ROLL-CLADDIM – A IC11-10D OF
IMPROVING PROPERTIES OF MATERIALS

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1. INIRODUCTION

Clad materials are laminar composites of similar or dissimilar metals or alloys bonded together surface to surface. Methods employed are direct sandwich hot or cold rolling, hot pressing, hot dipping, explosion bonding and casting etc[1]. Lack of combination of several different properties in a single material necessitates the use of cladding[2].

Examples of Cladded Metals

Sheets of strategic materials such as nickel, copper, aluminium, stainless steels etc, when cl.added to thick mild steel plates, possess combination of excellent corrosion resistance of the former and the high mechanical strength of the latter[2]. This is one example of savings in material cost in heavy structural engineering applications, such as in pressure vessel etc, and thus conserve the strategic materials.

* A laminated form of copper and aluminium has attractive combination of high electrical conductivity and light weight[3].

* The difference in the coefficients of thermal expansion of various metals is made use cf in making bimetals for use in thermostats and other temperature actuated devices[3T.

* Aluminium-clad steel sheets are in use in chemical, automotive, marine industries, rail road cars, refrigerators etc.

* Sheets of soft materials like lead, tin or indium, clad on to strong backing materials are used in the manufacture of antifriction bearings.

* A silver base alloy having poor springiness - properties may be cladded on to a hard phosphor-bronze or other springy materials to achieve maximum benefit of both the materials[4]. Such composites are finding increasing use in the electrical and electronics industries[5].

- Silver-cadmium contact alloy is used in internally oxidised condition and hence possesses poor joining properties with the backing material (due to the presence of oxides)[6,7]. When a thin sheet of pure silver is cladded to a thick plate of silver-cadmium alloy and the silver face brazed to the backing material, results in better brazed strength and service life compared to unclad contacts brazed to the backing material[8].

The most widely used clad metals in tonnage quantity are the stainless steel mild steel, copper clad mild steel, copper clad aluminium and silver clad silver-cadmium oxide contact alloys, which find applications in pressure vessels, chemical reactor vessels, chemical plant and electrical and electronics industries.

2. STEPS INVOLVED IN ROLL-CLADOIM

Surface preparation and making of a suitable pack, rolling at appropriatetemperature.

* Initial percentage of reduction of the pack in thickness in the single first roll-pass.

5. Evaluation of the joint properties: (i) Mechanical tests such as Olsen cupping, bend and tensile tests are generally employed to assess the bond strength and bond quality, (ii) Optical and SEM characterisation for assessment of the structure of the bond.

3. PREREQUISITES FOR CLADDING (Solid/solid bonding)

3.1 Cleanliness

Perfect cleanliness of metallic surfaces is very essential. This, however, is hardly possible to achieve in practice due to presence of thin films of oxides or adsorbed gases or liquids[9-10]. Even monomolecular thick layer of adsorbed films will inhibit metal to metal contact and proper bonding may not result because the interaction of atoms weakens very much beyond one atomic diameter. A number of processes like degreasing, pickling, wire brushing and heating in vacuum or in reducing atmosphere are used to remove the surface films[1].

3.2 Contact Between Surfaces

Proper bonding can be achieved only when the mating surfaces of the joining metals are brought into intimate contact so that the interatomic forces of attfaction can come into play between the atoms of the two metals to be bonded[4]. This can be expected when the atoms of the two metals come within a minimum distance. The condition is satisfied automatically when the two surfaces are in the liquid state and mix with each other; in the case of solid/liquid the condition appears also to be satisfied with certain exceptions. In the case of solid/solid bonding it appears that the application of high pressure is sufficient for bonding between them, provided no other factors interfere. For solid/solid bonding if the mating surfaces of the two metals or alloys are brought into contact sufficiently well, and if no intervening film of oxides or other contamination is present, it results in the joining of the two metals.

4. PROCESS PARAMETERS

4.1 Temperature of Cladding

Solid phase bonding is possible at both room temperature and elevated temperature under the above condition[4]. At room temperature very high deformation is necessary to bring the metals into close contact, and breaking the oxide film on the surface.

High temperature has the following advantages[11,12]: (a) it increases the **rate of** diffusion of contaminating films through the component metals, (b) it increases the plasticity of the metals thereby increasing the true area of contact for a given applied pressure and (c) it increases the mobility of metal atoms which thereby diffuse into one another and fill the voids.

