Dissimilar Joining of Metals by Powder Metallurgy Route

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CERTIFICATE

This is to certify that the thesis entitled "**Dissimilar Joining of Metals by Powder Metallurgy Route**" being submitted by Mr. **Abhijit Kumar Das** to the National Institute of Technology, Rourkela, for the award of the degree of **Masters of Technology** is a record of bonafide research work carried out under my supervision and guidance. The results presented in this thesis have not been submitted elsewhere for the award of any other degree or diploma.

This work in my opinion has reached the standard of fulfilling the requirements for the award of the degree of **Masters of Technology** in accordance with the regulations of institute.

Date: ------------------------------

Prof: Anindya Basu

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ABSTRACT

Dissimilar metal joints have a wide range of applications in electronic connectors, due to its physical and mechanical properties. In the present work powder brazing is chosen as a tool for joining of Cu-SS, Cu-Fe, and Cu-Ni.

Powder brazing of dissimilar metals has advantages over conventional joining techniques which does not involve melting of the base metal and thus avoids the problems associated with, variation in thermo-physical properties and leads to formation of high amount of undesirable compounds (high intermetallic layer at the joint interface) as a result high joint strength cannot be achieved, an able solutions to produce this type of joints has been developed.

In the present work three different types of powder are chosen for brazing, Copper (Cu)-Stainless Steel (SS), Copper-Iron (Fe), Copper-Nickel (Ni) powders. Cu weight (2 gram), stainless steel powder (2 gram), iron powder (2 gram), and Nickel powder (2 gram), then the specimen were compacted with varying loads (4, 5, and 6 tonne), the compacts were in the shape of cylinders. The compacts were sintered at 900 °c in argon atmosphere with a heating rate of (10 k/min), the specimens were cross sectioned using abrasive cutting machine, mounted and polished for macroscopic and microscopic observation. The mounted specimens were polished with emery paper of 1/0, 2/0, 3/0, and 4/0 and were subjected to chemical etching using nital solution. To study macro and microstructures of the specimen optical and scanning electron microscope was used. Form the macrostructures it was observed that there is no presence of cracks in all the joints. It was observed that with the increases in compaction load there is a better bonding between the joints. Microstructures did not show any presence of Intermetallics. Form the hardness data it was confirmed that there is a presence of Intermetallics due to marginal variation in the hardness at the interface in all the cases. From the compression test it was observed that with the Cu-Ni has shown improved strength compared to Cu-SS and Cu-Fe. At higher compaction loads the specimens has shown higher strength in the all the cases (Cu-SS Cu-Fe, Cu-Ni) may be due to better bonding.

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Chapter 1

INTRODUCTION

The fundamental goal of the present work is to join the Copper to Stainless steel, Copper to Nickel and Copper to Iron through powder metallurgy course. The broad utilization of these materials in industry needs to choose this mix of metal powders for unique metal joints. Powder metallurgical parts have imperative applications in aviation and force area, the present joints Cu-Steel discovers applications in auto commercial ventures as shrubberies, rollers in roller skates and a washer for hosing, electronic connectors and link joining,

Joints in the middle of ferrous and non-ferrous metals are of concern to industry in light of the fact that they join the quality and sturdiness of steel with the exceptional properties like erosion resistance, malleability and warm conductivity of copper.

The joining of divergent materials gives generally distinctive physical attributes, for example, liquefying temperature, vaporization temperature, coefficient of warm development, warm diffusivity, compound contradictorily i.e. ,development of moderate stages frequently exceptionally undesirable ,bringing about an extreme disintegration of properties. With respect to this a few arrangements are mechanical joining, conventional securing (jolts, bolts and so forth.), mechanical interlocking, and strong state joining.

Joining of divergent materials is turning out to be progressively imperative as specialists take a stab at decreased weight and enhanced execution for building structures.

Joining of divergent metals through routine (welding) procedure needs to address a few issues, for example, Copper behaviours heat vitality up to 10 times speedier than steels, which has a tendency to scatter warm rapidly far from the weld prompting troubles in the dissolving temperature of copper. Other than that there is a limited solubility of Cu in Fe. One more major problem in welding is hot cracking in the heat affected zone of steel as a result of copper penetration in to grain boundaries of steel.

Powder joining of disparate metals has points of interest over customary joining strategies which does not include liquefying of the base metal and hence maintains a strategic distance from the issues connected with, variety in thermo-physical properties and prompts arrangement of high measure of undesirable mixes (high intermetallic layer at the joint interface) subsequently high joint quality can't be accomplished, a capable answers for produce this sort of joints has been created. There are a couple issues related even with powder joining i.e. porosity, causes due to capture of oxides or contaminations. Most essential need is that the connected weight ought to be consistently conveyed over the contact zone.

In the present work three unique sorts of powder are decided for powder joining, Copper (Cu)-Stainless Steel (SS), Copper-Iron (Fe), Copper-Nickel (Ni) powders, then the example were compacted with changing loads, these compacted examples were sintered in inactive air. The examples were cross segmented utilizing grating cutting machine, mounted and cleaned for perceptible and tiny perception. The example were subjected to metallographic study (Optical and SEM), mechanical portrayal (Hardness, pressure test) to study the joint respectability.

Chapter 2

LITERATURE REVIEW

CURRENT LITERATURE SEARCH

Configuration architects are logically faced with the need to join disparate materials as they are searching for imaginative new structures or parts with tailor-outlined properties. In some cases a segment needs high-Temperature resistance in one zone, great consumption resistance in another. Structures may oblige quality or wear resistance in one district solidified with high quality in another region. Improving the capacity to join unique materials with composed properties are enabling better approaches to manage light-weighting auto structures, upgrading procedures. For vitality creation, making cutting edge therapeutic items and purchasers devices, and various other collecting and mechanical jobs. Joining disparate materials is often more troublesome than joining the same material or composites. With minor complexities in structure: of course, various divergent materials can be joined adequately with the fitting joining process and specific techniques.

Chan jo Lee[1] has mulled over configuration of gap securing procedure for joining of unique materials-AL6061-T4 composite with DP760 steel, hot squeezed 22MnB5 steel and carbon fibre fortified plastic. Flat broke securing process, the bendable material is situated highest (2 mm) and the fragile material-into which a gap is shaped is situated beneath that. The upper sheet is indented into the die cavity through the hole in the lower sheet (1.6 mm) and spread so that the two sheets interlock geometrically. Gap securing instruments were composed taking into account the geometrical relationship between the molding volume and the joint quality (2.5 KN).Finite segment examination and sensible examinations were performed to affirm the sensibility of the crevice securing system. Cross-segment is great with the aftereffects of the limited component examination. At that point, a solitary lap shear test were performed to assess the joint quality .Regardless of the material mixes ,if a joint quality of abundance of 2.5Kn,which outcomes appropriateness of opening securing procedure to joining of two divergent metals.

Zhin zhang [2] inspected the impact of Al slight film and Ni foil layer on dispersing strengthened Al-Mg unique joints. Ni foil interlayer disposed of the progression of Mg-Al Intermetallics mixes, while advancement of an Al slight film to the interlayer redesigned the properties of the Mg-Ni Intermetallics mixes. The shear way of the joints was enhanced by the improvement of the Ni foil and Al thin film interlayer.

