Weickum, 2011).

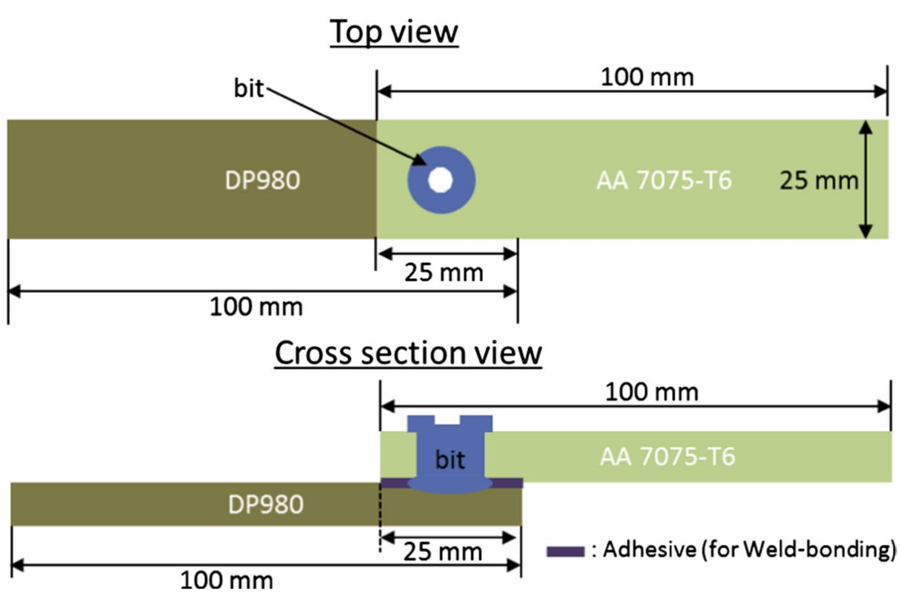

Figure 6. Preparation of lap shear test of sheets (Peterson, 2015).

load reproducibility. The peak load for this joint was 1.897 kN, which is greater than the required automotive standard value of 1.5 kN. Okazaki, 2018 studied the performance of friction bit joints of similar aluminium 7085 alloy sheets. According to this research, the number of flutes has a significant impact on the peak strength of the joint. A peak load of 10.23 kN was obtained for this similar joint.

3.2. Lap shear test

The strength of the friction bit joint of sheets is determined by lap shear testing (Huang et al., 2023; Weitzenböck, 2012). Peterson, 2015 prepared lap shear test coupons of DP 980 steel and AA

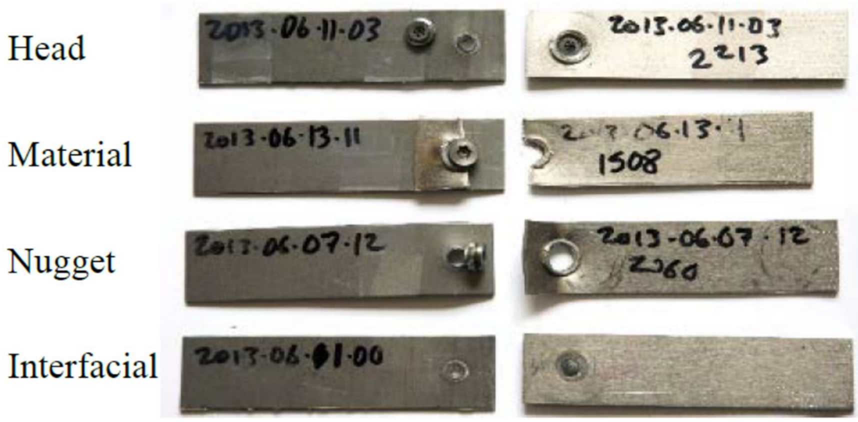

Figure 7. Four failure modes of FBJ joints (Peterson, 2015).

Table 3. Standard values of automotive joint strength (Atwood, 2016).

