Experimental and Numerical Testing of the Brazing of Engineering Ceramics Made of Alumina to SS 304

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Abstract

Material scientists have always faced a significant obstacle in the process of joining materials that are distinct from one another. The main aim of this research is to join stainless steel with alumina under pressure. The ceramic and stainless steel SS 304 were joined in this work by brazing with a torch and furnace. The study focused on a ceramic-to-stainless steel joint: a stainless steel 30 mm stripe that was brazed to alumina using the same brazing alloy and alumina to themselves. The joints were evaluated using numerical analysis, and the module was run by Ansys 18.2 in Solidworks 2017. The tensile strength of the experimental work reached 62 MPa during slow cooling with pressurized air at the furnace, as shown by the numerical analysis result. This is lower than the fracture of the ceramic material alumina.The Tensile Stress at 65.3MPa in the numerical analysis corresponds nearly exactly to the experimental work.

Keywords- stainless steel, alumina, brazing, metals.

I. Introduction

Dissimilar metals welding is used to describe the joining of two distinct materials [1]. Due to the significant differences in physical, mechanical, and metallurgical properties, this joining is more challenging than joining similar materials [2]. The increasing significance of hybrid properties in numerous modern industrial applications necessitates the joining of disparate metals [3].

The process of joining metallic components using heat, pressure, or both are known as welding. As the filler material is liquid at temperatures higher than 450 degrees Celsius (840 degrees Fahrenheit), this joining process is typically referred to as brazing rather than soldering [4]. It is distinct from the brazing process, in which only the filler metal is used. Joining by the soldering process, on the other hand, binds metals together using a nonferrous filler metal with a melt (liquids) at a temperature of fewer than 450 degrees Celsius. The distinctions between soldering, brazing, and welding Soldering and adhesive bonding are not appropriate for high-temperature applications [6]. Because the entire component can reach the same temperature when brazing, the kind of localized heating that can distort the welding process is avoided, so brazing causes less thermal distortion than fusion welding does. However, compared to other types of welding, brazing has several advantages because it does not require the base metals to be melted [2].

The American Welding Society (AWS) defines brazing as "a set of techniques of welding to generate the combining by heating to proper temperatures higher than (450 °C) and by using filler metals (braze alloy) that must possess a liquid temperature higher than (450 °C) but lower than the solidus of base materials" [7, 8]. Brazing is a type of welding that uses filler metals (braze alloy). The capillary attraction that exists between the perfectly aligned joint surfaces distributes the braze alloy [9]. The filler metals can effectively wet the surfaces of base materials if the following three essential requirements are met [10,11]:

1. The base material can alloy the filler.
2. Surfaces that are free of oxide and free of contamination from the base material
3. The filler and base material both reach working temperature.

Ceramic-metal joining can be achieved through direct or indirect brazing, depending on the ceramic surfaces and the type of filler, and assemblies that combine ferrous and nonferrous metals are simple to join [2].

A.Applications

Stainless steel-Ceramic joints Direct brazing is used to create the plasma-facing parts of their nuclear fusion reactors. Brazing is used for joining cooled TZM, steel, or copper structures to carbon base refractory tiles (graphite, C-C composite). In electrical engineering, components consisting of alumina are brazed into tight connectors and insulators. For the production of power electronic components, aluminum nitride brazing was created.

Due to its high thermal conductivity, superior thermal shock behavior, and corrosion resistance, silicon carbide has the potential to be employed in heat exchangers at high temperatures in the aerospace, automotive, and power generation industries [3]

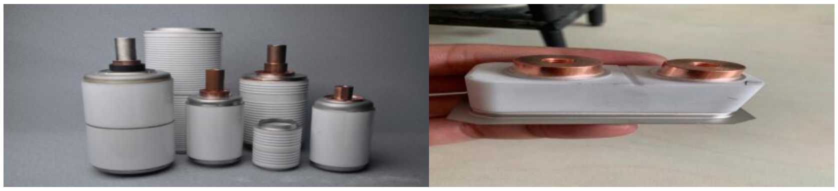

Figure 1. Cerimac's Uses for Stainless Steel Joint

II. Literature Review

The previous studies provide information about the binding of various metals to the brazing process, as well as variables and information about the binding's outcomes.