M .S. Srinath [3] has analysed on microstructural and mechanical properties of microwave took care of diverse joints. Microwave joining of stainless steel (MS) in mass structure has been viably done using a multimode utensil at 2.54 GHz and 900w.principles of crossbreed warming were used using a susceptor medium so as to begin coupling of microwave with the metals .Ni based metallic powder sand witch layer between the mass pieces. Tests were displayed to microwave radiation in climatic conditions. They portrayed by FESEM,X-Ray diffract or ,Micro hardness analyser, complete testing machine .Microstructure shows that faying surfaces were all that much merged and got fortified on either side of the base material. This prompts advancement of cementite and metallic carbides were affirm. Vickers Micro hardness of focus of the joint is 133hv ,0.58% is porosity, great unbending nature of the joint is 346.6 MPa, rate of extending is 13.58%.Fractography reveals that the joint failed in light of both shearing of the delicate carbides and oxides furthermore due to plastic stream of the malleable structure under flexible stacking.

C. Shanjeevi [4] inspected the evaluation of mechanical and metallurgical properties of dissimilar materials by contact welding. The materials are austenitic stainless steel (304L) and copper were explored by flexible test and hardness test .Metallurgical properties of OP,SEM and atomic force microscopy was used to look at the microstructure of the welded joint ,in like manner reviewed by EDX line in order to fathom the stages formed in the midst of welding. Bendable test, the quality is determined and the hardness test estimations are investigated in base metal and warmth impacted zone. The braced materials were conveyed by fluctuating the grinding weight, sensation weight and rotational speed through taguchis orthogonal display. The results was viewed the most significant flexible test procured in crushing welded joint was 2.52% higher than watchman material of copper. The effects of metallurgical depiction are discussed in light of the microstructural studies.

D. Durgalakshmi [5] inspected the on crisp state joining of disparate powder metallurgical preforms(viz. electrolytic accomplice tempered copper powder and steel powder preforms ,as the present work is a probability study, weight test was done was chosen to choose to record the inferences, related to the effect of a)volume ratio(CU-SS),b) thickness ratio(SS-CU),and c)strain. Both preforms was press-fitted and compacted between two parallel platens to distinctive strains .then, flexible test to insinuate the weld quality, both at pre sintering and post-sintering conditions of these joints, then metallography(optically ,SEM).the results are(CU-SS) of 1:4 subjected to cold curving rate of ε =0.6(with stream push as 1.0),density extent is 0.98 certifications extraordinary mechanical holding substantiated by gigantic interfacial region, reflecting weld quality extent of 0.89.It reasons that cut down the volume extent, cut down the thickness extent and perfect plastic distortion ,it should be possible to get a sound joint of sintered P/M parts of electronically toughened steel to copper powder after post-sintering.

B.Vamsi Krishnan [6] thought about Co-ejection of unique P/M preform, a researched course to make bimetallic tubes.it is exhibited that the authority of union (volume change) in the midst of synchronous distortion of p/m preforms diminishes the differential speed between the middle and sleeve as indicated by lower frustration propensity of ousts. High interfacial contact at the distinctive p/m preform interfacial and in this manner he high interfacial bond serves to sound stream more than a broad mixed bag of taking care of conditions. Also, the non-textures of disfigurement would be suited by the milder preform near to the interface through littler scale mechanical collaboration. It is acknowledged that the present system of making the bimetals fundamentally overhauls the collecting flexibility and reduces the contraption cost.

K. Jayabharath [7] investigated on the steady drive grinding welding qualities of sintered powder metallurgical (P/M) steel and formed copper parts. Remembering the finished objective to finish sound weld between these two materials the methodology parameters were redesigned and gathered that the preforms of lower densities with lower method parameters yield quality weldments, set up through post-weld tests. This study in like manner considers the effect of strategy parameters which fuse occupant preform densities, pounding weight. Wonder weight, and seethe off length on microstructure and mechanical properties of the welds. This work unites information on the parts of joining P/M part with made materials for practical judgment skills execution

R. Chandramouli [8] investigated test examinations on welding behaviour of sintered and molded Fe-0.3%-3% Mo low amalgam steel, which is done under TIG (tungsten inert gas) welding.

Rectangular segments of size 70 mm×15 mm×5 mm were blended ,compacted ,sintered of fundamental powders of iron ,graphite and molybdenum .two vague amalgam steel bits of proportional thickness were then welded both along longitudinal and transverse headings ,by TIG welding ,using filler material of suitable piece .The welded strips are inspected to flexible test ,hardness test ,microstructure and SEM fractography studies .the results are nippy/hot irritating of the sintered blend preforms has provoked enhanced thickness .The welded composite indicated higher unbending nature stood out from the un-welded base metal ,in view of fortifying by waiting nervousness .Similarly, the quality and hardness of the welded amalgam strips were found to be redesigned with the augmentation in thickness. No porosity was found in the weld metal or warmth impacted zone (HAZ) of the weld joint .However, the base metal had different small scale pores, however pore migration towards weldment has not been viewed.

Jinsun Liao [9] utilized gas tungsten curve welding of fine-grained AZ31B magnesium combinations (with different grain sizes and oxygen substance) made by powder metallurgy joined with hot expulsion, and the P/M magnesium compounds were subjected to gas tungsten bend welding (GTAW).porosities are seen in weld joints of the P/M AZ31B amalgams with high oxygen substance .utilization of a filler pole and/or on porosity in weld joints. At the point when oxygen content in P/M AZ31B amalgams is lessened to 440 PPM or less, stable weld joints without porosity are acquired. Mechanical test shows that the rigidity of the sound weld joints of P/M AZ31B composites is at the same level as that of weld joint of a regularly hot- expelled AZ31B composite

B. Vamsi Krishna [10] investigated solid state joining of special sintered P/M preform tubes (SS-CU and CU-AL) by synchronous cool removal. Effect of parameters, for instance, thickness extent, volume extent, interfacial point and strain on productive solid state joining of steel-cu and cu-al P/M preform tubes. The relationship between the strategies parameters and weld dissatisfaction partiality, three sorts of disfigurement, for instance, a) the misshaping/converging of the low quality P/M preform, the metal matrix curving of the low quality preform and the consolidating of amazing preform and, the mutilation of the joined material at the composite depending upon the method parameters. Over the top removal force and densification rate at the interface also achieve extended heterogeneous stream in the midst of co-ejection. In Cu-Al co-removal, on account of low ejection force, growing either the thickness extent or strain lessened frustration slant

.Experimentally derived ejection qualities are 5-25% higher than determined qualities for steel-Cu ejection and 15-30% less for Cu-Al removal. Due to the usage of immense bit of miss event essentialness in hardening/densification of P/M preforms the weld quality qualities is all in all to some degree not as much as in made metal joining.

M. Velu [11] inspected Metallurgical and mechanical examinations of steel-copper joints curve welded (got by shield metal round segment welding (SMAW) utilizing bronze and nickel base super compound filler materials. The weld spot of the joint with bronze-filler, exhibited porosity, while nickel-filler, has no. The malleable test, demonstrates the weldments with bronze filler is in focus of the weld .while nickel base filler softened up the shine affected zone (HAZ).SEM and EDS demonstrated layered weld interfaces and positive basic dispersals transversely over them .XRD considers around the weld interfaces did not uncover intermetallic mixes. Transverse turning test, showed that flexural qualities of the weldments were higher than the resistances. By and large shear quality shows unbelievable flexibility of joint. Shear attributes of the weld interface (Cu-Ni or Ni-steel), was higher than the yield way of weaker metal. Downsized scale hardness and charpy sways qualities were measured at all the fundamental zones over the weldments.

