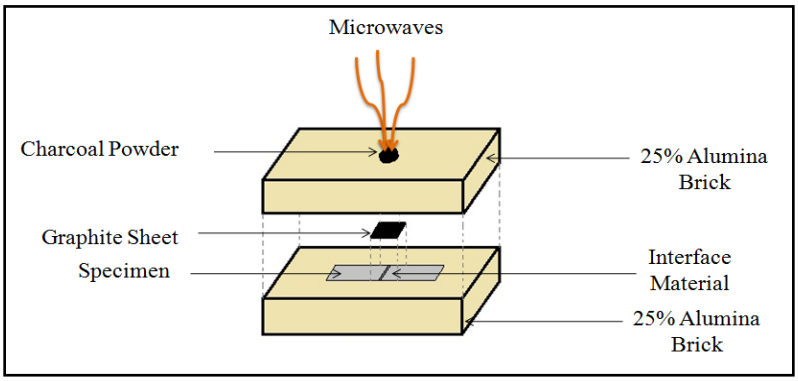

Fig. 1

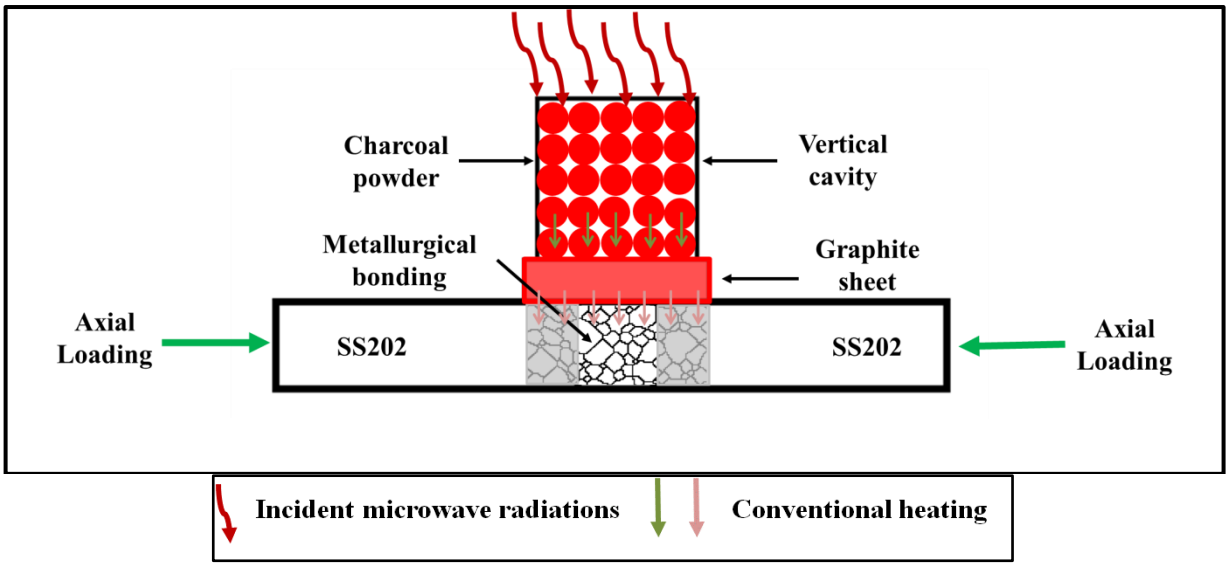

Fig. 2

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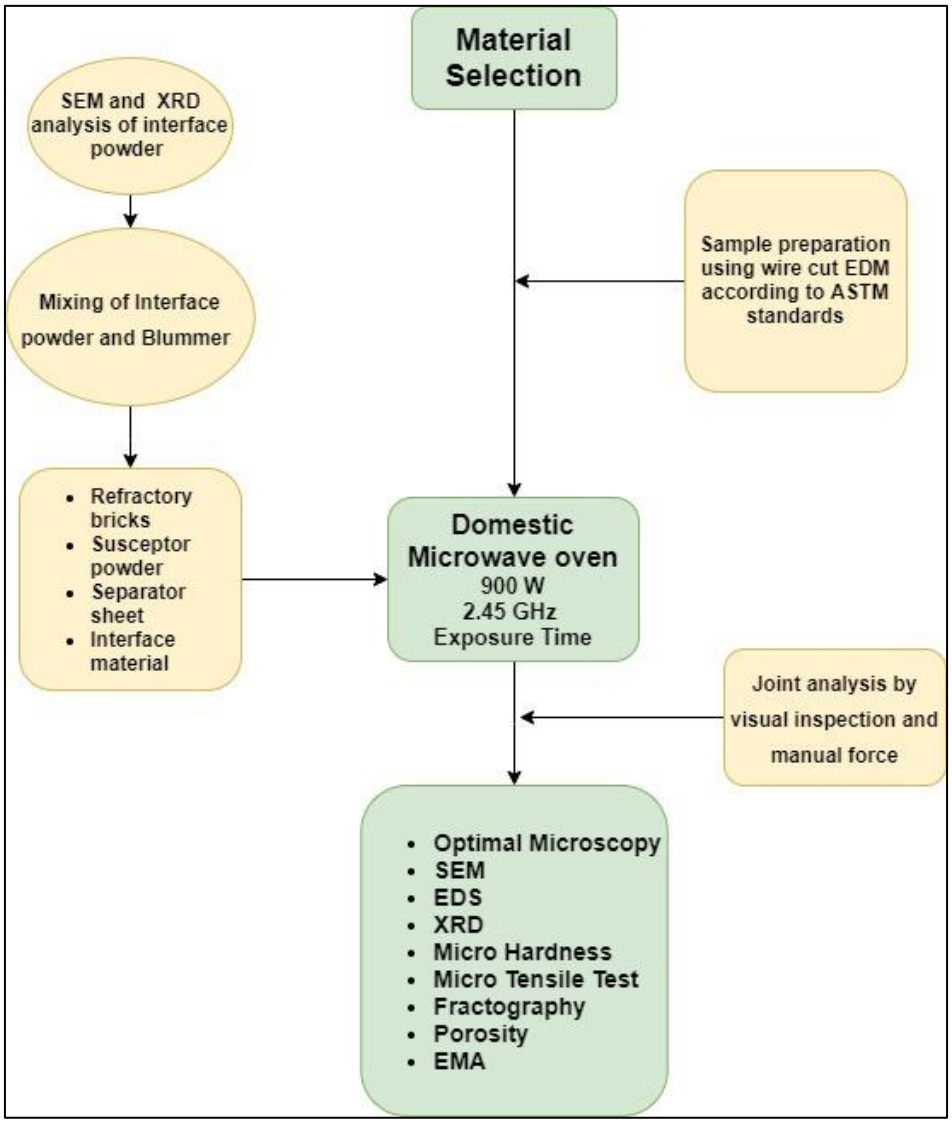

Fig. 3

