Stress corrosion cracking for dissimilar capacitive discharge welding joint with varied surface preparation and inputted energy

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Abstract. In this article is presented dissimilar welding joint that joins steel and brass bars. Due to its varied melting point the welding process of dissimilar metal has a higher degree of difficulties. Naturally, welding process embeds residual stress and provides voids at least in micro scale. The voids then act as a trigger to develop initial cracks which will grow under external load. Once, the welding joint is exposed to corrosive environment, it will be susceptible to Stress-Corrosion-Cracking (SCC) failure. The quality of the welded joints is considered based on SCC resilience. Two parameters of the Capacitive Discharge Welding Joint which have prominent effects were evaluated: surface preparation and inputted energy. With a proper surface preparation it is hoped optimum welded joints can be obtained. The experiment results show that the α₁ surface preparation, i.e. the sharpened steel interface while the brass is kept on perpendicular edge, provides better performance under SCC load. Highest inputted energy (120J) always provides the longest duration for joint exposed to SCC load before the failure. The high inputted energy gives high heat to melt the interface which in turn produces compact joint at the interface.

1. Introduction
There are method of joint can be found such as rivet, bolt or welding. Welding may the most prominent and widely used due to its effectiveness: easy to operate, high strength and avoid water leak. There are many welding method have been developed and one of them is Capacitive Discharge Welding (CDW). CDW is electric resistance method in which the high pulse electric current produce by high capacitor bank [1]. Scothmer mentioned automotive some industry in United States is starting to apply the CDW [2] which is endorsed by Panella since CDW provide fast and reproducible process [1]. Chiozzi modified the interface of the welded specimen. The waving interface was implemented to increase the area of fusion and improve the weldability [3]. Dattoma carried out research to obtain optimum welding parameter and surface of CDW. In this research activity, 150 cylindrical specimens with bore diameter 6 mm and different igniter dimensions were machined in AISI 304 austenitic stainless steel. Parameters and geometry igniter / tip were classified into 15 classes. The results shown that the class 14 geometric igniter : height / h = 0.7mm, diameter / d = 2mm, and welding parameters were: compressive force / F = 65kg, energy input / P = 45Kj was the most optimal [4].

The joint may be needed for different materials which for welding it is known as dissimilar welding. The dissimilar welding is applied when different properties are needed [5]. The joint of dissimilar metals
indeed is more complicated compared to same metals due to variation in physical, metallurgical and mechanical properties of the joined metals [6].

Ozlati welded carbon steel and austenitic stainless steel which can be considered as dissimilar welding. The obtained result was very good since the tensile test shown that the highest tensile strength was at welding area. The resulted flash also very neat which reduce the additional process after welding joint is obtained [7]. This research also observes the dissimilar welding joint by means Capacitive Discharge Welding.

Stress Corrosion Cracking describes the failure of materials due to the crack growth as a result of synergy of external mechanical load and corrosive environment [8, 9]. SCC caused catastrophic failures at the constructions, air plane and pipeline [10–12]. SCC was considered as the main phenomenon in the pipelines leaks and blow out with disaster consequences [13]. For certain materials the SCC depend on the aggressive corrosion environment and residual stress [14]. Residual stress is always embedded in the welding joint. Voids which are produced in the welding process trigger the development of cracks. Due to the importance to consider the SCC resilience of welding joint, the resulted welding joint will be evaluated from the SCC point of view.

2. Method

The dissimilar metal joint of steel and brass is obtained using CDW. Based on previous literature there are various geometry when stud or pins welding was applied [15–17]. Hou discussed varied tip geometry for dissimilar aluminum friction welding [18]. The interfaces or tips also been altered for varied welding process [1, 4, 19–21]. Varied surface preparation by means of geometry in this research are engineered as shown in Figure 1a up to Figure 1c, namely specimen $\alpha_0$, $\alpha_1$ and $\alpha_2$.

![Figure 1](image1.png)

**Figure 1.** (a) Specimen $\alpha_0$, (b) Specimen $\alpha_1$ and, (c) Specimen $\alpha_2$.

In this research, there was no specimen with sharpened edge on both sides since it is difficult to provide joint with pointed edges on both side due to misalignment. In Figure 2 is shown the schematic diagram and the photo of the CDW process.
The CDW Process (a) schematically and, (b) the photo.

The composition of the metals for dissimilar joint is shown in Table 1. In Table 2 is tabulated the mechanical properties of the metals. Welding parameters and constants are listed as in Table 3 considering the manual of the hot-spot CDW.

