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Effect of Process parameters on Linear Friction welding of Commercial Grade Pure Aluminum

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Abstract

This paper investigated the effects of process parameters such as burn off distance, oscillating frequency, and forging pressure on linear friction welding of commercially pure aluminium. Friction welding (FW) techniques are a group of techniques that are based on frictional heat between components that occurs during movement while under pressure. Linear Friction welding is a solid-state process in which one part moves in a linear fashion at high speed and presses against another part that is held stationary. Linear friction welding (LFW) is a very well specialized technology used by global gas turbine engine manufacturers to create bladed disc assemblies. The sample bar with a cross section of 25mmx25mmx140mm was used for the experimental testing. The results were obtained by maintaining amplitude and frequency at 1.5mm and 40Hz, respectively, and forging pressure at 10MPa, 15MPa, and 20MPa. It is observed that, Lower HAZ. Burn-off distance grew as forging pressure increases with time.

Key Words: Burn-off distance, Forging Operation, Friction welding, linear friction welding.

1. INTRODUCTION

The term "friction welding" (FW) refers to a class of technologies that rely on the frictional heat generated when two components move against one another while being compressed. The conditions of weld production, which are carried out by plastic deformation at high temperature and generated by the heat generation due to the presence of friction, are a common factor in friction welding. During the processes, the temperature increases, but it remains below the melting point and is dependent on the process variables and the welding materials [1]. The production of integrally bladed discs for aeroengines uses a solid-state joining technique called linear friction welding (LFW), which has established itself as a cutting-edge technology [2]. When heat is produced by friction between the pieces and force is applied, a plasticized layer forms at the contact. Due to the operating forces, most of this plasticized material in the weld zone is evacuated from the weld, forming the so-called flash. As a result, the component becomes shorter. The two pieces are eventually effectively fused together, with some plasticized material still present at the weld line. Samples having a rectangular cross section can be welded together using the LFW technique. This is due to the phenomenon of recrystallization, which is caused by high temperature and large deformation occurring in this region of the weld. The second region is a thermo-mechanical affected zone (TMAZ)[3, 4]. Although the microstructure in this zone also varies, the changes are not as noticeable as in the WZ due to smaller deformations and lower temperatures, which are related to a greater distance from the central weld line. The hot zone is in the third region (HAZ). In this area of the weld, there are no longer any plastic deformations visible; instead, only the influence of temperature, which might alter the microstructure, is visible. Between the base material and weld zone, HAZ and TMAZ are referred to as the transition zone. The weld's outer zone is made of a base material (BM). It is situated away from the main welding line, where it is not impacted by temperature changes or plastic deformation. The material in the welding zone (WZ) heats and plasticizes more quickly because of the increase in amplitude and frequency, which also shortens the time required for the friction stage. As a result, the other zones, which are farther away from the welding Centre, do not reach high temperatures. WZ, TMAZ, and HAZ are smaller thanks to the process's increased strength. Faster heat dissipation from the weld area and element shortening can be used to explain this effect. The effluent and heat are both evacuated from the weld location, lowering the element's temperature there. The heat emitted can also only have a temporary impact on the remaining material because of the shortened friction phase length. These advantages include but are not limited to lack of defects connected with solidification, such as porosity or hot cracking, or possible increase in mechanical properties in WZ due to recrystallization[5]. Additionally, the method has a high reproducibility because it doesn't require additional consumables and its settings are simple to control. It is possible to create welds that are comparable and distinct. The main drawbacks include flash, which forms during welding and must be cleaned up, shape restrictions on welded sections, and the necessity of using plastically malleable components.

In the present work Linear friction welding (LFW) of commercially pure aluminum of rectangular section machined using EDM is carried to understand the effect of process parameters like Burn off distance, oscillating frequency and forging pressure on CP Aluminium widely used in aerospace and automotive parts.

2. EXPERIMENTAL PROCEDURE

In order to create frictional heat, a stationary portion is pressed against a part that is linearly reciprocating during the linear friction welding (LFW) process as shown in Figure 1. Material at the weld contact deforms and plasticizes because of heat and stress that are applied perpendicular to the weld interface. A significant amount of this plasticized material is evacuated from the weld as flash as a result of the component movement and force application working together. Surface oxidations and other impurities are eliminated together with the plasticized material, enabling metal-to-metal contact between the components and the formation of a joint.