M. Nekovie [12] investigated microstructure and mechanical properties of a laser welded low carbon-stainless steel joint, as it reports on trial examination to grasp and likewise control the alloying structure in laser welding of austenitic stainless steel and low carbon steel. An EDS is used to separate the alloying piece, microscopy and flexible test were used to study the microstructure and, mechanical execution of the welded joint separately. The examination demonstrated more than a certain specific point imperativeness the material within the melt pool is all around mixed and laser column position can be used to control the mechanical properties of the joint. This finding was insisted using a numerical model in light of computational fluid components (CFD) of melt pool. Systems to control the amalgamation inciting passionate changes in hardness, microstructure and mechanical properties of the different laser welded joint are analyzed. An overwhelmingly austenitic mix zone is gained with a bar parity, of 0.2-0.4mm, towards the stainless steel. A pole equalization towards low carbon steel realized a martensitic microstructure.

Chengwu Yao [13] has considered the interface microstructure and mechanical properties of laser welding copper-steel dissimilar joining. By and large, the high reflectivity of copper to Co2 laser propelled the weakness in joining copper to steel using laser welding. The microstructure close the interface between cu plate and the intermixing zone was dissected. For the welded joint with high weakening of copper, there was a move zone with diverse filler particles close to the interface. In any case, if the crippling degree of copper is low, the move zone is simply make close to the upper side of the interface .at the lower side of the interface, the turbulent Bursting direct in the welding considered to the outlined to the entry of fluid metal into CU. The welded Joint with lower weakening degree of copper in the mix zone shows higher adaptability. On The bases of the microstructural assessment at the interface of the welded joint, a physical Model was proposed to delineate the headway of the unique joint with low crippling degree of copper.

F.khodabakhsh [14] has inspected metallurgical attributes and frustration mode move for move of disparate resistance spot-welds between ultra-fine grained and coarse-grained low carbon steel sheets. The unique resistance spot welding of low carbon steel sheets with the same compound union and various ultra-fine-scale and little scale structures was assessed. By the SPD of little scale as-got steel sheets utilizing the CGP process, the UFGED structure was made. The central metallurgical and mechanical disclosures concerning these unique spot welds can be communicated as takes after: for both the low and high warmth data to the differently spot welded joints, the weld chunk cross areas were uncovered to be symmetrical, In little locales close to the HAZ of different spot welds on the UFGED side, an extremely plastic bent structure was immediately recrystallized as an outcome of the warming and cooling cycles amid the joining procedure at greatly high inputs, the effects of the UFGED structure on the microstructural inclines in the combination zone were diminished, and a uniform weld piece was surrounded whose properties just depended on the concoction organization (and not on the BM's early on structure). In flexible shear stacking of different spot welds, haul out disappointment continually happened from the CGED side of the spot welds because of its weaker tractable properties After growing the warmth include over the discriminating qualities for the IF to PF dissatisfaction mode move, the terminal space extended reliably, without astonishing headway in the FZ Vickers hardness profile.

H. Sabetghadam [15] has considered dispersion holding of 410 stainless steel to copper using a nickel interlayer. In the present work, plates of stainless steel (410) were joined to copper ones through a dissemination holding methodology using a nickel interlayer at a temperature extent of 800-950ºC. The holding was performed through pressing the examples under a 12-MPa pressure burden and a vacuum of 10-4 torr for 60 min. The results demonstrated the plan of particular dispersion zones at both Cu/Ni and Ni/SS interfaces amid the dissemination holding technique. The thickness of the reaction layer in both interfaces was extended by raising the taking care of temperature. The stage constituents and their related microstructure at the CU/SS and SS/NI dispersion holding interfaces were focused on using optical microscopy, examining electron microscopy-beam diffraction and natural examinations through vitality dispersive spectrometry. The came about entrance profiles were reviewed using an adjusted electron test small scale analyser. The dissemination move districts near to the CU/NI and NI/SS interfaces comprise of a complete strong arrangement zone and of different stages on (Fe, Ni),(Fe, Cr, Ni) and (Fe, Cr)synthetic casing works, invidually .The dispersion reinforced joint handled at 900 C demonstrated the greatest shear quality of around 145 MPa. The greatest hardness was procured at the SS-Ni interface with an estimation of around 432HV.

2.1: Material Joining

2.1.1: Welding

Welding is a metal manufacture process which is utilized to join metals by the sensation of blend. The work-pieces are softened utilizing warmth got from different vitality sources, for example, gas fire, electric circular segment, grinding, ultrasound, electron shaft, laser vitality, and so forth., to deliver a pool of liquid metal (weld pool), which on cooling hardens to shape exceptionally solid joints. Utilization of filler material and use of weight is additionally improved and more grounded joints [16]

The different sorts of welding techniques regularly utilized are:

- Arc welding
    - Shielded metal circular segment welding (SMAW)
    - Gas metal circular segment welding (GMAW)
    - Flux-cored circular segment welding (FCAW)
    - Gas tungsten circular segment welding (GTAW), or tungsten inactive gas (TIG) welding
    - Submerged circular segment welding (SAW)
- Gas welding

        - Oxy-acetylene welding
        - Air acetylene welding
    - Resistance welding
    - High Energy shaft welding
        - Laser shaft welding
        - Electron shaft welding
- Solid-state welding
        - Forge welding
        - Ultrasonic welding,
        - Explosion welding

2.1.2 Brazing

Brazing is a metal-joining procedure in which two metal/materials are joined together by dissolving and streaming a filler metal into the joint, in brazing process the filler metal has a lower liquefy.

The molten metal braze flows, wets, and solidifies to bond the contacting components; the liquid braze wicks into a gap of approximately 0.5mm width to create the metallurgical bond. Most powder metallurgy brazing occurs at far higher temperatures than soldering, well over the 450ºC (the typical nominal temperature used to separate soldering from brazing).Typical braze materials are used on copper, nickel, and silver, with the additives to depress the melting point.

The difference between brazing and welding; in welding process fusion takes place along with base material and filler material. In case of brazing melting of filler material without melting the base material. The filler metal wets and forms a bond [16].

It is similar to soldering, except the temperatures used to melt the filler metal are higher for brazing.

2.1.3: Torch Brazing

Light brazing is by a long shot the most widely recognized technique for automated brazing being used. It is best utilized as a part of little creation volumes or in specific operations, and in a few nations, it represents a lion's share of the brazing occurring. There are three primary classes of light brazing being used: manual, machine, and programmed light brazing [16].

2.1.4: Furnace Brazing

Heater brazing is a self-loader procedure utilized broadly as a part of mechanical brazing operations because of its versatility to large scale manufacturing and utilization of untalented work. There are numerous focal points of heater brazing over other warming routines that make it perfect for large scale manufacturing. One principle favourable position is the simplicity with which it can deliver huge quantities of little parts that are effortlessly jigged or self-finding. The procedure likewise offers the advantages of a controlled warmth cycle (permitting utilization of parts that may twist under restricted warming) and no requirement for post braze cleaning. Basic airs utilized include: dormant, lessening or vacuum climates all of which shield the part from oxidation. Some different preferences include: low unit cost when utilized as a part of large scale manufacturing, close temperature control, and the capacity to braze various joints immediately. Heaters are regularly warmed utilizing either electric, gas or oil contingent upon the kind of heater and application. On the other hand, a percentage of the hindrances of this strategy include: high capital hardware cost, more troublesome outline contemplations and high power utilization [16].

2.1.5: Silver Brazing

Silver brazing, here and there known as a silver welding or hard binding, is brazing utilizing a silver amalgam based filler. These silver composites comprise of a wide range of rates of silver and different metals, for example, copper, zinc and cadmium [16].

2.1.6: Braze Welding

Braze welding is the utilization of a bronze or metal filler bar covered with flux to join steel work pieces. The gear required for braze welding is essentially indistinguishable to the hardware utilized as a part of brazing. Since braze welding ordinarily obliges more warmth than brazing, acetylene or methyl acetylene-prodiene (MAP) gas fuel is usually utilized .the name originates from the reality no slender activity is utilized [16].

