Non-fusion joining of aluminium

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SYNOPSIS

This paper deals with various processes for non-fusion joining of aluminium. The processes of soldering have been dealt in details suggesting various soft solder flux combinations, hard solder flux combinations for flux soldering, friction soldering and reaction soldering. Brief details of brazing alloys and fluxes have also been given.

Usefulness of pressure welding in joining electrical conductors and other small items has been discussed giving details of the process and types of pressure welding equipments available commercially. Brief mention has been made to newer processes like ultrasonic and explosive joining.

JOINING of aluminium is now a well established technology. Successful joining can be done by TIG and MIG welding, pressure welding processes, brazing and soldering processes. Conventional fusion processes of joining aluminium are well known and are widely used in India by all major fabricators. On the other hand, though non-fusion joining processes like soldering, brazing and pressure welding have wide field of applications the correct process and material required are not very well known ; as such there is a specific need in India, at present, to disseminate the knowledge on joining of aluminium especially by these processes which a small fabricator can handle.

Since small industries are called to fabricate components from commercial grade aluminium only and most of the fabrications, by such fabricators, are that the joint does not require a high strength like a welded joint, attention has mainly been focussed to the soldering processes. Other non-fusion joining processes like brazing and cold pressure welding have also been described. Brazing, which is sometimes termed as high temperature soldering, has wide application in industries in India, whereas cold pressure welding though not very widely in use is now finding wide application especially for joining of wire butt ends and terminals of contactors.

The difficulty of joining aluminium arises out of the tenacious oxide film which is formed spontaneously on its surface. The high conductivity of aluminium makes it necessary to provide and maintain high heat at the joint head continuously while the soldering is carried out, making aluminium joining by soldering a special problem.

Soldering

Soldering is employed especially in the manufacture of irregular and complicated shapes and in constructions requiring joining of parts with marked differences in thickness e.g. joining of foil shaped parts to heavy castings. The use of the process is however generally limited to small assemblies and for such joints where the soldering tool can be well manipulated.

The problem of aluminium soldering is three-fold. Firstly the great difficulty encountered in soldering aluminium is attributed, as mentioned earlier, to a tenacious oxide layer which forms very rapidly and easily on exposure to air and is extremely difficult to remove. The aluminium oxide is a refractory material, chemically very inert, and has a very high melting point of about 2000°C. There is no fluxing material known yet which will dissolve it at soldering temperature.

Secondly aluminium has a high heat conductivity. Cooling occurs very rapidly so that a relatively high heat input is necessary to maintain a stable soldering temperature at the joint.

The third problem arises from the position of aluminium in the electromotive series.[1] Solder joints in aluminium corrode electrolytically because galvanic cells are established in corrosive environments between aluminium, the various phases in the solder, and the layer that forms at the aluminium and solder interface.

To ensure a good strength of the soldered joint, the electrode potential of the solder interface should be at lower level than the electrode potential of the solder material.

Joint design

Practically in all cases, the solder joint has the smaller strength in the structure unless the joint is specially designed. The strength of a properly made solder joint is affected apart from the composition of the solder and parent material, by the thickness of solder layer in the joint, the joint design and the susceptibility of the joint to corrosion. A selected solder, flux and metal

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combination should have a specific joint gap at soldering temperature to give a maximum shear strength. It has been found out that smaller the thickness of the solder, greater is the strength of the joint. However, a small clearance in case of aluminium solder joint may prevent good access of flux and solder, resulting into incomplete filling of the gap and consequent lowering of strength. So an optimum gap is to be chosen. For higher soldering temperature smaller gap may be suitable due to higher fluidity of the solder.

For the same reason, it has been recommended that the size of the overlap should be smaller than in solder joints of other alloys, as greater overlap is liable to cause incomplete filling of the gap and penetration of the fluxing material which is difficult to remove. For soldering sheets of less than 1 mm the overlap recommended[2] is seven times the thickness and in soldering sheets more than 1 mm the size of the overlap should not exceed 3 to 4 times the thickness. The length of the overlap in tubular joints should not surpass 12 mm. If the strength of the joint is an important requirement, locked joints should be used wherever possible, to mechanically reinforce the solder joint.