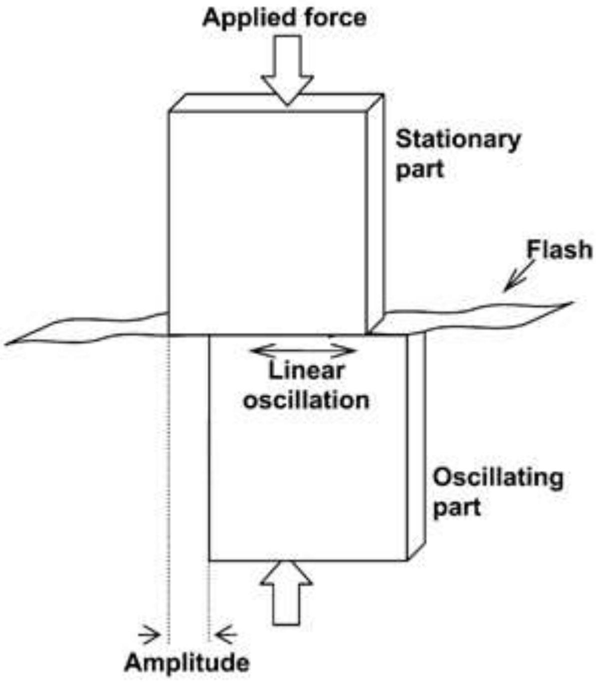

Figure 1. Schematic diagram of the linear friction welding process

The process's high capital expense for the equipment is one of its key drawbacks. The LFW process can only be used to produce components with a high value-added because of the high cost of the equipment and tooling. Due to this, the technology has mostly been used to produce bladed discs for aviation engines and other specialised purposes. But because machines based on the idea of stored energy—as opposed to direct drive—have much lower costs, it may be acceptable to justify the LFW of lower-value-added components. The procedure also has the drawback of being somewhat noisy.

There have been a few brief literature reviews on LFW, although they tend to concentrate on particular aspects of the process, like energy input or the use of the technique for blisk manufacturing. Both assessments have avoided attempting to provide a comprehensive and in-depth summary of the procedure, which is what this document seeks to achieve. This review should therefore be a useful addition to the body of existing research on LFW.

2.1 Sample preparation

CP Aluminum samples of the below dimensions were machined using wire EDM. Cross sectional area for welding was polished till EDM striations are removed.

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Dimensions of the sample: 25*25*140 mm
Area of cross section – 25*25
Length of sample – 140 mm

There are several parameters involved in LFW which can have a significant impact on the joint properties. These parameters include:

The number of oscillations (of the reciprocating part) accomplished in a second is the study's definition of oscillation frequency.

Oscillation amplitude: the largest deviation of the oscillating sample from its equilibrium location (equilibrium position is when the displacement between the oscillating and stationary sample is zero, i.e. samples are aligned)

In the rubbing or frictional phase of the process, pressure is exerted perpendicular to the weld interface. This pressure is referred to as "friction pressure." The nominal area of contact with zero amplitude is used to determine pressure.

Forge pressure: the pressure that is often provided at the end of the operation (after oscillation has stopped) for a certain amount of time to consolidate• burn-off distance: the distance that the parts are allowed to shorten (shortening is caused by the removal of plasticized material from the weld) before the amplitude is decayed and the forge pressure is applied.

3.0 RESULTS AND DISCUSSION

Small specimens were cut from the weld cross section and polished for taking macrographs of the weld region. Figure 2.1 and 2.2 shows micrographs of weld specimens.