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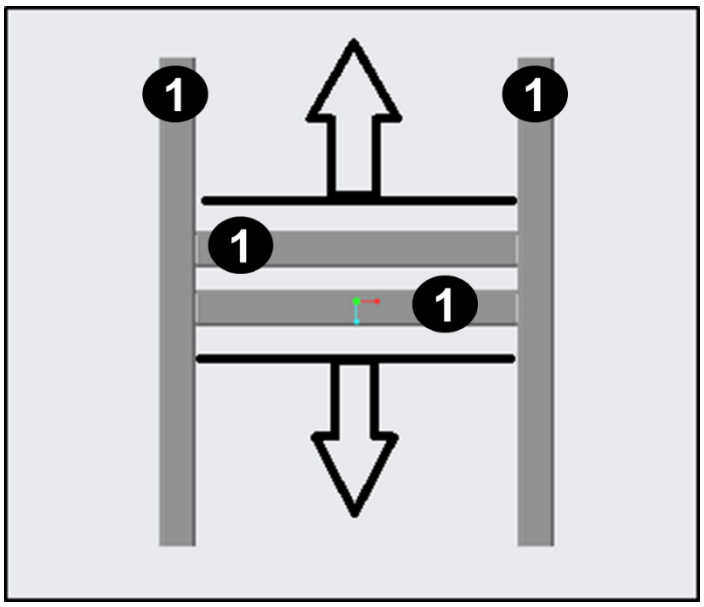

Fig. 4

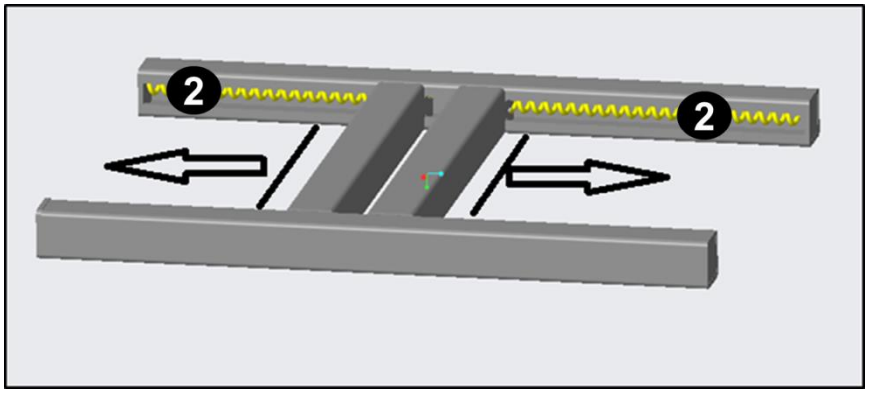

Fig. 5

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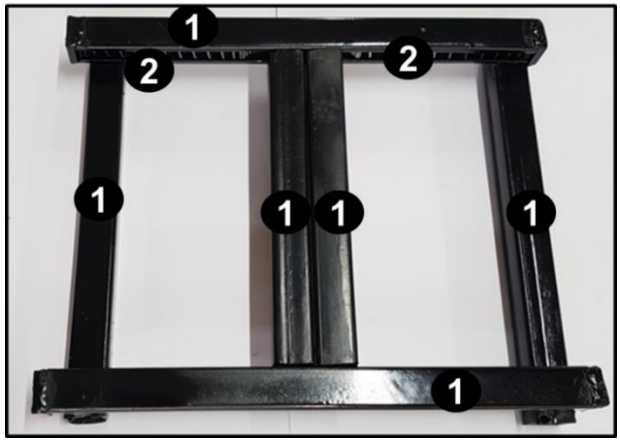

