e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 3, March 2024

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 8.423

|e-ISSN: 2319-8753, p-ISSN: 2347-6710| www.ijirset.com | Impact Factor: 8.423| A Monthly Peer Reviewed & Referred Journal |

|| Volume 13, Issue 3, March 2024 ||

| DOI:10.15680/IJIRSET.2024.1303135 |

A Technical Review of Hybrid Welding of Dissimilar Metal Joint

Raval R Rohit*, Rishabh D. Makwana, Pratik Kikani, Milan Pankhaniya , Mayur R Chotaliya, Darshan H. Bhalodia

Department of Mechanical Engineering, Atmiya University, India [1,2,3,4,5,6]

ABSTRACT: New era of the Industrial Revolution, a new method is established in the welding of similar/dissimilar metals. Welding of dissimilar metals still possesses a significant challenge because of their incompatible material properties and structure. Using new materials in automobiles, aerospace has made dissimilar metal welding a very essential part of industrial application. Microwave Hybrid Heating (MHH) is a technique that has acquired a lot of attention in the recent years because of its precise and controlled heating and it can help in selective heating of materials. This process can join many materials and is also cost-effective and environment friendly. This paper reviews the successful joining of dissimilar metals through two non-conventional welding techniques namely Microwave hybrid heating and Tungsten Inert Gas welding but mainly focusing on the recent Microwave hybrid heating process with regards to the materials, susceptor medium, exposure time and the various techniques used for characterization of the joints. It can be concluded from the findings that limited study has been carried out in the field of dissimilar welding of metals through the above processes, especially microwave through microwave hybrid heating and there is scope for improvement and research

KEYWORDS: Hybrid Welding, Advance Welding Technique

I. INTRODUCTION

The combination of distinct materials provides intriguing opportunities in modern industry applications, whereas the driving concept is to design parts with the right material in the right place. Consequently, a great deal of attention has been directed towards dissimilar welding and joining technologies. In the automotive sector, for instance, the concept of "tailored blanks", introduced in the last decade, has further highlighted the necessity to combine dissimilar materials. As far as the aeronautic field is concerned, most structures are built combining very different materials and alloys in order to match lightweight and structural performance requirements

Using steels, aluminum alloys, magnesium alloys in automotive applications and to achieve good quality joints of these dissimilar metals has always been a challenge because of the formation of brittle, crack sensitive, and corrosion resistance joints [2]. Various methods used for welding dissimilar metals in industrial applications are categorized into Fusion welding, non-fusion welding and low dilution welding. The application of these various welding techniques depends upon the material's mechanical and thermal properties [3]. The challenges that occur when welding dissimilar metals include the formation of the transition zone between joints, undesirable in metallic compounds formation, different melting points of the metals to be joined, and different coefficients of thermal expansion which can restrict the joints to be used in industrial applications [4, 5]. Considering the limitations, it is very much required a novel way of joining dissimilar metals to join the metals which can address the above challenges.

II. MICROWAVE HYBRID HEATING

Microwave heating is one of the recent ways of processing materials [11, 12]. The applications of microwaves in the cladding of stainless steel have been successfully reported by the authors [13–16]. Microwave hybrid heating makes use of microwave susceptors which are materials that have higher dielectric losses at room temperature and can absorb microwave energy and translate it into heat. The main functions of the susceptor are to heat the materials from room temperature to critical temperature and decrease energy losses at high temperatures [17]. Charcoal with loss tangent of 0.14–0.38 and skin depth of 6–11 cm is mostly used as a susceptor, where the temperature range is 500–600ºC. Silicon Carbide (SiC), Graphite powder are some of the other susceptor mediums that can be used based on the applications [18]. Heating time, power level, can significantly affect the weld strength. It was observed that low input power and

|e-ISSN: 2319-8753, p-ISSN: 2347-6710| www.ijirset.com | Impact Factor: 8.423| A Monthly Peer Reviewed & Referred Journal |

|| Volume 13, Issue 3, March 2024 ||

| DOI:10.15680/IJIRSET.2024.1303135 |

finer size of the powder resulted in good metallurgical bonding and produced higher strength of the joints [19]. The Microwave hybrid heating setup shown in Fig. 1. consists of various parameters, which include the specimen to be joined, the interface material which is a combination of metallic powder and epoxy resin in a specific ratio, susceptor powder to absorb the microwaves and increase the heating of the base material, a separator sheet which separates the susceptor powder and the base materials and refractory bricks made of alumina for absorbing microwave radiations and it can be used as a fixture [20].