2.1.7: Cast iron Brazing

The "welding" of cast iron is typically a brazing operation; with a filler bar made mainly of nickel being utilized albeit genuine welding with cast iron bars is additionally accessible. Bendable cast iron channel may be additionally "miscreant welded," a procedure which associate joints by method for a little copper wire intertwined into the iron when beforehand ground down to the uncovered metal, parallel to the iron joints being shaped according to center funnel with neoprene gasket seals. The reason behind this operation is to utilize power along the copper for keeping underground pipes warm in frosty atmospheres [16].

2.1.8: Vacuum Brazing

Vacuum brazing is a material joining procedure that offers noteworthy points of interest: amazingly clean, prevalent, sans flux braze joints of high honesty and quality. The procedure can be lavish in light of the fact that it must be performed inside a vacuum chamber vessel. Temperature consistency is kept up on the work piece when warming in a vacuum, significantly diminishing lingering burdens because of moderate warming and cooling cycles. This, thusly, can essentially enhance the warm and mechanical properties of the material, subsequently giving one of a kind warmth treatment capacities. One such ability is warmth treating or age-solidifying the work piece while performing a metal-joining process, all in a solitary heater warm cycle [16].

2.1.9: Soldering

Welding is a joining process in which materials are fortified together utilizing a warming system and a filler metal without dissolving the base/guardian material. The filler metal melts, wets the base material. Wetting of the base material by filler metals happens by the employments of flux

The real distinction in the middle of welding and brazing is the temperature of warming. Fastening for the most part happens at beneath 450 º C were as brazing happens at over 450 º C [16]

2.2: Dissimilar material Joining:

2.2.1: Dissimilar Material Joining By Electron Beam Welding

Electron pillar welding (EBW) has been an enthusiasm for some specialists because of its elements, high vitality thickness, low warmth information, little Heat influenced Zone and reasonable bar size. With the change in innovation this strategy is pertinent to different metal mix yet the Joining of disparate metals are exceptionally extreme errand because of the variety in thermo physical properties.

EBW procedure may confront a few difficulties however it may offer opportunities to decrease the issues and produce agreeable joints. EBW can take care of issues identified with contrast in softening basically than a curve welding process because of high vitality thickness. Warm conductivity issue can be diminished to some degree by coordinating the shaft effectively to the obliged area. The aforementioned issues can be unravelled by this strategy. This makes EBW a practical procedure to tackle a few issues connected with divergent mix.

2.2.2: Dissimilar joining of metals by laser beam welding

The joining of two unique materials gets to be tricky, because of the wide variety in thermo physical properties (warm extension, Density, Specific warmth, warm and Electrical conductivity). To answer a percentage of the aforementioned issues specialists has directed numerous studies on disparate metal joining by utilizing different joining strategies, for example, Resistance welding ,hazardous welding , erosion mix welding , dissemination holding , cool metal exchange,. Routine welding strategies may not be appropriate because of principle issue range is the substantial contrast in dissolving focuses and alloying of both the metals drives arrangement of high measure of undesirable mixes therefore high joint quality can't be accomplished.

Since laser welding has favourable circumstances over different methods because of low warmth info process, little HAZ, therefore maintains a strategic distance from the issues related to contradictorily. Capable answers for produce this kind of joint have been produced.

2.3: Powder Metallurgy:

A framework for making parts by crushing or forming metal powders which may be in the meantime or thusly warmed to make an intelligible article.

Powder metallurgy [17] consolidates works out, for instance, the creation of metal powders, portrayal of those powders, mixing and treatment of powder before compaction, and change of powders into valuable designing shapes, including a sintering step. Most generally the system relies on upon events that can be seen similarly as vital laws of warmth, work, and misshapening as associated with powders. The normal condensing is P/M [17].

Powder Processing

Those steps associated with the joining of a powder into a thing, including compaction and sintering. Powder handling overall incorporates a sweeping number of variables that effect the last thing size and properties. For example, delicate powders are anything but difficult to smaller to about full thickness, hard powders restrict crushing and oblige high polymer substances for forming. The hard particles are densified amid sintering. Thusly, molecule hardness is a broad parameter.

Powder preparing accesses the few parameters to connection the last thing ascribes to the mix of molecule size, weight, shear rate, temperatures, time, and other adaptable parameter [17].

Powder Forging (P/F)

The plastic deformity and surprise forming of a sintered powder metallurgy conservative at high strain rates and lifted temperatures, where the minimized is compelled to full thickness and complies with the last shape utilizing a manufacturing stroke. The powder is initially constrained into preform, sintered to 75 to 90% thickness. Hot manufactured to last size with spiral extension to round out the manufacturing pass on as the smaller experiences an annoying stream. In the wake of manufacturing the part is warmth treated and machined. In the fashioning stride there are numerous variations in the horizontal imperative and strain rate. On the off chance that the preform weight is firmly observed, then producing gives a thick smaller near to the last shape. Pass on divider imperative is critical in deciding the real stretch and strain conditions that give densification without breaking. Ointments likewise have an extensive impact on fashioning. Without oil, the produced powder shows low-thickness districts on account of delay the punch or pass on divider. Grating reasons circumferential elastic anxieties as stream happens in the kick the bucket. A blend of poor grease and unnecessary strain without imperative prompts splitting. Temperature decides the anxiety important to accomplish densification. Common ferrous manufacturing operations don't surpass 1200ºC and range more like 8000°C to expand apparatus life. Generation rates are in the scope of four forgings for each moment [17].

BLENDING

The concentrated mixing of powders of the same apparent association yet from particular creation packages or atom size ranges. Blending is proposed to clear separation that may be affected by vibration in the midst of transport. Powders disengage by size when vibrated, as blended nuts where the best move to the top in the midst of vibration. Such detachment prompts uneven compaction and sintering. But there are three reasons of powder isolation (separates in atom size, thickness, and shape), size detachment is overwhelming. A powder will satisfactorily isolates by size if the little particles encounter the voids between the considerable particles.one aftereffects of size partition is that the general apparent thickness reduces with size detachment. A sporadic atom shape will breaking point size withdrawal .In like way, less size division happens with particle sizes underneath for the most part 100 micron as a delayed consequence of the more cover atom disintegration. Blending is the typical method to exhaust size separation after transport. Immaculate blending is for brief time, utilizing dry powder [17].

2.3.1: Compaction

Powder compaction is the procedure of compacting metal powder in a kick the bucket through the use of high weights. Ordinarily the instruments are held in the vertical introduction with the punch instrument shaping the base of the cavity. The powder is then compacted into a shape and after that shot out from the bite the dust pit. The thickness of the compacted powder is specifically corresponding to the measure of weight connected. Average weights territory from 80 psi to 1000 psi (0.5 MPa to 7 MPa), weights from 1000 psi to 1000000 psi have been acquired. Weights of 10 tons/into 50 tons/in (150 MPa to700 MPa) are generally utilized for metal powder compaction. To accomplish the same pressure proportion over a segment with more than one level or stature, it is important to work with various lower punches [17].

Compaction Mechanics

The examination of misshaping of powders under the movement of stress.it includes major laws of anxiety, strain, strain rate, warm softening, strain solidifying, and strain rate setting for both adaptable and plastic behaviour. Constitutive correlations ascend out of the examination of compaction mechanics that are used in restricted segment examination to anticipate thickness, quality, contact, splitting, [17].

Compaction Pressure

The crest weight joined with a powder smaller amid the densification piece of the compaction stroke.