Fig. 6

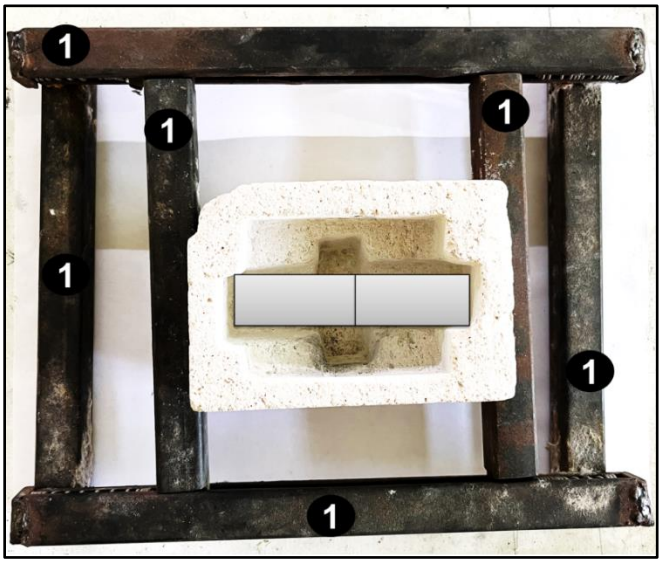

Fig. 7

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FORM 2

THE PATENTS ACT 1970

(39 of 1970)

&

THE PATENT RULES, 2003

COMPLETE SPECIFICATION

(See section 10 and rule 13)

1. TITLE OF THE INVENTION: -

A PROCESS OF AXIAL LOADING INSIDE THE MICROWAVE APPLICATOR FOR JOINING DIFFERENT MATERIALS

2. Applicant(s)

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3. PREAMBLE OF THE DESCRIPTION

The following specification particularly describes the invention and the manner in which it is to be performed

Title of The Invention

A PROCESS OF AXIAL LOADING INSIDE THE MICROWAVE APPLICATOR FOR JOINING DIFFERENT MATERIALS

Field of the Invention

This invention is relating to manufacturing process, specifically in joining of two materials to improve the joint strength and to ease the microwave joining.

Background of the Invention

In the area of microwave joining, different materials are already joined using microwave hybrid heating. However, it is always difficult to provide additional axial loading to enhance the mechanical properties of the joint. This designed setup of axial loading provides axial loading to the joint inside microwave applicator and provides additional strength to the joint.

JP2015054323A MICROWAVE HEATING JOINING METHOD discloses a microwave heating joining method in which local heating performance is good and a junction characteristic of a junction layer can be enhanced.SOLUTION: A microwave heating joining method according to an embodiment is a method for joining metal junction members 1, 2 by use of a microwave, and comprises: an arrangement process in which a microwave sensitive material 4 and a junction assistant 3 made of metal are arranged on at least parts of junction surfaces 11, 21 of the joint members 1, 2; a microwave radiation process in which a microwave is irradiated onto the microwave sensitive

material 4 so as to generate a heat in the material 4 thereby melting the junction assistant 3; and a removal process in which the microwave sensitive material 4 is separated from the melted junction assistant 3.

CN105470769A Superconducting material joining method discloses a superconducting material joining method. A microwave chamber is provided, wherein the microwave chamber is provided with a first heat absorbing plate and a second heat absorbing plate corresponding to the first heat absorbing plate; a first superconducting material and a second superconducting material are placed between the first heat absorbing plate and the second heat absorbing plate in the microwave chamber, wherein an overlapped region is provided between the first superconducting material and the second superconducting material, and a pressure is applied to the first heat absorbing plate and the second heat absorbing plate; and microwave energy is applied to the microwave chamber, the first heat absorbing plate and the second heat absorbing plate convert microwave energy into heat energy to enable the first superconducting material and the second superconducting material to be joined at the overlapped region.

US2014224789A1 METHOD FOR JOINING TWO DISSIMILAR MATERIALS AND A MICROWAVE SYSTEM FOR ACCOMPLISHING THE SAME discloses method for joining two materials, and a system for accomplishing the same. The method for joining two materials, in this aspect, includes

placing an article including two dissimilar materials within a waveguide structure, the article located between a microwave source and reflective surface of the waveguide structure. The method for joining the two materials, in this aspect, further includes subjecting the article to microwaves from the microwave source while changing a relative position of the article with respect to the reflective surface to dynamically change a microwave field distribution within the waveguide and join the two dissimilar materials.