4.2 Material Specification for Cladding

For stainless steel clad mild steel and copper clad mild steel, 18/8 stainless steel, copper with high purity and commercial mild steel are to be used. For silver clad silver-cadmium alloy, silver sheet of 99.99% purity and silver cadmium alloy containing 10% cadmium are used. To eliminate any trace of oxide layer on the mating surfaces of the stainless steel, copper, silver, mild steel and silver-cadmium alloy plates the plates should be degreased, pickled and finally throughly washed, cleaned and brushed.

4.3 Pack Preparation

Preparation of the pack prior to rolling is considered to be of vital importance. The economy and the final yield of the composite plate or sheet mainly depend on the pack preparation as wrong preparation of the pack assembly may increase the cropped end after rolling thereby reducing the final yield. A correct pack design may give an yield of about 95% of the total finished afea.

As the pack, for cladding either stainless steel to mild steel or copper to mild steel consists of two pairs of metal combinations (4-ply), a parting medium is necessary to separate the clad plates after rolling. A parting medium should be such that i: does not hinder the bonding of the components of the pack, and must be capable of spreading along the surface of the interface during rolling. Moreover, it should also help in the easy separation of the clad plates after the operation of cladding is over. The function of the spacers used are around (Fig.la) was to create a discontinuity in the thermal conductivity from the welding electrode to the costly metal (stainless steel or copper) placed inside the pack for cladding. This discontinuity not only prevents oxidation of the costly zetals, but also consumes some oxygen entrapped inside during welding. Welding of the periphery of the pack is important as it holds the pack intact during rolling and it provides an air tight compart:ent (free from any macro or micro holes) so that the interface of stainless steel or copper and mild steel does not get oxidised during heating and hot rolling.

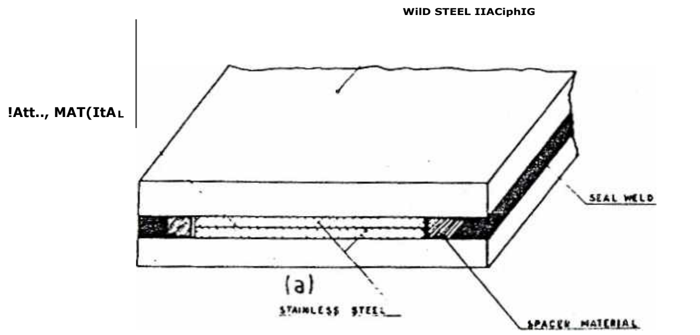
The design of the 4-ply pack used for cladding of stainless steel/mild steel plate and copper/mild steel plate is shown in Fig.la. In the clad combination, components of each pair are mated together and a parting medium is used in between the two pairs. The periphery of the pack is welded all round after providing suitable spacers on all the four sides and using suitable electrodes.

For silver clad silver cadmium alloy, pure silver sheet and silver-cadmium alloy plate of required thickness, length and width are so chosen as to give the required gauge sheet. after cladding. Thickness ratios of the silver sheets to silver-cadmium alloy plates are kept 1:5 and 1:10 respectively. A 2-ply pack consisting of one silver sheet and one silver-cadmium alley plate is used for roll-bonding. The front edge of the pack is made slightly tapered (Fig.1b) like a wedge for easy bite during rolling and also for subjecting it to the desired reduction in the first pass for sound bonding.

5. CASE STUDIES

The optimum rolling temperatures for stainless steel clad mild steel and copper clad mild steel are found to be 1100°C and 900°C respectively which give atleast 6010 reduction to the pack at the first heating and rolling cycle without causing any damage to the peak. The cladded pack is then subsequently hot and cold rolled to give higher percentage of reduction. Finally the clad components are separated by edge trimming.

For silver clad silver cadmium alloy, oxide initiation temperature of the alloy is determined. Small samples of the alloy are heated in air at different temperatures for 2-3 hours. Increase in weight of the samples, electrical conductivity and hardness values are taken as a 7easure for determination of the initiation of oxidation te7perature (Fig.2). It is obser.lad that the oxidation does not start below the temperature range of 500°C to 550°C. For cladding, 2-ply packs of silver and silver-cadmium alloy are heated in a muffle furnace in the temperature range of 500-550°C and soaked for 1 hour. Subsequently, they are rolled with an initial reduction in thickness of 20, 25, 30 and 35% in a single pass. After initial reduction, each of the hot-rolled packs is cooled and tested for bond quality. The cladded packs are subsequently hot and cold rolled to provide final requisite reduction in thickness.