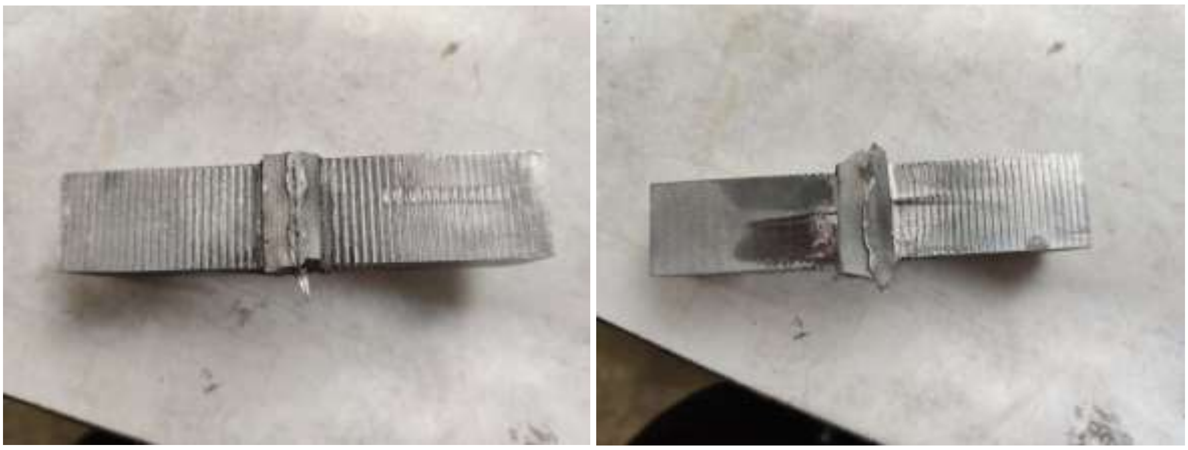
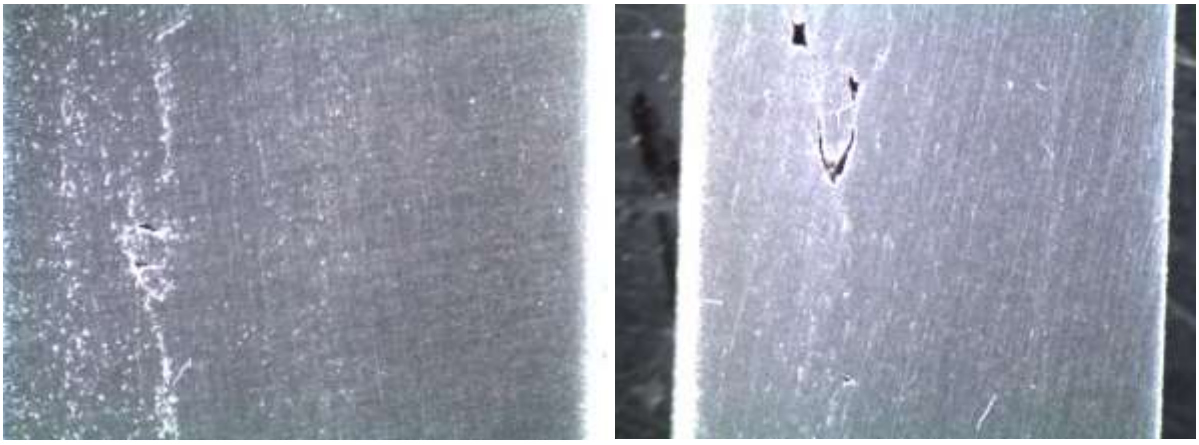


Fig 2.1(a-b) Weld specimens



(c)

Fig 2.2 (c) Macrographs of weld section

From Macrographs it is observed that at 25 MPa the best weld joint among all was obtained with comparatively very less defects and compared to all the welds the best weld was obtained for forging pressure 25 MPa.

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Table1.1. Details of Process parameters in Linear friction welding

Experiment No	Amplitude(mm)	Oscillating Frequency (Hz)	Forging Pressure (MPa)
1	1.5	40	10
2	1.5	40	15
3	1.5	40	20

Process parameters were selected as shown in Table1.1 keeping amplitude and frequency constant and Forging Pressure.