CN106631086A Analysis method for microwave joining of ceramic materials in multi-mode sintering cavity belongs to the technical field of ceramic material analysis, and relates to an analysis method for microwave joining of ceramic materials in a multi-mode sintering cavity. According to the invention, through characteristics of grain growth, progression and interface of different joining materials obtained at different joining temperatures, factors of influencing densification of the joining materials are found out; according to distribution of a test sample in a temperature field in the process of joining, influences of a microwave electromagnetic field and thermal expansion coefficient, thermal conductivity and the like of a material on distribution of the temperature field of the material are figured out; meanwhile, according to the distribution situation of the microwave electromagnetic field in the process of joining of the test sample, the range of uniform distribution of the microwave electromagnetic field is controlled, and influences of distribution of the

microwave electromagnetic field on a microwave joining mechanism of structural ceramic are analyzed. The analysis method provided by the invention has simple process, scientific principle and precise analysis results, can accurately control the range of uniform distribution of the microwave electromagnetic field and determines the factors of influencing densification of the joining material according to analysis results, and provides a basis for preparation of a complex-shaped test sample of the structural ceramic.

None of the prior art indicate above either alone or in combination with one another disclose what the present invention has disclosed. Present invention is Axial loading inside the microwave applicator for joining different materials.

SUMMARY OF THE INVENTION

This summary is provided to introduce a selection of concepts, in a simplified format, that are further described in the detailed description of the invention.

This summary is neither intended to identify key or essential inventive concepts of the invention and nor is it intended for determining the scope of the invention.

To further clarify advantages and features of the present invention, a more particular description of the invention will be rendered by reference to specific embodiments thereof, which is illustrated in the appended drawings. It is appreciated that these drawings depict only typical embodiments of the invention and are therefore not to be considered limiting of its scope. The

invention will be described and explained with additional specificity and detail with the accompanying drawings.

A material joining process is incomplete without the axial load to get sufficient bonding and strength of the joint. However, it is difficult to provide any type of additional loading to the specimen inside the microwave cavity, due to the lack of space and design for axial loading. Metallic materials are repellent of microwave radiations which causes arc at the edges resulting in more difficulties to provide axial loading inside the microwave cavity. Considering all the difficulties an axial loading is implemented inside the microwave cavity which provides sufficient pressure to the joint for better intermetallic bonding between the substrate and interface material. The designed step-up is independent of the size of the specimen and could be applied to any type of joint say butt, lap, and T-shaped joint. The current designed setup can be applied to different shapes and structures such as rectangular, pipes or hollow pies, etc.

Discloses herein a process of Microwave hybrid heating for Axial loading inside the microwave applicator for joining different materials comprising the steps of: Using a susceptor material which absorbs the microwave radiations at a higher rate; converting these absorbed radiations are then converted into heat; so that the material interaction with microwave radiations caused less variation in temperature gradient (ΔT); for joining purpose the microwave hybrid heating is first used on superconductors and ceramics; later first

interaction of microwave radiation on bulk metals is proposed; Wherein said absorption of microwave radiation by the materials was due to increased skin depth at elevated temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

The illustrated embodiments of the subject matter will be understood by reference to the drawings, wherein like parts are designated by like numerals throughout. The following description is intended only by way of example, and simply illustrates certain selected embodiments of devices, systems, and methods that are consistent with the subject matter as claimed herein, wherein:

Figure 1 Parameters of the process & product

Figure 2 Heating mechanism along with axial loading

Figure 3 Flow chart for the microwave joining process

Figure 4 Top view of the axial loading setup with rectangular bar

Figure 5 Side view of the axial loading setup with spring

Figure 6 Real time setup of axial loading

Figure 7 axial loading applied to the sample

The figures depict embodiments of the present subject matter for the purposes of illustration only. A person skilled in the art will easily recognize

from the following description that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles of the disclosure described herein.

DETAILED DESCRIPTION OF THE INVENTION

The detailed description of various exemplary embodiments of the disclosure is described herein with reference to the accompanying drawings. It should be noted that the embodiments are described herein in such details as to clearly communicate the disclosure. However, the amount of details provided herein is not intended to limit the anticipated variations of embodiments; on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the scope of the present disclosure as defined by the appended claims.

It is also to be understood that various arrangements may be devised that, although not explicitly described or shown herein, embody the principles of the present disclosure. Moreover, all statements herein reciting principles, aspects, and embodiments of the present disclosure, as well as specific examples, are intended to encompass equivalents thereof.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of example embodiments. As used herein, the singular forms “a",” “an” and “the” are intended to include the plural forms as well, unless the context clearly

indicates otherwise. It will be further understood that the terms “comprises,” “comprising,” “includes” and/or “including,” when used herein, specify the presence of stated features, integers, steps, operations, elements and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components and/or groups thereof.