Soldering methods

Soldering of aluminium is rather a difficult job unless correct solder-flux combination is used and correct technique is known and employed. The soundness of the soldered joint is largely dependent on the skill of the operator to distribute the solder and flux at the joint and abrade the joint with his tool—all of which is very important in getting a good joint.

With the fluxes and solders available today, aluminium can however be soldered by using any of the under mentioned normal soldering methods. The ease of soldering is of course dependent upon a number of factors. The more important of these factors are alloy composition, solder composition and flux composition, the shape of the parts being soldered and the design of joints.

The tenacious oxide film on aluminium, makes aluminium soldering a special problem and the problem of soldering aluminium is basically a problem of removing the oxide skin on the aluminium at the soldering temperature. This can be done in two ways :[3]

(a) Mechanical removal of the oxide scale simultaneously with application of molten solder or fluxless 'friction soldering'.

(b) Removal of the oxide layer by means of a suitable flux (flux soldering).

Friction soldering

Due to difficulty encountered in finding out suitable flux-solder combination, earlier processes of solder joining were mostly friction soldering. In this method the joint surfaces are heated to the melting point of the solder being used. The molten solder is then spread over the joint surface which is then vigorously scraped with an abrading tool. The scraping action breaks up the aluminium oxide film and allows the molten solder to make intimate contact with the base metal. The removal of oxide film by friction is achieved in two ways.

1. Mechanical scale removal by means of quartz brush or wire brushing with the application of solder. The same result can also be achieved by using an abrasive pencil solder, which is essentially a rod sintered from a mixture of soldering metal powder and a refractory material like asbestos powder. The optimal proportion of the components are stated to be :[4] 10% by weight of asbestos and 90% soldering alloy. The asbestos particles added to the molten solder apparently play the role of abrasive agents.

The parts to be pretinned are preheated to a temperature exceeding by 25–50°C the melting point of the solder involved, and then tinned by means of the abrasive pencil by passing its ends several times over the surface to be tinned. Usually the thickness of the solder layer should not exceed 0·05 mm.[5]

In soldering, the pretinned surfaces placed one above the other, are rubbed against each other to obtain a smooth thin seam, and then cooled. Tinning by means of an abrasive pencil may be done without any special preparation of the surface such as pickling, steel brushing, emery cleaning and degreasing. Further, the process offers an easy visual inspection of the work during soldering. Non-tinned portions of the surface appear as dull spots through the bright lustrous tinned layer.

2. Aluminium alloys may also be tinned by using a low-melting solder, having a wide crystallisation range. In this case, the first grown solid crystals act as abrasive bodies which remove oxide film and as such the use of abrading tool is not required. Solders with a narrow range of crystallisation and particularly eutectic solders with sharp freezing point is therefore unable to remove the oxide skin from the surfaces to be soldered and cannot be used as friction solder.

According to German Standard[6] of solder (DIN 1732), friction soldering may be carried out with the following zinc bearing solders.

Chemical composition	Liquid temperature	Solidus temperature
1. 85% Zn & 15% Al	450°C	390°C
2. 60% Zn & 40% Sn	370°C	200°C
3. 56% Zn & 44% Cd	340°C	280°C

The above solders have been used for joining cables and cast aluminium parts.

A suitable low melting solder containing 60% Sn and 40% zinc has also been used for friction soldering of small joints and foils up to 0·2 mm thick. Another useful solder[7] of this group is 56% tin, 34% zinc and 10% cadmium which melts at 250°C. These solders have freezing range of 140°C and 90°C respectively.

Friction soldering readily lends itself to automation. For this purpose tools are available which vibrate in molten solder with a frequency of 100 vibrations/sec. For soldering with such tools solders having 80% Sn and 20 zinc and 90% Sn, 10% zinc have been used. The latter is reported to give a smoother surface of the soldered joint but is somewhat less corrosion resistant.

Flux soldering

This method employs a pickling treatment which etches the surfaces. Dilute phosphoric or hydrofluoric acid may be used. The surface is then tinned while being protected from oxide formation by a layer of stearin. Alternatively, the molten solder may be applied together with an alkali halide flux. This process is suitable for quantity production where close control is possible.

