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Feasibility study on Joining of Copper Pipes Using Microwave Energy

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Abstract — *Pipe joining is an essential requirement in the piping industries as it is used to carry high pressurized liquid and gases at high temperature. Researchers have reported many pipe joining processes which are used to join metallic pipes with appreciably good joint efficiency but producing sound and eco friendly joint is an industries concern. A rejection and rework of joint was observed in conventional joining processes long year back resulting in consumption of energy source and time. Now a day's piping industries emerging with new technologies due to rigorous research in this field. Few researchers have reported that microwave hybrid heating (MHH) technology is emerges as metal joining process. Microwaves joining of bulk metals have revealed that the MHH process is capable of producing joints with Eco-friendly processing, reduced processing time, enhanced energy saving, better mechanical and metallurgical properties than conventional processes. This is a new technique have been used for joining metallic bulk materials hence it is used for feasibility study of joining of Copper pipe. This paper reports joining of Copper pipes using copper powder (5 µm) as an sandwich material in a multimode microwave applicator at 2.45 GHz and 900 W. Charcoal was used as a susceptor materials for initial heating of metallic pipes. The initial experimental observations and results of copper pipe joining have been discussed.*

Keywords- *Copper pipes, Microwave energy, Sandwich material, Powder*

I. INTRODUCTION

The extensive use of metallic pipes in the industries such as oil, chemical, sugar, automotive, structural industries, paper and process is to transport high pressure liquids and gases [1-13]. It transmission of liquid is solely depends on the metallic pipes due to its higher strength and durability. The use of metallic pipe as a single unit is most suitable option for transportation of these kinds of liquids and gases; however, production of pipes as a single unit encountered various problems such as requirement of large production facilities, handling of produced components, cost of the processing etc. Consequently, the production facilities reach its extreme limits. Joining is only the technique that has potential to overcome such problems however; the pipe joint obtained necessitates adequate strength and efficiency to overcome onsite failures. It has been observed the failure of joint many times due to poor joint efficacy which affects the functionality of pipes on site. The various pipe joining techniques are used by industries which facilitates the welding of pipes end by incorporating the filler materials in between by the application of heat, with or without the application of pressure. Now a days, various conventional pipe joining techniques like SAW, TIG, MIG, Friction welding etc. are widely used for joining the metallic pipes such as stainless steel, mild steel, low carbon steel, aluminum, cast iron. Joining of metallic pipes is one of the inefficient joining processes due to its geometry. Circular shape of the pipe causes difficulties to the welder to weld the pipes as molten metal comes down which is difficult to handle. To produce good joint of pipe, welder should be well qualified for it, unskilled worker produced inefficient pipe joints. Hence, this condition prone to atomization of the joining technique. The various challenges such as rework of joint, higher lead time, controlling environmental hazards, more energy consumption and wastage of materials encountered during the joining of metallic pipes.

II. LITERATURE SURVEY

The conventional pipe joining techniques were reported with satisfactory joints in metallic pipes; however, industries are searching a suitable process which is capable enough to produce better and rapid joint which results in saving of more productive time and energy by avoiding frequent rework in maintenance of pipe joints. Some of these issues can be addressed using MW energy for joining metallic pipes due to their rapid and more uniform heating characteristics. The microwave joining of bulk metallic material was established in year 2009 [14] and was reported in the form of Indian patent. It was reported by few researchers that microwave energy can be used for joining of bulk metals such as copper, mild steel, stainless steel plates [15-23]. It has been reported by researchers that use of microwaves for joining of bulk metals have revealed that the process is capable of producing joints in lesser processing time with better mechanical and metallurgical properties than conventional processes. Initially, it was assumed that metallic materials are incompatible to microwave radiations as they reflect microwaves owing to their high conductivity and poor skin depth. Later, microwave joining technique was emerged as a new bulk metal joining process. A heat transfer phenomenon of microwave energy is totally different than conventional heating processes. Heat generation with heat transfer from (inside) core of the material to (outside) surface of material takes place in microwave processing which is reverse in case of conventional heating. It has been reported that microwave energy is used to joined engineering materials such as metal, ceramics, polymer, CMC's and PMC's due to the unique heating characteristics such as volumetric and selective heating, Eco-friendly, power saving and reduction in processing time [15-31]:

III. EXPERIMENTAL PROCEDURE

3.1. EXPERIMENTAL SET UP

Microwave hybrid heating technique is used to join engineering materials like ceramics, polymers and metals. Microwave absorption is solely depends on material characteristics. Metallic materials reflect the microwave energy at room temperature when it exposed to microwave irradiation . Susceptor material plays an important role in joining of metallic materials. Susceptor absorbs Microwave energy rapidly and heat was generated when exposed to Microwave. The interfacing materials and faying surfaces of the metallic pipes start heated due to transfer of heat from susceptor through conduction heat transfer mode. Some energy was radiated inside the cavity. The conventional heating of metallic pipes, pushes its temperature above a critical temperature. After reaching beyond the critical temperature, the metallic pipes coupled with Microwave energy and start microwave energy absorption. The experimental setup was developed to join copper pipe. The ceramic fixture was develop to hold the work piece and to place the susceptor material for uniform heating of the joint. The slurry was prepared by adding approximately 10% of binder (epoxy resin) in copper powder and was uniformly placed over entire surfaces of copper pipes to be joined. At the initial stage slurry helps to bind the substrates and maintained the alignment of it. The binder used in slurry also absorbed microwave energy and it gets evaporated above 300^{0}C. There was no additional effect of epoxy resin observed in formation of the pipe joint.
The microwave energy melts sandwich layer and faying surfaces of copper pipes led to fusion of candidate materials hence, the joint was formed. The steps of the joint development are shown in the Fig.1. The parameters used for development of the pipe joining are summarized in Table.1.