It should also be noted that in some alternative implementations, the functions/acts noted may occur out of the order noted in the figures. For example, two figures shown in succession may, in fact, be executed concurrently or may sometimes be executed in the reverse order, depending upon the functionality/acts involved.

In addition, the descriptions of "first", "second", “third”, and the like in the present invention are used for the purpose of description only, and are not to be construed as indicating or implying their relative importance or implicitly indicating the number of technical features indicated. Thus, features defining "first" and "second" may include at least one of the features, either explicitly or implicitly.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which example embodiments belong. It will be further understood that terms, e.g., those defined in commonly used

dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

These and other advantages of the present subject matter would be described in greater detail with reference to the following figures. It should be noted that the description merely illustrates the principles of the present subject matter. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described herein, embody the principles of the present subject matter and are included within its scope.

1. Process of microwave joining

Microwave radiations are extensively used for the materials that are good absorbers, however bulk metallic materials are reflecting of microwave radiation at room temperature. The absorption of microwave radiation is also dependent upon the skin depth of the material. The higher the value of skin depth, higher will be the absorbed radiations.

$$\delta = \sqrt{\frac{\rho}{\pi f \mu_r \mu_o}} \qquad (3)$$

Where, 'δ' is skin depth (μm) is termed as depth till which current flows in a conductor, 'ρ' is resistivity (μ Ω-m), 'f' is the frequency of microwave applicator (GHz), 'μ' is magnetic permeability (Hm^{-1}) which is used to

measure a material's resistance to the magnetic field or to measure the degree by which magnetic field can penetrate through a material ($\mu=\mu_r\times\mu_o$), 'μ_r' is relative permeability and 'μ_o' is absolute permeability. Bulk metallic materials reported low skin depth because they do not allow radiations to be absorbed. Since it is difficult to process the metals under microwave radiations, a new hybrid heating technique was proposed using susceptor powder which is termed Microwave hybrid heating (MHH). In MHH, a susceptor material is used which absorbs the microwave radiations at a higher rate; these absorbed radiations are then converted into heat. Hence the material interaction with microwave radiations caused less variation in temperature gradient (ΔT) which gives various advantages like volumetric heating which reduced residual stresses, and eco-friendly. However, for joining purpose the microwave hybrid heating was first used on superconductors and ceramics. Later first interaction of microwave radiation on bulk metals was proposed. This absorption of microwave radiation by the materials was due to increased skin depth at elevated temperature. At temperature greater than 1000º C the diffusion of Ni powder begins with the base metal. When temperature reaches approx. 1400ºC intermetallic bonding takes place with the exchange of elements between base metal and interface material **Figure 2**. This whole process takes place with the microwave heating and conventional heating both.

2. Parameters of the process & product

Sr. No.	Parameters	Description
1.	Applicator	Domestic microwave oven
2.	Frequency	2.45GHz
3.	Capacity	32L
4.	Power output	900Watt
5.	Base metal	SS304, SS316, SS202
6.	Susceptor material	Charcoal powder
7.	Interface material	99% Pure Nickel based powder (20µm)/SS powder (20µm)
8.	Epoxy	Blummer 1450 XX
9.	Mixing proportion	75:25
10.	Separator material	Graphite Sheet (1mm)
11.	Upper refractory Bricks	25% or 50% Alumina with vertical cavity of 10mm diameter
12.	Lower refractory	25% Alumina
13.	Rectangular bar	Mild steel (mm) 260×20×20 260×20×20 170×20×20 170×20×20 170×20×20 170×20×20
14.	Spring	Stainless steel (mm) 120×10×2 120×10×2 120×10×2 120×10×2

3. Technical Features of the Invention

a) It is feasible to apply axial loading design under the microwave radiations.

b) Using this setup axial loading can be applied to rectangular bars, hollow rectangular bars, pipes, hollow pipes etc.

c) Joining thick and long bulk materials is possible using this designed axial loading

d) Better strength of joint can be produced.

4. Limitations of the previously existing design for microwave processing:

- Due to the limitation of the designed crucible setup used in microwave oven it was difficult to provide the axial loading
- There is no feasible axial loading design under the microwave radiations.
- Limitation of joining thick and long bulk materials
- Limited strength of the microwave welded joint

5. Advantages over the existing welding setups and processes

- It is feasible to apply axial loading design under the microwave radiations.

- Using this setup axial loading can be applied to rectangular bars, hollow rectangular bars, pipes, hollow pipes etc.
- Joining thick and long bulk materials is possible using this designed axial loading
- Better strength of joint can be produced.