A suitable flux should be chosen whose main requirements are that it shall be completely fluid at and below the soldering temperature, it must act as a solvent for oxides and other unwanted substances over the soldering temperature range, or form a slag with infusible substances. Finally, it must remain sufficiently fluid after fluxing the metal surface to be easily displaced by the molten solder.[8]

Suitable fluxes may be grouped into two main groups :[9]

1. The relatively new organic fluxes basically chloride-free.
2. The much older inorganic fluxes containing mainly chlorides.

Organic flux soldering

Usefulness of organic fluxes lies in their non-corrosiveness and good flow characteristics. These fluxes readily dissolve Al_2O_3 and greatly improve the wettability of the surface to be soldered by the low melting solders. They, therefore, find wide use in low temperature soldering below 270°C though they are relatively expensive. The organic fluxes are active in the approximate range 175°–250°C.[10] Above 250°C, these organic fluxes carbonise and char, leaving a residue that prevents soldering, for this reason, they should not be used in direct contact with soldering irons or torch flames. During soldering these organic fluxes react with the oxide and remove it from the aluminium.

Also during this reaction, gas bubbles form in the flux, and due to these gas bubbles, it is almost impossible to make porosity-free lap joints using these fluxes. This often limits their use to soldering line-contact and similar joints where the flux can be easily displaced by the solder.

The organic fluxes are of various types but they may be mainly composed of organic fluoride such as borontrifluoride, mono-ethanolamine, a vehicle such as methyl alcohol, a heavy metal fluoborate such as cadmium fluoborate and a plasticiser such as stearic acid. These may be activated by ammonia and some of these fluxes have been modified to include chloride to act as accelerators. The organic fluxes are generally syrupy liquids which operate at temperatures up to about 250°C. These are not suitable for use with high melting temperature solders.

Table I gives the composition of some of the organic fluxes recommended by Russian authors.[11]

TABLE I Composition of some of the organic fluxes recommended by Russian authors

	Composition%		
Components of flux	1	2	3
Cadmium fluoborate	10±0·5	10±0·5	—
Zinc fluoborate	—	2·5±0·5	10±0·5
Ammonium fluoborate	8±0·5	5±0·5	8±0·5
Triethanolamine	82±1	82±1	82±1

Table II gives the composition of the soft solders for joining aluminium alloys using organic fluxes. The first solder in Table II can also be used with a flux solution containing 20% phosphoric acid and 10% nitric acid in water (swabbing necessary).[7]

TABLE II Composition of the soft solders for joining aluminium alloys using organic fluxes

Zn	Sn	Cd	Cu	Ag	Al	mp°C
10	90	—	—	—	—	200
20	80	—	—	—	—	250
32–34	—	52·5–48·5	6·5–7·5	—	9–10	240–260

Chloride fluxes

Amongst chloride based fluxes two types are available : chemical and reaction types. The chemical fluxes act with the oxide film to remove it exposing the metallic surface to the solder or reaction type where the flux penetrates the oxide film and thereafter the exposed aluminium reduces the metallic salt of the flux and the metal from the flux is deposited on the aluminium surface making it suitable for soldering. The chemical chloride (or fluoride) fluxes mostly contain alkali chloride with substantial percentage of lithium chloride which is very active and favours dissolution of aluminium chloride. Some of the chloride fluxes whose fluxing action is through chemical action are listed in Table III.

The other types of chloride fluxes are based on heavy-metal chlorides and generally contain chlorides of zinc and tin which react with aluminium at temperatures between 280° and 380°C to form aluminium

TABLE III Composition of some of the fluxing mixtures for soldering aluminium and its alloys

Flux	NaF	NaCl	$ZnCl_2$	LiCl	KCl	Others	Soldering temp.°C
1.	10±1	—	8±2	32±3	50±45	—	420
2.	6–1	—	19–24	42±2	28±2	—	320
3.	10	10	—	37	42·5	$NaFALF_3$ 0·5	380
4.	5	—	10	38	47	—	560
5.	7	25	8	13	47	$SnCl_2$ 0·05	550
6.	—	—	—	41	51	$KF-AlF_3$	570

chloride, which is a gas at these temperatures and its evolution breaks up the oxide film on the surface and the freshly formed heavy metal is then available for wetting by the solder.[12]

Addition of fluorides, i. e. potassium, calcium boron fluorides have been made to improve various behaviour of these groups of fluxes. Compositions of some of the reaction fluxes are given in Table IV under the heading of Reaction soldering.