Standards joint strength		
Tests	Steel strength	Steel/Aluminium joint strength
T-Peel	> 2kN	> 1.5kN
Cross-Tension	> 5kN	> 1.5kN
Lap-Shear tension	> 18kN	> 5kN
Fatigue	0.10-0.75 kN	0.10-0.75 kN

7075 alloy sheets with dimensions 100 mm x 25 mm. Then, the coupons were arranged in an overlapping manner and fixed in the FBJ gripper to form a joint. Figure 6 shows the prepared layout for this test. The coupons were pulled by an Instron machine at a range of 10.16 mm/min. A key advantage of the FBJ process is its minimal heat-affected zone compared to other joining processes, which contributes to a sufficiently larger joint strength. From this research, different types of failure modes (Figure 7) such as head, material, nugget, and interfacial, were identified. The automotive industry code of practice, as highlighted in Table 3, states that a lap-shear tension test should perform optimally when the failure load surpasses 5 kN. The study from Miles et al., 2009 on the FBJ process of DP980 and AA 5754-O resulted in high-performance fastening, with an average peak load to failure for both externally and internally driven bits of 6.5 kN, above the industry standard. The FBJ process consists of two phases, cutting and joining. First, rigorously slow from 450 to 500 RPM, the bit cuts through the upper sheet of the structure; then, the bit increases from 2160 to 2640 rpm to generate heat and aid in the bonding of the bit with the bonded surface layers. Because of the low rotational speed, the bit retains its sharpened edge, but at increased rotational speeds, the frictional heat exceeds the frictional limit allowing the bit to adhere to both sheets.

Additional research has included practical applications of FBJ with a wider variety of material combinations. Miles et al., 2013 also developed various joint combinations of an aluminium alloy and grey cast iron using the FBJ process. A 4140 steel bit material was used to create a diffusion bond between the two metals. The interfacial material is shown in Figure 8, which displays that a thin 0.85 mm steel sheet was used to generate suitable frictional heat for sufficient bonding. An overall maximum lap shear load of 6.8 kN was obtained for a 6 mm thick aluminium sheet connected to an 8 mm thick cast iron sheet which again, exceeded the automotive industry standard of 5 kN listed in Table 3. Lim et al., 2018 studied lap shear failure load for a carbon fiber polymer to DP 980 steel friction bit joint and compared it to the same combination made by adhesive bonded and weld bonded joint. The FBJ joint was made with parameters of plunge speed 2000 rpm, plunge feed rate 171.5 mm/min, joining speed 2100 rpm, and joining feed rate 171.5 mm/min. For their work they obtained lap shear failure load of 6 kN for the FBJ joint, 14.8 kN for the adhesive bonded joint, and 13.3 kN for the weld bonded joint.

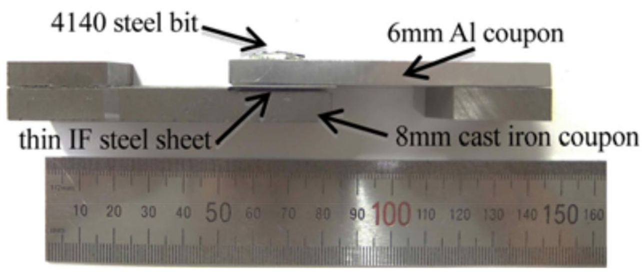

Figure 8. Arrangement of lap joint of aluminium and cast iron (Miles et al., 2013).

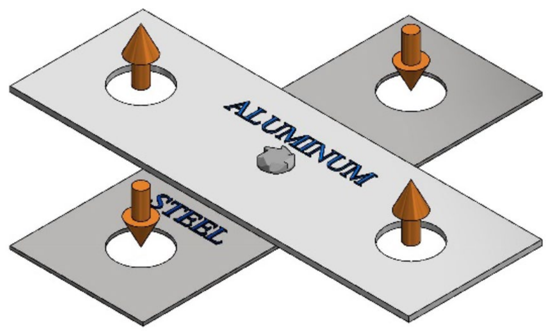

Figure 9. Arrangement of cross-tension test (Atwood, 2016).

3.3. Cross tension test

The cross tension test was conducted to determine the tensile force of an FBJ joint. The specimens are overlapped perpendicularly to one another to form a cross in the cross-tension test as seen in Figure 9 (Atwood, 2016). The testing machine grips both ends of each coupon to apply the force and measures the maximum amount of tensile force before failure. Siemssen, 2008 conducted the cross-tension tensile test on FBJ joints of dissimilar combinations of aluminium with steel, with an extension rate of 10.16 mm/min, and the maximum cross-tension tensile strength was recorded at 2.52 kN. Miles et al., 2009 measured the cross-tension tensile test of the FBJ joint of AA 5754 and DP 980 sheets. The process conditions were used for this work as a cutting speed of 725 rpm, a cutting feed rate of 100 mm/min, a joining speed of 1200 rpm, and a joining feed rate of 150 mm/min. The bit material of D2 steel was used for this joint to obtain a sufficient bonding of two sheets. The interfacial-type failure mode that obtained within the bit material itself is illustrated in Figure 10 during its testing. Peterson, 2015 conducted a cross-tension tensile test on FBJ-jointed DP 980 steel with AA 7075 alloy coupons. The interfacial failure mode occurred in all the coupon joints. The result of average tensile strength was 2.818 kN, which is 1.88 times more than the standard requirement by Honda.