3.1 Input parameters: 1.5 mm, 40 Hz, 10 MPa

Figure 3.1 to 3.3 shows the Variations for different parameters

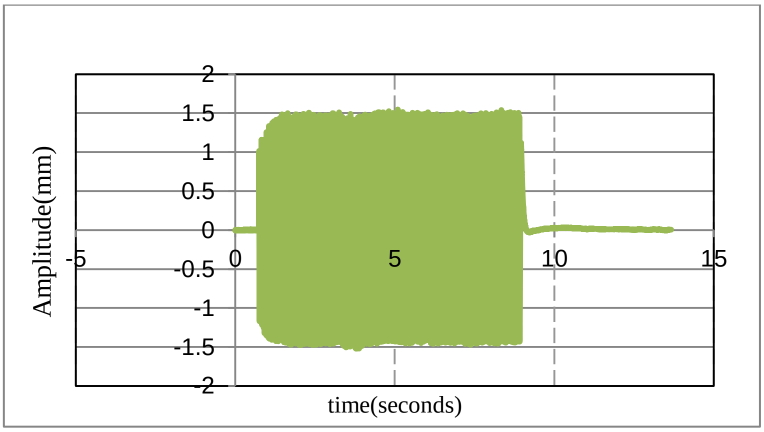

Fig 3.1 Variation of condition and friction phases as amplitude

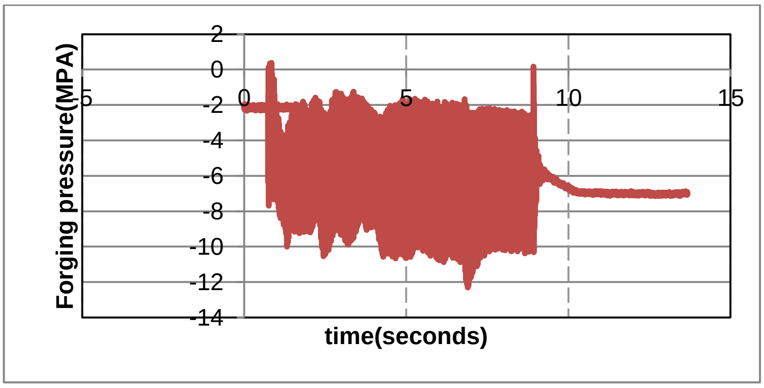

Fig 3.2 Variation of condition and friction phases as Forging Pressure

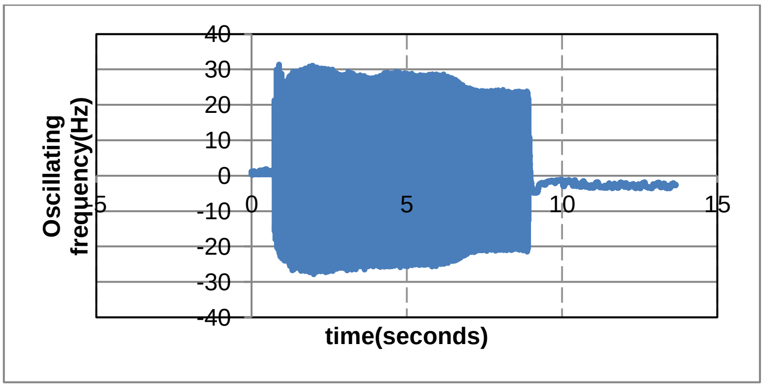

Fig 3.3 Variation of condition and friction phases with Oscillating frequency

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In the initial experiment, the process parameters were 1.5mm amplitude, 40Hz oscillation frequency, and 10MPa pressure. Heat is produced at the interface as the compressive force (friction force) increases to a predetermined amount. Because of the shearing motion, the material near the interface turns plastic and flows as flash out of the weld. between the two components and the force being used. The pieces shorten because of this material loss from the weld (or burn-off). When a pre-set loss of length, or burn off distance, is reached, this phase typically ends and the next is initiated. However, the frictional phase may also last for a set period (burn-off time) or a number of oscillation cycles before the subsequent phase is initiated (burn-off cycles).

3.2 Input parameters: 1.5 mm, 40 Hz, 15 M. Pa

Figure 4.1 to 4.4 shows the Variations for different parameters.