Figure captions should appear below the figure in Title case (first letter of each word capital). When referring to a figure in the body of the text, the abbreviation "Fig." should be used. Figures should be numbered in the order they appear in the text. **Table** captions appear centered above the table in Title case. When referring to a table in the text, no abbreviation is used and "Table".

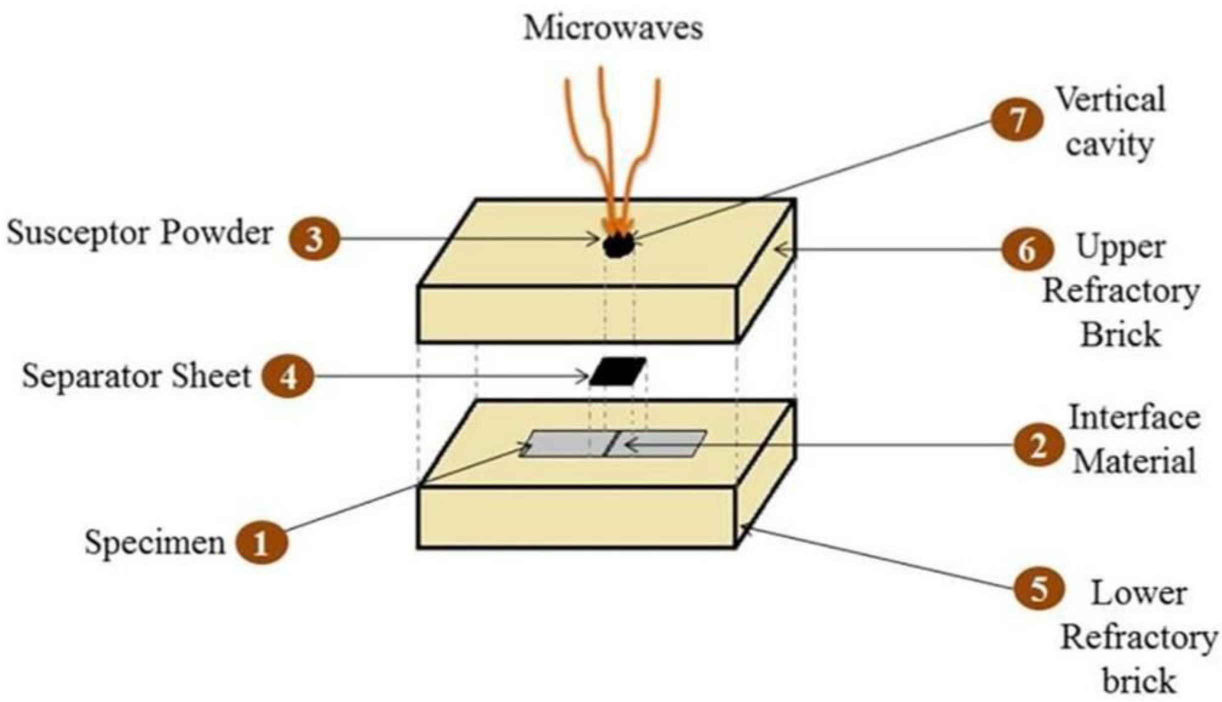


Fig. 1. Schematic representation of Microwave Hybrid Heating [20].