2.3.2: Sintering

Sintering process in which warmth is connected to a powder conservative to confer quality and respectability. Temperature utilized ought to be well beneath the liquefying purpose of the powder constituents.

After compaction, neighboring powder particles are held together which offers the minimized green quality. At sintering temperature dispersion procedure reasons necks to frame and develop at these contact focuses [17].

Sintering Mechanism

A few nuclear movement forms that can work to move mass amid warm cycle prompting the development of molecule to molecule bonds, with an associative loss of surface range and sometimes shrinkage. The components fall into two classifications surface transport and mass transport. The previous gives holding, surface region diminishment, however no shrinkage or densification since mass stream is from raised focuses on the pore surface to sunken focuses on the pore surface. For metals surface dispersion is the overwhelming system. Then again mass transport ordinarily stores the mass at curved pore surface, yet that mass begins from sources regularly inside to the particles or structure the bury molecule or structure the surface range decrease and shrinkage that affects a higher thickness, grain limit dissemination is the most vital mass transport component for most metals [17].

Favourable circumstances such as:

- Through this strategy permits to acquire Complex shapes.
- High dimensional exactness.
- Reliability and repeatability on substantial large scale manufacturing.
- Excellent surface completion.
- Stability during the time spent huge arrangement.
- Good mechanical qualities.
- Saving material

2.4: Different combinations of joint:

Importance of joining Stainless Steel-Copper Copper-Nickel and Copper-Iron

Copper/Stainless Steel

In the field of power period and transmission, cryogenics, electrical and equipment, copper-steel blends are periodically utilized as a part of light of their electrical conductivity of copper tends to quickly diffuse warmth a long way from the weld, provoking difficulties in setting off to the condensing temperature. The main problem in welding of copper to steel is hot part in the glow affected zone in perspective of copper softening and invading into the grain furthest reaches of solid steel.

Copper/Iron

Solid state welding was utilized to join low bury dissolvability metal couple Cu-Fe, and the microstructure and mechanical properties of the joints were analyzed. The interface was free of deformaties. Checking electron microscopy, essentialness dispersive spectrometry, and atomic force microscopy and nano space results revealed that a potential zone of pseudo-parallel compound was open at the faying surface, where nanoscale particles were moved to the opposite side by facilated scattering. Attributable to the part of scaled down scale contact and facilated spread the interfacial quality was made progress.

Copper/Nickel

The expansion of nickel to copper improves its quality and strength furthermore the imperviousness to consumption, disintegration and cavitation in every basic water including sea water and salty, treated or debased waters. The included purpose of enthusiasm of astounding imperviousness to biofouling gives a material ideal for application in marine and concoction situations for boat and pontoon outlines, desalination plants, warmth trade hardware, sea water and weight driven pipelines, oil apparatuses and stages, fish developing enclosures and sea water confirmations screens, et cetera.

Joining of Copper- stainless, Copper-Nickel and Copper-Iron utilizing welding procedures experience's issues due the huge contrast in warm conductivities of the materials which prompts high inward push, contortion and hot breaking between the metals. These issues can be decreased through applying powder metallurgy course. As there is no dissolving in this procedure which thusly diminishes the issues connected with liquefying, this will enhance the joint uprightness and decreases the arrangement of complex structures.

2.5: Objective of work

The present study is focused on joining of Copper (Cu)-Stainless Steel (SS), Copper-Iron (Fe), Copper-Nickel (Ni) powders through powder metallurgy route.

- To study the joining behaviour of different materials.
- To investigate the metallographic characterization of the joints.
- To investigate the mechanical characterization of the joints.

Chapter 3

EXPERIMENTAL WORK

3.1: Joint Preparation:

In the present work three different types of powder are chosen, Copper (Cu)-Stainless Steel (SS), Copper-Iron (Fe), Copper-Nickel (Ni) powders. Cu weight (2 gram), stainless steel powder (2 gram), iron powder (2 gram), and Nickel powder (2 gram), then all three specimen were compacted with varying loads (4, 5, and 6 tonne), the compacts were in the shape of cylinders. The specimens were subjected to sintering phenomena. The treatment was carried out at 900 °c in argon atmosphere with a heating rate of 10 k/min, and holding for 2 hours followed by air cooling, the specimens were cross sectioned using abrasive cutting machine, and some of the cut samples were mounted to study the cross section of the joints.

The mounted samples were polished. The polishing procedure of this alloy include polishing with emery paper of 1/0, 2/0, 3/0, and 4/0 and the polished specimens were thoroughly cleaned with running water and specimens were subjected to chemical etching using Nital solution. Macroscopic examination of joints was analysed using optical microscope and scanning electron microscope having Energy-dispersive X-ray spectroscopy (EDS) attachment.

Micro hardness measurements were carried out across the joints on the mounted cross section. The hardness survey was carried out throughout the surface form one end to other end, considering midpoint as a centre. The micro hardness measurements were carried out using an automatic LECO Vickers micro hardness tester fitted with a diamond indenter. A 25 gm load and dwell time for 10 sec were kept constant for all indentations and the distance between the two indents was maintained 150 µmin order to avoid possible effects of strain field caused by nearby indentation. An average of 3-4 indentations taken in identical locations was reported.

Compression test was carried on the sintered specimen according to the standards to find the joint integrity.

3.2: Characterization:

3.2.1: Microstructure Analysis by Optical Microscope

Microstructures of the Specimens of every one of the three CU-SS, CU-FE, CU-NI (4, 5 AND 6 TON) were inspected under an optical magnifying lens (Leica, model: DM 2500 M) and agent photos were recorded. The microstructures were additionally picture examined with the assistance of Leica picture chief IM 50 product.

3.2.2: Hardness Measurement

Hardness values of CU-SS, CU-FE, and CU-NI (4,5 AND 6 TON) were measured using Vickers hardness testing machine maintaining indentation load of 50 gm and dwell time of 10 s (Loco Model, LV 700, and MI USA) with distance of 10 micron between each indentations. Minimum 20 readings were taken for each specimen to obtain the average value. Tests were performed as per ASTM standard E384

3.2.3: Compression test

The pressure test, in which the example of stature and distance across (239.03 mm and 230.11 mm) is subjected to a compressive burden, gives data that is helpful for assessing powers and force necessities in these procedures. This test is typically completed by packing a strong tube shaped example between two all-around greased up level kicks the bucket (platens). In view of contact between the example and the platens, the example's round and hollow surface lumps, an impact is called barrelling.

3.2.4: Scanning electron microscopy (SEM)

Examining electron microscopy (SEM) is a system for high-determination imaging of surfaces. The SEM utilizes electrons for imaging, much as a light magnifying instrument utilizes noticeable light. The benefits of SEM over light microscopy incorporate much higher amplification (>100,000X) and more prominent profundity of field up to 100 times that of light microscopy. Subjective and quantitative substance examination data is likewise gotten utilizing a vitality dispersive x-beam spectrometer (EDS) with the SEM.

Chapter 4

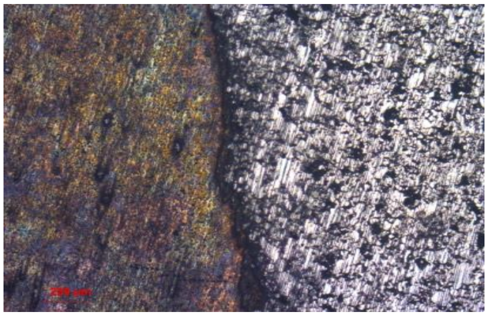
RESULTS AND DISCUSSIONS

4.1: Copper (Cu) -Stainless Steel (SS)

4.1.1: Optical Micrographs

Form the figure 1 microstructure it can be watched that there is no vicinity of splits in all the joints. It was watched that with the increments in compaction load there is a superior bonding between the joints. Microstructures couldn't affirm any vicinity of Intermetallics.

