Process Capability & Fascinating applications of Friction Stud welding

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Abstract. In earlier days, welding only involves joining two metals of same kind and dissimilar metals were usually joined by fasteners. Friction Stud welding is a true engineering marvel of making welds between dissimilar metals without any melting or fillers involved. The friction stud welding doesn’t involve heat generation from electricity and it is purely based on friction. Besides these facts the friction stud welding has numerous advantage and applications. This paper focuses on the process of stud welding, application and its limitations.

Keywords. Friction; Temperature Distribution; Stud Welding; Impact strength; Dissimilar Joints.
1. Introduction

Friction stud welding [1-23], Friction Plug Welding [24-28], Diffusion bonding [29, 30], Friction Welding [31-44] Friction Drilling [45-63], and Friction Riveting [64-67] are few processes employed for joining of dissimilar metals. Friction stud welding, a solid phase welding technique that uses a stud rotating at a high speed, being forced against a substrate and generating heat by friction [2,5]. The metal surfaces reach the temperature of plasticity and they flow plastically under pressure, surface impurities are expelled and a forged weld is formed [7]. The melting point of metals are much higher than the maximum temperatures attained. It is a unique type of friction welding process. Portable equipment for friction stud welding is available for the use on construction work sites, offshore, underwater and in workshops [12,46]. These units are portable and are lighter and smaller than the large static friction welding machines. The weld time being short, around only 4 seconds for a 10mm diameter stud. Weld quality is consistently high, and when destructively tested, failure invariably occurs in the weaker parent material and well away from the weld.

1.1 Significance of Friction Stud Welding

The friction stud welding process is well suited for deep water naval applications, short-term emergency repairs and for submarine rescue. Ocean engineers pursued the application commercially for offshore platform repairs. Moreover, Aluminum/stainless steel friction stud welded joints are inevitable in pipes of liquid propellants in Satellite Launch vehicles and rocket fuel tanks [50]. Recently, there is a need of joining a steel ear thing pin, which is in the shape of a stud to an aluminum car body. Production of burner assembly of fossil boilers and smart valve blowing system requires an irresistible need of friction stud welding of M12 steel studs [22].

2. Process Capability of Friction Stud Welding

- The relatively low temperature of weld formation indicates that the process could be adapted for applications such as welding on live pipelines and in explosive environments. Some of the potential problems encountered with arc welding such as contamination of the weld with hydrogen, nitrogen and oxygen, in the presence of electric arc and liquid phase in the metal, are avoided.
- The rapid weld cycle time is typically around 5 to 10 seconds and this method of weld formation results in a fine grain structure. In the “as welded” condition the residual stresses are compressive which tend to result in good fatigue life [9].
  2.1 Limitations
  The process can only be used for the welding of relatively small components such as studs or plugs, which can be rotated at high speed, onto a work piece.
  - The systems used are limited typically 25 mm diameter studs and plugs for filling holes up to typically 25 mm diameter (plug welding). The system requires a rigid clamp for holding the welding tool on the work piece and withstand the force applied to the stud during welding.
  2.2 Applications
  - Joining a steel ear thing pin to an aluminum car body
  - Production of burner assembly of fossil boilers and smart valve blowing system
  - Joining of anodes in an off-shore drill rig
  - Friction Stud Welding through paint in seawater discharge pipes
  - Friction Stud Welding was used to weld 150mm long M12 steel studs during hull repair.
3. Experimentation

The schematic of the experimental set-up is given in Fig. 1. In the present work, friction stud welding is carried out with 12 mm diameter aluminium stud and 12 mm diameter mild steel workpiece with processing conditions mentioned in Table 1. The lathe machine has been modified into the friction stud welding machine. The tool post has been replaced by the pneumatic cylinder and tool holder. The tool inserts for the tool holder has been prepared to hold the stud of diameter 6, 10, 12mm. Two pneumatic cylinders are used to generate axial pressure cylinder and to apply dynamic braking respectively. The brake used is band brake system. The hand braking system has been modified to pneumatic braking system to reduce the braking time because the braking time as an effect on the quality of the weld. The pneumatic circuit has been modified. The 2/2 solenoid valve has been replaced by 3/2 solenoid valve which would cut the power to the electric motor and actuates both axial pressure cylinder and pneumatic braking cylinder. The quick exhaust valve has been connected at one of the opening of pneumatic braking cylinder. The axial pressure cylinder produces the both friction pressure and forging pressure required for the process.

![Experimental arrangement](image)

Figure 1: Experimental arrangement

| S.NO | PARAMETER             | RANGE   |
|------|-----------------------|---------|
| 1    | FRICTION PRESSURE     | 2.0 bar |
| 2    | FORGING PRESSURE      | 4.0 bar |
| 3    | FRICTION TIME         | 6 sec   |
| 4    | FORGING TIME          | 3 sec   |
| 5    | SPEED                 | 1600 rpm|
3.1 Geometry of parts

The experiment specimens were machined from mild steel and aluminium on geometry in below. Geometry of parts is given in Fig. 2 and Fig. 3. Friction stud welding of aluminium with mild steel is characterised by extremely short welding times and high frictional and compressive forces. As a result, the joining plane is kept extremely narrow, to prevent the build up of intermetallic compounds and phases.

![Figure 2: Stud dimensions](image1) ![Figure 3: Workpiece dimensions](image2)

4. Results

4.1 Impact Strength

Impact strength is the energy need to break a specimen by an impact load. The dissimilar joints are subjected to Charpy testing to find the impact strength and their results are given in Table 2.

Table 2: Impact strength

| MATERIAL                        | IMPACT STRENGTH (Joules) |
|--------------------------------|--------------------------|
| Pure Aluminium Vs Pure Aluminium | 15                       |
| Mild steel Vs Mild steel         | 13                       |
| Pure Aluminium Vs Mild steel     | 15                       |
| AA6063 Vs AISI 1030              | 15                       |

4.2 Microstructure

![Figure 4: Pure Aluminium Vs Pure Aluminium](image3) ![Figure 5: Mild steel Vs Mild steel](image4)
Microstructure shows the mechanism of bonding during friction stud welding. Figure 4 shows the microstructure at the interface of friction stud welded pure aluminium-aluminium joints. Figure 6 shows the microstructure at the interface of friction stud welded aluminium-mild steel joints. Figure 7 shows the microstructure at the interface of friction stud welded AA 6063 – AISI 1030 joints.

5. Conclusion
Friction stud welding finds more applications in repair works and hole fillings. This is also suitable for welding small components. The friction stud welding can be probably exploited for particular application as the mentioned above and utilized especially in case of welding of dissimilar metals. Friction stud welding of different dissimilar materials such as Aluminium-Copper, Aluminium-Brass, and Aluminium-Stainless steel can be done by varying the critical process parameters. Online monitoring of the entire process could be carried out with a dedicated computer system.

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