6. Components of the applicator with reference numerals

1. Six metallic rectangular hollow bars- *used to construct main structure of the axial setup having mild steel material.*
2. Four springs-*used to provide the force during the contraction of the spring.*
3. Ceramic wool-*used to provide masking to the setup to avoid direct contact with microwave radiations.*

7. Arrangements of the components with each other

There are six rectangular hollow bars out which, four are fixed bars and two are moving bars. Four springs are used in the setup, which are placed in between the hollow rectangular bars having, sliding motion and contraction and expansion of the spring. Ceramic wool is used for the masking of the setup.

We Claim:

1. A process of Microwave hybrid heating for Axial loading inside the microwave applicator for joining different materials comprising the steps of:

Preparing the sample for microwave hybrid heating using junction material susceptor material which absorbs the microwave radiations at a higher rate; converting these absorbed radiations are then converted into heat; so that the material interaction with microwave radiations caused less variation in temperature gradient (ΔT);

Using an axial loading setup inside microwave oven, axial load is applied to the joints;

wherein Power output is 900Watt; base metal is used of SS304, SS316, SS202 of rectangular bar and pipes.

2. The method as claimed in claim 1, wherein Susceptor material is Charcoal powder and Interface material is 99% Pure Nickel based powder (20μm)/SS powder (20μm); with Mixing proportion is 75:25.

3. The method as claimed in claim 1, wherein Separator material is Graphite Sheet (1mm); Upper refractory Bricks are 25% or 50% Alumina with vertical cavity of 10mm diameter; and Lower refractory is 25% Alumina.

4. The method as claimed in claim 1, wherein Epoxy is Blummer 1450 XX.

5. The method as claimed in claim 1, wherein Domestic microwave oven is used as applicator; in the frequency of 2.45GHz. and 32l capacity;

Wherein said absorption of microwave radiation by the materials was due to increased skin depth at elevated temperature; and at temperature greater than 1000º C the diffusion of Ni powder begins with the base metal; When temperature reaches approx. 1400ºC intermetallic bonding takes place with the exchange of elements between base metal and interface material;

6. The method as claimed in claim 1 characterized and claim increase in the mechanical properties of the joint

Dated this August 26, 2022

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Mr Rahul Samyal, Dr. Ashok Kumar Bagha & Dr. Raman Bedi