(a) (b)

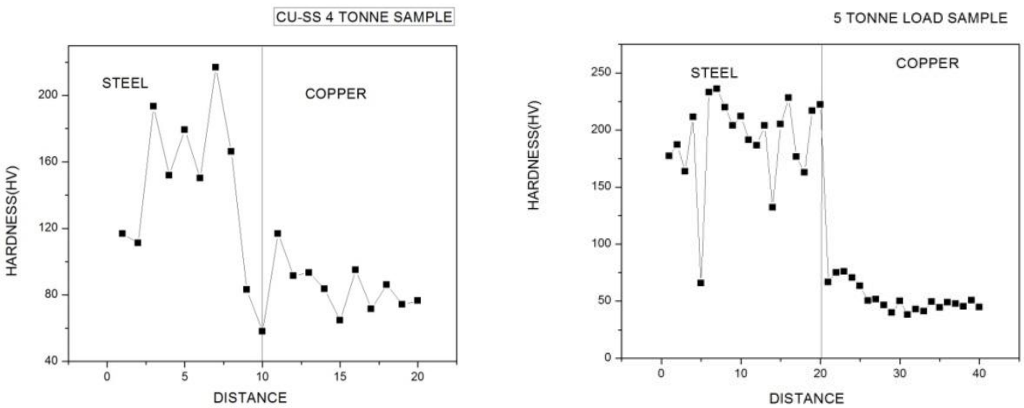


(c)

Fig 1: Optical image of interface between Cu-SS sample a) 4 ton b) 5 ton c) 6 ton

4.1.2: Hardness Test:

Figure 2 demonstrates the hardness graphs of Cu-SS sample a) 4 ton b) 5 ton frame the diagram it can be watched that copper has low hardness contrast with Stainless steel. Form the hardness it was affirmed that there could be a vicinity of Intermetallics because of negligible variety in the hardness at the interface in all the cases. Form the hardness it can be watched that there is a slight diffuse in the hardness information in the event of 4 ton than contrast with 5 ton information this is may be because of vicinity of porosity or at higher loads the specimen could be reinforced better.



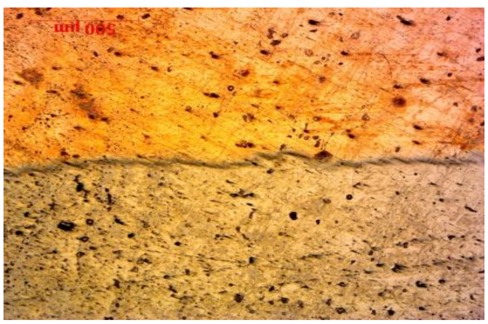
a) 4 ton b) 5 ton

Fig 2: Hardness graphs of Cu-SS sample a) 4 ton b) 5 ton

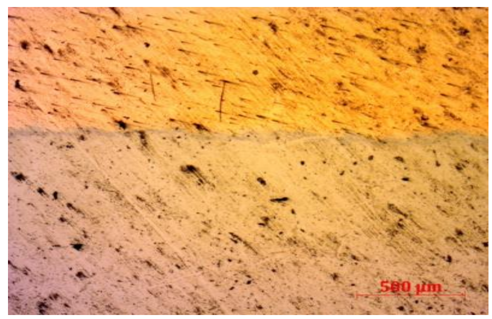
4.2: Copper (Cu) - Iron (Fe)

4.2.1: Optical Micrographs:

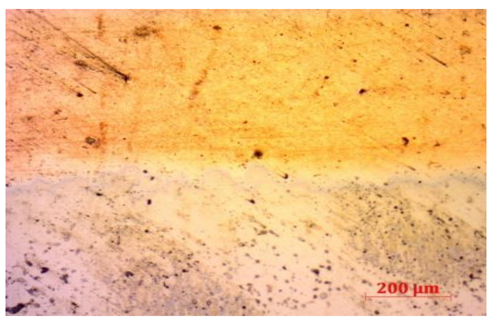
Form the figure 3 microstructure it can be watched that there is no vicinity of cracks in all the joints. It was watched that with the increments in compaction load there is a superior bonding between the joints. Microstructures did not demonstrate any vicinity of Intermetallics. Some dark spot can be watched form the figure 5 it might be porosity it is more conspicuous in the 4 ton sample with the expanding load there is no vicinity dark recognize that has lessened.



(a)



(b)

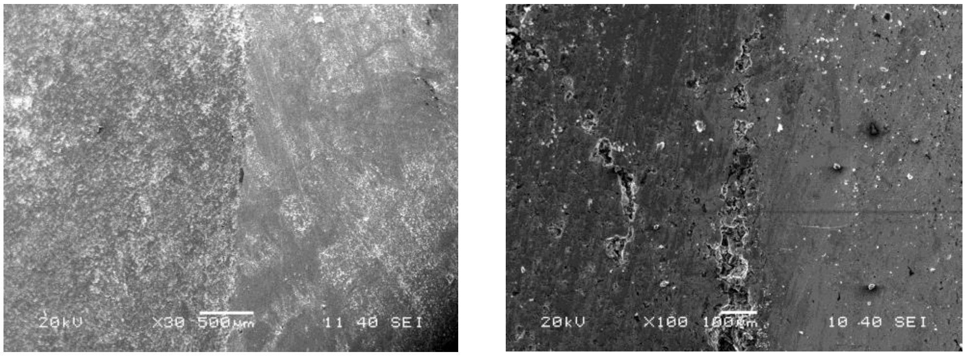


(c)

Fig 3: Optical image of interface between Cu-Fe sample a) 4 ton b) 5 ton c) 6 ton

4.2.2: SEM Analysis:

From the figure 4 SEM picture of interface between Cu-Fe test a) 6 ton (30X Mag)b) 6 ton (100X Mag) microstructure it can be watched that there is vicinity of cracks in joints. There is no vicinity of intermetallic in the microstructures even at higher amplification.



a) 6 ton (30X Mag) b) 6 ton (100X Mag)

Fig 4: SEM image of interface between Cu-Fe sample a) 6 ton (30X Mag) b) 6 ton (100X Mag)

4.2.3: Energy Dispersive X-Ray Spectrometer (EDS) Analysis:

Figure 5 demonstrates the EDS Analysis of Cu-Fe interface. A quantitate chemical analysis information is acquired by using an energy dispersive x-ray spectrometer (EDS) form the figure it can be seen there is a dispersion is higher at the interface.

