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ExperimentalInvestigation on Diffusion Bonding of Dissimilar Metals

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Abstract. Diffusion bonding is one of the metal joining process to join same and well as dissimilar metals. In this project stainless steel and copper plates were joined together with the interlayer of cupronickel sheet. The temperature was maintained in the range of 800 - 8500C. At the same time of heating compression load also acting on the specimensupto 5 MPa. To prevent the oxidation process vacuum of 10-4 Torr was maintained. The experiment was conducted for 60 Min. distinct diffusion zones were formed in the joined area of the specimens. The experiments were conducted with different temperatures and pressure. The shear strength of the specimens was tested and at 8250C have maximum shear strength of 8.47KN.

INTRODUCTION

Diffusion Bonding is one of the metal joining process to join similar and dissimilar metals. This process can be done with and without interlayer. Diffusion bonding is a expensive process compare to other metal joining process like fusion welding. But the main advantage in the Diffusion Bonding is the joining of dissimilar metals. Mainly diffusion bonding was applicable in the corrosion resistance applications. Corrosion resistance material was deposited on the top surface of the base metal. The top surface metal may have different thickness. Diffusion bonding process is a more energy consuming metal joining process.

Diffusion bonding with interlayer, the inter layer is melted and the joining was attained. This type of joining used in both similar and dissimilar metals. The interlayer influence the mating surface to bond together. During this process the melted interlayer comes out from the joints and remove the oxides form the joints.[1-3]

During the diffusion bonding inter metallic compounds will form due to the higher temperature and time. This will reduce the strength of the joints. By defining the optimum parameters we can reduce the intermetallic compounds formation. Optimum bonding parameters will give good mechanical properties to the diffusion bonded components.

For the effective joining surface finish and flatness of the components were very much important. Very high surface finish is required to get the sound joints. If the surface finish is not food, the components cannot be joined together. The components should be mirror polished before diffusion bonding process. Final polishing should be done with diamond paste. At last the components surface should be cleaned to remove grease and oil.

During the diffusion bonding process the atoms were exchanged from one region to another by concentration gradient. This process increases the driving force of atoms for diffusion. Due to the diffusion process the

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composition of the metals were varied at the interface. During the joining of titanium and stainless steel diffusion of 'Fe', 'Cr', 'Ni' and 'Mn' into the titanium and forms various intermetallic compounds. [3, 6]

MATERIALS AND METHODS

In this project we are going to use SAE 304 stainless steel and copper. It is a mostly commonly used stainless steel. This steel has not conduct temperature and electricity. This steel has good corrosion resistance than other steels. It is most widely used steel because it has good formability. It can be shaped to various shapes. The melting point of this steel is 1400-14500C. The composition of this steel is given the table 2.1. [7, 8]

TABLE 1. Composition of stainless steel 304 alloy

Composition	Cr	Ni	C	Mg	Si	Co	Ti	Va	Fe
Weight Percentage(%)	18.37	8.31	0.030	1.80	0.500	0.11	0.015	0.070	69.69

Another metal is copper. Copper has good thermal and electric conductivity property. In pure form copper has less strength. It has good ductility and less hardness. To improve the property of the copper it is added with alloys. One of the alloy used is Nickal (Ni). It will form cupro nickel. It has very high corrosion resistance. It has some strengthening elements like iron and manganese. The copper looks like silver in colour.

The Stainless Steel alloy (304) and Pure Copper metal bar of 50mm x50mm x 5 mm dimensions are purchased and these bars are cut into 10 pieces of 50mm x 50mm x 5mm dimensions. The impurities on the surface of these materials are then removed by grinding machine and then dimensioned accurately by using cutting machine. For the inter layer coating to adhere strongly to the surface, these materials are given a mirror polishing using emery sheet of various grades such as 100, 220,400, 600, 800. This mirror polishing technique helps in removing the impurities completely from the surface and hence the coating and bonding strength become stronger.