Table 1. The chemical composition carbon steel and brass rods used in this study.

| Materials | Composition (weight %) |
|-----------|------------------------|
|           | Fe  | C   | Si  | Mn  | Cu  | Zn  | Sn  |
| Steel     | Balance | 0.1 | 1   | 1.40 | -   | -   | -   |
| Brass     | -   | -   | 0.3 | -   | Balance | 5.9 | 0.8 |

Table 2. The mechanical properties carbon steel and brass rods used in this study.

| Materials | Mechanical Properties |
|-----------|-----------------------|
|           | Melting point °C | UTS N/mm² | Hardness BHN | Density (g/cm³) |
| Steel     | 1450                | 1036       | 120           | -             |
| Brass     | 899                 | 888        | -             | 8.4           |

Table 3. Parameters used for this study.

| No | Parameters            |               |
|----|-----------------------|---------------|
| 1  | Electrode pressure    | 39.2 N        |
| 2  | Weld Energy           | 80, 90, 100, 110, 120 J |
| 3  | Specimen diameter     | 1.6 mm        |
| 4  | Voltage               | 75 VDC        |
| 5  | Drop height           | 5 mm          |

After the dissimilar joint with varied condition is obtained, the Stress-Corrosion-Cracking test was applied. The SCC test was carried out in laboratory scale. The testing apparatus for SCC was design deliberately for this research using Constant Load Test (CLT). In his research, Chida compared varied SCC test those are CLT, Slow Strain Rate Test (SSRT) and Conventional Strain Rate Test (CSRT) which provide equal results [22]. CLT is used in this research due to in simplicity and easy to be made using typical materials. The drawbacks of the CLT is the quite long duration of the experiment. The sketch of the apparatus shown in Figure 3. The constant dead load was applied at one edge which provides tensile load at specimen on another edge.
3. Results and Discussion

The main results of this research is the duration of the dissimilar joint exposed to SCC load which can be seen in Table 4.

Table 4. The stress corrosion resilience.

| Weld Energy | $\alpha_0$ | $\alpha_1$ | $\alpha_2$ |
|-------------|------------|------------|------------|
| 80J         | 00:52:40   | 00:59:49   | 00:55:52   |
| 90J         | 00:56:04   | 01:08:18   | 00:59:13   |
| 100J        | 00:58:17   | 01:12:51   | 01:05:46   |
| 110J        | 01:01:03   | 01:16:26   | 01:10:03   |
| 120J        | 01:05:53   | 01:21:45   | 01:15:19   |

The independence variables are inputted energy namely 80 J, 90 J, 100 J, 110 J and 120 J; and surface preparation, i.e., $\alpha_0$ and $\alpha_1$. The energy is in the range defined by manual book of CDW machine [15]. The physical meanings of the $\alpha_0$ and $\alpha_1$ can be confirmed in Figures 1, 2 and 3. The dependence variable are time to failure. The Table 4 is presented in a graphic as shown in Figure 4.

Based on the Figure 5 it can be said that, for certain inputted energy the $\alpha_1$ specimen always provides better SCC resilience. The $\alpha_1$ specimen is dissimilar joint with pointed tip for steel whilst brass was kept blunt (perpendicular tip). For the pointed tip of brass and blunt tip of steel produce better joint quality
compared to blunt tip for both metals. However, the results of the point tip at brass still below the point tip at steels.

Figure 5. $\alpha_0$ (left), $\alpha_1$ (centre) and $\alpha_2$ (right) for heat input equal to 120 J.

Figure 6. $\alpha_0$ for heat input equal to 120 J.

Figure 7. $\alpha_1$ for heat input equal to 120 J.

Figure 8. $\alpha_2$ for heat input equal to 120 J.
Based on macro photos (Figure 6,7 and 8) the flash can be evaluated. Observing the flash it can be predicted the strength of the joint. The thicker flash indicates the strongest joint [23, 24]. From the flash it can be predicted that the same trend also obtained from the developed flash, it is the list of joint for 120J heat input obtained from $\alpha_0$, $\alpha_2$, $\alpha_1$ from the weaker to the stronger joints respectively.

4. Conclusions
Surface preparation does affect the quality of the dissimilar joint by means of SCC resiliencies. The pointed tip of steel provides optimum results. 120 joules is the best welding parameter of all the parameters used in this research. The steel has good weldability with a pointed tip and high weld energy because it will make the steel melted in a higher amount and binds brass more tightly. The lower the energy used, the weld joint will be more susceptible to SCC.

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