Reaction soldering

Reaction soldering is essentially a process of joining achieved by means of solders which form as a result of a chemical reaction during soldering. There are three kinds of reaction soldering processess differing in the methods of formation of the solder.[13]

1. Reduction of the solder from the metallic salts (fluxes).
2. Evaporation of the volatile components of the solder or flux.
3. Contact reaction soldering in which a low melting liquid solder forms on the interface between the parts to be soldered.

The first method is applied mainly in the soldering of aluminium parts and the process may clearly be visualised if considering the example of soldering aluminium with zinc chlorides which occurs according to the reaction : $3ZnCl_2 + 2Al = 2\ AlCl_3 - 3\ Zn$. The aluminium chloride vapour formed during the reaction volatilizes. Zinc reduced in the course of this reaction (at a temperature of 419°C) melts and flows into the gap between the parts.

In this method as already briefly mentioned, chlorides of heavy metals e. g. tin, zinc, cadmium and lead are mixed in suitable proportions and spread over the joint surfaces. When heated, the salts are reduced to metallic state with the simultaneous production of corresponding salts of aluminium. During the production of the salt, the heat of reaction becomes sufficiently high to crack the oxide film and allow penetration of the solder metal which alloys with the base aluminium. The reaction temperature is relatively high but reaction fluxes can be devised to give the desired results at even 200°C or less.

Examples of compositions of these fluxes are given in Table IV

TABLE IV Composition of some of the reaction soldering fluxes (chloride fluxes)

$ZnCl_2$	$SnCl_2$	NH_4Br	NH_4Cl	NaF	Temp. of reduction of metal C
90	—	8	—	2	420
90	—	—	8	2	380
—	90	—	8	2	330
90	—	—	10	—	410
88	—	—	10	2	—
—	90	—	10	—	360
55	28	15	—	2	—
45	28	15	—	2	—
76·5	13·5	8	—	2	380
76·5	13·5	—	8	2	370
72	18	8	—	2	340
46·8	43·2	8	—	2	330
46·8	43·2	—	8	2	320

Residues from the above fluxes are corrosive to aluminium, as such these must be removed if the joint is to be left exposed to the atmosphere.

Reaction soldering has been tried only on a limited scale and its nature is confined to joints of suitable design. This process has not so far achieved experience for production application but has been employed for cable jointing where individual strands exceed 0·02 in diameter.

Selection of solders

Selection of a solder has to be considered from functional point of view i.e. types of components to be joined, the strength requirement of the joint, its service requirement from the point of view of corrosion and finally cost and availability. Cheapest and most easily available solder may sometime be sufficient for a particular job requirement and in that case use of a costlier solder is uncalled for. Selection of the type of solder, therefore, can be made from the knowledge of behaviour of various solders. This is therefore discussed here in some details.

TABLE V Compositions of soft solders

Sn	Zn	Al	Ag	Cu	Cd	Others	MP°C
70-80	20-30	—	1·2	—	—	—	260-280
50-65	40-44	2-4	2-3	—	—	—	320-350
49	50	—	—	0·5	—	0·5P	350
40	60	—	—	—	—	—	300
—	44-46	13-14	—	9·5-10·5	33·5-29·5	—	320-340
50-55	44-50	4·2	2·3	—	—	—	320-350
91	9	—	—	—	—	—	204

Soft soldering

A series of solder compositions are used having melting points up to 275°C which are known as soft solders. This kind of solder is used only in soldering less important parts subjected to small load and working in non-corrosive media. These solders are composed mainly of elements little soluble in aluminium i. e. lead, tin and cadmium forming seams, which adhere poorly to the parent metal and the small period in the course of which molten solder touches the base metal is not sufficient for diffusion to occur and hence strong joint formation is not possible with this group of solders. However, in order to accelerate the diffusion process, which is a function of temperature, they can be modified by addition of such elements which increase the melting temperature of the solders to some extent. Table V gives the list of soft solders.