3.4. Fatigue test

Fatigue testing is important for automotive applications because fatigue fracture tends to be a common failure mode for engineered components (Campbell & Tiryakioğlu, 2022; Zakaria et al., 2013). Therefore, to assess the long-term performance of a bonded structural assembly, the same lap shear test samples are used for fatigue testing. The Instron equipment used for the fatigue test is capable of continuously applying a pulsating a load at a set frequency. For the fatigue test for samples, a load was applied from 0.100 kN to 0.750 kN at a frequency of 20 Hz. The samples for automotive applications must have a minimum life expectancy of 10 million cycles. Atwood, 2016 conducted a fatigue test on the FBJ joint samples of DP980 steel and aluminium AA 7075 and found, as result of this work, that there was no failure after 10 million cycles to indicate that every one of the tested

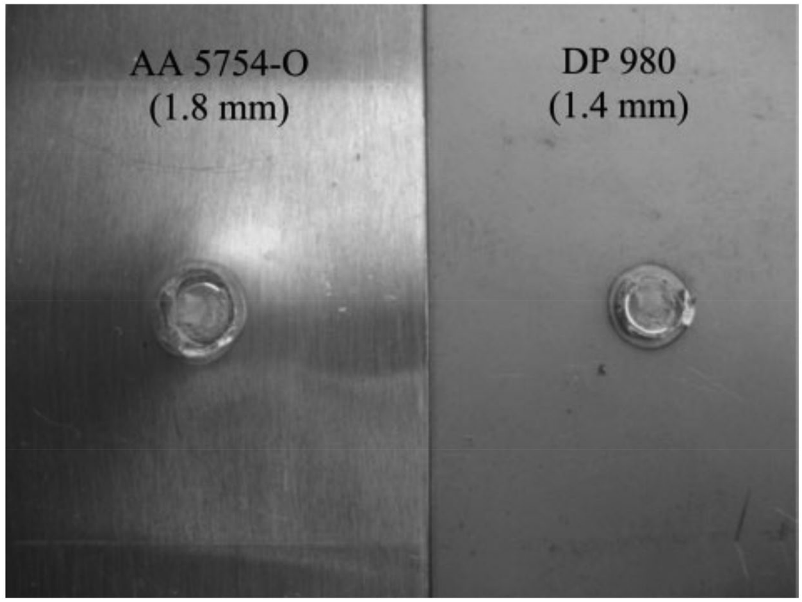

Figure 10. Failure mode of cross tension tensile test on coupons (Miles et al., 2009).