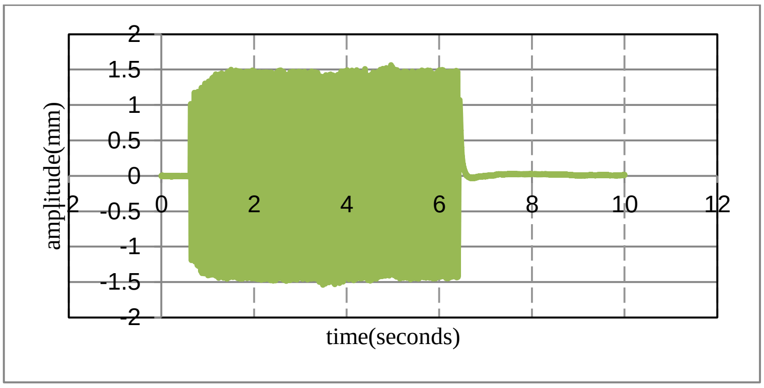

Fig 4.1 Variation of condition and friction phases as amplitude

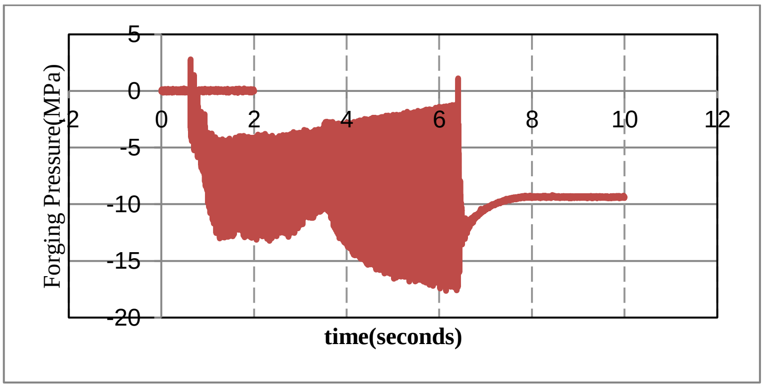

Fig 4.2 Variation of condition and friction phases as forging pressure

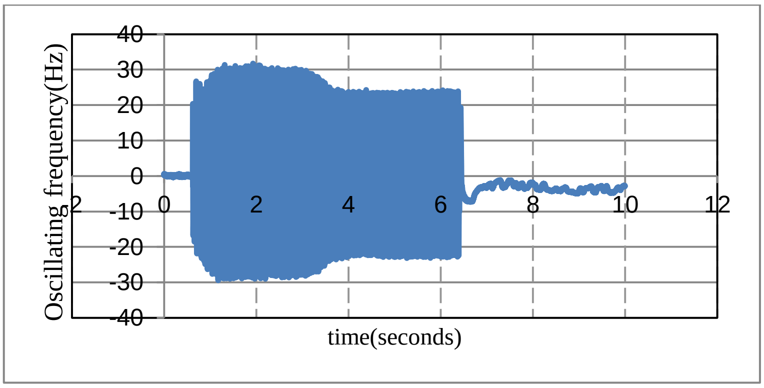

Fig 4.3 Variation of condition and friction phases with oscillating frequency

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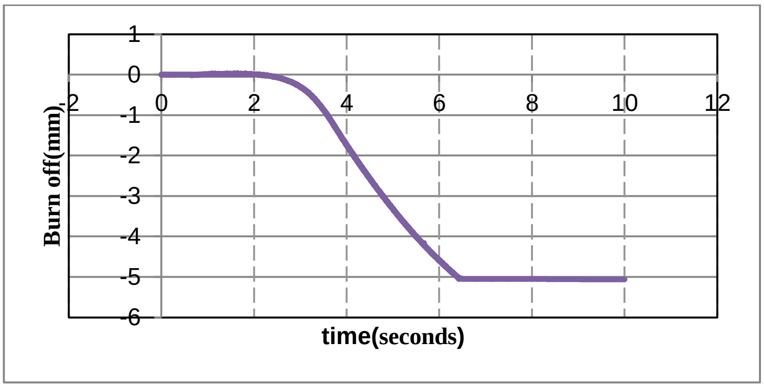

Fig 4.4 Burn off(mm) VS Time(s)

During second experiment with process parameters of amplitude 1.5mm and oscillating frequency of 40Hz and Forging Pressure 15MPa.The compressive force (friction force) is increased to a set level and heat is generated at the interface. Friction phase is observed more with this experiment.