III. EXPERIMENTAL

The adhesive was applied to the faying surfaces and the two sheets are assembled before spot welding on the second stage. The presence of remaining gap after the welding process is important for manufacturing of hybrid joints with adhesive, because it can influence the thickness of adhesive layer and therefore the final tensile strength. According to da Silva et al. (2018), the best tensile strength can be expected, if the thickness of adhesive layer is between 0.1…0.2 mm and increasing adhesive thickness over 0.2 mm leads to a decrease in the adhesive strength. For the described technology the gap between the sheets can be adjusted and controlled by the changing the diameter of the insert element.

|e-ISSN: 2319-8753, p-ISSN: 2347-6710| www.ijirset.com | Impact Factor: 8.423| A Monthly Peer Reviewed & Referred Journal |

|| Volume 13, Issue 3, March 2024 ||

| DOI:10.15680/IJIRSET.2024.1303134 |

Test materials and experimental procedure The joining of aluminum to steel was conducted on 1.0 mm thick EN AW 6016 – T4 alloy sheets and 1.5 mm thick boron steel 22MnB5 with Al-Si coating of 150 g/m2, press hardened at 930 °C for 6 min. The chemical composition of test materials is provided in Table 1. Cylinder insert elements (IE) made of Cu-, and Fe-based (CrNi-steel) wires with a diameter of 1.6 mm were manually cut to the length of 10 mm. The chemical composition of the used materials is shown in Table 2 as well as mechanical properties (Table 3). For determination of joint properties with adhesive layer a one component epoxy based crash resistant structural adhesive Dow Betamate™ 1630 V with tensile strength of 29 MPa, as reported by the manufacturer Dow Automotive Systems (2012), was used. The manufactured specimens with adhesive were cured by heat treatment for 30 min at 180 °C, simulating the typical automotive paint bake process. The riveting connection serving as a reference was prepared with the HDX 6.5 × 6.0 rivet (hardness 555 ± 30 HV, coating ZnNi + B18E). This rivet was specially developed by Hornbostel (2009) for joining high and ultra-high strength steel with aluminum.

Welding system in C-construction with a 1000 Hz medium frequency (MFDC) inverter from Nimak with a magnetic force control unit "magneticDrive". The force during the welding process is applied, using an electromagnet and is being held constant during the welding process allowing for electrode follow-up. Welding current, voltage drop between the electrodes, electrode force and displacement were monitored for each weld, using an HKS WeldQAS measuring device with a measurement frequency of 256 kHz. Insert elements were made from conventional filler wire, which allowed their cost-effective manufacturing and modification of geometry and chemical composition. Advantage of a cylindrical insert element made of wire is that the linear contact between the sheet and the element with a relatively small contact surface was formed. Small contact surface enables welding with short welding times of several milliseconds and as a result, a very low total heat input. This is beneficial in case of a hybrid joining process, where adhesive is not thermally damaged as in case of conventional resistance welding. By combination of high welding current with extremely high current ramping (between 3 and 12 kA/ms for the investigated insert elements and sheet combinations) and small contact surface between metal sheet and the insert element, a very high current flux density through the contact surface in the joint plane was achieved. Supported by the magnetic follow-up unit, this allowed using extremely short welding times of down to 10 ms.

Table 1

Chemical composition of sheet metals (in wt.-%).

	C	Mn	P	S	Si	Al	Ti	B	Fe
22MnB5 + AS150	0.23	1.18	0.0109	0.0008	0.25	0.04	0.04	0.0032	Balance
	Cr	Mn	Cu	Mg	Si	Al	Ti	B	Fe
EN AW 6016	0.18	0.13	0.07	0.39	1.27	Balance	0.03	-	0.26

|e-ISSN: 2319-8753, p-ISSN: 2347-6710| www.ijirset.com | Impact Factor: 8.423| A Monthly Peer Reviewed & Referred Journal |

|| Volume 13, Issue 3, March 2024 ||

| DOI:10.15680/IJIRSET.2024.1303135 |

Table 2

Chemical compositions of wires for insert elements (in wt.-%).

	C	Si	Mn	Cr	Mo	Ni	Sn	Cu	Nb	Fe
Cu-based	–	0.28	0.27	–	–	< 0.005	4.97	Balance	–	< 0.005
Fe-based	0.02	0.88	1.84	20.0	0.11	9.95	0.01	0.1	0.01	Balance

Table 3

Mechanical properties in as-delivered condition.