The flux No. 2 and 3 given in Table III might be suitable for these solders. Amongst these low melting solders 91% tin and 9% zinc composition flows easily and has the highest resistance to corrosion.[14] Reliability of aluminium joints made with low melting solders depends on the corrosion stability of the solder involved and its adhesion to the base metal. Aluminium and aluminium alloys joint with the above solders exhibit a satisfactory corrosion resistance under common atmospheric condition. However, low melting solders should be avoided in joining aluminium parts exposed to acids, salts and salt or alkaline solution. Likewise, they should not be used to join aluminium vessels intended for storage of food products.

Hard solders

Another group of solders are available whose melting point is above the melting point of soft solders and are cheapest, strongest and have excellent corrosion resistance. Only difficulty that arises in its use is in the technique due to high melting point of the solders.

Pure zinc, zinc with 5% aluminium are the basic compositions of such solders. There are, however, several variations to these primary solders wherein addition of various other metals are made to improve one property or the other.

It has long been known that the best solder for aluminium, in so far as resistance to corrosion is concerned, is pure zinc, but pure zinc has a relatively reduced wetting effect on aluminium. The wetting power

TABLE VI Compositions of some of the high melting solders

Zn	Al	Cu	Others	Melting temperature °C
70	30	—	—	440-510
80-94	6-20	—	—	—
95	5	—	—	380
95	4	1	—	385
90	8	2	—	—
89	7	4	—	377
80	12	8	—	410
55-64	22-30	14-15	—	420
85	8	5	0·6 Pb, 1·4 Sn	420

can be improved by additions of aluminium or copper.

Aluminium or copper increases the wetting power of zinc but the fluidity is lowered with increase in aluminium content. Addition of small amounts of Pb and Sn improves the fluidity. A list of high melting solders is given in Table VI.

Zinc-aluminium alloys containing aluminium 5–10% show reduced spreadability. The addition of 0·5% Mg or Si improves the spreadability and also the corrosion resistance.

Zinc-aluminium alloy having 70% zinc and 30% aluminium has a good corrosion resistance property.

Silver has also the increased corrosion resistance effect in Zn-Ag solders. The following composition has been used.

Zn	Ag	mp.
95	5	420–450°C

The constituents that increase the melting point of Zn (Al, Cu, etc.) possess maximum corrosion stability. On the other hand a low melting element like Pb, Cd or Sn impairs its corrosion resistance[15] (Fig. 1).