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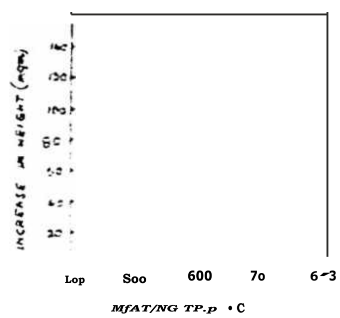


It is observed that in case of the stainless steel clad mild steel and copper clad mild steel a minimum reduction of 40% of the pack thickness in a single pass is essential to achieve sound bonding at an optimum rolling temperature of 1100°C and 900°C respectively. At a lower temperature, higher roll load will be necessary, and at a temperature higher than the optimum, objectionable surface defects have been observed.

From the Fig.2 (for bonding of silver to silver-cadmium alloy) it is observed that oxidation of alloying ele:ent does not start below 550°C as the samples have shown negligible increase in weight after heating. No increase in electrical conductivity or hardness values are observed. As such, to achieve a favourable condition for bonding of the metal components, the hot-rolling of the pack can be carried out in the temperature range of 500-550°C.

From the Table I it is evident that satisfactory bond is not obtained with an initial reduction of 20/25 of the pack thickness in a single pass at rolling temperatures of 500°C, 525°C or 550°C.

Table I: Schedules for roll-cladding (silver/silver-cadmium alloy)

Expt. number	Rolling temp. (°C)	% reduction in pack thickness	Observation	Remarks
I	500	20	Weak bonding	Separates readily
		25	-do-	-do-
		30	-do-	-do-
II	525	20	Weak bonding	Better bonding than Expt.No.1
		25	-do-	-do-
		30	Fair bonding	Separated by mechanical force
III	550	20	Good bonding	Separated by mech. force
		25	Better bonding	Difficult to separate
		30	Sound bonding	Could not be separated

However, rolling at a temperature of 550°C with a reduction of 30% in a single pass can produce a bonded area of 80 to 85%. In the composite pack with 35% initial reduction in a single pass at 550°C the bonded area is 90% and above. A minimum reduction of 30% of the pack thickness with subsequent 2/3 roll passes, each of 20-25% reduction at the optimum roll-bonding temperature of 550°C is necessary for producing a satisfactory cladded composite. Rolling at a temperature higher than the optimum established, results in an initiation of undesirable oxidation in the silver cadmium alloy and unsatisfactory bonding.

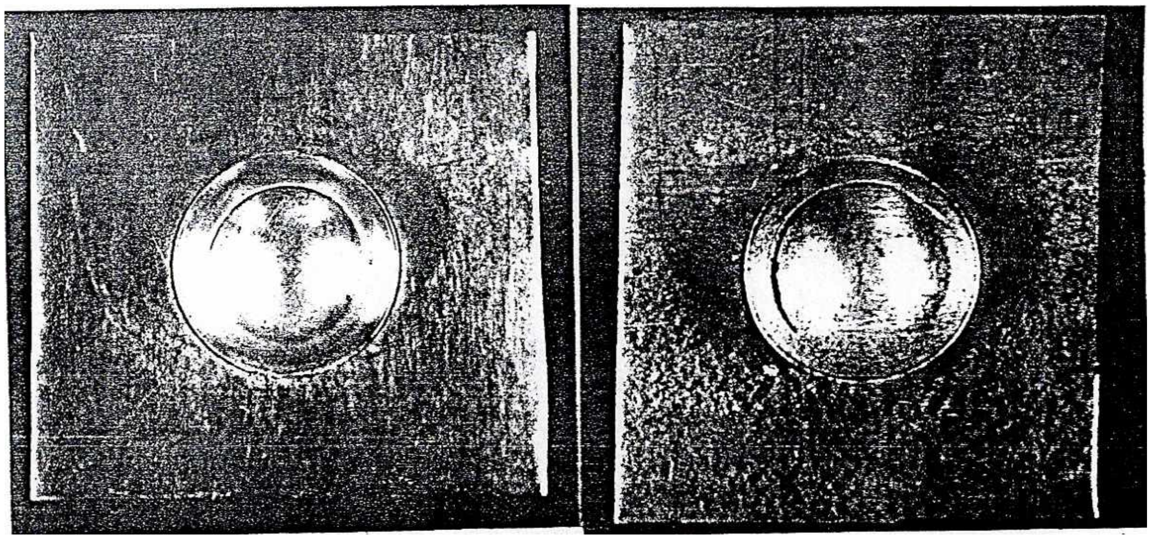
From the results of the Olsen Cupping and Bend Tests (Table II), it is evident that the two components of the composite have failed simultaneously and the fracture faces reveal no signs of separation of the stainless or copper sheet from mild steel or silver sheet from the silver-cadmium alloy (Figs.3 & 4); generally the two plates have failed together. Even the slightest tendency of the clad metal to peel off at the dome of the cup during the test have not been observed. Moreover, failure of the clad sheet (silver) alongwith the base metal (silver-cadmium alloy) indicates a strong bonding and also ductile nature of the composite material.