Material	Yield point Rp0,2 [MPa]	Tensile strength Rm [MPa]
AW 6016 T4	160 ± 6	277 ± 8
22MnB5 + AS150	415 ± 9	565 ± 8
Cu-based	937 ± 10	1095 ± 6
Fe-based	849 ± 20	1050 ± 30

Table 4

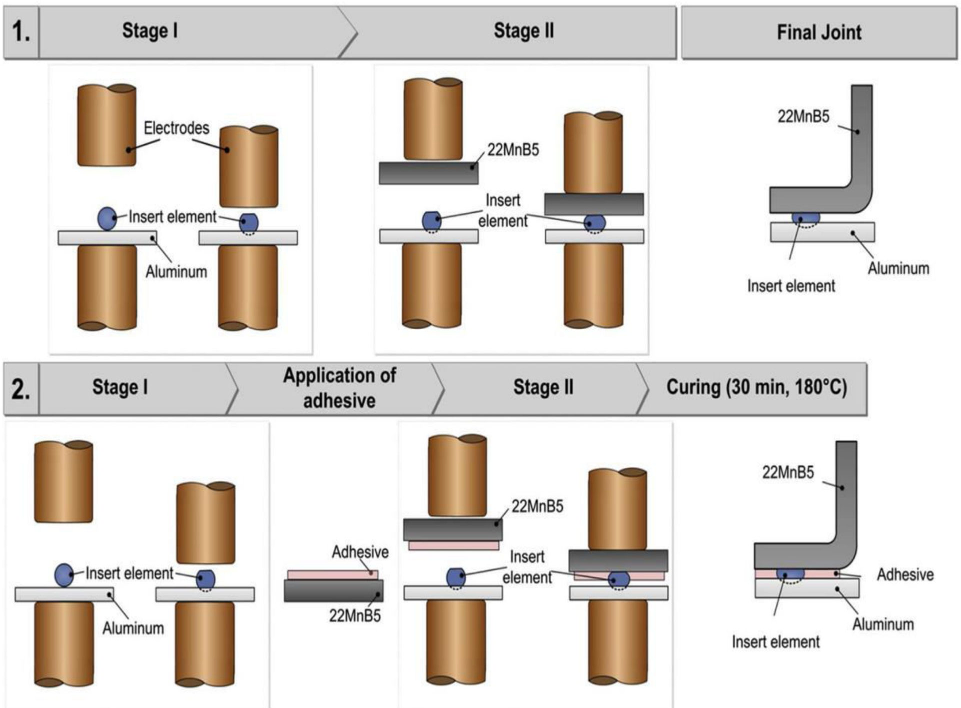
Welding parameters for stage I and II for both inserts elements.

Stage	Stage I		Stage II			
Insert element	Fe	Cu	Fe		Cu	
Electrode force, F [kN]	2		4			
Welding time, t [ms]	10		16			
Welding current, I [kA]	8	22	I_{min} 11	I_{max} 20	I_{min} 19	I_{max} 27

Self-pierce riveting with and without adhesive bonding

The joints were performed, using a riveting system RIVSET® Gen² from manufacturer Böllhoff. The hydraulically operated system can apply a maximum setting force of 78 kN and a blankholder force of 8 kN. A C- frame with an outreach of 300 mm made the connection between hydraulic cylinder and die. The whole machine is suitable for using with industrial robots. However, in the used laboratory setup the machine was fixed on a base without an automatic rivet supply.

A sufficient undercut in the bottom sheet. That is why the selection of a suitable die is very important. In this study the die SM 120 0130 was used for all joints. It offers enough space for the punched steel piece and the small sheet of aluminum and is constructed to promote flaring of a rivet by a small bump in the middle DVS-EFB 3410 (2010)