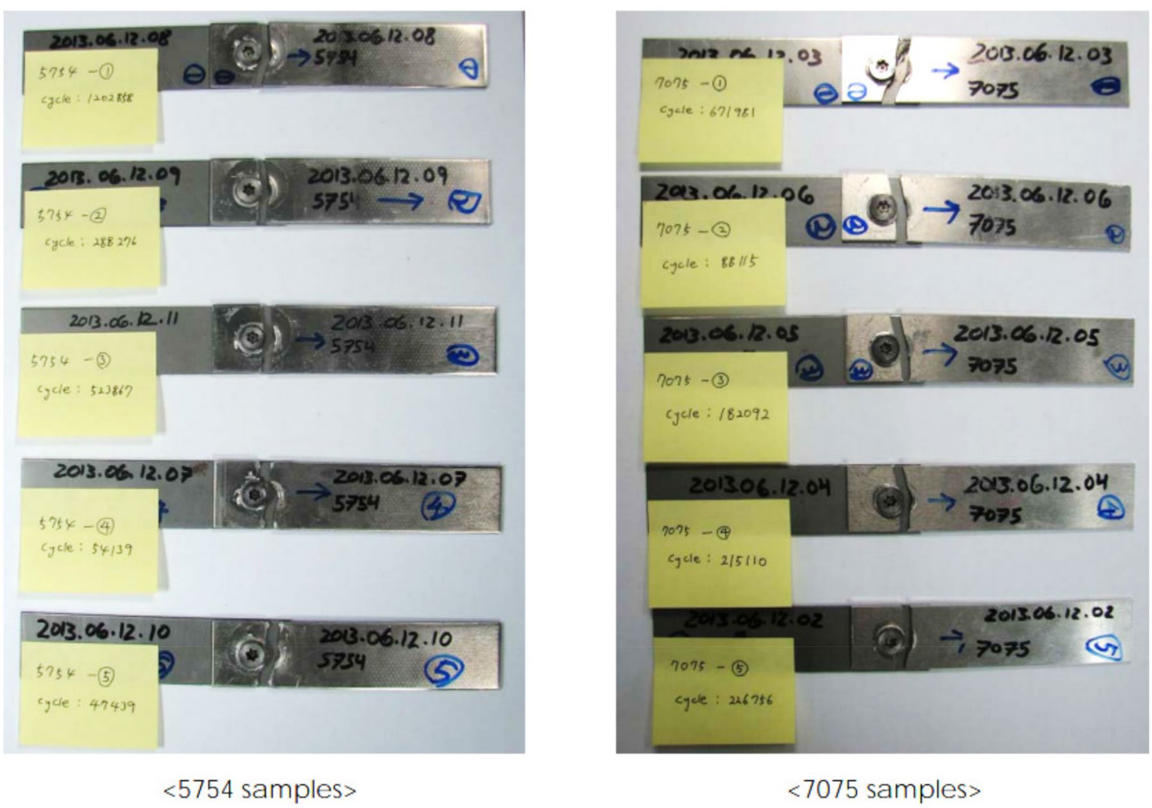

Figure 11. Material failure modes in all the samples of fatigue test (Squires, 2014).

samples exceeded the minimum loading conditions. Squires, 2014 carried out cyclical fatigue testing on FBJ joints of DP 980 steel/AA 7075 and DP 980 steel/AA 5754. The authors noted significant variability in the fatigue behaviour of the AA 5754 specimens, while variability in the AA 7075 specimens is notable, although to a lesser extent. All specimens exhibited a material failure mode, as can be seen in Figure 11. This material failure mode is when the aluminium itself is fractured, but the FBJ bit and joining area are intact.

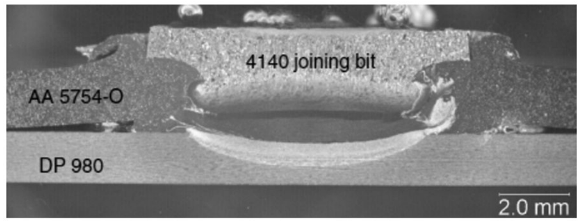

Figure 12. Microstructure image of FBJ joint (Miles et al., 2009).

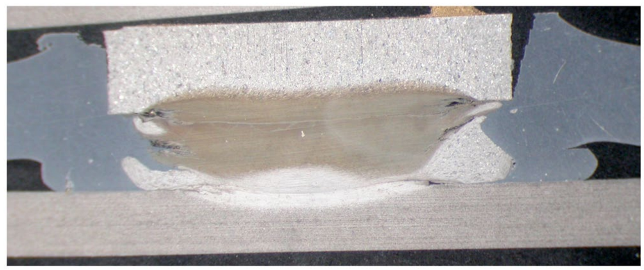

Figure 13. Void occurs at interface of aluminium and bit (Siemssen, 2008).

4. Microstructure examination of FBJ joint

Miles et al., 2009 and (Siemssen, 2008) both investigated the microstructure of a FBJ that connects 1.8 mm AA 5754-O to 1.4 mm DP 980 steel using a 4140 steel bit (Figure 12). This research shows the existence of a void at the junction of the joining bit, and the steel bottom sheet (Figure 13). This defect was reported as the primary reason for poor joint strength, during cross-tension tensile testing. The elimination of these observed voids in subsequent trials was the main goal for enhancing the joint strength performance of the FBJ method. It's important to understand that while the connection between the outer parts of the bit material and the aluminum top sheet is strong, most of the joint's strength actually comes from the steel joining at the point where the bit meets the bottom sheet.

Due to the integrated flange, this bonding between the bit and aluminum top sheet has no direct impact on how well the formed joint performs in testing, but it does aid in stabilizing the joint against torque forces. The mechanical grip offered by the bit tip's flange would be the sole barrier against rotational loading in the absence of this metallurgical bond between the interface of aluminum and bit. The cross-sectioned FBJ sample is displayed in both regular and zoomed-in SEM images of FBJ joints connecting DP 980 steel sheet to carbon fiber reinforced plastic sheet in Figure 14 (Lim et al., 2018). Figure 14a shows no visible defects in the consolidated bonding between the combining bit and DP980. Figure 14(b,c) displays SEM images near the combining bit and carbon fiber composite. The CFRP matrix occupied the area between the CFRP and the joining bit at a distance of between 0.5 and 1.0 mm from the edge of the connecting bit. In this section, as shown in Figure 14(d,e), carbon fibers close to the joining bit have been shifted by the joining bit's rotating motion during the joining stage.