The cladded contact tips, after internal oxidation and brazing to the backing materials (Fig.5) have shown satisfactory perfor7ance than the unclad contact alloy. The comparative properties of the clad and unclad product are given in Table II.

The microstructure of the cross-section of the clad material reveals continuity of the bond. Voids or layers of intermediate product are not observed in the bonding interface (Fig.6).

Comparative properties of clad and unclad alloys

combination	Density gm/cc	Hardness VPN	UTS kg/mm^2	Elongation (%)	Electrical conductivity % IACS	Olsen cupping test, depth of cup (mm)	Bend test 180° reverse bend	Service life
[illegible]	[illegible]	[illegible]	47	30	–	8.0 (no separation)	No separation	–
[illegible]	[illegible]	[illegible]				9.0 no separation)	No separation	-
[illegible]	[illegible]	[illegible]			[illegible]	13.90 no separation)	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]			[illegible]	13.50 no separation)	No separation	[illegible]



(a) (b)

Fig.3: Photographs of specimens after Olsen cupping test
(a) Ag sheet outside the cup
(b) Ag sheet inside the cup

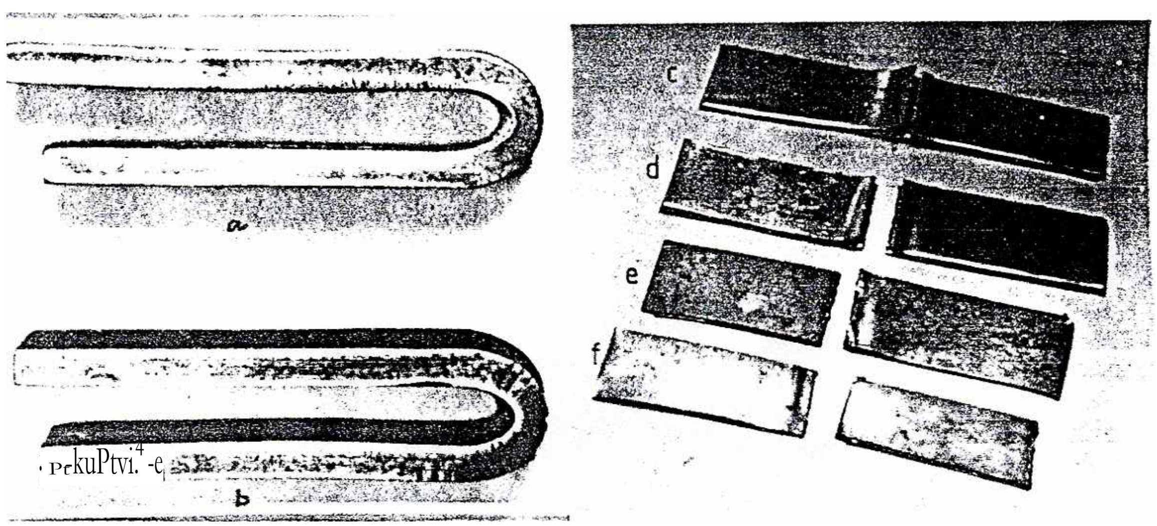
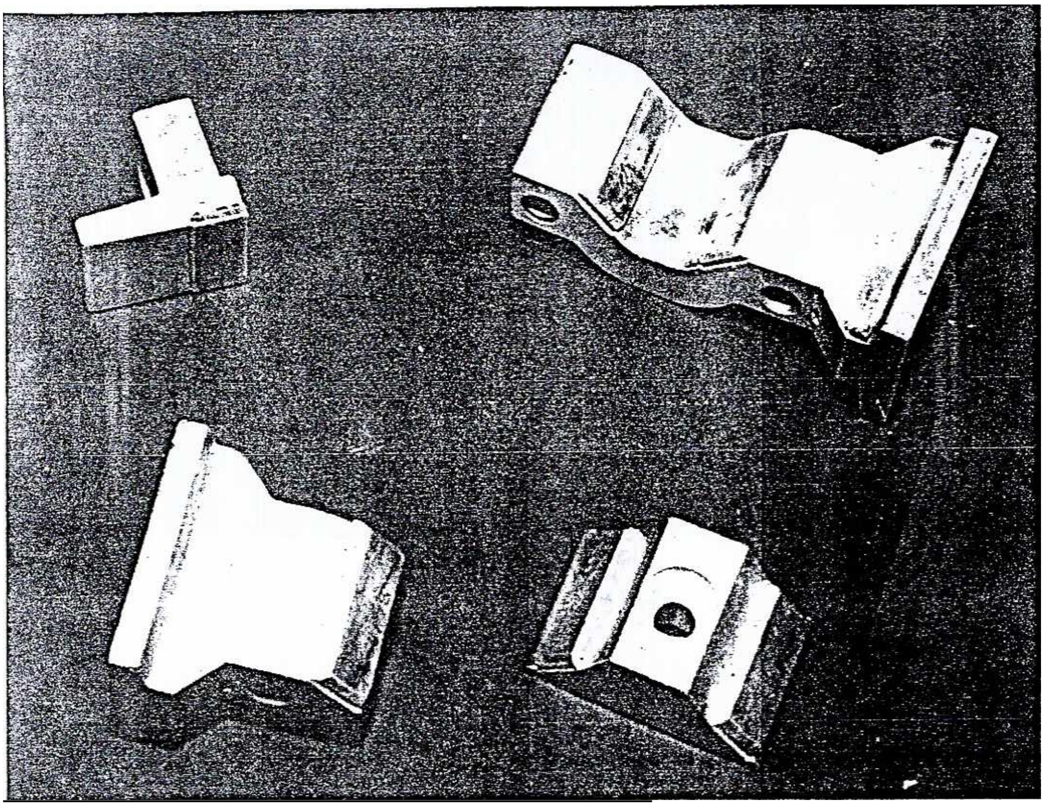


Fig.4 Photographs of bend test sa:Iples showing bonding quality (a) Clad sheet out-side no separation; (b) Clad sheet inside, no separation; c) Bad, separates readily; (d) Fair, can be separated bN, Elech. force; (e&f) Sound bonding, cannot be separated



(a)

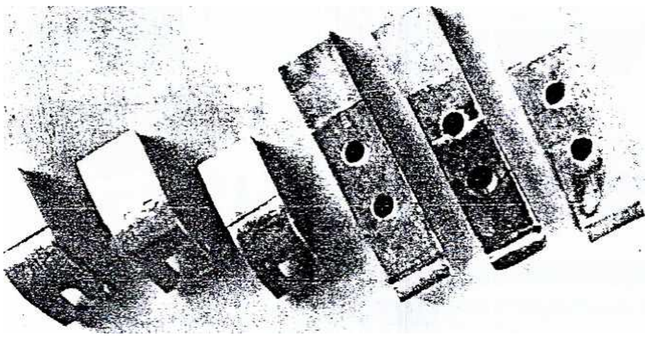


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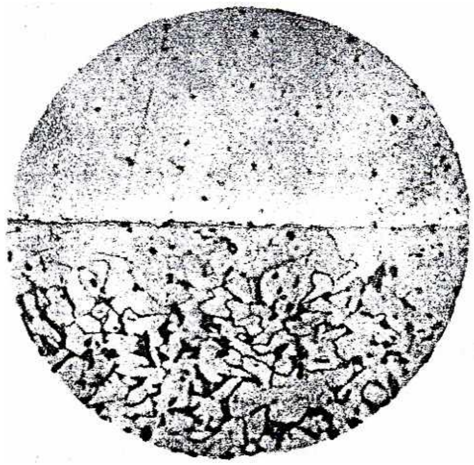
Fig.5: Cladded contact samples tested at
(a) Indian Railways
(b) Steel plant