Sheet: 1/4

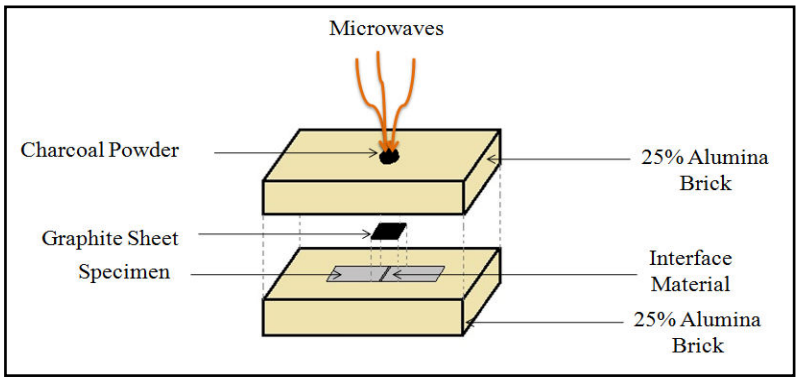

Fig. 1

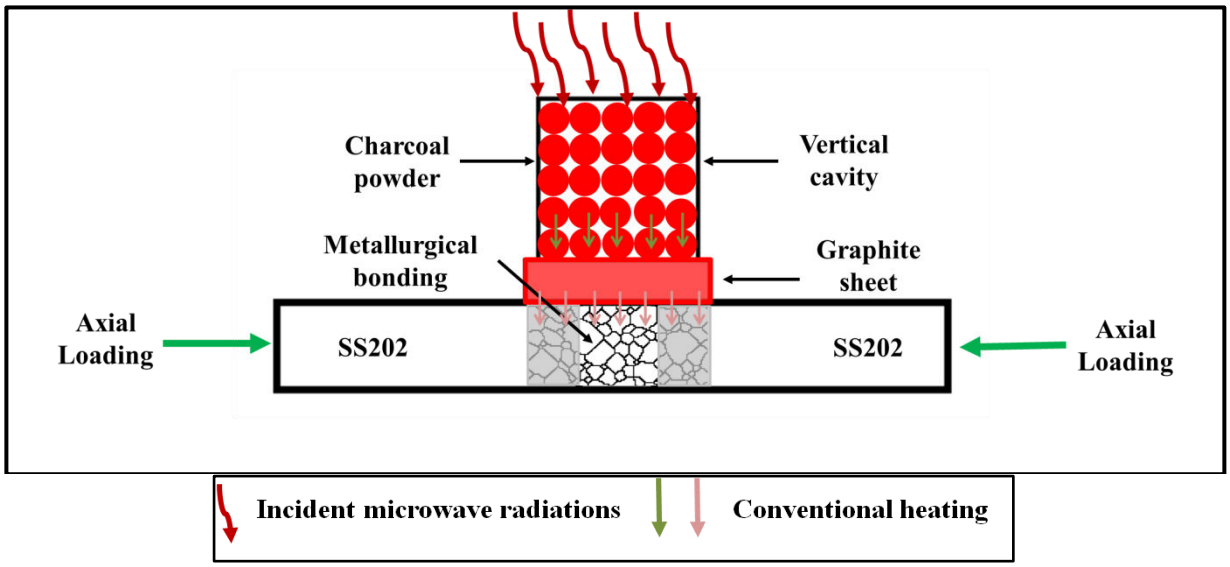

Fig. 2

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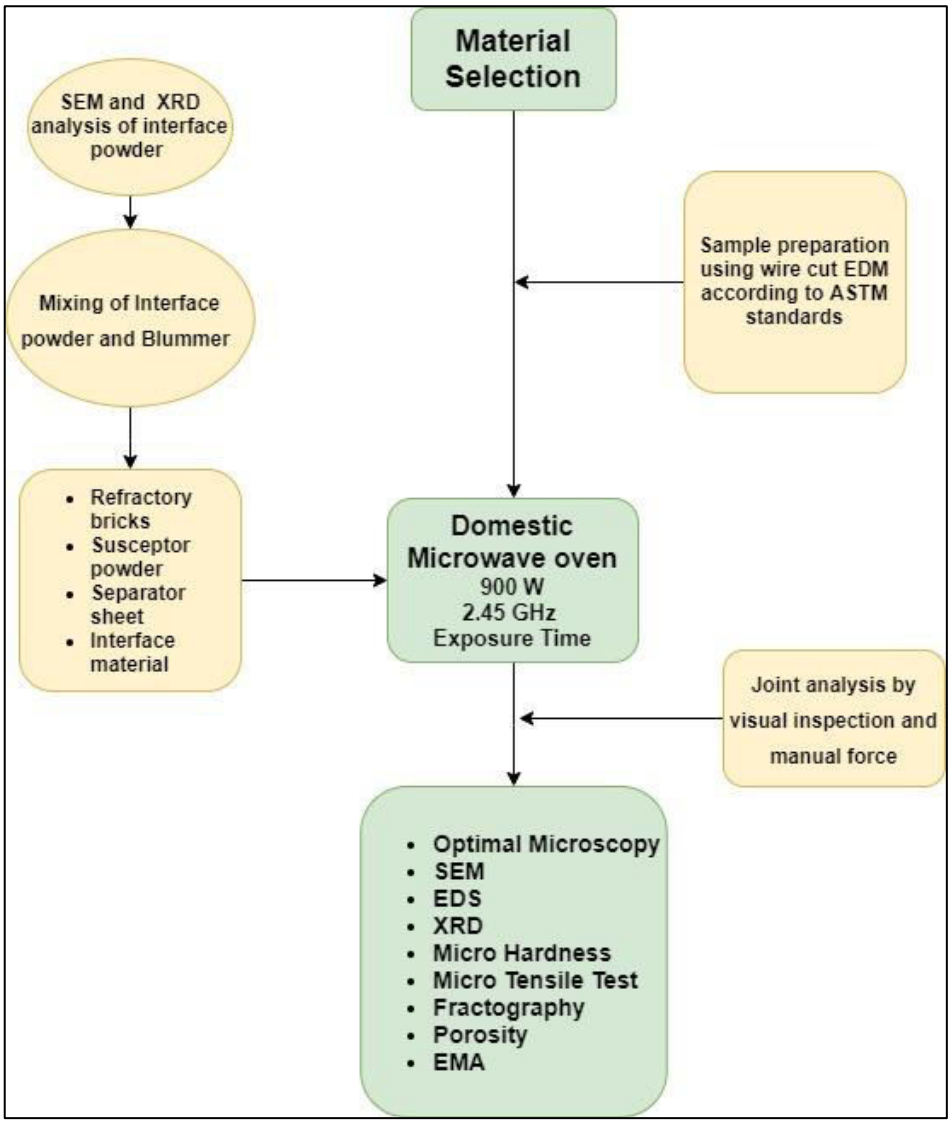

Fig. 3

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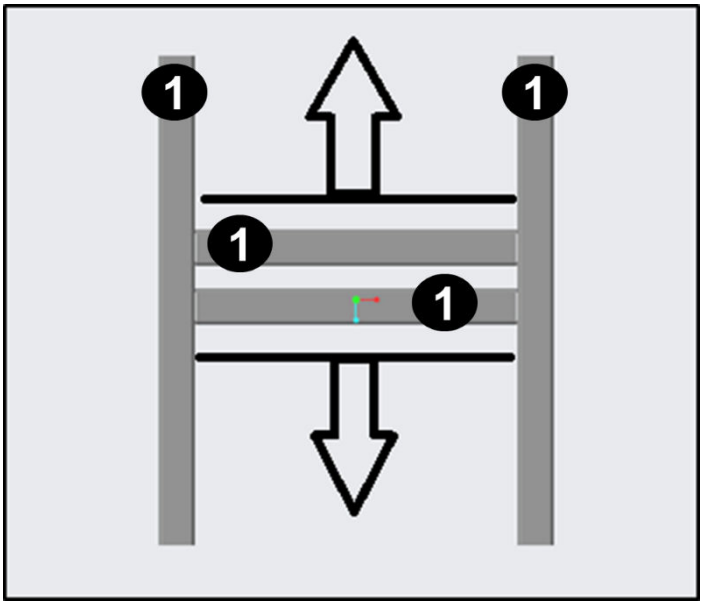