5. Corrosion behaviour of FBJ joint

FBJ joints can be protected from reactions of oxidation and galvanic corrosion by using adhesive, according to corrosion tests (Anes et al., 2016; Wen et al., 2024). A complete 30-cycle corrosion test was done, where each cycle included 15 minutes of being soaked in or sprayed with a 0.5% NaCl solution, then 5½ hours at 25 °C and 95% humidity, followed by 18 hours of drying at 50 °C and 70% humidity (Ekerenam et al., 2025; Yoo et al., 2023). The relationship between weld strengths and the programmed parameters was recently investigated at Brigham Young University (Squires, 2014). This study produced the best joint results. Testing for corrosion has been done on FBJ welds both with and without an additional adhesive layer (Lim et al., 2015; Pan et al., 2021). This study on adhesives

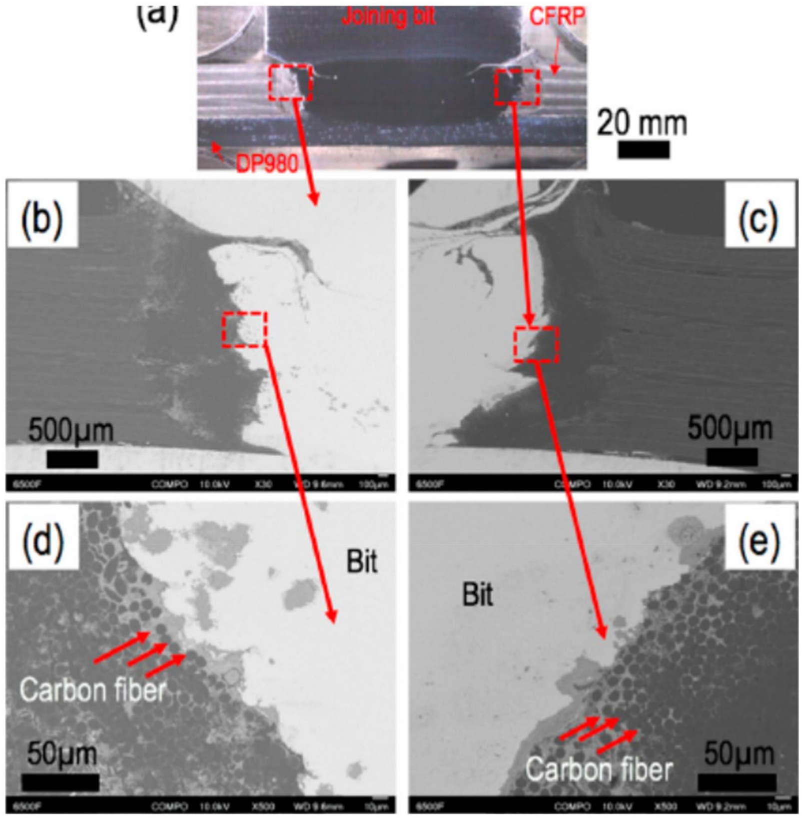

Figure 14. Microstructures of FBJ cross-section view (Lim et al., 2018).

found that while the additional layer successfully preserved the structural stability of the joints in a corrosive environment, it provided essentially no improvement in joint strength compared to FBJ welds without an adhesive layer (Lim et al., 2018).

6. Summary

Friction Bit Joining (FBJ) has emerged as a very promising process to address the difficulties in joining dissimilar materials used in the automotive and aerospace industries. This paper provides a comprehensive assessment of the FBJ process, mechanical properties, microstructure and corrosion resistance. The review highlights the substantial potential that FBJ has in producing highly strong joints which match or exceed automotive standards. The review determined that FBJ joints provide more exceptional strength than industry standard average mean peak lap shear loads on DP 980 Steel to and AA 7075-T6 at 12.9 kN versus 5 kN, and T-peel tests on GADP 1180 steel to AA 7085-T76 joints peaked at 1.897 kN versus the 1.5 kN standard. This is an impressive load considering that a key requirement for FBJ was that it preserve the mechanical integrity of both parent materials. The samples were reported to have excellent fatigue life, enduring greater than 10 million cycles before failure. Microstructurally, these samples formed solid-state metallurgical bonds, although a few researchers claimed small voids were observed at the bit-steel interface, which may also have some influence on strength. Overall, this paper established that FBJ is practical, effective, and more economical for producing structures that are lightweight and high-strength, and it may be suitable to revitalize the more expansive application of dissimilar joints in future technologies.

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No potential conflict of interest was reported by the author(s).

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