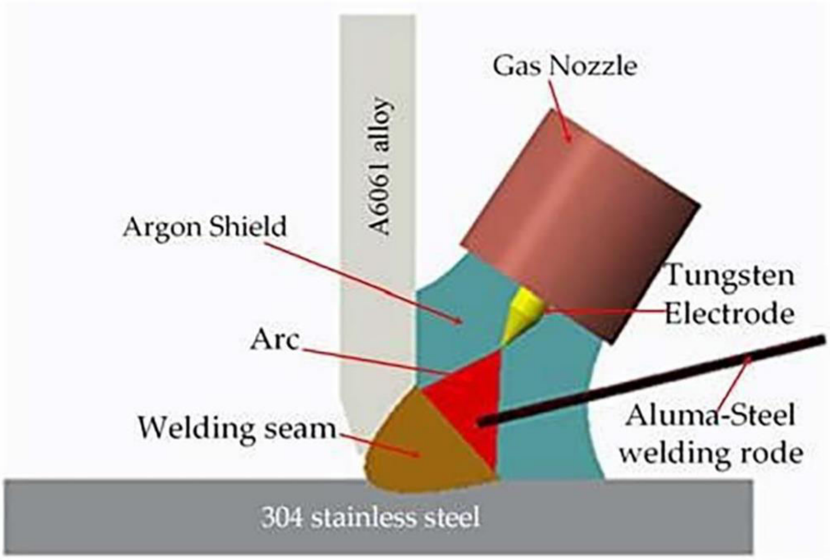
|e-ISSN: 2319-8753, p-ISSN: 2347-6710| www.ijirset.com | Impact Factor: 8.423| A Monthly Peer Reviewed & Referred Journal |

|| Volume 13, Issue 3, March 2024 ||

| DOI:10.15680/IJIRSET.2024.1303134 |

IV. CONCLUSIONS

Dissimilar metal welding has found increased applications in the recent industrial era with manufacturers trying to take advantage of lightweight materials to manufacture products. This paper focused mainly on two techniques of joining dissimilar metals.



ACKNOWLEDGMENTS

The authors would like to thank AiF for funding the IGF-Project IGFNo. 20164 BR / FOSTA P1294 of the German Research Association for Steel Application FOSTA, which was part of the program to support cooperative industrial research Industrielle Gemeinschaftsförderung IGF by the Federal Ministry for Economic Affairs and Energy, following a decision of the German Bundestag. Equal thanks go to all companies, colleagues and students who contributed their support, knowledge and effort to the project.

REFERENCES

[1] R. Chaudhari, R. Parekh, A. Ingle, Reliability of Dissimilar Metal Joints using Fusion Welding: A Review, (2014) 98–104.

[2] Md. Abdul Karim, Y.-D. Park, A Review on Welding of Dissimilar Metals in Car Body Manufacturing, J. Weld. Join. 38 (2020) 8–23.

[3] P. Kah, M.S. Jukka Martikainen, Trends in joining dissimilar metals by welding, Appl. Mech. Mater. 440 (2013) 269–276.

[4] R. Chaudhari, P.K. Loharkar, A. Ingle, Applications and challenges of arc welding methods in dissimilar metal joining, IOP Conf. Ser. Mater. Sci. Eng.. 810 (2020).

[5]Carlone, P.; Astarita, A.; Palazzo, G.S.; Paradiso, V.; Squillace, A. Microstructural aspects in Al–Cu dissimilar joining by FSW. Int. J. Adv. Manuf. Technol. 2015, 79, 1109–1116. [CrossRef].

[6]Jeong-Won, C.; Huihong, L.; Hidetoshi, F. Dissimilar friction stir welding of pure Ti and pure Al. Mater. Sci. Eng. A 2018, 730, 168–176.

[7]Boccarusso, L.; Astarita, A.; Carlone, P.; Scherillo, F.; Rubino, F.; Squillace, A. Dissimilar friction stir lap welding of AA 6082-Mg AZ31: Force analysis and microstructure evolution. J. Manuf. Processes 2019, 44, 376–388. [CrossRef].

[8]Mehta, K.P.; Carlone, P.; Astarita, A.; Scherillo, F.; Rubino, F.; Vora, P. Conventional and cooling assisted friction stir welding of AA6061 and AZ31B alloys. Mater. Sci. Eng. A 2019, 759, 252–261. [CrossRef]

[8]Da Silva, L.F.M., Öchsner, A., Adams, R.D., 2018. Handbook of Adhesion Technology. Springer International Publishing, Cham.