3.3 Input parameters: 1.5 mm,40hz,20 M.Pa

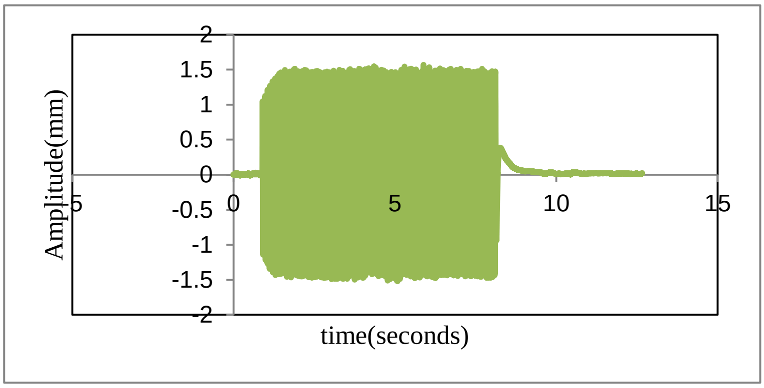

Fig 5.1 Variation of condition and friction phases as amplitude

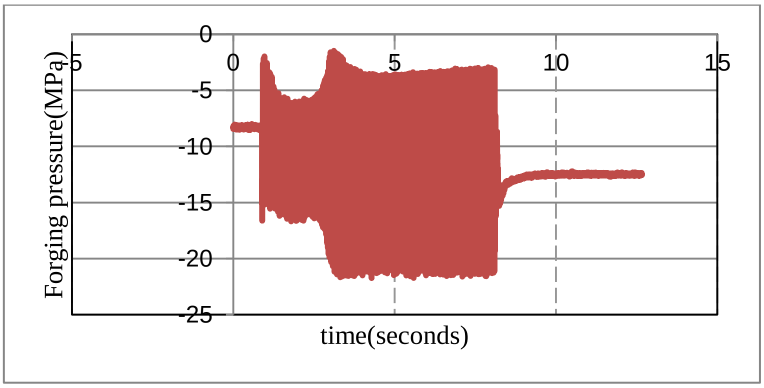

Fig 5.2 Variation of condition and friction phases as forging pressure

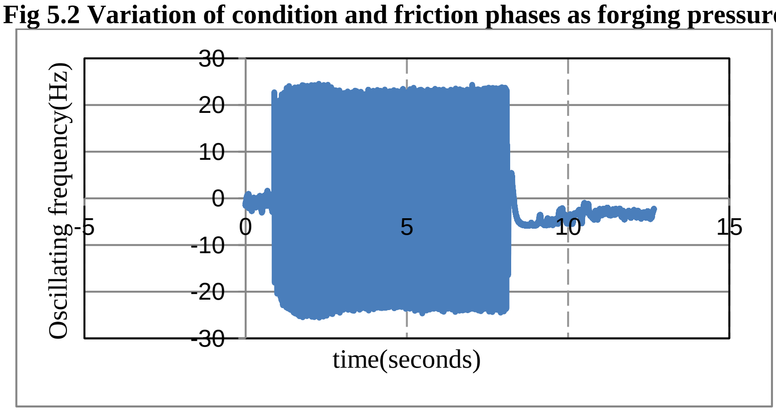

Fig 5.3 Variation of condition and friction phases with oscillating frequency

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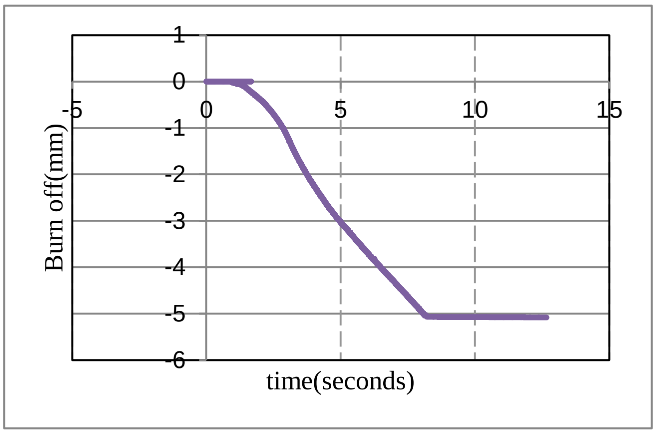

Fig 5.4 Burn off (mm) Vs time(s)

It is observed that in general the welding time keeps decreasing as we keep increasing pressure or forging load for each experiment except for forging pressure 20 MPa where some time increase was there. Commercially pure aluminium is adequately welded using LFW, even though it possesses relatively poor high temperature mechanical properties and very high thermal conductivities. However, high parameters like, high applied forces relative to the material strength, and high amplitudes and frequencies are used to get the heat concentrations required to produce sound welds.

4. CONCLUSION

Based on the Experimental results, following conclusions were drawn,

1. In Commercially Pure Aluminum a weld joint is obtained but only very little flash was observed coming from the weld center that was observed.

2. From the three experiment results obtained we can observe that for each experiment as the pressure increases the burn off rate for each experiment keeps on increasing.

3. It is observed that in general the welding time keeps decreasing as we keep increasing pressure or forging load for each experiment except for forging pressure 20 MPa where some time increase was there.

4. From Macrographs it is observed that at 25 MPa the best weld joint among all was obtained with comparatively very less defects and compared to all the welds the best weld was obtained for forging pressure 25 MPa.

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