2.1.1 Brazing a DSS (Duplex stainless steel) and ceramic joint Hye Sung Na et al.[3] investigated in 2007 the brazing of DSS (Duplex stainless steel) and ceramic using the AWS 4764 filler alloy. An (OM) and an (SEM) were used for the microstructural observation with (EDS). The stainless steel phase's interface was breached by the insert Meta, which then transitioned into the phase with base metal's microstructural properties. Additionally, pieces of stainless steel entered the liquid insert metal after breaking off. The specimens showed base metal fractures, and their shear strength was only about half that of the Cu-Cr alloy.

Changqing Ye[6] investigated the dissimilar materials of ceramic (T2) and stainless steel (1Cr18Ni9Ti). They were joined using the vacuum brazing technique, with the filler metals B-Ag72Cu and Ag-21Cu-25Pd. They were examined with the use of EDS, SEM, and OM. The distribution of microhardness in the fusion zone was measured using the microhardness test. The best filler metals to use when vacuum brazing stainless steel with copper or a copper alloy are B-Ag72Cu and Ag-21Cu-25Pd. Because of its higher wetting capacity, Ag-21Cu-25Pd brazing filler metal is superior than B-Ag72Cu filler metal when utilized in intricate composite structural components. The microhardness of dendrites was on average HV 117.

Swathi Kiranmayee M et alin 2012 [5] investigated brazing a Cu-Cr-Zr-copper alloy to 321 stainless steel sheet joints. Three millimeters of metal were present in each sheet. The Cu-Mn-Ni-Sn-Fe alloy foil, which contained traces of Si and B, was examined under a light microscope and in an EDS-equipped SEM, both of which were used as brazing fillers. In contrast to the necessary strength of 150 MPa, the joint brazed at 1030 °C for 30 minutes exhibited an optimum shear strength of 155 MPa.

Zhuhai Chen and colleagues [7] [Ceramic and 201 stainless steel were joined using a hybrid process (brazing and laser welding) in the study. All of the base metals had dimensions of (50 x 50 x 2) mm3. An OM and an SEM equipped with an EDS system were used to examine the joint microstructures. Due to laser welding's high supercooling level and high cooling rate, In the fusion welding mode, the liquid phase in the fusion zone experiences secondary and primary liquid separation. A thermal stress mismatch in the fusion zone led to several microcracks, which are being repaired by the liquid copper filling.

III. Design of the Joint

Lap and butt brazed joints are the only two fundamental types. All other joints are the only places where these two basic types can be altered. Typical brazed joint types are shown in the figure2.

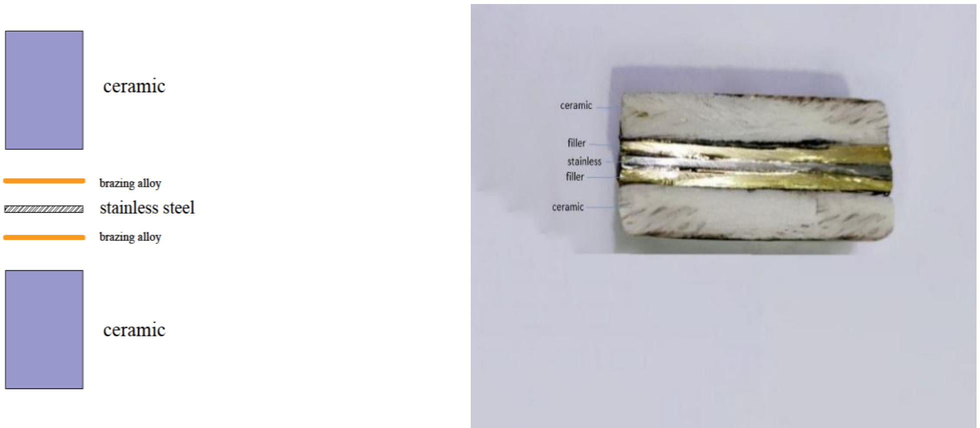

Figure 2: Exploded view of the material/alloy brazed test

The butt joint is used when the thickness of the lap joint is undesirable and when the strength of the brazed joint is sufficient to meet these requirements[2]. The bonding area between lap joints may be larger than that between abutting joints. Indeed, the joint as strong as feasible by varying the overlap area.. An example tensile test specimen was drawn and analyzed with Ansys 18 using Solidworks 2017. Stress, strain, and deformation constitute the mechanical analysis.

The joining of materials happened in a furnace with slow cooling in a furnace and fast cooling in the air.