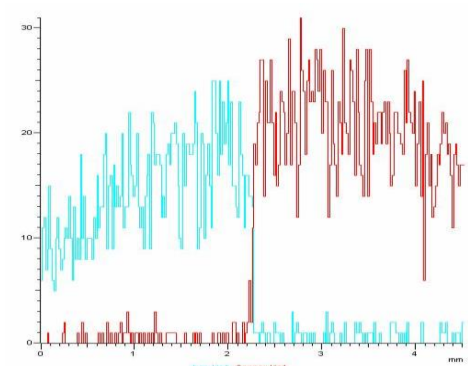
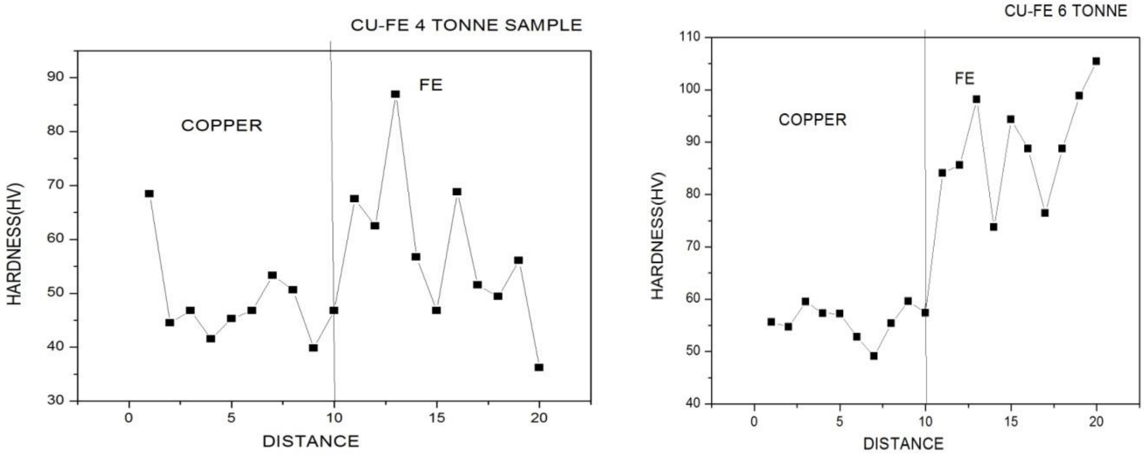


Fig 5: EDS Analysis of Cu-Fe interface

4.2.4: Hardness test:

Figure 6 demonstrates the hardness graphs of Cu-Fe sample a) 4 ton b) 5 ton form the graph it can be watched that copper has low hardness contrast with Iron. Form hardness data it was affirmed that there could be a vicinity of Intermetallics because of minor variety in the hardness at the interface in all the cases. Form the hardness it can be watched that there is a slight variety in hardness of the 6 ton sample this may be because of less porosity.

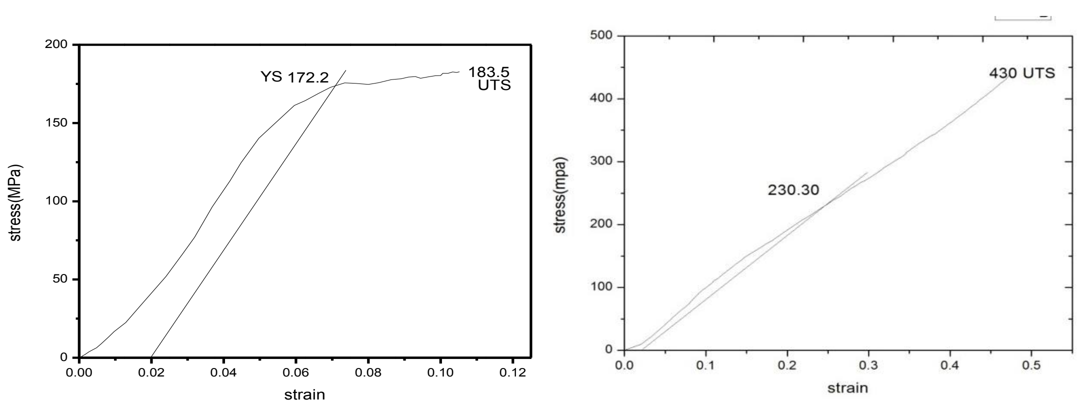


(a) (b)

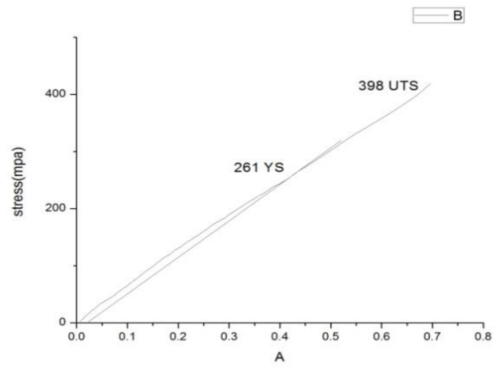
Fig 6: hardness graphs of Cu-Fe sample a) 4 ton b) 6 ton

4.2.5: Compression Test

Figure 7 demonstrates the hardness graphs of Cu-Fe sample a) 4 ton b) 5 ton c) 6 ton form the diagram it can be watched that with the expanding the compaction load there is an expanding in the strength of the joint up to 4 tonne load however at 6 tonne load there is a slight decrease in the strength of the joint.



(a) (b)



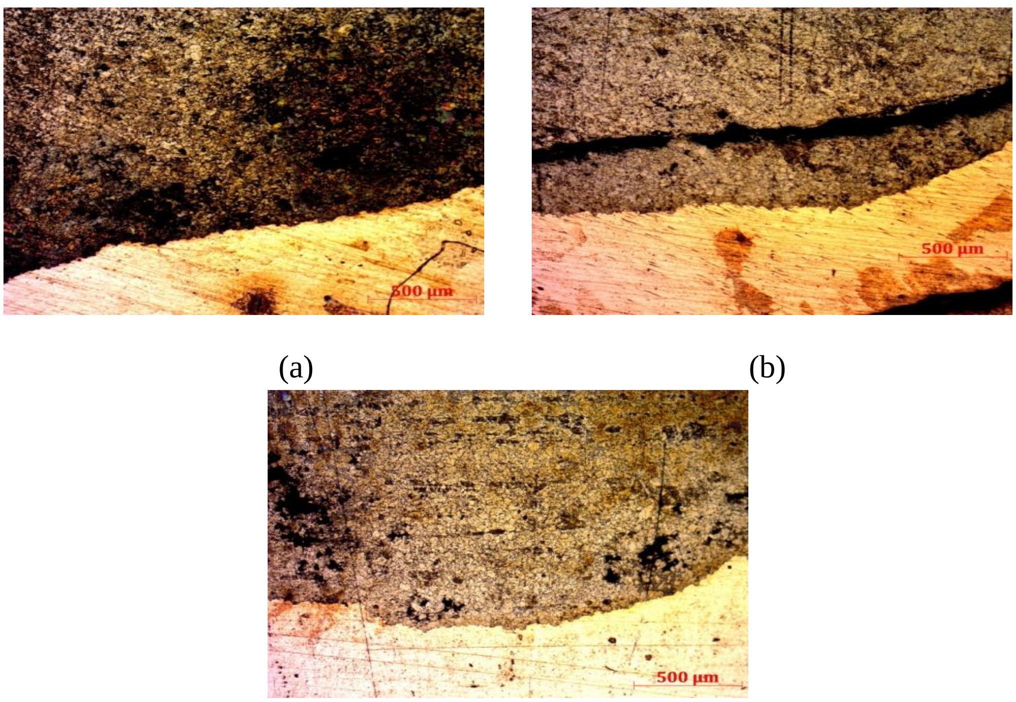
(c)

Fig 7: Stress strain plot obtained from compression test of Cu-Fe sample a) 4 ton b) 5 ton c) 6 ton

4.3: Copper (Cu)-Nickel (Ni)

4.3.1: Optical Micrographs:

Form the figure 8 microstructure it can be watched that there is no vicinity of cracks in all the joints. It was watched that with the increments in compaction load there is a superior bonding between the joints. Microstructures did not demonstrate any vicinity of Intermetallics. Some dark spot can be watched structure the figure 5 it might be porosity it is more noticeable in the 4 ton sample with the expanding load there is no vicinity dark detect that has reduced.