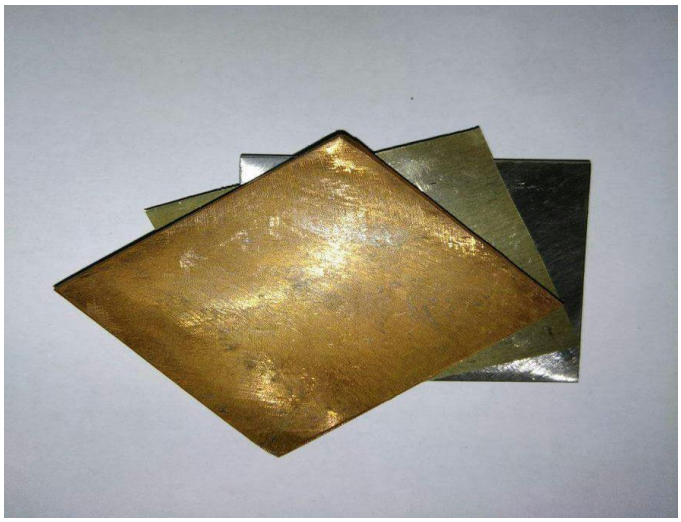

FIGURE 1. Test specimens

Inside chamber should be made of 8 mm thick heat resistant steel suitable to withstand the temperature and should have inside usable chamber dimension of 220 mm diameter x 100 mm diameter round. The bottom part of the retort should be closed with a thick block of the same material top ram shaft made on the same material, fixed along with the furnace with water cooling arrangement and suitable sealing for vacuum. The topside should be similar in construction to the bottom, but the top lid should be fully opened for removing the die and the job. Vacuum seal should be provided at the top between lid and the retort flange with water cooling arrangement on both sides to prevent the seal from overheat.

TABLE2. Details of the Furnace

Inside chamber material	heat resistant steel
Inside usable chamber size	220 mm diameter x 100 mm height Approx.
Outer casing overall dimension	380 mm height x 500 mm
Max design temperature	1000^0C
Rating	4000 watts
Power supply	Heating control: By thyristorised heat control
Controller	Self-tuning type PID digital controller
Vacuum pump	Direct drive 200 LPM

FIGURE 2. Diffusion Bonding Machine

BONDED SPECIMENS AT VARIOUS PARAMETERS

The specimens were heated using induction furnace up to specified temperature and the pressure of 5 MPa was applied. Generally the levels of temperature selected will be in the range of 0.6 – 0.8 tm. Fig shows the diffusion bonded samples with different combinations of bonding parameters like temperature, pressure and holding time in the diffusion bonding machine of max temp 8500C and pressure 5 MPa. After diffusion bonding, the sampleswere cooled to the room temperature in the furnace.Then the specimen were cut by using EDM process. [9-11].

FIGURE 3. Bonded Specimen at Various Parameter

TABLE 3. Parametersof the Experiment

S No	Temperature (^{0}C)	Pressure(Mpa)	Holding Time (Min)	Remarks
1	750	50	30	No bonding
2	800	50	30	Bonded
3	825	50	30	Bonded
4	850	50	30	Bonded
5	875	50	30	Deformed

RESULT AND DISCUSSION

To find the strength of the bonded components, the components were tested in the universal testing machine. The bonded specimens were prepared from the bonded components. The prepared specimens tested for shear test. The testing method shown in the figure 4.

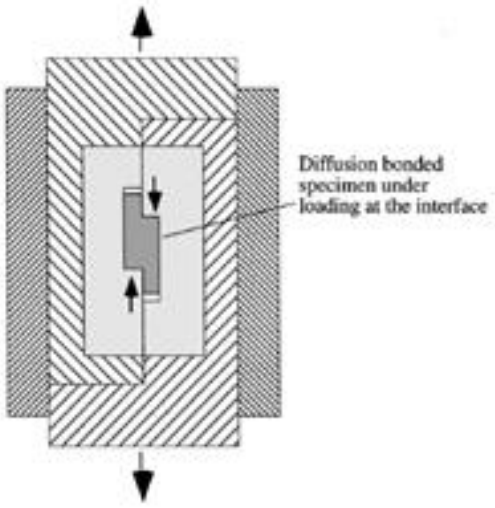

FIGURE 4. Shear testing of the specimen

Through the testing method the shear strength of the specimens found. The test results were tabulated in the table 4.

TABLE4. Parameters of the Diffusion Bonding

Sample No	Temperature ^{0}C	Pressure MPa	Holding Time (min)	Breaking Load (KN)
1	**800**	**5**	**30**	**3.75**
2	**825**	**5**	**30**	**8.38**
3	**850**	**5**	**30**	**4.54**

The maximum shear strength of about 8.38 KN was obtained at diffusionbonded specimen processed at 825° C under the load of 5 MPa for holding timeof 30minutes.It has been observed from above results that the shear strengthincreases with increase in the temperature up to 850° C. With increase intemperature the diffusion rate of atoms increases which helps in formation ofintermetallic compound at interlayer. This helps to increase the shear strength ofthe bonded specimen.