Joining using a torch is used to compare also.

Pressure add using two plate metal in some experiment to know influence of pressure of brazing process.

A.Numerical Result

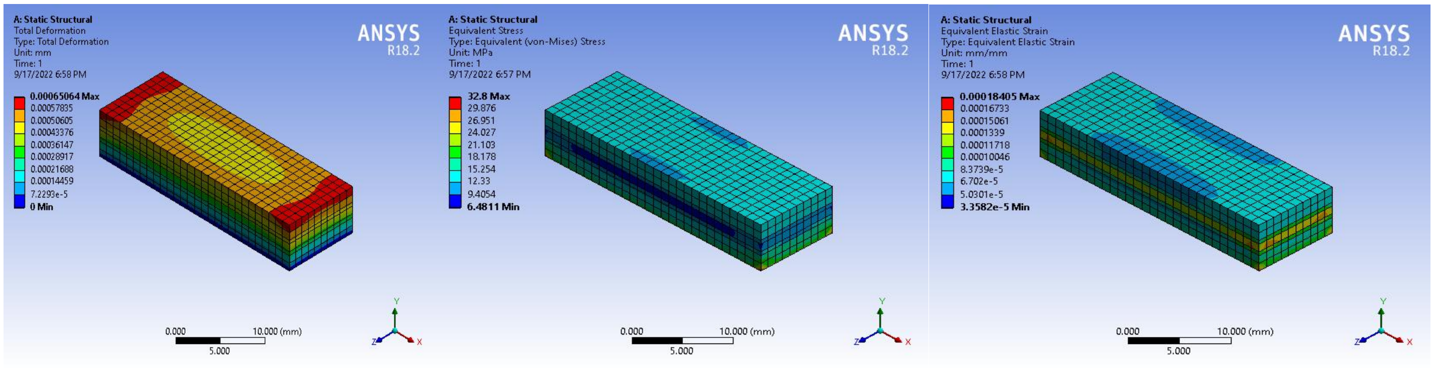

Figure 3: Joint ceramic/304SS that Brazing by Ansys 18.2

The numerical analysis of the brazing of dissimilar material ceramic to stainless steel by brazing alloy.

With 35609 elements and 54290 nodes, the specimen of research has been drawn using SolidWorks 2017 and analysis with Ansys 18.2.

The specimen is to compare experimental and numerical, the maximum stress is 65 MPa, maximum strain is 0.00018.

The stress distribution along the specimen is good due to the regular shape of the specimen, the deformation along the specimen is not high also the strain is low to avoid any problem in the design.

B. Experimental result

Microstructure Examination.

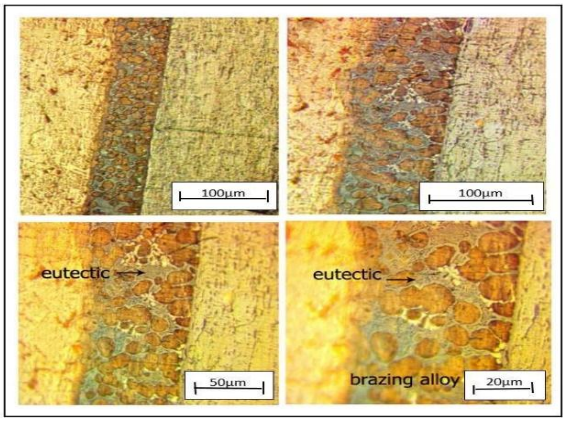

Figure 4.The result shows that the stress distribution in the joint zone is less than the fracture of ceramic material alumina. Optical Microscopy for Joining of Cu/304SS by under tension Brazing with Various Amplification (a)100x (b)200x (c)400x (d)600x

The specimens that cool in the air from brazing temperature will getting a high cooling rate Therefore, it failed in the interface between SS/brazing alloy, with a low value of strength, in addition to the thermal stresses generated due to its rapid cooling.

From OM obtained different microstructure, the specimens that braze in torch have eutectic with distribution nodular copper. That may be due to from brazing alloy (filler metal containing 21-23% Cu) during bearing at high temperature, which is controlled temperatures in furnace temperature and faster cooling rate so the Cu precipitation as nodular. The specimens that braze in the furnace have agglomeration eutectic in the center of the brazing alloy.

Mechanical Assessment.