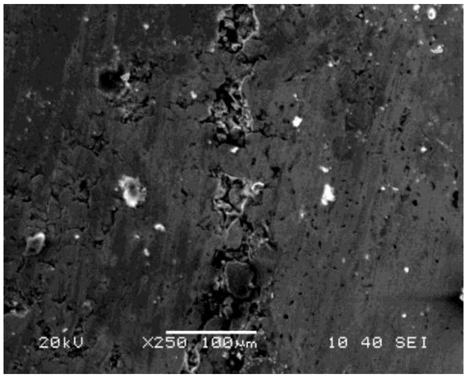
(a) (b)

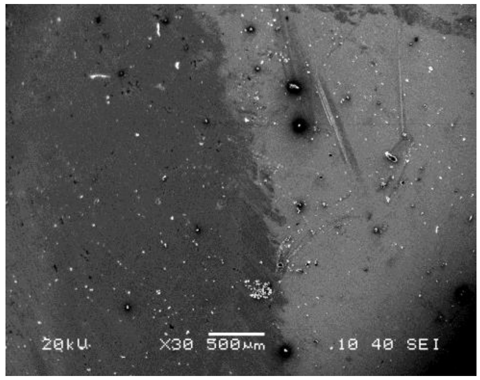
(c)

Fig 8: Optical image of interface between Cu-Ni sample a) 4 ton b) 5 ton c) 6 ton

4.3.2: SEM Analysis:

From the figure 9 SEM image of interface between Cu-Ni sample a) 6 ton (250X Mag)b) 6 ton (30X Mag) microstructure it can be watched that there is vicinity of cracks in joints. There is no vicinity of intermetallic in the microstructures even at higher amplification. We could likewise watch that at lower amplification there is dispersion taking place form Cu- Ni.





(a) (b)

Fig 9: SEM image of interface between Cu-Ni sample a) 6 ton (250X Mag) b) 6 ton (30X Mag)

4.3.3: Energy Dispersive X-Ray Spectrometer (EDS) Analysis:

Figure 10 demonstrates the EDS Analysis of Cu-Ni interface. Quantitative chemical analysis information is acquired by using an energy dispersive x-ray spectrometer (EDS) form the figure it can be seen there is a dispersion is higher at the interface.

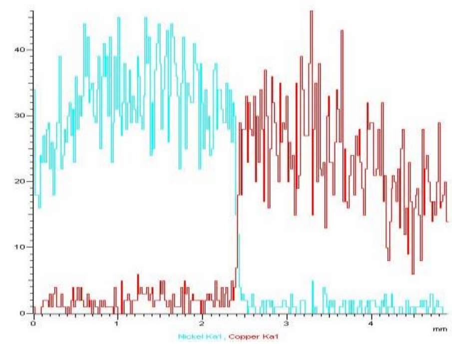
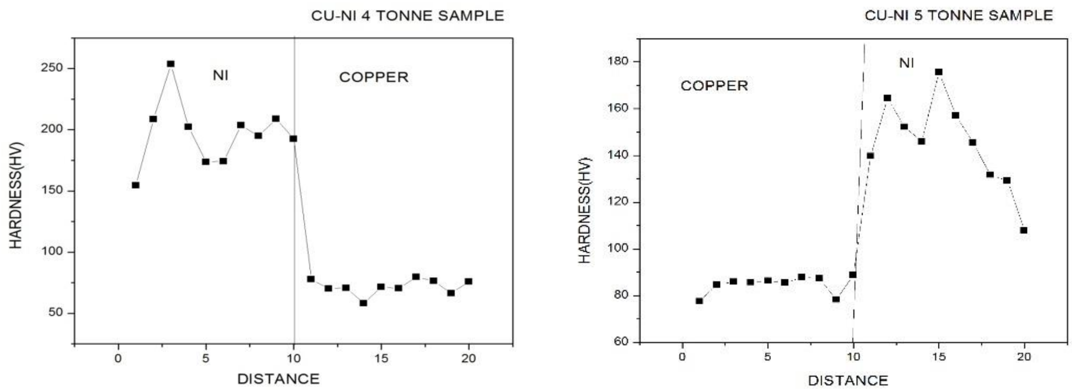


Fig 10: EDS Analysis of Cu-Ni interface

4.3.4: Hardness Test:

Figure 11 demonstrates the hardness graphs of Cu-Ni sample a) 4 ton b) 5 ton form the diagram it can be watched that copper has low hardness contrast with nickel. Form hardness data it was affirmed that there could be a vicinity of Intermetallics because of marginal variation in the hardness at the interface in all the cases.

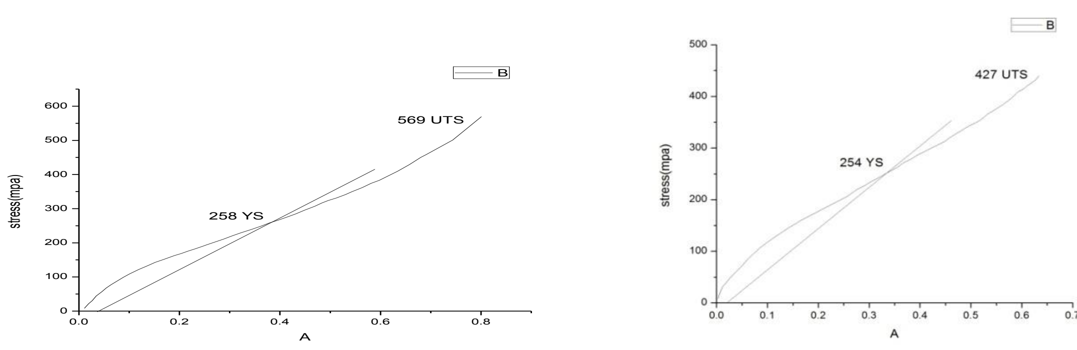


(a) (b)

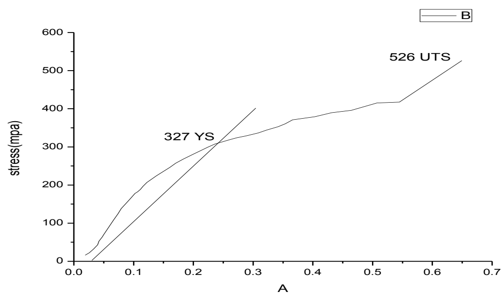
Fig 11: Hardness graphs of Cu-Ni sample a) 4 ton b) 5 ton

4.3.5: Compression Test:

Figure12 demonstrates the hardness graphs of Cu-Ni sample a) 4 ton b) 5 ton c) 6 ton form the diagram it can be watched that with the expanding the compaction load there is an expanding in the strength of the joint this could be because of better diffusion of Cu in Ni and all the more over at higher compaction load there is better bonding happens.



(a) (b)



(c)

Fig 12: Stress strain plot obtained from compression test of Cu-Ni sample a) 4 ton b) 5 ton c) 6 ton

Table 1: Consolidated compression data of all the joints

TABLE	CU-FE 5 TONNE	CU-FE 4 TONNE	CU-FE6 TONNE	CU-NI 4 TONNE	CU-NI 5 TONNE	CU-NI 6 TONNE
UTS	430	183.5	398	569	427	526
YS	230.30	172.2	261	258	254	327

Chapter 5
CONCLUSIONS

- Porosity is not visible from optical micrographs.
- Good bonding is watched from the optical micrographs
- Intermetallics are not noticeable from the optical micrographs furthermore from the SEM investigation.
- Cu-Ni has indicated higher mechanical properties.
- There is no break arrangement in the intermetallic region.
- Cu-SS has indicated enhanced mechanical properties of the joints.
- Form the hardness information it vicinity of Intermetallics can't be administered information because of minor variety in the hardness at the interface in all the cases. To affirm this future study is needed.

Chapter 6

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