Fig. 4

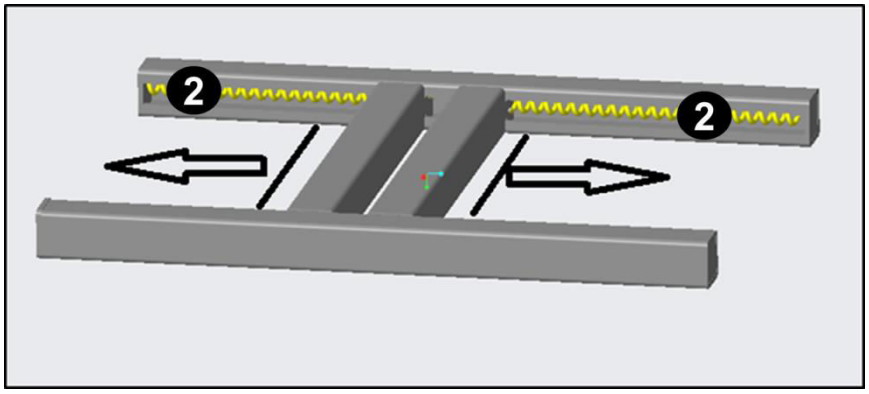

Fig. 5

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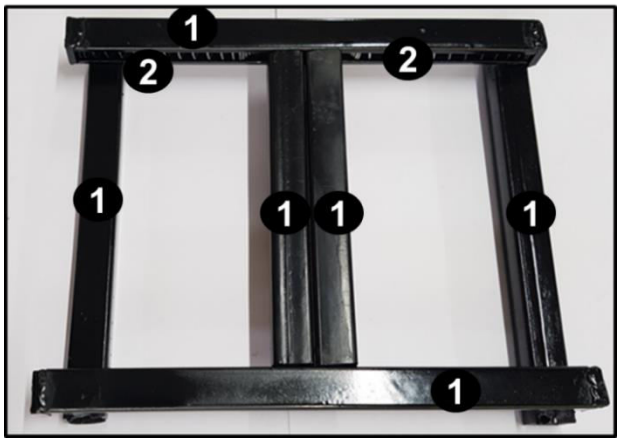

Fig. 6

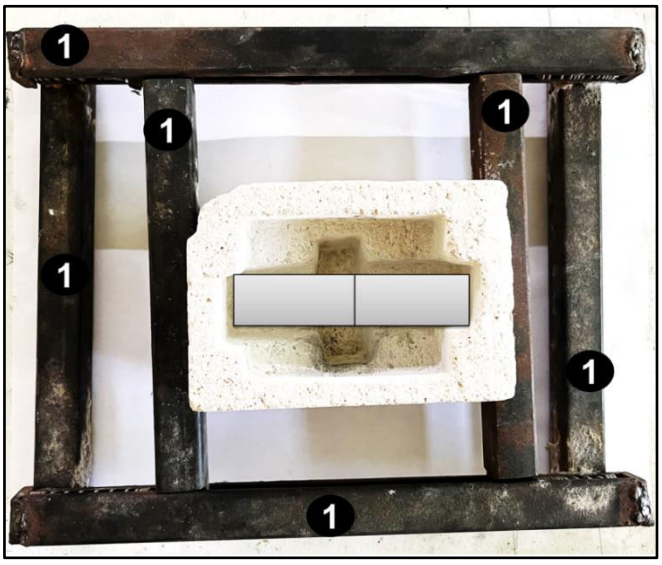

Fig. 7

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ABSTRACT

A PROCESS OF AXIAL LOADING INSIDE THE MICROWAVE APPLICATOR FOR JOINING DIFFERENT MATERIALS

A material joining process is incomplete without the axial load to get sufficient bonding and strength of the joint. However, it is difficult to provide any type of additional loading to the specimen inside the microwave cavity, due to the lack of space and design for axial loading. Metallic materials are repellent of microwave radiations which causes arc at the edges resulting in more difficulties to provide axial loading inside the microwave cavity. Considering all the difficulties an axial loading is implemented inside the microwave cavity which provides sufficient pressure to the joint for better intermetallic bonding between the substrate and interface material. The designed step-up is independent of the size of the specimen and could be applied to any type of joint say butt, lap, and T-shaped joint. The current designed setup can be applied to different shapes and structures such as rectangular, pipes or hollow pies, etc.