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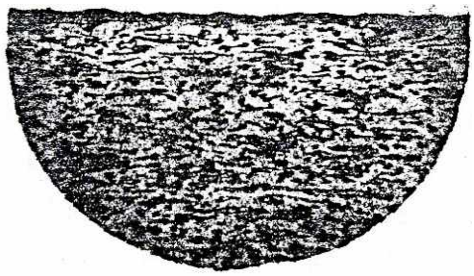

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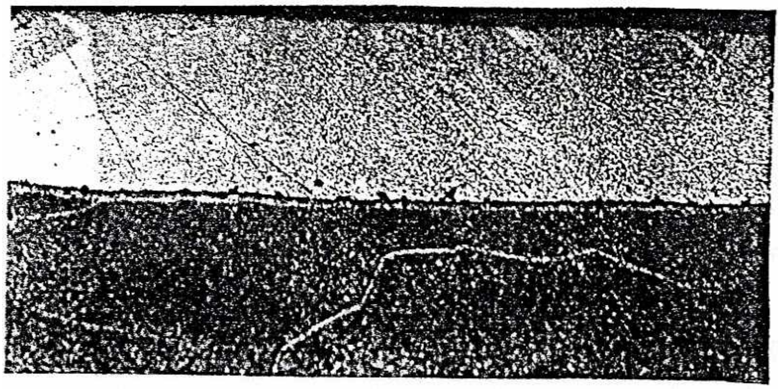
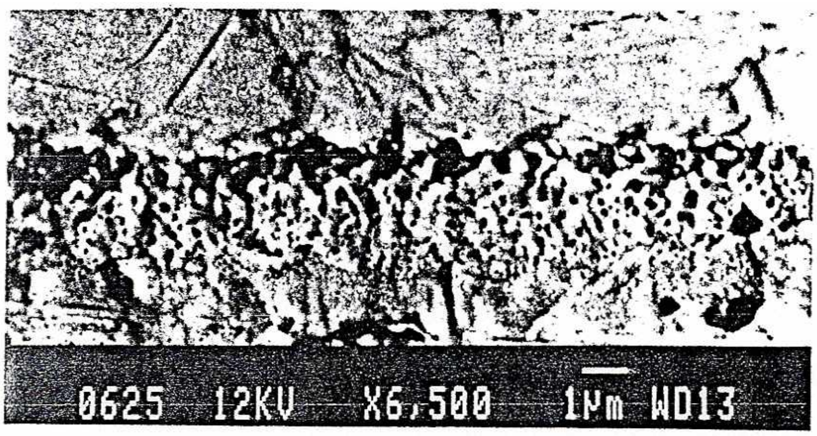


(c)



(d)

Fig.6: Structure of interface of the clad products

(a) Stainless steel clad mild steel (etched portion mild steel) X 125

(b) Copper clad mild steel (etched portion mild steel) X 125

(c) Ag clad AgCdO alloy (etched portion AgCdO alloy) X 400

(d) Ag clad AgZnO alloy (etched portion AgZnO alloy)

6. RC 14ORK ON CLAD METALS

Extensive research work was carried out at the National Metallurgical Laboratory, Jamshedpur for the development of various types of clad metals such as (i) stainless steel clad mild steel, (ii) copper clad mild steel, (iii) copper clad aluminium, (iv) aluminium clad mild steel, (v) silver clad silver cadmium or zinc oxide cc tact alloys etc. Some of clad products were tested at Indian Railways, Bokaro Steel Plant and Bhilai Steel Plant and satisfactory perfor7ance was reported.

7. CONCLUSIONS

* Stainless steel/mild steel or copper/mild steel clad can be produced by roll-cladding technique with an initial reduction of 40% of the pack thickness in the first single pass in the temperature of 1100°C and 900°C respectively.

• For silver/silver cadmium oxide or silver/silver zinc oxide contact alloys the initial reduction is 30% in the temperature range of 500-550°C.

* The clad products possess good bond strength coupled with ductility and are ideal for further processing.

o Cladded contact alloy shows better service life than 'unclad contact alloy.

o Cladded products have immense scope of applications.

ACKINIXEEDGENENT

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