[9]Zhou, X.; Chen, Y.; Li, S.; Huang, Y.; Hao, K.; Peng, P. Friction Stir Spot Welding-Brazing of Al and Hot-Dip Aluminized Ti Alloy with Zn Interlayer. Metals 2018, 8, 922.
[10]Bellmann, J.; Lueg-Althoff, J.; Schulze, S.; Hahn, M.; Gies, S.; Beyer, E.; Tekkaya, A.E. Thermal Effects in Dissimilar Magnetic Pulse Welding. Metals 2019, 9, 348. [CrossRef]
[11]Xue, X.; Pereira, A.; Vincze, G.; Wu, X.; Liao, J. Interfacial Characteristics of Dissimilar Ti6Al4V/AA6060 Lap Joint by Pulsed Nd:YAG Laser Welding. Metals 2019, 9, 71. [CrossRef]
[12]Jarwitz, M.; Fetzer, F.; Weber, R.; Graf, T. Weld Seam Geometry and Electrical Resistance of Laser-Welded, Aluminum-Copper Dissimilar Joints Produced with Spatial Beam Oscillation. Metals 2018, 8, 510. [CrossRef]
[13]Dokme, F.; Kulekci, M.K.; Esme, U. Microstructural and Mechanical Characterization of Dissimilar Metal Welding of Inconel 625 and AISI 316L. Metals 2018, 8, 797. [CrossRef].
[14]Xue, P.; Zou, Y.; He, P.; Pei, Y.; Sun, H.; Ma, C.; Luo, J. Development of Low Silver AgCuZnSn Filler Metal for Cu/Steel Dissimilar Metal Joining. Metals 2019, 9, 198. [CrossRef]
[15]Yang, J.; Wang, L. Optimizing the Local Strength Mismatch of a Dissimilar Metal Welded Joint in a Nuclear Power Plant. Metals 2018, 8, 494. [CrossRef]

Books

1. "Welding Metallurgy" by Sindo Kou Unlocking the Secrets of Welding Metallurgy
2. "The Procedure Handbook of Arc Welding" by Lincoln Electric
3. "Pipe Welding Procedures" by Hoobasar Rampaul
4. "Welding Symbols Quick Card" by Builder's Book.
5. "Welding Essentials" by William L. Galvery Jr. and Frank B. Marlow
6. "Welding Print Reading" by John R. Walker
7. *"Welding Processes Handbook" by Klas Weman*

ConferencePapers

1. **"Arc Welding Processes"**: This paper delves into various arc welding techniques, including GMAW, SMAW, GTAW, FCAW, SAW, MCAW, and PAW. It covers design considerations, heat flow, residual stress, distortion, metallurgy of weldments, weld quality, and nondestructive testing of weldments[1].
2. **"Fusion Joint Welding"**: Investigates fusion joint welding parameters, such as current, shielding gas, standoff distance, travel speed, and wire feed[2].
3. **"Computational Models for GTA and Laser Welding Processes"**: Dr. Bag's research explores computational models for GTA (Gas Tungsten Arc) and laser welding processes. His work has significant implications for welding and joining technologies[3].

Newspaper and Magazine Articles

1. "***Remote*** Manufacturing Redefines the Skilled Workforce" (AWS Welding Journal February 2004). This article explores how remote work is shaping the manufacturing industry, redefining skilled labor, and contributing to industry 5.0. It discusses evolving lele-Manufacturing technologies and their impact on the ***workforce*** 2. "Determining the Cost of Welding (AWS Welding Joumal, January 2004): Part one of this article covers three basic methods for computing welding costs: cost per unit, cost per length, and cost per weight "Weld Setting Optimization.

2."Hul Job Openings***: Cobot Champion" (AWS Welding Journal):*** Addressing the skilled labor gep in American manufacturing, this article discusses the need for cobot champions and their role in bridging the workforce shortage

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

9940 572 462 6381 907 438 ijirset@gmail.com

www.ijirset.com

Scan to save the contact details