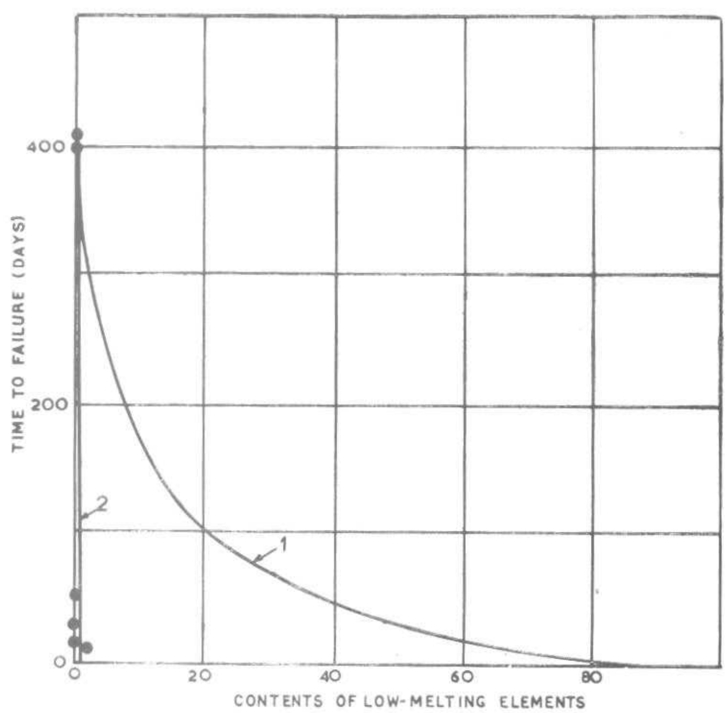
Brazing

Although the characteristic difference between hard soldering and brazing are not defined sharply, some authors[16] differentiate between the high temperature soldering and brazing by the fact that the brazing temperature is higher than that of the hard soldering. The fluidity of the brazing metals at their working temperatures may be superior and hence in some cases brazing alloys have been found more simple to apply than hard solders. High temperature solders for aluminium are mostly zinc based whereas brazing filler metals are basically aluminium based with addition of silicon and copper. As these have relatively high melting points, they may be used for soldering aluminium alloys having high melting temperatures. Table VII gives the composition of these brazing alloys.

It will be seen from the table that nearly all of them contain appreciable amounts of silicon and for this reason, the corrosion resistance of brazed joint is of a high order. Further, the joints have higher

TABLE VII Composition of brazing alloys

Al	Cu	Si	Zn	Cd	Sn	Melting temp. °C
88·3	—	11·7	—	—	—	577
90	—	10	—	—	—	590
67	27	6	—	—	—	550
52–50	20	3·5	24–26	—	—	500
63	10	7	—	15	5	530
80	—	—	20	—	—	575



1 *Effect of low melting elements added to zinc base solders on the corrosion resistance of soldered aluminium joints (1) tin and cadmium, (2) lead and bismuth*

TABLE VIII Composition of some brazing fluxes

$ZnCl_2$	LiF	NaCl	KCl	LiCl	KF	$KHSO_4$	KF AlF_3	Brazing temp./°C
—	—	31	44	15	7	3	—	—
—	—	—	51	41	—	—	8	570
7-12	8-10	25-30	30-55	15-30	—	—	—	—

mechanical properties at room temperatures as well as at elevated temperatures. Copper is added to Al-Si alloys to lower the brazing temperature but such additions should be done cautiously since copper reduces the corrosion resistance of the joints quite seriously. It, however, enables the joint strength to be improved by heat treatment where this is feasible.

Suitable brazing fluxes are basically mixtures of alkali metal chlorides and fluorides, with special additions for different conditions. Table VIII gives the compositions of some of the fluxes.

Standard brazing processes such as torch, twin-carbon arc, furnace, induction, dip and block brazing are used and in all these brazing processes adequate temperature control should be maintained.

Joint types

Lap joints rather than butt joints are generally used and in making the joints, press or tight fits must be avoided in assembling the parts to facilitate filler metal flow and minimise flux entrapment. Clearances up to ·010″ are suitable for joints with laps of less than ¼″ long. Clearances up to ·025″ are used for longer laps. The correct clearance for any given joint is best determined by trial.

Performance of joints

In all cases brazing temperatures exceed the temperature at which annealing occurs in the base material. It follows, therefore, that furnace or flux bath brazed parts made from the non-heat-treatable aluminium alloys have mechanical properties corresponding to full annealed condition of these materials.

The heat-treatable base metals are also annealed by brazing but their strength can substantially be increased either by a heat-treating operation applied after the parts are brazed or by quenching the parts from the brazing temperatures. The latter procedure is not always feasible and the results depend on the geometry of the part. The heat-treatable base metal can be quenched in an air blast, a water spray or a tank of hot or cold water. A slight delay after removal from the brazing temperature is necessary to permit the filler metal to solidify before the part is quenched, otherwise the dimensional changes that occur on quenching will open the joints. Air quench is the slowest quench of these mentioned above.

On some complicated parts cracking of the joints may occur even though the filler metal has solidified. In such cases the parts are allowed to cool and are heat-treated in a separate operation. Since proper heat treating time and temperature depend on the aluminium alloy involved, the manufacturers should be consulted for particulars.

Typical applications

Since both furnace and salt bath brazing are widely used, it is possible to make many joints simultaneously and hence as a production process it has many advantages. Radiators, heat exchangers and refrigerator assemblies are some of the complicated parts made by brazing. Thin sections can be readily attached to thick sections by brazing.

Cold pressure welding

Cold pressure welding is done at room temperature by applying sufficient pressure to effect plastic flow at the inter-faces of the parts being joined.