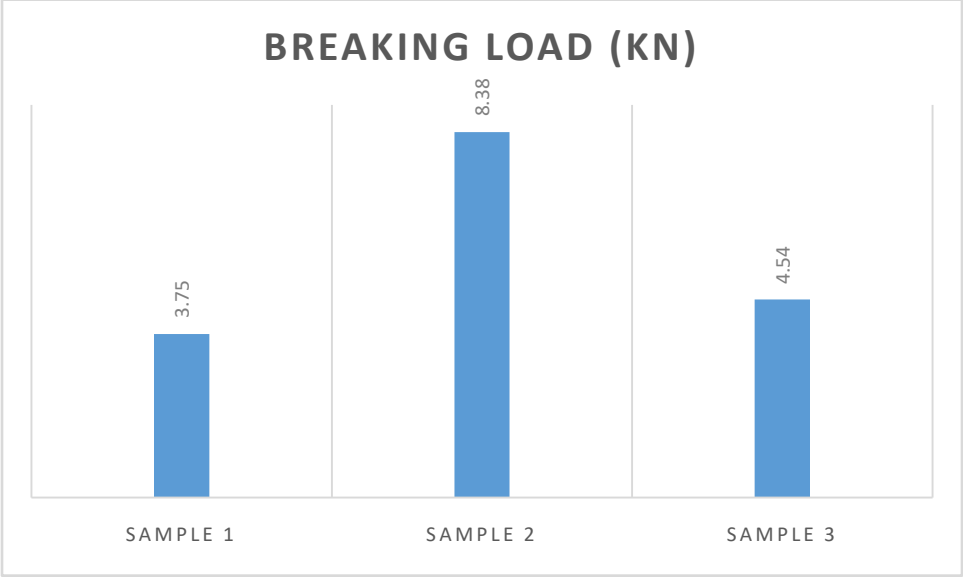

FIGURE 5. Breaking Load of the Samples

CONCLUSION

The diffusion bonding of Stainless steel 304 alloy to Copper metal with Cupronickel interlayer was carried out at various parameters. The characterization of diffusion bonded joints reveals that the maximum bond strength (shear strength) of 8.45 kN have been obtained at diffusion bonded joints processed at temperature 8250C for 30 minutes under the load of 5 MPawith Cupronickel interlayer, due to the better coalescence of mating.

REFERENCES

1. Arafin, M. A., Medraj, M., Turner, D. P. and Bocher, P. “Transient liquid phase bonding of Inconel 718 and Inconel 625 with BNi-2: Modelling and experimental investigations”,Mater. Sci. Eng. A, Vol. 447, 125-135, 2007.
2. Krishtal, M. A. “Diffusion in metals”, Tula Polytechnical Institute, Vol. 7, 71-78, 1973
3. Basu, R. “Diffusion bonding and Fracture in Ti-6Al-4V superalloy”, The Arabian J. Sci. Eng., Vol. 33, 249-262, 2008.

4. Dhinakaran, V., N. Siva Shanmugam, and K. Sankaranarayanasamy. "*Experimental investigation and numerical simulation of weld bead geometry and temperature distribution during plasma arc welding of thin Ti-6Al-4V sheets*." The Journal of Strain Analysis for Engineering Design 52, no. 1 (2017): 30-44.
5. Kundu, S. and Chatterjee, S. "Structure and properties of diffusion bonded transition joints between commercially pure titanium and type 304 stainless steel using a nickel interlayer", J. Mater. Sci., Vol. 42, 7906-7912, 2007
6. Kundu, S., Ghosh, M. and Chatterjee, S. "Diffusion bonding of commercially pure titanium and 17-4 precipitation hardening stainless steel", Mater. Sci. Eng. A, Vol. 428, 18-23, 2006.
7. Budinski, K. G. "Engineering Materials Properties and Selection", Prentice Hall of India, New Delhi, 552-558, 1998
8. RR GokulakrishnanSriram, V. Dhinakaran, Jagadeesha T " *Finite Element simulation of Temperature Distribution and Residual Stress in Single Bead on Plate Weld Trial using Double Ellipsoidal Heat Source Model*" International Journal of Recent Technology and Engineering 8, no. 1S2(2019): 133-138
9. Duarte, L. I., Ramos, A. S., Vieira, M. F., Viana, F., Vieira, M. T. and Kocak, M. "Solid state diffusion bonding of gamma-TiAl alloys using Ti/Al thin films as interlayers", Intermetallics, Vol. 14, 1151-1156, 2006.
10. Elrefaey, A. and Tillmann, W. "Soild state diffusion bonding of titanium to steel using a copper base alloy as interlayer", J. Mater. Proc. Tech., Vol. 5, 2746-2752, 2009.
11. Ghosh, M., Chatterjee, S. and Mishra, B. "The effect of intermetallics on the strength properties of diffusion bonds formed between Ti-5.5Al-2.4V and 304 stainless steel", Mater. Sci. Eng. A, Vol. 363, 268-274, 2003