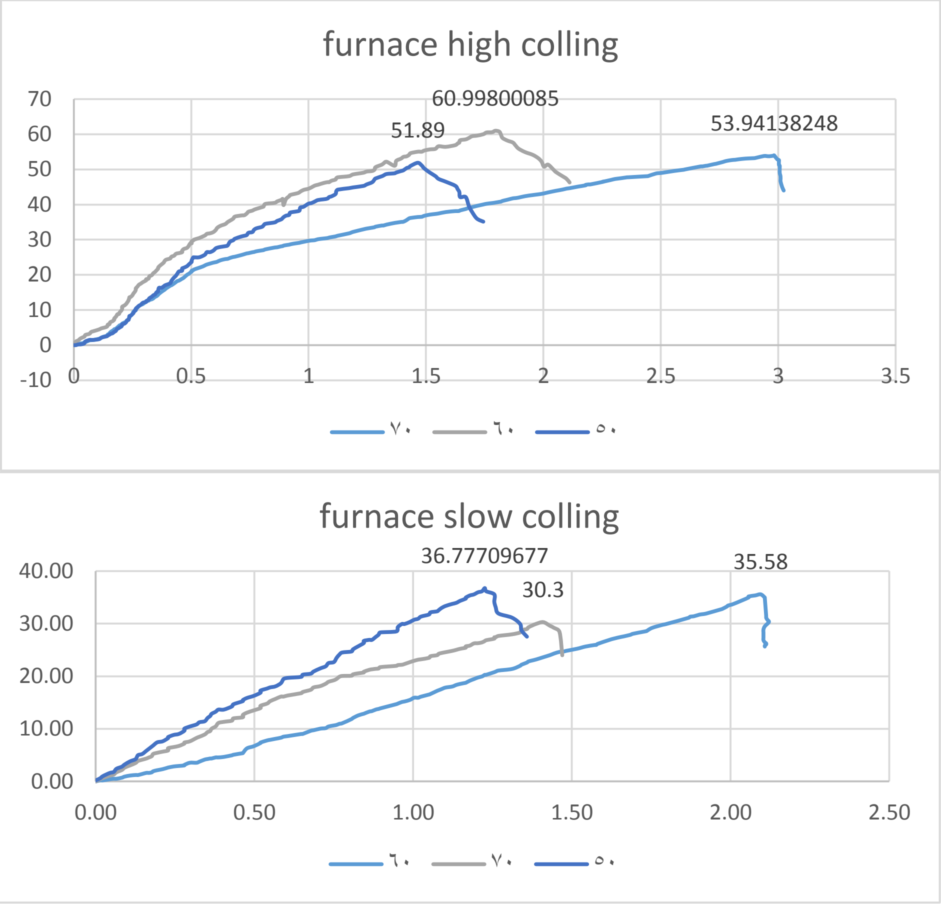

Figure 5. tensile stress Joint ceramic/304SS that was Brazing by the furnace under pressure, slow cooling

The sample that was brazed and left it in a furnace brazing slow cooling had the highest tensile stress strength (60.12 MPa). Figure5 The joint strength may fall appreciably due to excessive voids (because of the cooling rate), flux inclusions, etc. Larger clearances will permit greater flexibility in machining but result in weaker joints and waste filler metal, this is due to the softness of the brazing alloy to produces more ductility in the joint.

IV. conclusion

Brazing filler metal was used to join ceramic and austenitic stainless steel type 304. The joining was done with a torch and a furnace, with flux and a vacuum acting as protection. In addition to EDS and SEM, microhardness and tensile tests were used to evaluate the strength of the brazed joints. XRD was used to predict the newly developed phases.

The following can be concluded based on the findings of this study:

1. In torch brazing, the tensile stress strength of a joint of samples is lower than that of a joint of samples' pressure. The specimen's torch-brazing failed at the stainless steel-brazing alloy interface.

2- The numerical analysis reveals that the stress district, but not the joint zone, is less than the fracture of ceramic material alumina. 3- The highest value of tensile stress strength was reached (60.99 MPa) at a pressure 60 N/m2 in the sample that was brazed and left in a furnace cooling. This was achieved by brazing dissimilar material ceramic to stainless steel using an alloy.

At the outcome.

In the experimental work, the tensile strength reached 6.99 Mpa at furnace slow cooling with pressure 60N/m2

The Tensile Stress at numerical analysis 65.3MPa

As result, the numerical analysis almost approximate to the experimental work

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