Cold pressure welding is finding increasing application, specially in the field of electrical and electronics industries. Various aluminium alloys can be successfully joined to each other or to other metals like copper, steel, etc. by this method. The advantages of this process are that the joint possesses none of the weaknesses inherent in the cast structure associated with fusion technique. An added advantage is that corrosion resistance of the welded zone is excellent and is equal to that of the parent alloy in most cases.

Since this is a non-fusion joining process, neither cast structure nor HAZ exists. Segregation, selective volatilization or oxidation of alloying constituents and other characteristics normally associated with fusion joining are all absent here.

Pressure welding technique

The production of a sound pressure weld depends upon bringing as many as possible of the metal atoms present on the faying surfaces into intimate contact with each other.

Extraneous dirt, absorbed gas, oils or oxide films present on the surfaces interfere with such contacts and reduce the strength of the joint. As such the surfaces have to be properly cleaned manually or degreased in a tank and then the weld faces of aluminium are usually mechanically abraded. The ends or edges of parts that are to be joined by butt welding are usually sheared immediately before welding. Longer delays between shearing and welding will result in decreased joint strength. The method most commonly employed to prepare the surface of aluminium for lap pressure welding is solvent degreasing followed by brushing the surface with a power driven, stainless steel wire brush.

The strongest aluminium assemblies result at about 60% deformation. The joint strength of the assembly varies with the alloy being welded and the shape of the die.

Practical joint designs for pressure welding are limited to variations of the simple butt and lap types.[17]

Butt welding

Butt joints between any combination of aluminium alloys can be cold pressure welded successfully. Though there is no limit to the size of the parts to be welded by this process when the parts are thinner or smaller in diameter than 0·02″ the die alignment becomes difficult. Commercial use of pressure-welding is presently restricted to parts ranging from wire 0·04″ in dia. to 3/4 × 4″ rectangular bars. Small parts can be hand-welded with a hand tool similar to the one shown in Fig. 2.

Lap welding

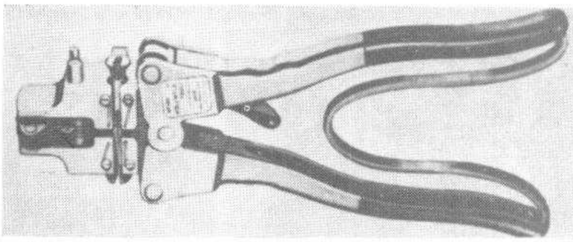
After the surfaces have been prepared, the parts to be lap joined are placed between the pressure welding dies or indentors. As the indentor penetrates, the oxide films shatter. The underlying metal squeezes through the crack. Wherever metal extruded from the faying surfaces comes into contact a solid phase bond is formed. A hand-operated lap-welding tool, with four types of indentors is shown in Fig. 3.

Applications

Room temperature butt pressure welding is used to splice re-draw rods, single-strand wires and rectangular bars. It is also finding application in joining aluminium stranded conductor wires to lugs and tags of copper or steel. There are also a large number of other applications in electrical and electronic fields involving practically all types of metals and alloys.

Ultrasonic joining

The process is an improvement on cold pressure welding. Aluminium and its alloys are most readily weldable by this process of joining which is gaining fast popularlity for fabrication purposes due largely to the following characteristics:[18]

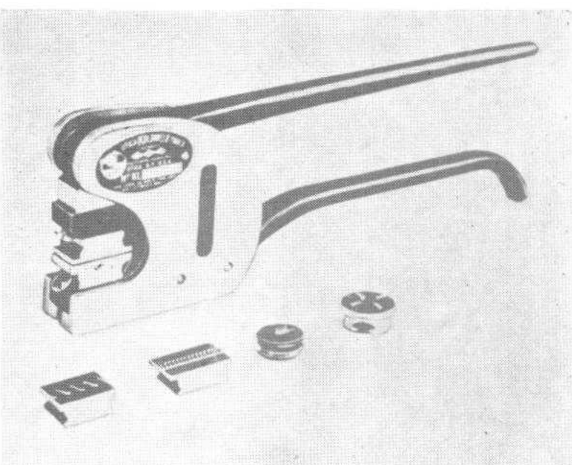


2 *Hand tool for butt-welding wire (courtesy Utica Koldweld Division, Kelsey-Hayes)*

1. It produces best bonds between aluminium and dissimilar metals.
2. Best available process for reliable, accurate control in jonining thin aluminium foil and fine wires.
3. Joins many heat-sensitive materials and components with no adverse heat effect.