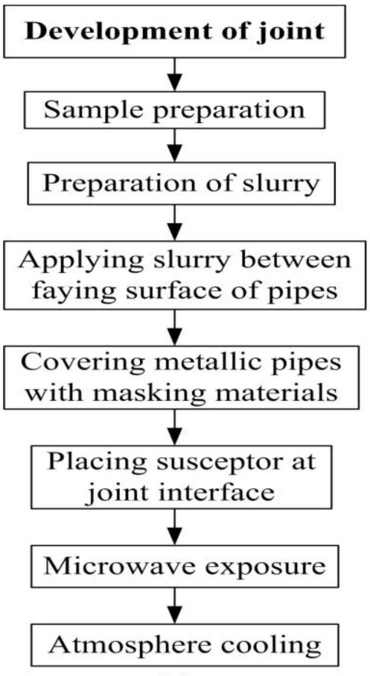


Fig. 1. Steps involve in joint development

Table.1. Microwave processing parameters

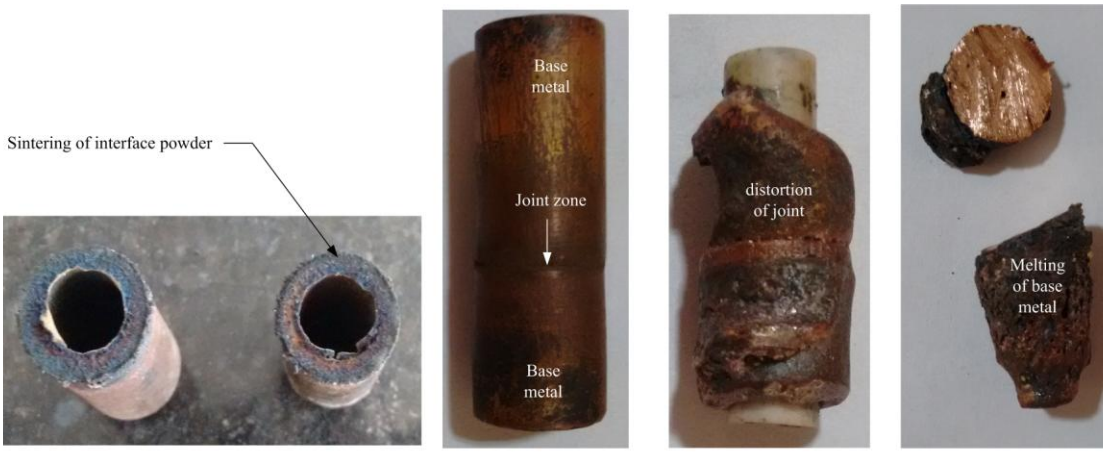
Parameters	Description
Microwave frequency	2.45 GHz
Candidate material	Commercially available copper pipes
Interface material	Copper powder (5 μm)
Susceptor materials	Charcoal powder
Exposure time	480 s
Exposure power	900 W

3.2. INITIAL OBSERVATION

The experimental was perform to check the feasibility study of joining of copper pipes using microwave energy. The trial were carried out for copper joint using charcoal as a susceptor material with different exposure times at 900 W. The initial observation shows that increase in microwave exposure time up to 300 s, No melting of faying surfaces taking place resulting in No fusion. The sintering of interfacial copper powder with base material was observed leading to joining of copper pipes having very poor joint efficiency as shown in Fig. 2 (a). Melting of interfacing powder was observed beyond 360 s; however, no melting of the base metals was achieved. Observations of some experimental trials are presented in Table.2. This can be attributed to formation of oxide layer which require more energy to melt the faying surfaces of copper pipes. Use of charcoal as susceptor ensures heating of joints above melting point of metals. It was observed that the exposure time below 440 s was not sufficient for proper heating and melting of interfacing powder and the base metals (Fig.2 (a)). However, popper fusion of base metal and interface powder was observed at 440 s as shown in Fig. 2 (b). As the temperature increases and exposure time approaches to 600 s, over heating of base metal was observed and the joints got distorted (Fig.2 (c)) and beyond 720 s, the base metal get melted as shown in Fig.2(d).

Table.2. Effect of exposure time on joining of copper pipes

Sr.No	Power (W)	Susceptor	Exposure time (s)	Results
1	900	Charcoal	300	No fusion
2			360	Joining by sintering of interface material
3			440	Proper fusion of faying surfaces
4			600	Fusion but distortion of joint takes place
5			720	Melting of substrates



(a) (b) (c) (d)

Fig.2. Effect of exposure time on copper pipe joint at a) 360 s b) 440 s c) 600 s d) 720 s using charcoal as susceptor

IV. CONCLUSION

Microwave energy offers unique characteristics during heating of metallic pipes. Microwave hybrid heating (MHH) technique provides a possible route for joining of metallic pipes. The experimental trials shows that it is possible to join copper pipes by incorporation copper powder as a sandwich material through microwave hybrid heating technique. Selection of material such as susceptor and fixture material plays an important role as both helps in microwave joining of metallic pipes. A good bonding of copper pipes was obtained at 440 s exposure time at 900 W using charcoal as susceptor material.

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