The process employs a static force and the superimposed high frequency vibratory energy to make the bond. The equipment resembles that used for electrical resistance welding save its operating principle and that at least one of the materials to be joined must be in the form of a sheet or wire. Besides, the process is also ideally suited for welding very thin gages of aluminium and foils to itself or to any thickness of another shape of aluminium.

Ultrasonic joining is apparently a true solid state



3 *Hand-operated lap-welding tool with different types of indentors (courtesy Utica Koldweld Division, Kelsey-Hayes)*

bonding process. No electrical current passes through the weld region. No external heat is supplied and the amount of heat that is produced during joining is not sufficient to melt the material so as to have any effect upon the mechanical or metallurgical properties of aluminium or to produce the degradation that is obtained in some types of fusion joining processes.[19]

Aluminum wire and ribbon have been successfully bonded to metallized surfaces on a variety of non-metallic substrates such as alumina and other ceramics, glass and silicon. Aluminium can also be ultrasonically welded directly to certain ceramics and to other non-metallic materials. For example, aluminium ribbons and wire can be spot-welded to glass.[20]

Explosive joining

Explosive joining is another solid phase bonding in which metal surface with suitable geometry and orientation are brought together with a high relative velocity and pressure, so that a large amount of plastic interaction occurs between the surfaces. Short standoff operations are suitable for explosive joining involving metal foil, sheet or thin metal plates. Water is usually used as the energy transmitting medium for such operations.[21]

The requirements[22] for a strong bond between two surfaces to occur are that, virgin surfaces free from contaminants should be created and that sufficient pressure should be applied to bring the surfaces within inter-atomic distances between each other. The geometrical parameters, which affect the explosive welding include the plate thickness, explosive thickness, the included angle, the length and width of the plate, type of explosives, metal properties and buffer material.

Explosive eliminates the need for heavy press and in addition the bonded zone creates additional metal-to-metal contact plus mechanical interlocking to give a good bond strength and uniformity with minimum deterioration of the properties of the bonded metals. When explosive joining is carried out in vacuum, the noise from the explosive is greatly reduced and can be compared favourably with hammering and rivetting noises. Further, explosives function reliably in vacuum and since there is no melting of any part, the danger of molted metal floating out of the joining or boilling away is avoided.[23]

This is a new process which is still in the experimental stage to find new uses of the technique. It has got the special advantage that no special equipment is necessary for explosive joining and comparatively bigger and heavier parts can be joined with ease.

Two, now fairly widely used, important applications of the technique are :

1. Connecting high voltage stranded aluminium conductors to a collar by explosive joining or swaging.

2. Joining butted ends of two aluminium pipes by joining them to an external sleeve using an internal explosive.

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Discussions

Dr **R. T. Parker** (Alcan Research and Dev. Ltd., England) : For what purpose does the author consider soldering will be used in India ?

Mr **L. J. Balasundaram** (N. M. L.) : To what extent is pressure welding used in joining aluminium as compared to other methods of joining ?

Mr **B. N. Das** (Author) : In India soldering of aluminium can be used in electrical industry e. g. for manufacturing of electrical lamp and radio valves, etc. It can also be used extensively in sheet metal fabrications of various domestic items of utility, cans and containers, etc. which are not heated.

In reply to the point raised by Mr Balasundaram, pressure welding is mainly used to join butt ends of single strand wires of aluminium, redraw rods and rectangular bars. It is also used to join aluminium conductor ends to copper terminals. It is now widely used for the manufacture of heat exchanger in refrigerators. Pressure welding has advantages over other methods of joining in that like fusion welding it does not have weak cast structure of the joint; its advantages over solder joints are obvious. Corrosion resistance of the pressure welded zone is a special advantage of the process. Compared to other process for joining aluminium this process is very simple.